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## 1. Abstract

This thesis investigates and compares the volatility in the retail fuel market in Stavanger and Brent crude oil. Gasoline and diesel prices have been collected from gas stations in Stavanger in 2020 and 2021, and are used for the thesis' main goal of developing an algorithmic mathematical model for refueling vehicles at optimal times for consumers that could be used in practice. The collected data suggests that there is higher volatility in the retail fuel market in Stavanger compared to the Brent crude oil market. Gas stations follow a characteristic Edgeworth cycle pattern that have price spikes occur when restarting their price cycles. These occur for the most part at the same time across all gas stations monitored in Stavanger. This pattern can be difficult for consumers to predict. Therefore, a practical refueling algorithm could be useful. There are many factors that go in to such a model to make it efficient such as price spike analysis from the Edgeworth cycle pattern found in retail fuel markets and estimating volatility using GARCH(1,1) method.

## 2. Acknowledgements

I would like to thank my supervisor, Associate Professor Alex B. Nielsen, for his constant support and feedback during the writing of this thesis. Additionally, I would like to express my gratitude to my family and friends who have supported me throughout my education and the writing of this thesis. Without your support and faith in me, I would not be where I am today.

# A COMPARISON OF PRICE FLUCTUATIONS BETWEEN BRENT CRUDE OIL AND RETAIL FUEL PRICES IN STAVANGER - AN ALGORITHMIC MODEL FOR REFUELING

OLA NES

## Contents



*Date*: June 14, 2021.

## 3. Introduction

In 1967, Norway struck oil in one of its oil fields and ever since, oil has played a major role in Norway's economy. Stavanger is called the oil capital of Norway as oil has been vital to the city and has created many jobs [1]. There are several important oil organizations that have their headquarters located in the city such as Equinor, Petoro, Oljedirektoratet and Petroleumtilsynet. The oil products gasoline and diesel are the two most commonly utilized fuels for both private and commercial cars. It is essential for many people and corporations all over the world to refuel their vehicles on a regular basis for transportation. Most of them refuel their vehicles at gas stations. These stations advertise their gasoline and diesel prices on large price boards that have a dynamic pricing system that allows prices to be updated in an instant (see Figure 1). Despite advertising fuel prices visibly to everyone passing by, most gas stations will not disclose their historical fuel prices to members of the public.

Gasoline and diesel sold at gas stations in Norway are primarily made from the raw material Brent crude oil. Brent is a benchmark for oil in Europe and is a term used for oil produced in the North Sea [2]. It would be reasonable to assume gasoline and diesel prices are correlated with Brent crude oil prices, however as petroleum economist Klaus Mohn explains:

"Many wonder why the price of gasoline does not fall when the oil price is crashing, like it does now. It is important to remember that approximately 60 percent of the price of Norwegian gasoline prices are taxes. The cost of crude oil is only 30 percent of the price, and the remaining 10 percent is the stations' profit. When only such a small component of the gasoline price fluctuates, it will not impact the big picture much." Klaus Mohn 2016 (translated from Norwegian)[3]

In the Petroleum section, Brent crude oil and retail fuel markets in Norway are discussed along with what components their prices consist of. There are other components besides Brent crude oil that make up fuel prices such as taxes, transportation cost, administrative fees, and exchange rates. After accounting for these components, the Analysis section will show that the correlation between cost price gasoline and diesel and Brent crude oil is not strong.

The Methodology section describes details of what and how data was collected along with the characteristic Edgeworth cycle pattern prices follow. Since gas stations will not disclose historical price data to be used in this thesis, prices must be recorded in person outside each gas station monitored in this thesis. In 2020, a Circle K gas station in Stavanger was monitored and its price data serves as a test data set for analyses and the development of algorithmic trading models that will simulate how much money can be saved when refueling. The developed models are then used with a 2021 data set as a validation test. The validation data set consist of price data from seven gas stations that were monitored in 2021, five of which are located in Stavanger, one at Karmøy and one in Førresfjorden.

In Norway, fuel prices usually fluctuate by small amounts throughout the week, however, there exist some significant price changes that on average occur once a week and that take place at most gas stations at the same time. These price increases are what is called positive price spikes. Price spikes are the result of gas station chain headquarters sending out recommended prices which gas station franchisees have to follow [4]. These price spikes follow a characteristic pattern called an Edgeworth cycle. This will be discussed in the Methodology section and analyzed in the Analysis section.

Economic markets such as stock markets and commodity markets are assumed to follow a Markov process [5]. This means it is impossible to make algorithms that reliably beat the market because all information influencing prices, is reflected in the latest price. This type of market is called an efficient market. If such algorithms can be made, then the market is not an efficient market.

The Algorithmic models section describes algorithmic trading models that simulate how much money can be saved off the retail fuel market in Stavanger since it is not an efficient market. These models are developed based off the analyses in the previous section. Commodities such as Brent crude oil are speculated in on the international commodity market, which is much closer to an efficient market.

If profitable trading algorithms can be developed for the retail fuel market in Stavanger, it cannot be an efficient market. These trading models are not something that can be used in practice since it would require the possibility of being able to sell fuel back to the stations. Instead, it can simulate how much money can be saved by buying fuel at cheaper prices and then sell it back to gas stations at more expensive prices, generating a profit from the difference. The most efficient trading algorithm is the model that buys fuel the cheapest and sells it at the most expensive time. This model is made the basis for a practical refueling algorithm that can be used in practice and it serves as the main goal of the thesis. Using this refueling algorithm to refuel 60 liter gasoline once every two weeks saves between 127 kr to 160 kr depending on the gas station it is used at.

## 4. Petroleum

This section describes what oil, gasoline and diesel are, why they are essential components of modern society, how they are traded and what determine their value.

4.1. **What is Brent crude oil, gasoline and diesel?** The word Petroleum originates from Latin, meaning rock oil [6], and is a term that encompasses oil and gas. Oil is the remains of plants and animals which have been compressed deep within the earth for millions of years. Brent crude oil is unrefined petroleum which is extracted from the North Sea from the Brent, Forties, Oseberg and Ekofisk oil fields. Crude oil is sent to refineries where they produce many different fuels from the oil including gasoline and diesel. There are two operational oil refineries in Norway: one in the county of Vestland near Bergen, Mongstad Refinery run by Equinor, and one in the county of Telemark near Sandefjord, Esso Refinery run by ExxonMobil. Brent crude oil is favorable for gasoline and diesel distillation due to its properties of being a light and sweet oil, meaning it contains less impurities, which decreases the cost of refinement [2]. Brent Crude is a standard pricing benchmark in Europe for oil from the North Sea. Other famous benchmarks are OPEC Reference Basket, Dubai Crude and Oman Crude from the Middle East and West Texas Intermediate in North America. Oil is typically bought and sold in future contracts and are traded on commodity exchanges [5].

Gasoline and diesel are the most common fuels for both private and commercial cars. Petroleum products are also used for heating and electricity through gas powered stoves and power plants in some countries. Petroleum products are made through a separation process. Diesel only needs to be separated from crude oil, while gasoline needs to be refined as well to gain its necessary characteristics. Chemicals are added to gasoline to prevent detonation, and the octane rating denotes how much compression gasoline can withstand before detonation. The numbers, 95 and 98 found on different types of gasoline at gas stations, denote the octane rating of the gasoline. If gasoline detonates in the engine, it could cause harm to the engine, called engine knocking. Most gasoline powered cars use 95 gasoline, while some older cars need 98 gasoline to keep gasoline from damaging the engine. 95 is the standard octane rating sold in Norway. Historically, gasoline contained lead in the form of TEL (tetraethyllead), but it has since been replaced by other chemicals that are more suitable for the environment such as methanol, ethanol, or MTBE [7].

4.2. **Buying and selling oil.** Oil is one of the most bought and sold commodities and it can be traded in a variety of ways. The most common of which is to buy or sell oil future contracts, which is a derivative contract where one party agrees to buy a specified amount of oil for an agreed upon price on a settlement date in the future. A derivative is a contract between two or more parties whose value is determined by an underlying asset such as a stock, bond, currency or in this case a commodity. On the settlement date, the buyer settles money for the commodity. Oil is sold by the barrel, which is approximately 159 liters, and is sold in US dollars [5]. There are many investors speculating in the price of oil and instead of settling future contracts, they let them rollover, meaning they sell their contracts before the settlement date to not have to physically take care of the oil. This causes volumes of oil to be bought and sold many times over in a day. Speculators trade oil because it is volatile, meaning there are opportunities to make a profit from trading it [5].

Future contracts have a premium attached which the buyer pays for. This covers handling and storage fees. Longer future contracts hold higher premiums since oil must be handled for longer periods of times [5]. In April 2020 there was a plummet in demand and a storage complication which led to West Texas Intermediate (WTI) oil contracts having negative value, which is the first time in history oil has had a negative value. The premiums for oil storage became more expensive than the value of the oil itself as there were no places to physically store more oil [8]. The spot price is what oil is worth at that moment in time. There are other ways to speculate in oil such as trading stocks, options (calls and puts), CFDs (contracts for difference) and other derivatives.

There is a fairly simple relationship between the futures price and the spot price, given by this formula: [5]:

$$F_0 = S_0 e^{cT} \tag{1}$$

$F_0$ is the future contract price, $S_0$ is the spot price of oil, $e$ is Euler's number, $c$ ($c = r + u - y$) is the cost of carry (which includes the risk-free interest rate ($r$), storage costs ($u$) and convenience yield ($y$)) and $T$ is the time to maturity in years. This formula carries assumptions such as no transaction cost and the existence of a risk-free interest rate, which is a theoretical concept that represents the hypothetical interest rate an investor would be expected to pay for a risk-free investment [5]. Even though all investments carry some risk, it has historically been widely accepted that the risk-free rate can be modeled after the long-term yield of

US Treasury bonds as they have been relatively risk-free. In recent years, other countries' bonds have had better ratings such as Denmark, Sweden and Norway [9].

4.3. **What affects the oil price?** The oil price is an important component of the world's economy as it is the primary raw material used for fuel. Without it, there would be few effective ways to transport people and goods across and between countries as the world is still heavily dependent on it. There are several factors that influence its price.

- All commodities, oil included, are affected by supply and demand. Overproduction and recessions negatively impact the oil price, while demand and booming markets positively impact it. Political instability can lead to less demand if industries that are dependent on oil are affected, but it can also lead to more expensive oil if there is instability in oil-producing countries such as those in the Middle East. Another important factor is market sentiment. This refers to the consensus of what a commodity is worth at the moment and in the future. If there is concern that there will be less demand or oversupply, the commodity is going to decrease in value, however, if there is concern that there will be an increased demand or shortages, then it increases in value simply by speculation [10]. Even though oil is an asset that can be invested in, it is primarily used for consumption in production. Hence it is not an investment asset, but a consumption asset. Consumption assets have convenience yield. It can be beneficial to have a consumption asset at hand in case there is a sudden shortage in the market. Companies without the necessary consumption assets may have to cease production, whereas companies holding extra can continue their production [5].

  As the world moves towards energy sources that produce less carbon emissions, some people are predicting that oil will reach a peak in price soon. The demand for oil has decreased during the COVID-19 pandemic due to people needing to commute less, however, the demand is scheduled to increase to normal levels again as most citizens in high-income countries will be vaccinated at the end of the summer of 2021 if vaccinating plans are executed as planned [11]. As emerging Asian countries grow their economy, the demand for oil is expected to increase [11]. Even though high-income countries are becoming less reliant on oil, it is still going to be an important commodity for years to come [12]. To reduce demand for oil, there are proposals for actions in Western countries such as reducing the need for commuting by maintaining and expanding home office arrangements, reducing the number of business flights and the demand for plastic, increasing the number of electrical vehicles and taxes on fossil fuels and phasing out fossil fuel for heating [11].

- Since oil is traded in US dollars, prices are tied to the exchange rate of it. A stronger US dollar means oil companies are going to make greater profits in their own countries, however, countries with large oil productions often have their economy strongly correlated with the price of oil, meaning their currency follows the price of oil. Norway's economy closely follows the price of oil and gas as it accounts for 42.2 percent of Norway's total exports in 2020, which amounted to 325.2 billion kroner [13].
- Like other commodity markets, the oil market tends to be cyclical. When the price is high, more oil fields become profitable, which leads to an increase in supply as more oil fields are operated. Over time, there will be a decrease in price as there becomes an oversupply when many oil fields are operated, which might lead to oil fields becoming unprofitable and halting or ceasing production, completing the cycle. Countries and companies who own large oil supplies have an interest in keeping the oil price high. Some organizations such as OPEC, Organization of the Petroleum Exporting Countries, which controls approximately 40 percent of the world's oil supply, has tried to stabilize the price of oil by restricting oil production in their countries: Algeria, Angola, Congo, Equatorial Guinea, Gabon, Iran, Iraq, Kuwait, Libya, Nigeria, Saudi Arabia, United Arab Emirates, and Venezuela. This is to profit well of their oil production [10]. Norway is not a member of OPEC. To be one, a country needs to have similar interests as the organization. As a European country, Norway is quite different than most of the OPEC members who are mostly located in the Middle East and Africa. If Norway were to join OPEC, it would need to follow OPEC's production limits and lose their sovereignty of their largest export. To be a member, three quarters of the organization need to approve the new member. Despite not being a member of OPEC, Norway can still reap the benefits of countries restricting their oil production, which stabilizes the price of oil. Although Norway has not expressed any interest in joining OPEC, Norway has restricted its oil production in 2020 in the wake of the COVID-19 pandemic by 250 000 barrels in June and 134 000 barrels in the latter half of 2020 [14].

4.4. **Gas stations in Norway.** Most gas stations in Norway use a dynamic pricing system that allows them to change fuel prices instantly. Prices typically change several times throughout a given day. Gas stations close on a price that does not change until the morning the next day. While this system is not exclusive to Norway, it is not common in all countries as some of them only change the price once a day, once a week or sometimes only once a month, and when changing prices, they might only have small fluctuations [15] [16] A.6. About once a week, gas stations are given recommended fuel prices from headquarters [4]. This is when fuel prices spike in value. Price spikes only last some hours before prices begin to decrease, which they keep doing the rest of the week. It is not quite evident why most of the gas stations do this, however, this price pattern resembles what is called an Edgeworth cycle, which will be discussed later in this section.

Franchisees make the same amount of money regardless of fuel prices as they are subsidized when prices decrease. Headquarters do this to compete with other local gas stations [3]. This pricing strategy is industry-wide adopted, and there are only a few chains that do not use it, such as Tanken. All gas stations disclose their gasoline 95 and diesel prices on large price boards that are visible from the road (see Figure 1). Other fuels like gasoline 98 and colored diesel are advertised on smaller price boards visible from the parking at the station.


FIGURE 1. Example of a price board at Uno X. Diesel (D) and gasoline (95).

Despite gas stations clearly disclosing their fuel prices on price boards, current and historical prices are not available online. According to The Norwegian Competition Law (Konkurranseloven) by The Competition Authority, gas stations are not allowed to disclose fuel prices in a manner that lets competitors obtain them and restrict competition [17].

"The competition rules do not prohibit one-sided actions to adapt to competitors' existing or expected market behavior. However, the rules are hindrances for any direct or indirect contact between competitors whose purpose or effect is to restrict competition." The Competition Law's guideline to § 10 (translated from Norwegian) [17].

The competition rules make it difficult for gas station competitors to attain prices from each other, however, it is not impossible. If a gas station wanted to know their competitors' prices, they could simply record prices of their competitors' price boards. While it is not as effective as calling them or looking up prices online, these rules are not much of a hindrance for competitors with the intent of limiting competition. Other goods and services markets have dedicated price comparison websites such as Prisjakt [18] that track prices between competitors.

There are applications such as Drivstoffappen [19] and Facebook groups that use peer-to-peer systems to keep track of fuel prices in areas like Stavanger. These are highly dependent on their userbases since this is where all data come from. While they can be useful, they are unfortunately not updated frequently enough for this thesis to rely upon when collecting fuel prices in Stavanger. Some gas stations get updated once a day, but most of them do not get updated that frequently. Consumers who casually want to know fuel prices in their area might find what they are looking for if they are lucky, but these applications and groups can hardly be the main source of data collecting for a data set in a thesis.

Prices are not available online due to the competition rules, however, calling them over phone or contacting them by email, is permitted. Still, most gas station chains in Norway will not disclose current or historical prices by phone or email either. The only way to attain fuel prices is to show up in person and look at the price board outside the station. Of the gas station chains monitored in this thesis, only YX and Tanken are willing to disclose their prices. YX is willing to disclose current prices by calling them, while Tanken is willing to share both current and historical prices over email. The rest of the chains, Circle K, Uno X, Shell and Esso are not willing to do either.

All the largest gas station chains in Stavanger are represented in this thesis, Circle K, Uno X, YX, Shell, Esso and Tanken. The following is a brief historical review.

- In 2016, Statoil sold all of their gas stations to a Canadian conglomerate, Alimentation Couche-Tard, who rebranded the stations to Circle K [20].
- Uno X and YX are owned by the same conglomerate, Reitangruppen. These two are sister companies, but are also competitors. They both have stations throughout Norway and Denmark [21].
- Shell is owned by Royal Dutch Shell (UK and Netherlands) and is one of the largest oil producers in the world [22].
- Esso is ExxonMobil's international trademark for its gas stations, however, in Norway they are only a supplier of fuel to Esso stations, while the stations themselves are owned by Certas Energy Norway AS and are operated by Tiger AS (NorgesGruppen) A.1.
- Tanken is owned by Joar Skorpe who started the chain in 2015 and has stations throughout Rogaland. Tanken is the only gas station chain monitored in this thesis that only updates their prices once a week [23].

4.5. **Pump prices.** Gasoline and diesel are primarily made from oil; however, it is a common misconception that crude oil is the main factor that determines fuel pump prices. It is just one of many factors that determines them. In fact, oil and pump prices can change in opposite directions [24]. Due to high taxation on fuel, oil only affects approximately 30 percent of pump prices [3]. A model for calculating retail cost price gasoline and diesel will be presented later in this section.

Beside oil prices, other big factors are taxes and exchange rates. In Norway there are three taxes that are included in the pump price; veibruksavgift, CO2 tax and VAT (Value Added Tax). Veibruksavgiften and the CO2 tax for gasoline and diesel are different from each other and are updated once a year. The VAT of fuel is 20 percent of the final retail price, meaning it adds a percentage on top of the other taxes (see Table 1).

| Year | 2020 | | 2021 | |
|---|---|---|---|---|
| Fuel | Gasoline | Diesel | Gasoline | Diesel |
| Veiavgift | 4.91 kr/l | 3.62 kr/l | 5.01 kr/l | 3.58 kr/l |
| CO2 Tax | 1.25 kr/l | 1.45 kr/l | 1.37 kr/l | 5.16 kr/l |
| VAT (pump price) | 20% | 20% | 20% | 20% |

TABLE 1. Fuel taxes in Norway in 2020 and 2021.

Fuel taxes are decided by politics and every year they are updated. In 2020, the CO2 tax was increased, however, the veiavgift was deducted the same amount to keep fuel taxes net the same. To reach the climate goals of reducing carbon emissions by 40 percent by 2030, political parties in Norway are discussing which actions are needed. One example includes increasing the CO2 tax from today's 590 kr/ton to 2000 kr/ton by 2030. This would mean an increase of pump prices of 4.10 kr/l on gasoline and 4.70 kr/l on diesel. Since the increase in CO2 tax in has been mitigated by reducing the veiavgift before, some political parties suggest reducing the veiavgift by the same amount as not to make it overly expensive for consumers to refuel their cars [12]. This action would not be felt by the average consumer, however, this change in taxation would affect businesses who have large CO2 emissions. Figure 2 shows fuel taxation and how increases and decreases would affect the retail fuel prices.

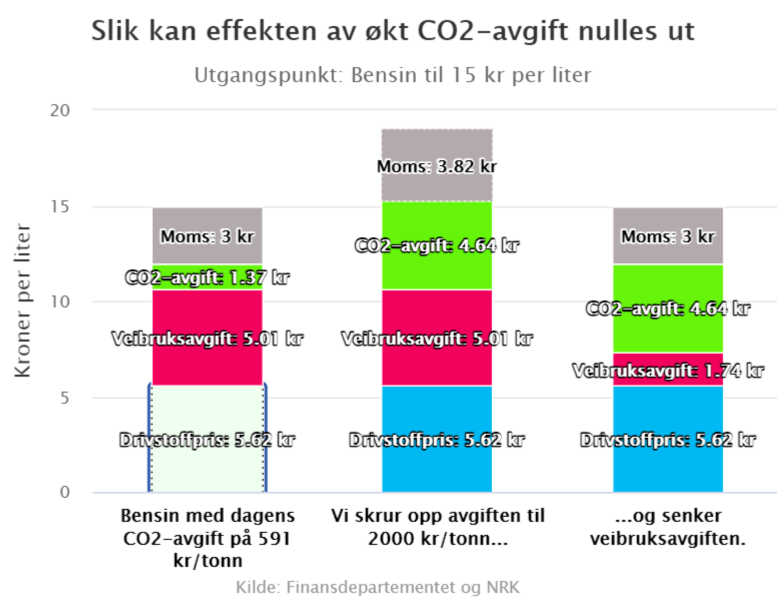


Figure 2. Proposed fuel taxes by 2030 in Norway by Norwegian political parties. Taken from NRK article [12].

On a long-term perspective, gasoline and diesel prices are steadily increasing over the years as seen in Figure 3.

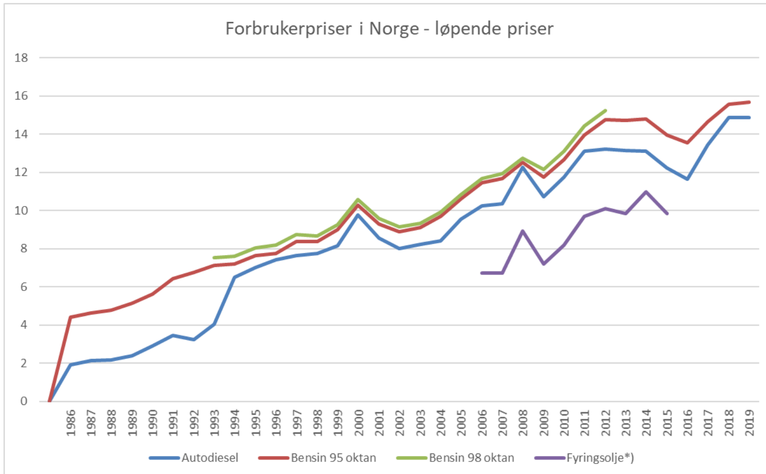


FIGURE 3. Retail fuel prices steadily increasing over the years in Norway in the time frame 1986-2019. Taken from SSB research [25].

4.5.1. *How do gas stations determine retail pump prices?* None of the gas stations monitored in this thesis except Tanken A.4 would like to disclose how they calculate their pump prices. Uno X has given a simplified breakdown and an estimate of what pump prices will cover [26]. The sister company YX, has also referred to the same calculations as Uno X A.7:

Station cut: 10 percent

- Transportation
- Station operating cost
- Marketing
- Administration fees
- Profits

Cost of fuel from the international market: 30 percent

- Price of fuel
- Season variation
- Exchange rates of USD-NOK
- Production volume
- Storage fees
- Market sentiment

Taxes: 60 percent

- CO2 tax

- Veibruksavgift
- 20 percent VAT

From this breakdown, it can be assumed that the station cut is 10 percent of the mean pump price. Calculating the cost price of fuel for each day then becomes:

$$(2)\quad costprice = pumpprice \cdot (1 - VAT) - veiavgift - CO2tax - 0.10 \cdot avg_{pumpprice}$$

This calculation does not take oil refinement cost into consideration. Crude oil is sold to refineries where it is distilled into different fuels such as gasoline and diesel, among many others. The cost of refinement is taken into consideration in the approximate 30 percent that is the cost of fuel from the Uno X breakdown, but it is difficult to estimate how much is of the cost price is refinement cost. Still, it should not heavily affect the correlation analysis between gasoline and diesel cost prices and Brent crude oil prices. Like other non-transportation operating costs, is not expected to vary much day to day.

Price spikes occur about once a week at all gas stations in Norway that have a dynamic pricing system. They do this because headquarters send out recommended prices that the franchisees must follow. Gas station chains profit more from people having to refuel at more expensive prices. Since fuel is an essential commodity that many people depend on for transportation and most of them do not keep inventory of it aside from the tank of their car, some people will have to refuel on expensive days as cars have to be refueled on a regular basis. It seems that a lot of people wait until their tank is almost empty before they consider stopping to refuel. In the Analysis section in Table 6, this thesis shows that most of the price spikes occur at the same time at all of the monitored gas stations in Stavanger. Since price spikes occur at the same time, people who are running low on fuel are going to be paying much more to refuel than those people who can wait for a cheaper price.

Like electricity bills, fuel prices fluctuate with market volatility, and at the end of the day, it is consumers who pay for these fluctuations. When it is cold and little wind outside, electricity markets like Norway's experience a price spike as water magazines run low, wind turbines stay still, and consumers use more power for heating. Consumers depend on having access to electricity and most of them do not know what the electrical power price is before the bill arrives. Similarly, fuel for cars is also essential for a lot of people, and refueling them can come at a high cost. In contrast to electricity prices however, fuel prices are promptly displayed on a large pricing board for all to see, but there is no indication of when prices are going to increase or decrease. It is a political question how much of these market fluctuations should affect the consumer. In extreme cases such as in Texas 2021 when inclement weather struck, some people were faced with life changing electrical bills as they were 70 times more expensive than normal [27]. In Norway electrical bills also increase several times over when cold weather strikes.

## 5. Methodology

This section encompasses what and how data has been collected as well as what the definition of a price spike is.

5.1. **Collecting data.** This thesis analyses prices of Brent crude oil, USD-NOK exchange rates, retail fuel prices and estimated retail cost prices (see the Pump prices subsection). Data are divided into two sets, the 2020 data set and the 2021 data set (see Table 2). The 2020 data serves as a test set for analysis and developing algorithmic trading models, and the 2021 data set is a validation set for those models. All definitions and models were made prior to analyzing the 2021 data to avoid over overfitting. Overfitting is when a function too closely corresponds to a particular data set, which could end up making the function inaccurate for other data sets. The 2021 data set will validate the models without being fitted for the 2021 data set.

Since gas station prices must be recorded in person every day, there are inevitably going to be missing some dates as it is time consuming to collect data. While the data collected is not perfect, most dates are covered and most of them have two prices recorded per day. Even though gasoline and diesel prices are only recorded twice a day, they do change more than twice a day as prices have been observed to change at least three times a day while out monitoring. It is likely they change more even more frequently than three time a day. Data collected for this thesis:

- From 20.03.20 - 10.01.21, gasoline and diesel prices were collected from Circle K Haugesundsgata 3 by Alex Bentley Nielsen. There are 257 observations in this data and 62 days without any data recorded in this time period (see Figure 4). Unlike Brent crude oil prices and USD-NOK exchange rates, gasoline and diesel prices fluctuate on holidays and weekends as well.
- From 04.01.21 - 20.05.21, gasoline and diesel prices were collected from Shell Madlaveien 263, Esso Gamle Madlaveien 1, Shell Haugåsveien 41, Uno X Breidablikkveien 2, Circle K Breiflåtveien 6, YX Vestre Karmøyveg 125 and Tanken Frakkgjerdvegen 124 by Ola Nes (see table 2). There are from 205 to 220 observations per station and 5 to 17 days with no data recorded

(see Figure 5). Circle K, Uno X and Tanken gas stations are unmanned, meaning they do not have a kiosk or any active employee working at the station.

- In both data sets, historical daily Brent crude oil prices were downloaded from Macrotrends [28]. Macrotrends has one price for Brent crude oil per trading day, which is the closing price for that day. There are on average 253 trading days in a year, which excludes weekends and holidays.

- In both data sets, historical USD-NOK exchange rates were downloaded from Excelrates [29]. This data has one price for the exchange rate between USD-NOK per trading day, which is recorded at 04:30 PM Central European Time and comes from the official exchange rates from the European Central Bank. For weekends and holidays, the last trading day exchange rate is used.

| Gas stations | Monitor time frame |
|---|---|
| Circle K Haugesundsgata 3 | 20.03.20 - 10.01.21 |
| Shell Madlaveien 263 | 04.01.21 - 20.05.21 |
| Esso Gamle Madlaveien 1 | 04.01.21 - 20.05.21 |
| Shell Haugåsveien 41 | 04.01.21 - 20.05.21 |
| Uno X Breidablikkveien 2 | 04.01.21 - 20.05.21 |
| Circle K Breiflåtveien 6 | 04.01.21 - 20.05.21 |
| YX Vestre Karmøyveg 125 | 04.01.21 - 20.05.21 |
| Tanken Frakkagjerdvegen 124 | 04.01.21 - 20.05.21 |

Table 2. Gas stations monitored in the 2020 and 2021 data sets.

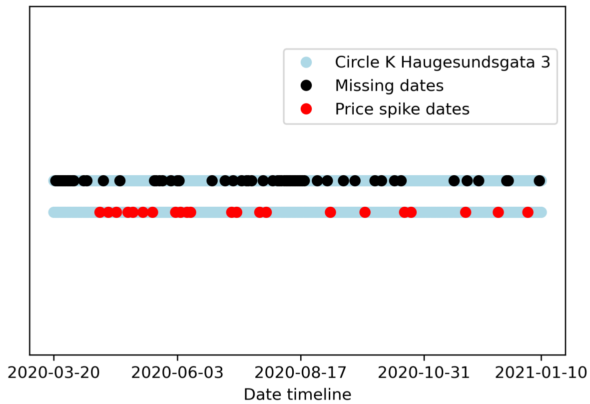


FIGURE 4. Circle K Haugesundsgata 3 missing data and price spike dates in the 2020 data. There are two weeks of missing data at the end of March and in August. In total, there are 235 days of data and 62 days without any data.

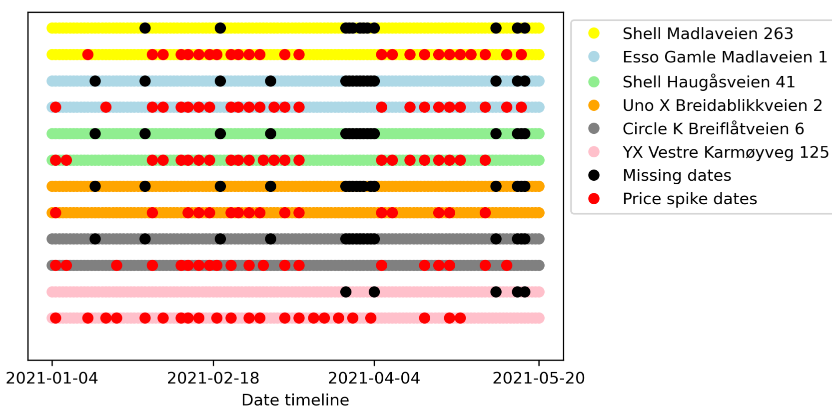


FIGURE 5. Missing data and price spike dates at the gas stations in the 2021 data set. In total, there are 122-131 days of data and 5-14 days without any data. Data from Tanken is complete and have no price spikes due to having fixed weekly prices.

Figure 6 and Figure 7 show maps over gas stations in Stavanger and Haugalandet. Marked in red are those monitored in 2021 and the one marked in yellow is the gas station monitored in 2020.

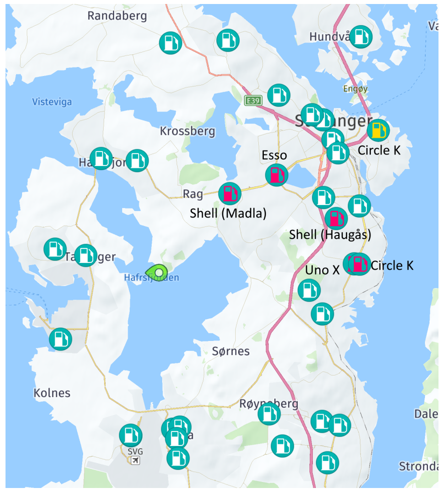


FIGURE 6. Gas station locations in Stavanger. Marked in red from left to right: Shell Madlaveien 1, Esso Gamle Madlaveien 1, Shell Haugåsveien 41, Uno X Breidablikkveien 2 and Circle K Breiflåtveien, which were monitored in 2021. The marked in yellow is Circle K Haugesundsgata 3, which was monitored in 2020 to 2021. The figure is generated from HERE WeGo's map over Rogaland from the HERE WeGo application [30].

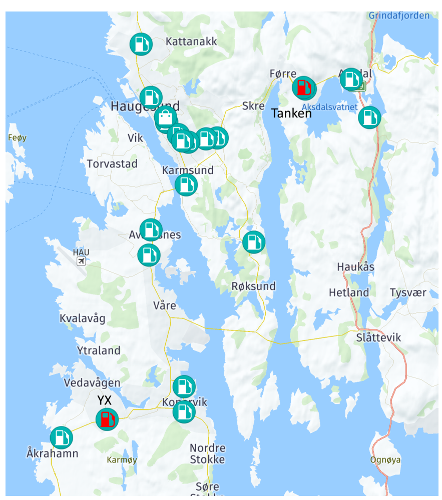


FIGURE 7. Gas station locations in Haugalandet. Marked in red from left to right: YX Vestre Karmøyveg 125 and Tanken Frakkagjerdvegen 124, which were monitored in 2021. The figure is generated from HERE WeGo's map over Rogaland from the HERE WeGo application [30]

The selection of gas stations monitored in this thesis are based of the proximity of the data collectors since prices must be recorded in person. To have a greater variety of gas station chains, YX and Tanken are also represented even though they are not located in Stavanger. Prices are recorded in a notebook along with the date and time rounded off to closest 5th minute. Later, the notes are put into an Excel spreadsheet A.2. Tanken prices are sent by email and YX current prices are obtained through phone calls. Shell and Circlek K have two stations represented.

All data collected, gas station prices, Brent crude oil prices, USD-NOK exchange rates and estimated volatility from the GARCH(1,1) method are put into the Excel spreadsheet A.2. This data is then imported into Python where functions for analyzing data, plots and algorithmic trading models are developed A.3.

5.2. **Interpolation.** There are some missing fuel price data in both data sets. When analyzing, one could look past these missing data points, or one could use interpolation. Interpolation is a statistical method by which related values are used to estimate unknown values [31]. There are several ways to do interpolations. There are several different types of interpolation such as piece-wise constant-, linear-, polynomial- and spline-interpolation. They all have different uses as some require less computation than others but lack the accuracy. Using interpolation for the missing data could be useful, however, none of these would accurately reflect price fluctuations since fuel prices tend to increase substantially once, then decrease by smaller amounts the rest of the time. Interpolation would not reflect the price spike. Therefore, it was not used. For correlation analyses and volatility calculations, the data were simply analysed sequentially.

5.3. **Price spikes.** Gas stations change their prices in a cyclic manner. Local gas stations are given recommended prices from headquarters about once a week and then throughout the week, their fuel prices are subsidized to compete with other local stations. Prices usually decrease with 1 krone or less each time prices change, however, when recommended prices are sent out, fuel prices increase with more than 1 krone, but it only stays this expensive for a short while before decreasing again. Within a couple of days, prices are around where they usually are after a price spike has occurred. This is what this thesis defines as a positive price spike. This sort of price pattern is called an asymmetric price pattern and is sometimes referred to as Rockets and Feathers because prices increase quickly, and then gradually decrease [32]. The opposite would be Balloons and Rocks, where prices slowly increase and quickly decrease, or what this thesis calls negative price spikes. Figure 8 and 9 show histograms of how price changes are distributed at the different gas stations monitored in 2020 and 2021.

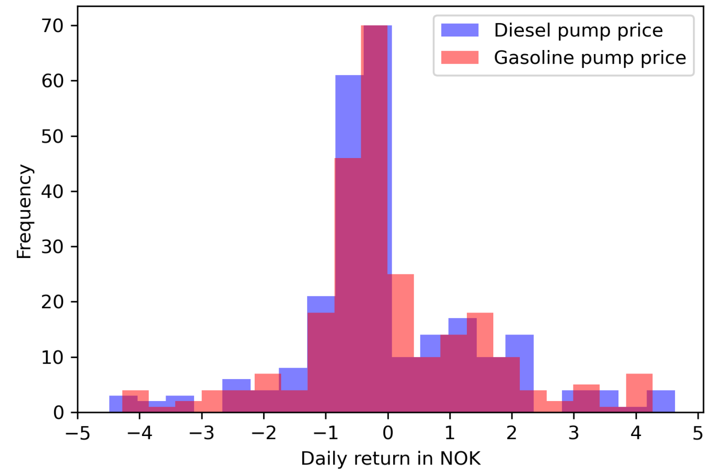


FIGURE 8. Histogram of daily returns of pump price gasoline and diesel pump prices in kr/l at Circle K Haugesundsgata 3 in the 2020 data set.

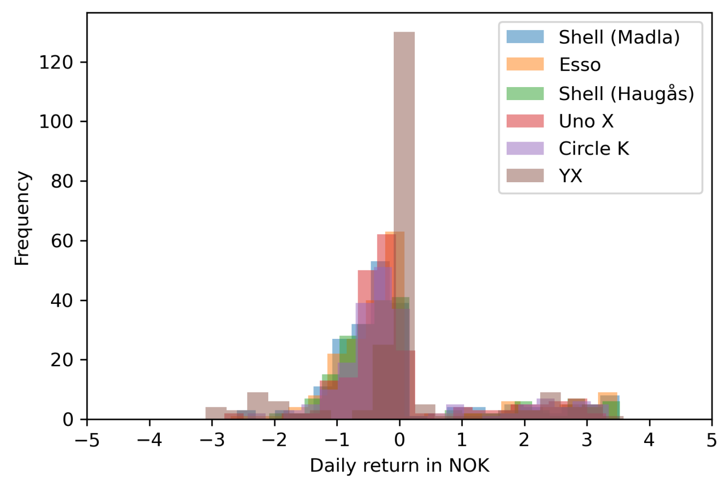


FIGURE 9. Histogram of daily returns of pump price gasoline in kr/l at the gas stations monitored in the 2021 data set.

Fuel prices decrease more than twice as frequently than they increase. Figure 8 shows that pump prices usually decrease by 1 krone or less, however, when they increase, they usually increase in the vicinity of 1.5 kroner. Therefore, defining a price spike as more than 1 kr could be appropriate, however, there are some days in the data sets missing, which means there could be room for calculating spikes on the day after the real spike day. To ensure that most spikes are counted regardless of missing data, the definition of a spike value should be between a value low enough to register when a price cycle has restarted and be a value high enough to where it does not register small price increases even though they are rare. Since gasoline and diesel prices also tend to be a constant 1 kr apart no matter if prices are cheap or expensive (see Gasoline and diesel correlation section), a constant spike definition would be more suitable than a percentage one. Therefore, the definition is: A price spike occurs if the pump price increases by 1.5 kr or more in one price change and then decreases by 1.5 kr or more within the next two days. Figure 10 shows that there are clearly more positive than negative price spikes with this definition as well as many other spike constants. Using this definition of a price spike, both the 2020 and 2021 data sets have a lot more positive than negative price spikes (see Table 3). The average number of price spikes per gas station from the 2021 data set is 21.83. The 2021 data set is 20 weeks long, meaning there are more than one price spike per week on average.

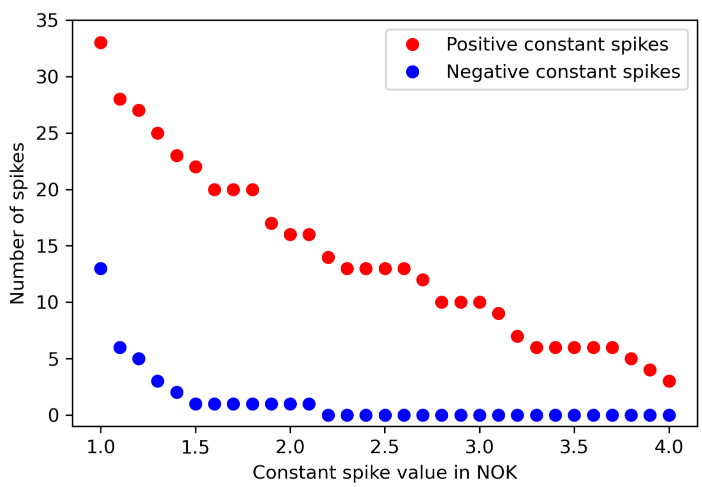


FIGURE 10. Distribution of constant positive and negative price spikes at Circle K Haugesundsgata 3 in the 2020 data set.

There are on average about 1 price spike a week in the 2021 data set as there are on average 21.83 price spikes per gas station on a 20 week period. Looking at the distribution of price spikes among the different gas station in the 2021 data set in Table 3, all Poisson errors are within the square root of the mean, except for Uno X. Uno X could have a different distribution of price spikes than the rest, however, from experience, it seems like Uno X has the shortest price spike length, meaning they are the last gas station chain to increase prices to recommended prices and they are the first to decrease it, meaning it is more likely to not record price spikes at Uno X compared to other gas stations.

| Gas station (2021) | Shell (Madla) | Esso | Shell (Haugås) | Uno X | Circle K | YX |
|---|---|---|---|---|---|---|
| Positive spikes | 25 | 24 | 23 | 16 | 20 | 23 |
| Negative spikes | 3 | 4 | 6 | 2 | 5 | 5 |
| No. obs. | 210 | 206 | 205 | 206 | 205 | 219 |
| Poisson errors | 3.17 | 2.17 | 1.17 | -5.83 | -1.83 | 1.17 |

TABLE 3. Distribution of constant positive and negative price spikes at the gas stations monitored in the 2021 data set. The number of observations is not the same as number of days since most days have two observations. The mean number of price spikes at gas stations is approximately 21.83. The square root of the mean is 4.67.

5.3.1. *Edgeworth cycles.* An Edgeworth cycle [33] describes a price pattern many gas stations in the world follow. This pattern takes on a sawtooth shape (see Figure 11). Like already seen, retail fuel prices in Norway have more decreases than increases, however, when they do increase, they tend to form a spike. This is very much like what the Edgeworth cycle describes. This is what is called asymmetric pattern of prices since there are a lot more decreases than increases. This phenomenon occurs when a supplier of commodities undercuts the competition to gain market share. Both businesses continue to undercut the other for market share until they reach a point where no one can undercut any more without losing money. One of them is then forced to increase the price again since lowering the price will not secure a large enough market share to sustain prices. The other businesses are soon to follow because they can now undercut by much less of a margin, and so begins a new cycle again [34].

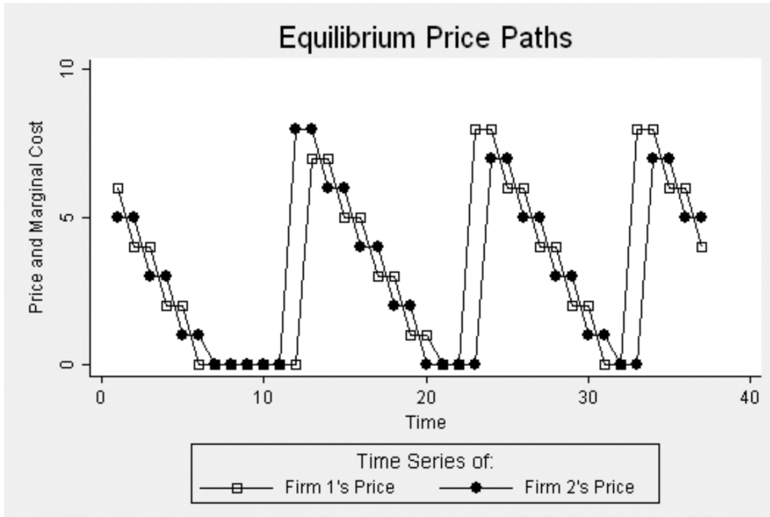


FIGURE 11. Example of Edgeworth Cycles between two businesses. Taken from Edgeworth Price Cycles: Evidence from the Toronto Retail Gasoline Market [34].

This pattern is found at gas stations in Norway as well. In contrast to other countries, cycles are not prompted by prices like in Figure 11, but at specific times [4]. Gas stations in Norway have weekly cycles, but the last price that prompts the restart, are different each time. Still, a cycle that restarts on a specific day of the week is beneficial for price sensitive consumers because it is predictable. While private consumers can predict the retail fuel market and make a decision of whether to only refuel on cheaper days, commercial consumers might not care as much and this is what gas stations profit off during more expensive days for the most part [4].

Gas station franchisees make a flat fee per liter fuel sold and fuel profits are unaffected by increases or decreases. Most franchisees do not make most of their profits from fuel, but other services such as sales from the kiosk, car washes etc. Still, franchisees profit from having low fuel prices as they entice customers to come to their gas stations where they might use some of their other services [35].

There have been observed changes in the price cycles of gas stations in Norway before [4], however, the findings from the Analysis section suggest that there is not a weekly cycle with a given day where the price cycle restarts. Spikes are found on nearly every day of the week on every monitored gas station (see Analysis section Table 4 and 5). The pattern still has the sawtooth shape like in the Edgeworth cycles, but they are not predictable to the average consumer like it used to be. This unpredictability is beneficial for gas stations as both commercial and private consumers cannot necessarily decide when to refuel and will ultimately have to refuel on more expensive days at times.

Figure 12 shows how gasoline prices change at the Circle K from 2021, and the graph does carry some resemblance to an Edgeworth cycle. These cycles are short and have drastic changes. Most of the gas stations from the 2021 data set have similar graphs to this Circle K, however, YX from Karmøy differs (see Figure 13). This gas station has more consistent pricing except for when there is a price spike. This could be caused by different competitive environments. There are fewer gas stations and less competition at Karmøy compared to Stavanger.

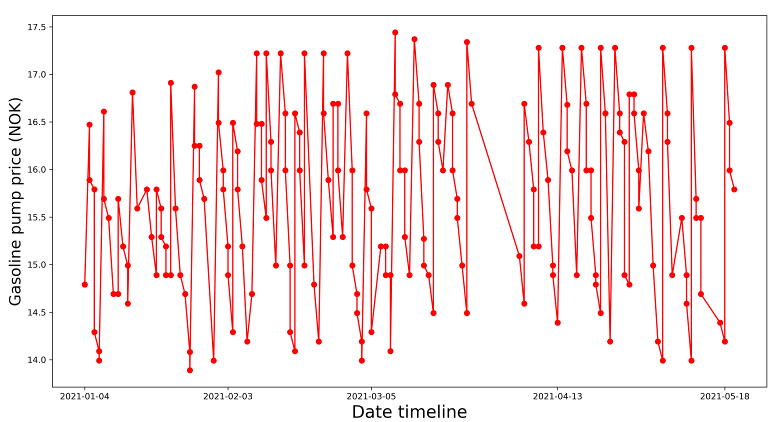


Figure 12. Daily price fluctuations of pump price gasoline at Circle K Breiflåtveien 6 in the 2021 data set.

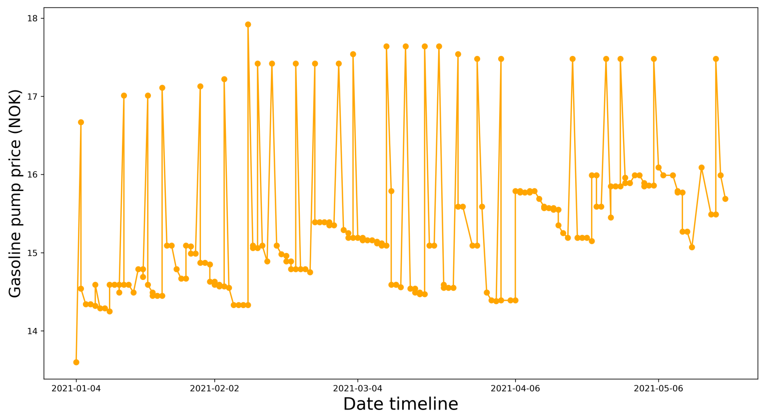


FIGURE 13. Daily price fluctuations of pump price gasoline at YX Vestre Karmøyveg 125 in the 2021 data set.

Tanken is the only gas station chain monitored in this thesis that does not update their prices daily. Instead, prices are updated once a week, and on some very rare instances, twice a week. Prices were disclosed over email. These prices come from Tanken headquarters and include CO2 tax, veiavgift and the cost price of fuel. Franchisees are free to adjust the station cut themselves, and prices must have VAT added A.4. Therefore, these prices are recommended by the gas station chain owner, Joar Skorpe. Figure 14 shows a plot over the daily price fluctuations sent out, and compared to other gas station chains that have daily fluctuations, these prices are constant throughout the week which makes Tanken a predictable gas station to refuel at. Compared to other gas station chains, Tanken tends to be more expensive (calculated from cost prices), however, since Tanken has no daily price fluctuations, consumers are guaranteed to avoid price spikes. This means that Tanken would be the optimal gas station to refuel at during price spike days or days soon after a price spike has occurred.

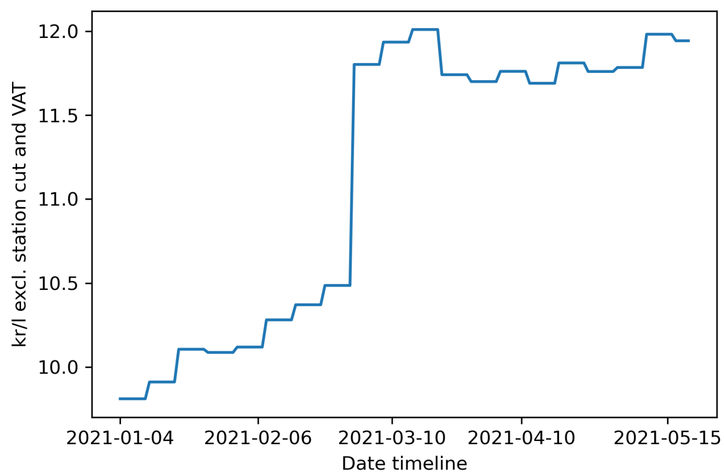


FIGURE 14. Daily price fluctuations of gasoline prices sent from Tanken Frakkagjerdvegen 124 in the 2021 data set. Station cut and VAT are excluded because that is how the data was provided.

## 6. Analysis

In the Analysis section, data collected in the 2020 and 2021 data set have been analyzed to find patterns in the retail fuel market, most notably to see if there is a pattern to the price spikes occurring at the start of a new Edgeworth cycle. Since gasoline and diesel are almost perfectly correlated with each other at most gas stations, only gasoline prices will be used in further analysis for simplicity. Other analyses include correlation between cost price gasoline and Brent crude oil prices, correlation between different gas station chains, checking spike timing across gas stations and comparing volatility between cost price gasoline and Brent crude oil prices both by returns and by the use of GARCH(1,1).

6.1. **Data.** Table 4 and 5 show a breakdown of what the mean gasoline price is for each day of the week. When first analyzing the 2020 data set, it would seem like the weekend is generally cheaper than the rest of the week. In 2020, the cheapest days on average were Saturday and Sunday. In 2021, this is no longer the case as Monday and Tuesday are the cheapest. Looking at how price spikes are distributed, it would seem like they are somewhat evenly distributed, but both data sets have none-to-few price spikes observed on Saturdays. That said, Saturdays are the least monitored day of the week in the 2021 data set, and there have been observed price spikes on gas stations that have more observations on that day of the week, meaning it could be an insignificant finding.

In contrast to other articles [3] and papers [4] from 2009 and 2016 that suggest gas stations have price spikes on Mondays and Thursdays, both the 2020 and 2021 data sets suggest the price pattern has changed since then. There is no longer any predictability of which day of the week there is going to be a price spike, or more accurately, there is no day of the week has no price spikes. This makes it difficult for price sensitive consumers to have any weekly refueling routine as weekday prices change from week to week.

One of the phenomena that motivated the writing of this thesis, is that most price spikes seem to take place on the same days and around the same time for all gas stations in the area, which is usually around rush hour. If there is a price spike at one gas station, the others follow shortly thereafter. Referring to the Edgeworth cycle; the reason why an Edgeworth cycle restarts, is because businesses no longer earn market share by undercutting their competitors since undercutting any more would make them unprofitable. When it is no longer possible to gain market share, one station goes back to the recommended expensive price and competitors can undercut by much less and still gain market share, thus the cycle restarts. Gas station headquarters decide when cycle restarts by sending out recommended prices. In the 2020 data set, only one gas station was monitored, however, looking at the 2021 data set, most price spikes do indeed occur at the same time (see Table 6). Since there are missing dates, there is a slight delay between monitoring each gas station and different gas stations start their price spikes later than others, this comparison is not going to be perfect. Still, it is conservative in that it will not show price spikes happening on different days, only the ones that appear on the same exact day. Therefore, establishing that there is a high percentage of spikes occurring on the same day is significant. Aside from YX, most gas stations do have a high percentage of their spikes occurring on the same day. This YX gas station is not located in Stavanger, but on Karmøy, and seeing how different this station is, it could suggest that the retail gasoline market on Karmøy is different than from the market in Stavanger, however, having only one gas station from Karmøy is not enough to represent the local retail fuel market there.

| Weekday | All | Mon | Tue | Wed | Thu | Fri | Sat | Sun |
|---|---|---|---|---|---|---|---|---|
| Mean (kr/l) | 13.75 | 13.63 | 14.22 | 13.79 | 13.93 | 14.01 | 13.29 | 13.29 |
| No. spikes | 22 | 4 | 4 | 4 | 4 | 1 | 0 | 5 |
| No. obs. | 257 | 36 | 38 | 34 | 36 | 41 | 33 | 39 |

TABLE 4. Distribution of day of the week mean gasoline prices, price spikes and number of observations at Circle K Haugesundsgata 3 in the 2020 data set.

| Shell (Madla) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Weekday | All | Mon | Tue | Wed | Thu | Fri | Sat | Sun |
| Mean | 15.72 kr/l | 15.47 kr/l | 15.35 kr/l | 15.83 kr/l | 15.98 kr/l | 15.84 kr/l | 15.74 kr/l | 16.10 kr/l |
| No. spikes | 25 | 1 | 4 | 6 | 5 | 2 | 2 | 5 |
| No. obs. | 208 | 36 | 38 | 37 | 36 | 30 | 15 | 16 |
| Esso | | | | | | | | |
| Weekday | All | Mon | Tue | Wed | Thu | Fri | Sat | Sun |
| Mean | 15.68 kr/l | 15.39 kr/l | 15.46 kr/l | 15.60 kr/l | 16.05 kr/l | 15.78 kr/l | 15.57 kr/l | 16.14 kr/l |
| No. spikes | 24 | 1 | 6 | 6 | 4 | 0 | 1 | 6 |
| No. obs. | 204 | 36 | 37 | 37 | 36 | 30 | 12 | 16 |
| Shell (Haugås) | | | | | | | | |
| Weekday | All | Mon | Tue | Wed | Thu | Fri | Sat | Sun |
| Mean | 15.64 kr/l | 15.46 kr/l | 15.23 kr/l | 15.56 kr/l | 15.99 kr/l | 15.82 kr/l | 15.55 kr/l | 16.14 kr/l |
| No. spikes | 23 | 1 | 4 | 5 | 5 | 2 | 0 | 6 |
| No. obs. | 203 | 36 | 37 | 37 | 36 | 30 | 11 | 16 |
| Uno X | | | | | | | | |
| Weekday | All | Mon | Tue | Wed | Thu | Fri | Sat | Sun |
| Mean | 15.34 kr/l | 15.17 kr/l | 14.98 kr/l | 15.26 kr/l | 15.67 kr/l | 15.46 kr/l | 15.22 kr/l | 15.82 kr/l |
| No. spikes | 16 | 1 | 3 | 4 | 3 | 1 | 0 | 4 |
| No. obs. | 204 | 36 | 37 | 37 | 36 | 31 | 11 | 16 |
| Circle K | | | | | | | | |
| Weekday | All | Mon | Tue | Wed | Thu | Fri | Sat | Sun |
| Mean | 15.65 kr/l | 15.41 kr/l | 15.38 kr/l | 15.62 kr/l | 15.89 kr/l | 15.96 kr/l | 15.41 kr/l | 15.90 kr/l |
| No. spikes | 20 | 1 | 5 | 3 | 3 | 3 | 0 | 5 |
| No. obs. | 203 | 36 | 37 | 37 | 36 | 30 | 11 | 16 |
| YX | | | | | | | | |
| Weekday | All | Mon | Tue | Wed | Thu | Fri | Sat | Sun |
| Mean | 15.33 kr/l | 15.02 kr/l | 15.36 kr/l | 15.26 kr/l | 15.46 kr/l | 15.26 kr/l | 15.29 kr7l | 15.95 kr/l |
| No. spikes | 23 | 1 | 4 | 3 | 5 | 2 | 2 | 6 |
| No. obs. | 217 | 38 | 37 | 39 | 37 | 30 | 19 | 17 |

Table 5. Distribution of day of the week mean gasoline prices, price spikes and number of observations at the gas stations monitored in the 2021 data set. Since Tanken only updates prices once a week, it is not possible for it to have any price spikes. Tanken prices are also disclosed with station cut and VAT excluded, making mean comparisons with other gas stations have no purpose.

| 2021 | Shell (Madla) | Esso | Shell (Haugås) | Uno X | Circle K | YX |
|---|---|---|---|---|---|---|
| Shell (Madla) spikes | 100% | 84% | 76% | 60% | 64% | 56% |
| Esso spikes | 88% | 100% | 83% | 63% | 67% | 58% |
| Shell (Haugås) spikes | 83% | 87% | 100% | 65% | 74% | 52% |
| Uno X spikes | 94% | 94% | 94% | 100% | 81% | 56% |
| Circle K spikes | 80% | 80% | 85% | 65% | 100% | 60% |
| YX spikes | 61% | 61% | 52% | 39% | 52% | 100% |

Table 6. Percentages of price spikes occurring on the same day at the gas stations in the 2021 data set.

6.2. **Pearson Correlation.** Correlation is a statistical measurement between two data sets. A positive correlation is when one data set increases or decreases the other data set does so as well, and when it is negative the data sets do the opposite of each other, meaning if one increases the other one decreases and vice versa. Usually, correlations are normalized to vary between +1 and -1, where +1 and -1 are perfect correlations and 0 is no correlation at all [36]. While correlation can say something about the relationship between two variables, it is not a proof of causality. Correlation does not imply causation; however, the opposite is true. If two variables cause each other, they must be correlated [36].

Pearson correlation, also called bivariate correlation, is a statistical linear measurement between two data sets. It is the co-variance between data sets that is divided by the standard deviation, which is then normalized. When calculating the Pearson correlation, the mean of the data sets is subtracted from each entry, which then makes the correlation vary between -1 and 1 [36]. The Pearson correlation is strictly linear, meaning that it leaves out many other models of correlation. Pearson correlation has been used in many different situations like studying black hole binary mergers [37]. The Pearson Correlation is defined by this equation:

$$X = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2\sum(y-\bar{y})^2}} \tag{3}$$

When taking the Pearson correlation on the collected data, the correlation analysis is done by time periods of 100 data points for the 2020 data set and 2021 data set. 100 data points is a large enough interval to where a strong correlation will be interesting to look at and is also not small enough to where chance of getting a randomly strong correlation where there should not be one is mitigated. Pearson correlation with Brent crude oil prices in 2021 only use 50 data points because there are less than 100 data points in total for Brent crude oil in the time frame within the 2021 data set. Other intervals such as 20, 30 and 50 data points did not provide any strong correlations or a signify any change in correlations. Therefore, 100 data points will be used for Pearson correlations where there are more than 100 data points, and 50 will be used where there are less than 100 data points to analyze.

6.2.1. *Gasoline and diesel prices.* Both gasoline and diesel prices were collected in this thesis. These prices are strongly correlated with each other and most of the time the price difference between them is 1 krone at each gas station. There are however exceptions shown in Figure 15 and 16. Gasoline and diesel price differences can be less to the point where they are the around the same price and on very rare occasions, gasoline is slightly cheaper than diesel. Normally however, gasoline is 1 krone more expensive than diesel no matter what the price, unless there is a price spike. Then gasoline tends to be slightly more than 1 krone more expensive. Also, unless there is a price spike, the last digits in both gasoline and diesel prices are almost always 9. This is for buyer psychology purposes since 15.99 kr/l looks cheaper than 16.00 kr/l even if it makes a minuscule difference to the average consumer.

Figure 15 and 16 show very strong correlations between gasoline and diesel for both 2020 and 2021 as to be expected. In 2020, there is a dip from May to June, which is most likely caused by the COVID-19 pandemic lockdown since there were big fluctuations in the oil market and fuel market. On April 20th, an oil benchmark, West Texas Intermediate, closed on a negative value, which was the first time in history oil had ever had negative price [38]. Oil futures expiring in May were affected by this, which could explain the drop in gasoline and diesel correlation. Towards July it stabilizes again though and stays stable for the rest of the monitor duration.

Most of the gas stations have very strong correlations all throughout the monitor time frame, except for YX and Tanken, which seems to steadily decrease for the latter end of the monitor time frame. Tanken has a different pricing strategy than most other gas stations since they only update prices once a week. Prices obtained in this thesis are not pump prices, but prices excluding station cut and VAT, which could be the reason why prices are less correlated with each other compared to other stations. Esso Gamle Madlaveien 1 has a sharp drop in correlation starting in February. Gasoline and diesel prices are more often not 1 kr apart compared to prices at other station after February. Prices tend to be closer to each other when not 1 kr apart. Table 7 shows the mean Pearson correlation values for gasoline and diesel prices, and these prices are strongly correlated with each other on most gas stations. Both prices behave similarly since they for the most the time have 1 krone difference and increase and decrease at the same time. Therefore, only gasoline prices will be shown in graphs, analyses, and algorithmic trading models from now on for simplicity.

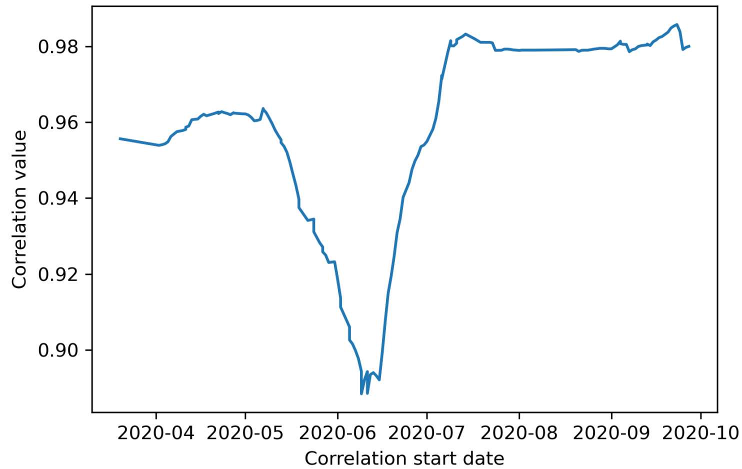


FIGURE 15. Gasoline and diesel pump prices Pearson correlation with 100 data points at Circle K Haugesundsgata 3 in the 2020 data set. The timeline shows the first date of the 100 data points. There is a dip in correlation in May-June. This is most likely caused by the big oil price fluctuations of April 2020 that affected oil future contracts that expired in May.

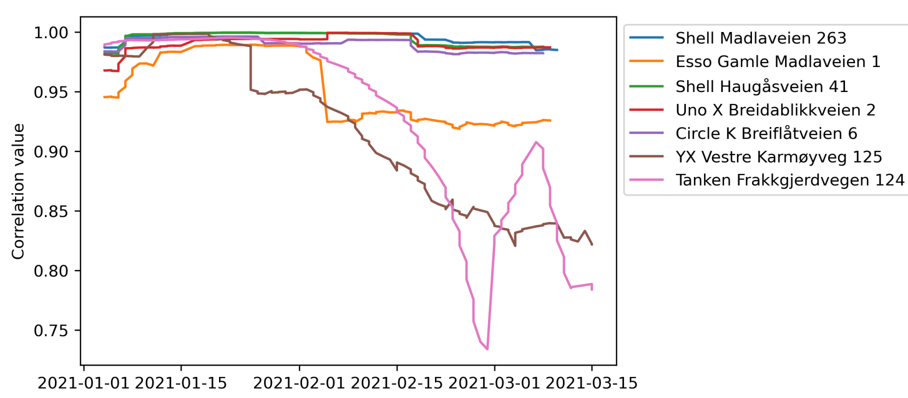


FIGURE 16. Gasoline and diesel pump prices Pearson correlation with 100 data points at the gas stations in the 2021 data set. The timeline shows the first date of the 100 data points. Fuel prices from Tanken are not pump prices, but are fuel prices without VAT and station cut.

| Gasoline and diesel mean Pearson correlation | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Gas station | Circle K (2020) | Shell (Madla) | Esso | Shell (Haugås) | Uno X | Circle K (2021) | YX | Tanken |
| Correlation value | 0.9565 | 0.9956 | 0.9524 | 0.9946 | 0.9905 | 0.9897 | 0.9156 | 0.9295 |

Table 7. Mean Pearson correlation values of pump price gasoline and diesel at the gas stations in the 2021 data set.

6.2.2. *Gas station correlation.* Gas stations that are in close proximity to each other have to compete with each other. Stations follow Edgeworth cycles because they undercut each other to gain market share. This cyclic pattern makes fuel prices have strong correlation across local gas stations. Table 7 and Figure 17 show that gasoline prices in Stavanger are strongly correlated across gas stations. Circle K is usually the first gas station to get price spikes, which could be the reason why its correlation is not as strong as other stations. Local minimum prices in Edgeworth cycles are at the end of the cycle, meaning the price is cheapest right before becoming the most expensive of the cycle. This means that if prices are monitored just as Circle K has increased its prices, several of the other gas stations might still be on their cheap fuel prices, making their correlations with Circle K weaker. YX is the least correlated gas station because it is located in a different competitive environment, Karmøy. There are more gas stations in close proximity of each other in Stavanger, which could explain why gas prices fluctuate less at Karmøy.

| 2021 Mean Pearson correlation | Shell (Madla) | Esso | Shell (Haugås) | Uno X | Circle K | YX (Karmøy) |
|---|---|---|---|---|---|---|
| Shell (Madla) | 1 | 0.8365 | 0.8226 | 0.8506 | 0.7347 | 0.4577 |
| Esso | 0.8365 | 1 | 0.8718 | 0.9109 | 0.6566 | 0.3832 |
| Shell (Haugås) | 0.8226 | 0.8718 | 1 | 0.9094 | 0.6678 | 0.3435 |
| Uno X | 0.8506 | 0.9109 | 0.9094 | 1 | 0.5973 | 0.4194 |
| Circle K | 0.7347 | 0.6566 | 0.6678 | 0.5973 | 1 | 0.4333 |
| YX (Karmøy) | 0.4577 | 0.3832 | 0.3435 | 0.4194 | 0.4333 | 1 |

Table 8. Mean Pearson correlation between the gas stations monitored in the 2021 data set. YX is located at Karmøy in a different local competitive environment, which could explain why fuel prices are less correlated with prices in Stavanger. Circle K is usually the first gas station to get price spikes, which could explain why it is the least correlated gas station in Stavanger in the 2021 data set.

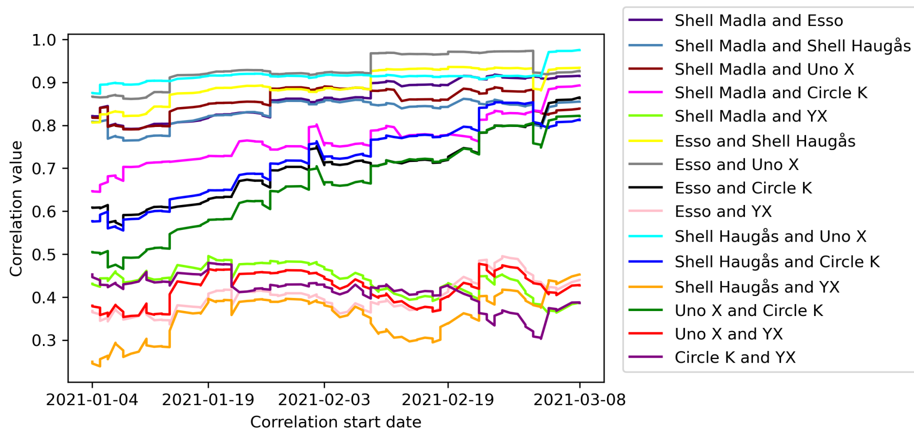


FIGURE 17. Pearson correlation using 100 data points between the gas stations monitored in the 2021 data set.

6.2.3. *Brent crude oil and gasoline correlation.* The strength of a correlation can change over time. Since Brent crude oil is the primary raw material of gasoline and diesel, it would be interesting to see if there exists a shifted correlation that is stronger than the original one with no shift. To do this, one variable can start at a later date than the other, simulating lag days. Through the mean correlation, one can see what amount of lag gives the strongest correlation on average.

The correlation between cost price gasoline and Brent crude oil is not very strong. The Brent crude oil price is in US dollars and per barrel (approximately 159 liter). Taking the mean of the Pearson correlation of these with 100 data points with no lag days between the data, the correlation value was only 0.30 in 2020. In 2021 the mean ranged from -0.09 to 0.10 with 50 data points with Pearson correlation. Data sets can be shifted using lag days on gasoline, meaning comparing today's gasoline price with older Brent crude oil prices. For the 2020 data set, 15 days of lag proved to grant the strongest correlation of 0.41, which is still not a strong correlation. For the 2021 data set there does not seem to be a consensus among gasoline prices from different gas stations of what lag interval is the most correlated with Brent crude oil prices. Judging by the mean correlation values, there is almost no consistent correlation at all between cost price gasoline and Brent crude oil prices. Figure 18 shows the correlation between cost price gasoline at Circle K Haugesundsgata 3 and Brent crude oil prices over time both with and without lag days and Figure 19 shows the correlation of cost price gasoline of the 2021 gas stations and Brent crude oil prices. Taking USD-NOK exchange rates into account, the correlation for the 2020 data set becomes slightly weaker as the mean correlation value without lag drops to 0.23 and to 0.40 with 18 days of lag, which is the most correlated lag time.

Gasoline and diesel sold at gas stations in Norway are primarily made from Brent crude oil, meaning there should be a correlation between them. Even though causality implies correlation, it does not mean the correlation has to be linear [36]. It is difficult to say why there is not a strong correlation. It could be another form of correlation other than the Pearson correlation. Not taking refinery cost into the calculation affects it, as well as the Uno X simplified breakdown of calculating fuel cost price A.5 might not be accurate.

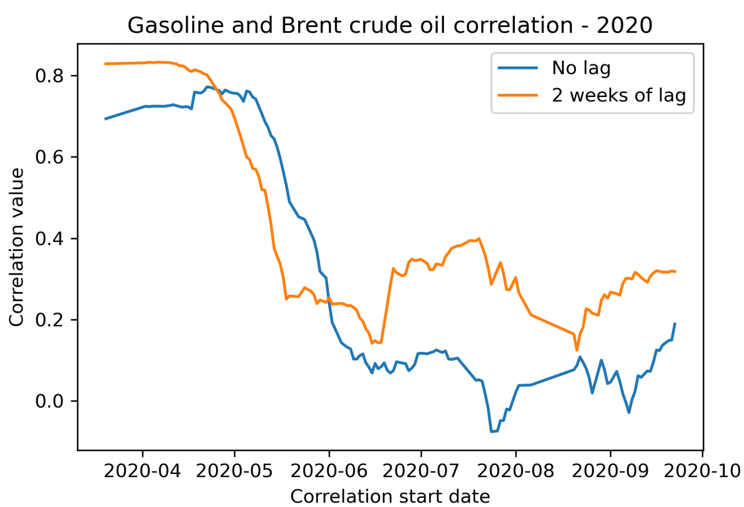


Figure 18. Pearson correlation of cost price gasoline at Circle K Haugesundsgata 3 in the 2020 data set and Brent crude oil prices with 100 data points with and without lag on gasoline prices.

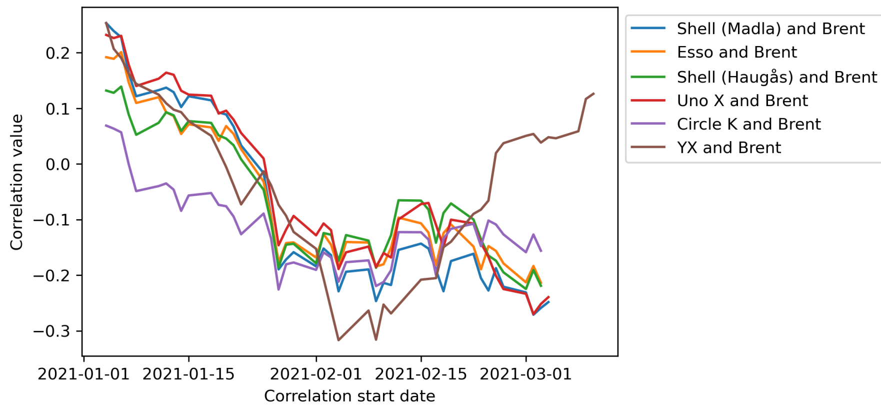


FIGURE 19. Pearson correlation of cost price gasoline at the gas stations monitored in the 2021 data set and Brent crude oil prices with 50 data points without lag on gasoline prices.

Even though there was not found a strong correlation between cost price gasoline and Brent crude oil prices, does not necessarily mean that the findings are statistically significant. Comparing the correlation method used in this thesis across different components that are related to the oil and fuel market however, the correlation between cost price gasoline and Brent crude oil prices are quite weak, whereas the correlation between gasoline and diesel and different gas stations are unquestionably strong. Judging from Figure 20, the Pearson correlation between the last day prices from gasoline and diesel prices using 50 data points appear to be near perfectly correlated compared to cost price gasoline and Brent crude oil prices using the same Pearson correlation. From this correlation analysis, there seems to be no connection between retail fuel prices in Stavanger and Brent crude oil prices even though there should be one.

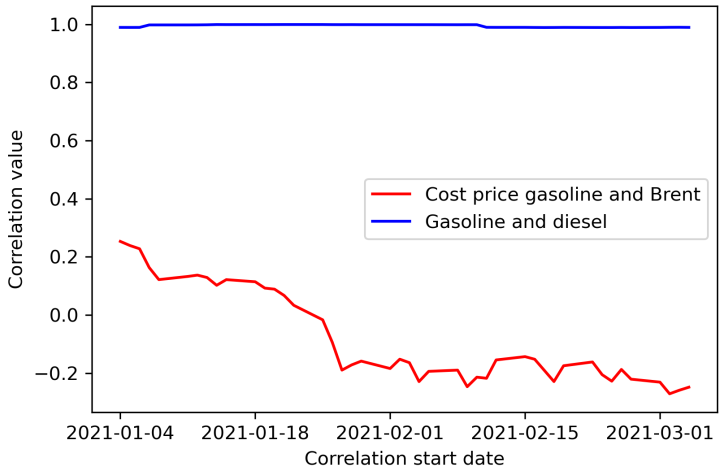


Figure 20. Comparing cost price gasoline (Shell Madla) and Brent crude oil prices (upper left), gasoline and diesel pump prices (Shell Madla) and gas station gasoline pump prices (lower left: Shell Madla and Esso, lower right: Shell Madla and YX) using Pearson correlation with 50 data points.

6.3. **Volatility.** Volatility is a statistical measure of how an asset is subject to change and how its returns are dispersed. Mathematically, it is the standard deviation of continuously compounded return [5]. If an asset is highly volatile, it carries high risk, but can also provide high gains. If an asset is volatile, there exists an opportunity to profit off it. Oil is considered to be volatile. It seems that fuel prices in Stavanger are quite volatile as the prices fluctuate a lot from day to day or in some cases just hour to hour. During the start of the COVID-19 pandemic, economic markets, including oil markets, experienced above normal volatility levels. Due to this, some of the data recorded in March-June can have higher volatility than normal.

Many people wonder why fuel prices do not follow fluctuations of Brent crude oil prices during huge market fluctuations. Some articles suggest this is because oil only makes up for about 30 percent of the pump price [3]. To take this into account, this thesis compares the volatility of cost price gasoline and Brent crude oil prices through looking at daily, weekly and monthly returns as well as estimating volatility through the use of GARCH(1,1).

SSB has a comparison of price fluctuations between gasoline, diesel and raw oil from the international commodity market (see Figure 21).

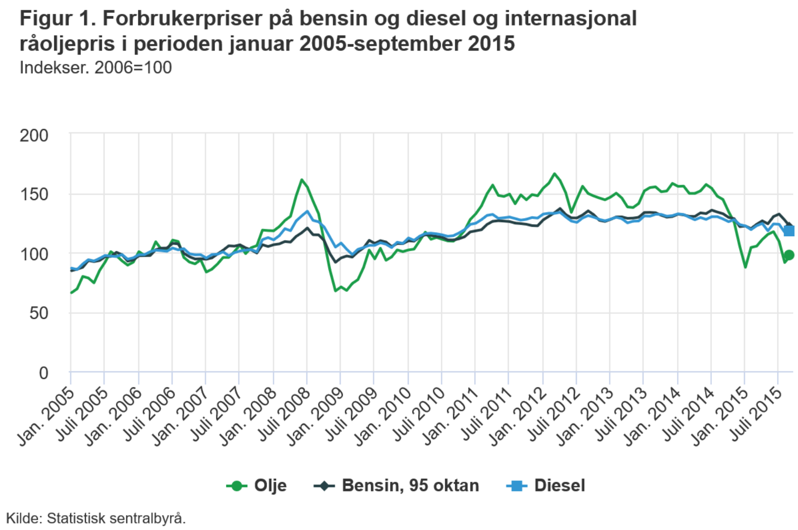


FIGURE 21. Comparing monthly returns between gasoline and diesel prices at gas stations in Norway and raw oil prices from the international commodity market from 2005-2015 [25]

6.3.1. *Comparing returns.* Since gasoline can have up to two prices per recorded day in this thesis' data sets while Brent crude oil only has one, daily gasoline prices are combined by taking the mean of the data per day. By comparing moving averages of daily returns of cost price gasoline and Brent crude oil, gasoline is unquestionably more volatile judging by the return fluctuations (see Figure 22).

Over a longer period of time such as averages of months, volatility is higher in oil prices than in the retail fuel market, according to SSB [24]. Looking at different return intervals, both daily and weekly returns (see Figure 22 and 23) have clearly more volatility in cost price gasoline compared to Brent crude oil. It is only until monthly returns (see Figure 24) they appear to be around the same.

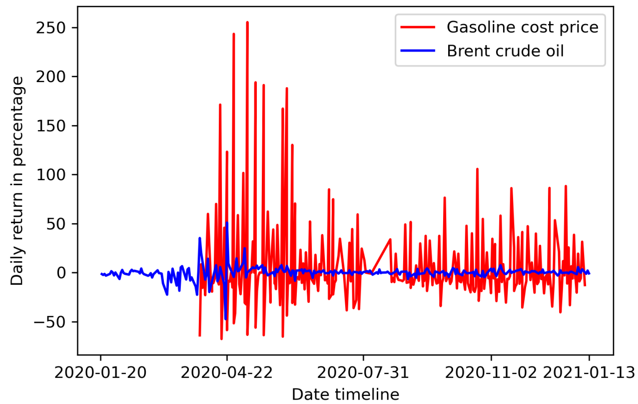


FIGURE 22. Comparing daily returns in percentage between cost price gasoline at Circle K Haugesundsgata 3 in the 2020 data set and Brent crude oil prices.

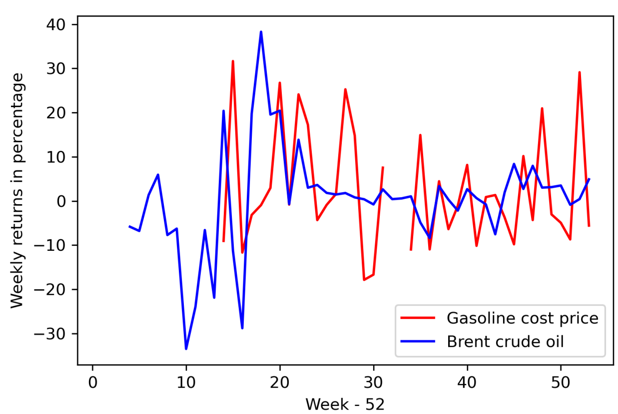


FIGURE 23. Comparing weekly returns in percentage between cost price gasoline at Circle K Haugesundsgata 3 in the 2020 data set and Brent crude oil prices.

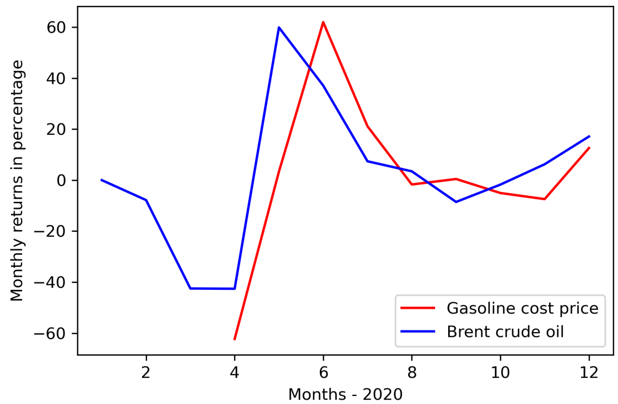


FIGURE 24. Comparing monthly returns in percentage between cost price gasoline at Circle K Haugesundsgata 3 in the 2020 data set and Brent crude oil prices.

6.3.2. *GARCH(1,1).* Estimating volatility is important in many areas such as economical markets because it can indicate how much risk is involved in investing and how much potential gain or loss there exists. One statistical model for predicting volatility in assets is called GARCH, which stands for: Generalized AutoRegressive Conditional Heteroskedasticity [39] and was developed by Danish economist Tim Bollerslev [39]. Error terms in statistical models are not necessarily linear. Heteroskedasticity describes error terms with irregular variation and a tendency to cluster. This makes GARCH a good model for estimating volatility in assets as volatility does tend to cluster in assets such as commodities. This volatility is conditional and fluctuates over time. AutoRegressive means that the volatility is going to depend on previous values, meaning if the model has small or large errors, the model's expected errors will be small or large as well. This differs from homoskedasticity models such as OLS (Ordinary Least Squares), which uses constant volatility [39] [40].

GARCH(1,1) is the most popular GARCH model and it uses the most recent observations of estimated variance rate and return [39]. There also exists a generalized model called GARCH(p,q), which is a multivariate version that can be used for two or more timeseries [5].

Here is the GARCH(1,1) equation for estimating volatility [5]:

$$\sigma_n^2 = \omega + \alpha u_{n-1}^2 + \beta \sigma_{n-1}^2 \tag{4}$$

$\sigma_n^2$ is today's estimated volatility, $\sigma_{n-1}^2$ is yesterday's volatility, $u_{n-1}^2$ is yesterday's return squared and $\alpha$, $\beta$ and $\omega$ are weights assigned to these variables that are approximated by maximizing the likelihood of the historical values of the data set. For GARCH(1,1) to be stable, the sum of $\alpha$ and $\beta$ needs to be less than 1. The first yesterday's volatility starts off as the first daily return. The equation for the likelihood is:

$$L_n = -ln(\sigma_n) - \frac{u_n^2}{\sigma_n} \tag{5}$$

In this thesis, the maximization process is done through Excel solver. Excel maximizes the sum of all of the likelihoods for a data set by trying different values for $\alpha$, $\beta$ and $\omega$ given the constraint that the sum of $\alpha$ and $\beta$ are less than 1 to keep GARCH(1,1) stable. Excel solver has three methods of solving equations: GRG Nonlinear, Evolutionary and Simplex LP. Simplex LP is strictly used for linear functions, while both GRG Nonlinear and Evolutionary can be used for solving non-linear functions. GRG stands for "Generalized Reduced Gradient". This method takes the slope of the function as the input values change and determines that it has reached an optimal solution when the partial derivatives equal zero. It is the fastest non-linear solver, although it is not as robust some of the other methods as it is highly dependent on its initial conditions. It could potentially fail by giving a local optimal solution close to the initial conditions instead of a global one [41]. It is still suitable for finding solutions for $\alpha$, $\beta$ and $\omega$ for the GARCH(1,1) in this thesis.

Estimating volatility using GARCH(1,1) for cost price gasoline in 2020 and Brent crude oil prices grants values for $\alpha$ (Gasoline: 0.104268 and Brent: 0.236790), $\beta$ (Gasoline: 0.864220 and Brent: 0.763210) and $\omega$ (Gasoline: 0.008690 and Brent: 0.000051). These are historically maximized for their respective data and are re-used for estimating volatility for cost price gasoline and Brent crude oil prices in 2021, but without historically maximizing them for them as to avoid P-hacking.

P-hacking, also called data dredging, is when a vast number of hypotheses and correlations are analyzed. What inevitably happens is that some hypotheses will indicate strong correlations even though there is no causation between the variables. Researchers must be careful when considering hypotheses and correlations to not infer false hypotheses based on insignificant correlations. It is important that scientists do not try to look for significant p-values by redoing experiments repeatedly in order to do get over the threshold of significance. The name P-hacking refers to manipulating data in order to get significant p values in statistics [42].

Similar to comparing daily and weekly returns of cost price gasoline to Brent crude oil prices, these prices are clearly not equal to each other in terms of estimated volatility using the GARCH(1,1) method either (see Figure 25 and 26). Cost price gasoline is clearly more volatile. There are other methods for estimating volatility that the thesis has not touched upon, however, judging from several of the methods utilized here and the fact that a correlation between cost price gasoline and Brent crude oil prices could not be established, it could be suggested that the dynamics of these markets are vastly different from each other despite that there should be a causation between them.

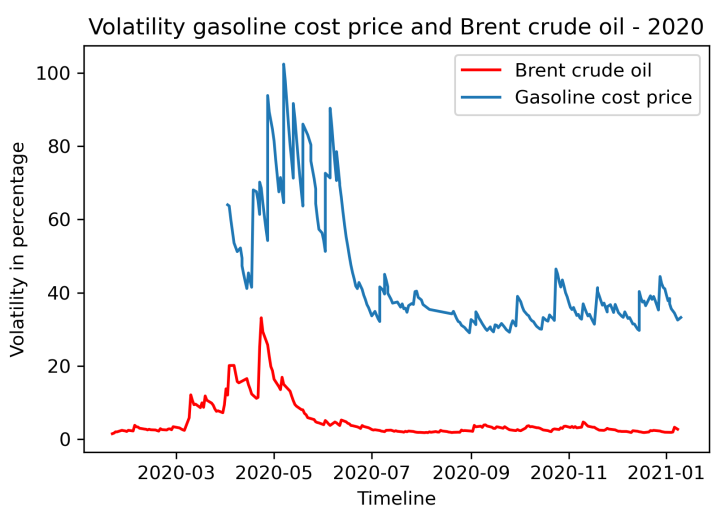


FIGURE 25. Estimated volatility of cost price gasoline at Circle K Haugesundsgata 3 in the 2020 data set and Brent crude oil prices using GARCH(1,1).

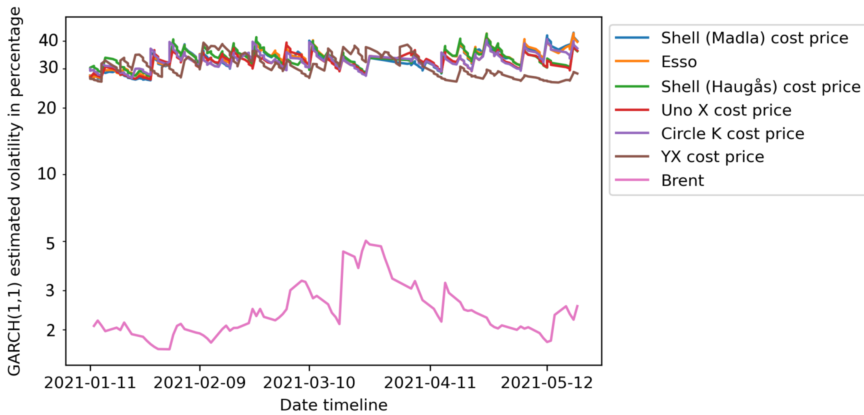


FIGURE 26. Estimated volatility of cost price gasoline at the gas stations monitored in the 2021 data set and Brent crude oil prices using GARCH(1,1). The y-axis is in log scale.

## 7. Algorithmic models

The data analyzed suggests that the retail fuel market in Stavanger and oil market are different from one another. It is not possible to reliably beat a market that follows a Markov process. Under the Efficient Market Hypothesis, efficient markets should follow a Markov process [5]. If it is possible to make an algorithm that makes money off the retail fuel market in Stavanger, it could suggest that this market is not an efficient one. Using the 2020 data set, this section will provide a variety of trading algorithms trying to beat the retail fuel market by using different strategies. A practical refueling model for consumers to use, will serve as the main goal of the thesis, which will be based off the most efficient algorithmic trading model.

7.1. **Definitions.** Any variable that follows a process in an uncertain way is said to follow a stochastic process [5]. A Markov Chain is a stochastic process that describes a sequence that is only dependent on the last event to describe the probabilities of the current state, meaning the state of element n+1 is only dependent on element n [43]. An example of a Markov chain is the board game Chutes and Ladders. The game is entirely determined by dice rolls. A six-sided die always has a sixth of a chance to land on a specific face of the die no matter what historical rolls it may have had. The new position on the board only depends on the last one, making historical positions irrelevant.

Market efficiency is the degree of how well information is reflected in prices of the market. A strong form of market efficiency will incorporate all information, public and private, that could affect the price into the price [44]. If this were true for the entire market, there would be no opportunity for arbitrage and nobody could reliably outperform the market since no investor could know anything more than the rest of the investors. Perfect market efficiency follows a Markov process because all the information is already reflected in the current price. No assets are over- or undervalued, meaning it only depends on its last price and not its history of tendencies. The price will only react to new information which cannot be predicted. Some markets are not perfectly efficient, there are different levels of efficiency in different securities. This means that there exist opportunities to outperform the market and opportunities of arbitrage. For instance, the stock market is assumed to follow a Markov process since there has not been found a pattern investors can follow reliably. If there was, the competition of the market would exploit it [5]. There exist statistical tests to check for different levels of efficiency in economic markets [45]. There was not enough time to use such tests on the retail fuel market in Stavanger, instead time was spent to develop algorithmic trading models that were used to develop a practical refueling model. While this is not a statistical market efficiency test, it does indicate that the retail fuel market in Stavanger is not following a Markov process, thus not being an efficient market.

A random walk is different from the efficient market hypothesis in that asset prices are believed to be random. Prices cannot be reliably predicted as anything could influence the price, even irrelevant information [46]. This is different from the market following a Markov process as that simply means all relevant information is reflected in the current price, however, both make it impossible to reliably beat the market.

Mean reversion is the theory that an asset will eventually revert to its mean value [47]. In investing strategies this would mean selling the asset if it is priced much higher than its understood mean or bought if it is priced much lower than its understood mean. Mean reversion does not follow a Markov process since it depends on historical data.

7.2. **Test models.** For the average fuel consumer in Norway, it can be difficult to predict when it is a good time to refuel. Therefore, having a model that indicates when it is a good time to refuel could be beneficial as it can save substantial amounts of money over time. Commercial vehicles that drive long distances every day such as transport trucks and taxis, along with private commuters could benefit well of such a model. In 2020, there was sold 968 million liters of gasoline and 2767 million liters of diesel in Norway [48]. If everyone were to follow such a model, there could be saved billions of kroner a year, however, if everyone would do so, gas stations would most likely have to change their pricing model to recuperate profits. Since there is a high volatility in the retail fuel market, there should be a way to make a model that indicates when it is a good time to refuel, thus saving money.

Retail fuel prices are most likely not following a Markov process since they tend to be mean reverting, thus not being an efficient market, meaning there could be a way to hypothetically beat the market reliably. Fuel prices are dependent on more than their current prices and looking at their daily returns (see Figure 12), they are following something that resembles an Edgeworth cycle.

7.2.1. *Constraints.* The developed algorithmic trading models in this section are theoretical and have some constraints that will serve as a basis for comparing profitability and efficiency of different models. The most efficient trading algorithm is the model that buys the cheapest fuel and sells it at the most expensive time, which is simulating how much money can be saved by refueling at more optimal times.

- Buying fuel from gas stations is not problematic in a practical setting, however, selling back to them is not something a consumer can do. Like the stock market, to simulate saving money by buying cheap fuel, these models can also sell fuel back to the gas stations at the same price they are selling it for. There are no transaction costs as there are none when refueling a vehicle in real life either. If there were transaction costs, the break even point would be more 1 krone per liter for the most efficient model, Super model since it makes more than 1 krone per liter transaction.
- To make it possible to buy or sell several days in a row, there is a fuel storage where bought fuel can be stored. If a model wants to sell more than it has in storage, it can do so by borrowing fuel. Similarly to shorting a stock, the negative storage needs to be filled up again by buying fuel to net zero.
- The gas tank volume of a normal consumer car is about 60 liters. For these models, the maximum buying and selling volume is 60 liters for all models except for the Spike model on price spike days.
- At the end of the input data set, models will have different amounts of fuel saved in their storage. To be able to compare them, all models must net zero in their storage by the last day. If a model has fuel left or owes fuel, it will have to sell or buy fuel by the last day price.
- Each model outputs profitability (how much money was made), the trade volume (how many liters of fuel were traded back and forth) and efficiency (how much profit was made divided by the sale volume). Achieving a

high efficiency is the goal of the models, however, there must be made a reasonable profit as well. Lower storage is also desirable as it would make the model more practical to execute.

- All models were developed by testing them on the 2020 data set only. Tweaking them while testing them on the 2021 data set would defeat the purpose as the models would suffer from data dredging and there would be no way to justify their efficiency in the future. There is a small overlap in the time frame of the 2020 and 2021 data set, however, since these data would be highly correlated, this overlap have been taken out of the 2021 data set when using it as a validation test.

7.2.2. *Test models.* The algorithmic trading models were developed on the basis of the analyses done in the Analysis section. The results of each test model with the 2020 data set can be seen in Table 9.

- **Constant model**: This model buys a full tank of fuel each time the price is below an arbitrary constant and sells each time it is above it. If the fuel price is exactly equal to the constant, it neither buys nor sells fuel. This arbitrary constant, also called tipping point, has been historically maximized for the 2020 data set to see just how efficient the model can be. Even though it would not be possible to do while actively trading fuel, this can serve as a benchmark for other models to beat and it gives valuable information of what tipping point is the most efficient. The tipping point is not the mean of the data set but is about 1 kr above it. The mean of gasoline from the 2020 data set is 13.75 kr, but the most profitable constant is any constant between the interval 14.80-14.97 kr. There are no prices in this interval in the 2020 data set, meaning all constants in this interval yield exactly the same result when used in the Constant model. When maximized, this model is one of the most efficient ones, however, its efficiency is purely theoretical as it has been historically maximized after analyzing all the data from the 2020 data set. Over a longer period of time, this model would lose some of its efficiency as fuel prices are steadily increasing over time (see Figure 3). This and many other models do not take this into consideration, however, Super model does so.

- **Mean model**: Similarly to the Constant model, this model also buys and sells depending if the current price is below or above a tipping point. This tipping point is the mean of the data set calculated up to that point. The mean is not a time averaged mean, but an observation averaged mean. It takes some time for the mean to converge to a value around the mean of the entire data set as it is heavily affected by price spikes in the beginning. Therefore, it is suspect to poor efficiency ratings in the burn-in period but performs better over time. In contrast to the Constant model, this model can be used for active trading as it does not need to be historically maximized, however, as seen with the Constant model, the mean is not the most profitable tipping point to trade around, it is somewhere around 1 krone above it. While this model is profitable, it is not nearly as profitable as the Constant model. Over long periods of time this model will become less efficient as fuel prices steadily increase. This is because old prices still affect the mean. If used for a long period time, older prices should have less weight than newer ones to make up for the drift increase of fuel prices. The Mean model is the equivalent of what strategy some price sensitive consumers would use as they try to time the market with their fuel needs. As discussed before, however, the retail fuel market in Stavanger is unpredictable and is hard to time even for price sensitive consumers.

- **Weekday model**: This model buys fuel on the cheapest day of the week and sells on the most expensive. After analyzing the 2020 data set, Tuesday is the most expensive day of the week and Saturday is the cheapest in general. Buying and selling only on these days means there are many opportunities where the model does not trade fuel, however, the model can be expanded to buy and sell on all days, differentiating weekdays between expensive and cheap days. These models perform quite poorly. Many consumers are still in the mindset that there are some days of the week that are always cheaper than others, and they will have to pay the consequences by buying expensive fuel when there are price spikes on those days and this model simulates that strategy.

- **Distribution model**: This model buys and sells fuel on a distribution scale. The more expensive fuel is, the more it sells with a maximum of a full tank, and the opposite is true. It has two equations and chooses between buying or selling depending on whether the new price is below or above the mean price of the data set. The equations are:

$$volume_{buy} = \frac{min_{constant}}{fuel_{price}} \tag{6}$$

$$volume_{sell} = \frac{fuel_{price}}{max_{constant}} \tag{7}$$

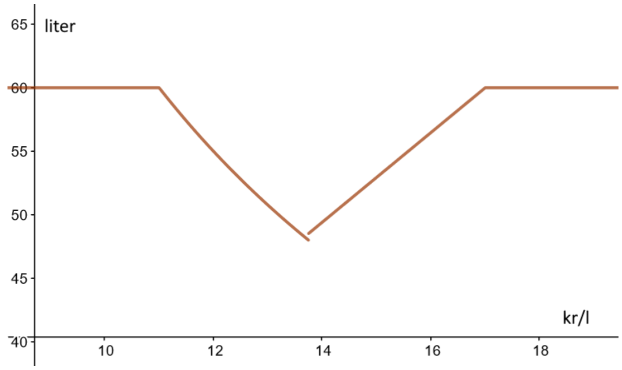


FIGURE 27. The distribution given by $volume_{buy}$ and $volume_{sell}$. The tipping point is the mean of the data set, which is 13.75 for gasoline at Circle K Haugesundsgata 3 in the 2020 data set. If prices go above the $max_{constant}$ or below $min_{constant}$, the model sells or buys the maximum 60 liters.

In this case, the $min_{constant}$ and $max_{constant}$ are set to the fuel price minimum and maximum of the 2020 date set, which would not make it practical to actively trade with, however, the model can be adjusted to work actively by calculating constants up to the point in the data set it is. This model is quite efficient as it buys and sells more on extreme prices. This makes this model one of the most efficient ones and it is slightly more efficient than the Constant model. The distribution could be improved upon by choosing a different distribution such as an inverted Gaussian distribution or have the distribution converge to zero at the mean price, however, the model works as it is, but given more time it could be improved upon. Over time, the model could lose some effectiveness as fuel prices steadily increase over time.

- **Spike model**: In contrast to the other models, this model does not have the constraint of having to sell a maximum of 60 liters. It can sell the entire storage; however, it cannot go negative (borrowing fuel). It only buys a maximum of 60 liters each time though. The model buys on all non-spike prices and only sells on spike prices, where it sells the entire storage. For this model to work in practice without having to analyze the whole data set, price spikes are determined if they only satisfy the first condition of increasing in price by 1.5 kroner or more in one price increase, instead of also having to satisfy the condition of the price decreasing again within a couple of days by the same amount. This ensures that this model will sell at expensive prices even though it does not always buy at cheap prices. Price spikes happen quite regularly, if the data set does not miss them, storage will not become a big issue as it keeps a relatively low storage volume. This model is the most efficient of all the test models except for the Super model. Since price spike constants do not change much over time despite fuel prices increasing, this model would most likely stay efficient over time. If for some reason gas stations would change their fuel market strategy regarding price spikes and remove them or drastically change how they operate, this model would not work.

- **Brent model**: This model tries to incorporate Brent crude oil prices to try to predict fuel prices, however, as discussed earlier, the correlation between fuel prices and Brent crude oil is not strong. Therefore, the profitability and efficiency of this model might be random chance. There are two versions of this model. One version of the model historically analyses the 2020 data set to find the best tipping point constant of where to buy and sell fuel, while the other model also takes into consideration which lag interval is the most profitable. For this model to work reliably, Brent crude oil and retail fuel prices need to be correlated. Even though 15 days of lag was the most correlated lag interval between cost price gasoline and Brent crude oil prices in the Analysis section, the best trading lag interval is one day of lag. It is unknown exactly why the most profitable lag interval is different from the most correlated lag interval, however, it could mean that since there is not a strong correlation between gasoline and Brent crude oil prices, it does not affect what lag interval is the most profitable. These models perform averagely, however, they both have huge fluctuations in profitability, meaning they have an element of chance on what their end results are.

- **Time model**: This model buys and sells fuel based on what time of the day it is. As discussed, price spikes usually occur around rush hour, therefore, this model sells only during rush hour times, which in this case is defined to be between 11:00-17:00. All other times of the day the model buys. This model does not work well with the 2020 data set because there is only a small percentage of prices that were collected in this time interval; however, the 2021 data set was mostly collected before this interval and during it. With the 2020 data set, the model buys a lot and fills up a large storage which it sells at the last day, making it highly dependent on the last day's prices as it sells almost all of the fuel it has bought in the entire period. This model is dependent on gas stations having more expensive prices during rush hour than before and after it, as well as the trader checking prices in both time intervals. It might not work all that well though considering prices decrease throughout each day except for the one time there is a price spike. Still, it is interesting to see how well it works with the 2021 data set.

- **Station model**: This model buys and sells fuel between different stations. It buys from one station and sells it to another one within the same time frame, making storage irrelevant for this model. Since the 2020 data set only consists of one gas station, this model cannot be used for that data set. Only the 2021 data set since that one contains prices from seven different stations. The model buys a full tank at the cheapest station and sells it to the most expensive station. If all stations have the same price, the model does not buy or sell. It is illegal for gas stations to share prices and cooperate, however, gas stations that are in proximity to each other, often have similar fuel pricing, making this arbitrage model less effective.

- **Super model**: This model combines the best elements of the previous test models to create the most efficient model. Since the Spike model was the most efficient of the previous models, this model also incorporates the constraint that lets this model sell its entire storage on price spike days. This makes it so that the model does not require much storage since price spikes occur approximately weekly. The Distribution model is also highly effective since it trades more fuel on extreme prices. The distribution with min and max constants are set to 12 and 18 at the start, but to hedge against increasing fuel prices, these are set to the minimum price +1 and maximum price +1 of the most recent 250 prices after 250 iterations. This ensures that the model will have longevity for years to come.

Utilizing estimated volatility from GARCH(1,1), this model adds a volatility modifier that prompts the model to buy more or less fuel depending on whether the volatility of the next day is higher or lower than the current one. If there is estimated to be higher volatility the next day, the model should trade more because it means prices are estimated to change more drastically tomorrow. The volatility modifier is calculated using this equation:

$$volatilitymodifier = volatility_{n+1}/volatility_n \tag{8}$$

If volatility is higher the next day, the volatility modifier will be larger than one, if it lower, the modifier will be less than one.

The tipping point is the calculated mean of the data set up to that point plus 1 krone since that seems to be a profitable tipping point based on the test data using the historical maximized Constant model. After 250 prices, it calculates the mean of the last 250 prices for longevity. It also have a price spike modifier which calculates how many days have passed since the previous price spike. The more time passed since last price spike, the more the model will buy. The price spike modifier is equal to the number of days since previous price spike day. If there have passed more than seven days, the price spike modifier is reset to zero since the data set could have missed a price spike.

This model can be used in practice and it does not need a lot of storage. The method of which the model decides how much fuel to buy and sell is similar to the Spike and Distribution model. When there is a price spike, the model works exactly like the Spike model in that it sells all its positive storage, and when there is not a price spike, it works similar to the Distribution model with some added volatility and spike modifiers:

$$volume_{buy} = \frac{min_{constant}}{fuel_{price}} \cdot volume \cdot volatility_{modifier} + spike_{modifier} \tag{9}$$

$$volume_{buy} = \frac{fuel_{price}}{min_{constant}} \cdot volume \cdot volatility_{modifier} + spike_{modifier} \tag{10}$$

To not overstep the max volume trade constraint, the model simply buys or sells 60 liters if the equations calculates buying or selling more than 60 liters.

- **Random model**: The Random model randomly buys or sells 0 to 60 liters of fuel on any given price. The profits and efficiency levels this model result in are different each time the model is simulated. This model serves as a comparison for the rest of the models to compare against after simulating it 10 000 times. The comparison will be discussed in the Results subsection.

7.2.3. *Results.* Table 9 show the profitability, trade volume and efficiency all the different test models for the 2020 data set. As mentioned before, the Super model is by far the most efficient model as it is the only one that makes more than 1 kr per liter traded bought and sold. It is not the most profitable it terms of most money earned since both the Constant model and Spike model earn more. In practice however, the Super model outperforms all other test models with having the least need for fuel storage, whereas some models needed an unpractical amount of storage (see Figure 31).

| Model | Profits (NOK) | Volume (liter) | Efficiency (kr/liter) |
|---|---|---|---|
| Constant model | 22 271 | 22 830 | 0.9326 |
| Mean model | 8 524 | 21 360 | 0.3991 |
| Weekday model (2 days) | 1 645 | 4 560 | 0.3608 |
| Weekday model (all days) | 1 616 | 17 880 | 0.0904 |
| Distribution model | 14 384 | 15 309 | 0.9395 |
| Spike model | 25 248 | 26 280 | 0.9607 |
| Brent model (no lag) | 17 734 | 30 600 | 0.5795 |
| Brent model (with lag) | 17 753 | 30 600 | 0.5802 |
| Time model | 18 340 | 28 680 | 0.6395 |
| Super model | 20 549 | 18 156 | 1.1318 |

Table 9. Algorithmic trading model returns for gasoline at Circle K Haugesundsgata 3 in the 2020 data set.

Figure 28, 29, 30 31, 32, 33 and 34 show how the different test models evolve over time. Many of the models are quite inconsistent in how they make profit and their efficiency levels. The Spike, Distribution and Super model are consistently at high levels of both profits and efficiency, meaning they are not arbitrarily profitable. The same cannot be said about the rest of the models. Analyzing their profitability and efficiency, they are all quite sporadic and volatile, meaning there is some element of luck if the model is going to end on a high profitability and efficiency.

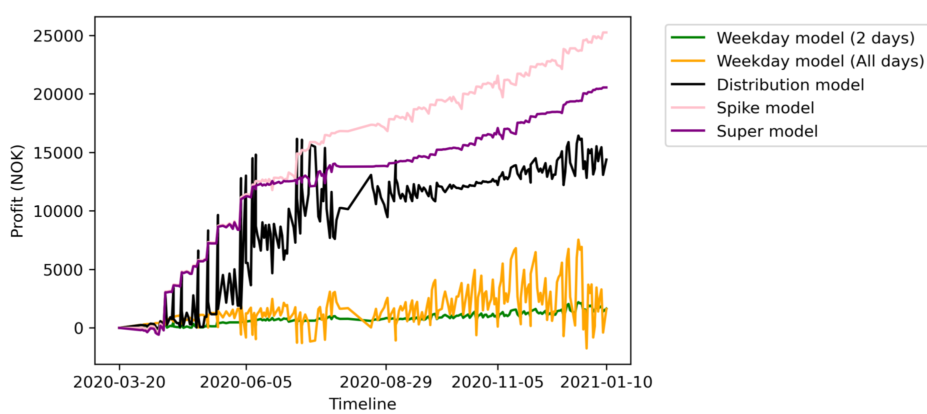


Figure 28. Test models profit at Circle K Haugesundsgata 3 in the 2020 data set.

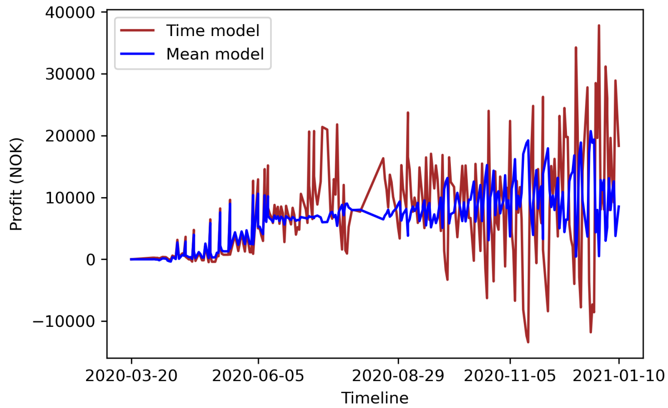


FIGURE 29. Test models profit at Circle K Haugesundsgata 3 in the 2020 data set.

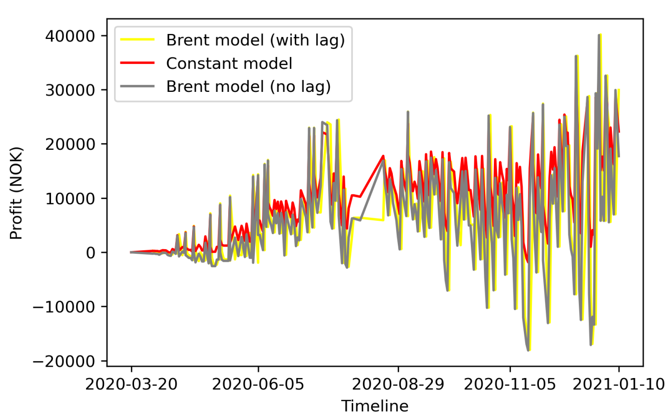


FIGURE 30. Test models profit at Circle K Haugesundsgata 3 in the 2020 data set.

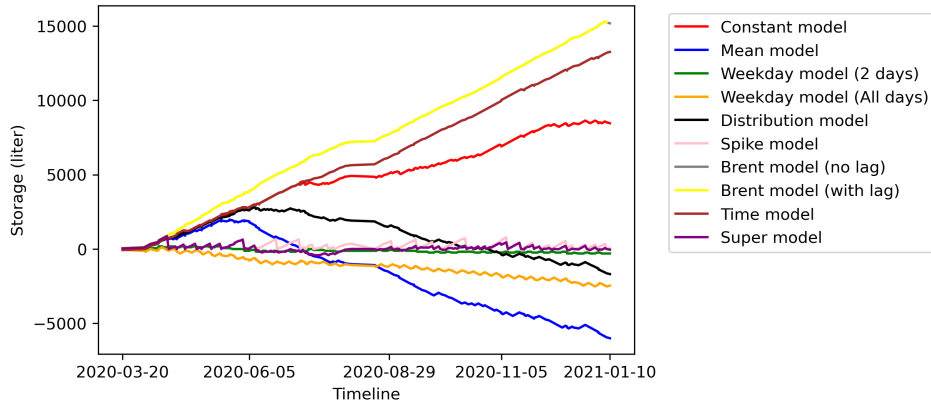


FIGURE 31. Test models storage needed at Circle K Haugesundsgata 3 in for the 2020 data set.

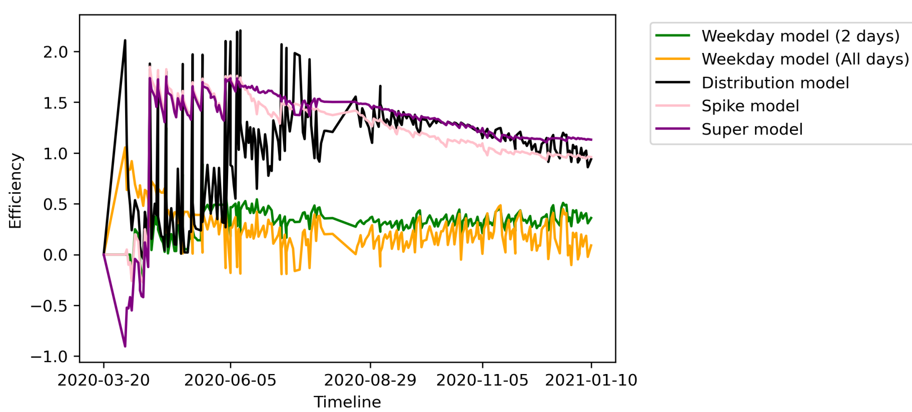


FIGURE 32. Test models efficiency at Circle K Haugesundsgata 3 in the 2020 data set.

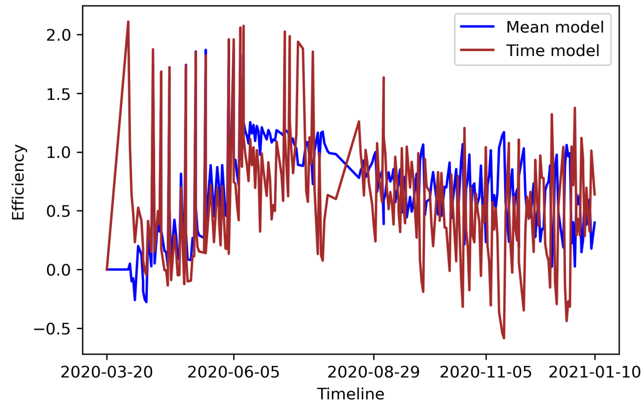


FIGURE 33. Test models efficiency at Circle K Haugesundsgata 3 in the 2020 data set.

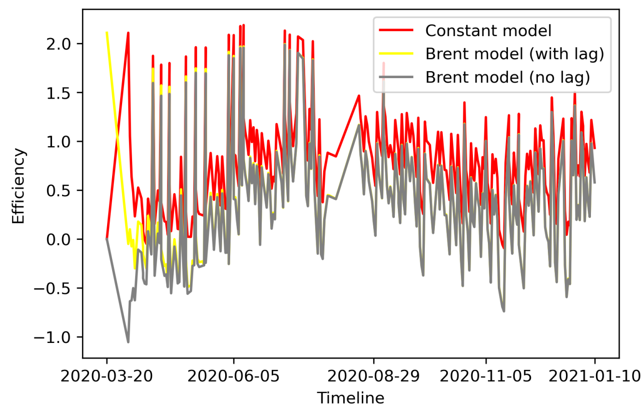


FIGURE 34. Test models efficiency at Circle K Haugesundsgata 3 in the 2020 data set.

The existence algorithmic trading models that can consistently beat the retail fuel market when analyzing a test set, does not necessarily mean the retail fuel market is not an efficient market even though it is indicated that it is not. Comparing the test models to a random model, however, could give an indication of how significant these models are. The Random model randomly buys or sells fuel each day from 0 to 60 liters and must follow the same constraints as the previous test models. Conducting this Random model with 10 000 simulations, the returns and efficiency are normally distributed, meaning it is random whether this model makes any profit. Its mean is approximately 0 and its standard deviation is approximately 1000 (see Figure 35 and 36). This would be the equivalent of non-price sensitive consumers who refuels their cars when they need fuel, having little to no care for fuel prices. Comparing the distribution of the Random model with the test models for the 2020 data set, some of the test models are significantly better. The only models that the Random model sometimes beat are the Weekday and Mean models, both of which are equivalent to some price sensitive consumers refueling strategy. The rest of the test models outperforms the Random model by far. The Super model is more than 20 times more profitable than the standard deviation of the Random model.

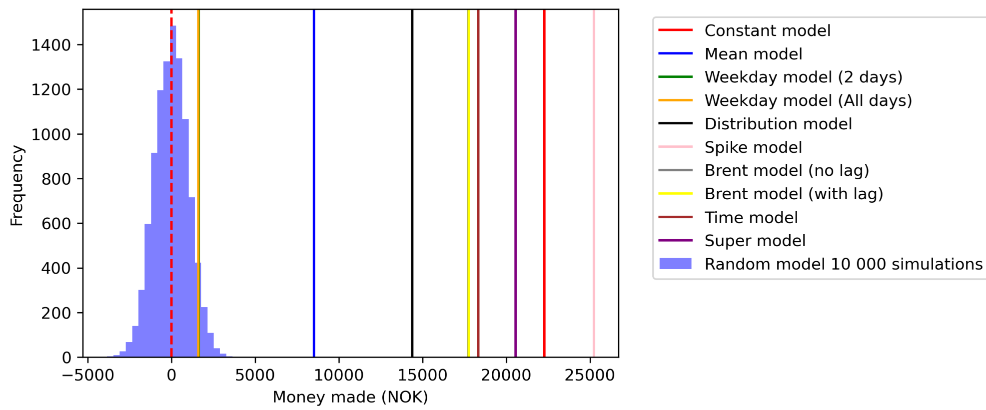


FIGURE 35. Comparing test models with random model profits with the gasoline prices at Circle K Haugesundsgata 3 in the 2020 data set. 10 000 simulations, mean = 0, standard deviation = 1000.

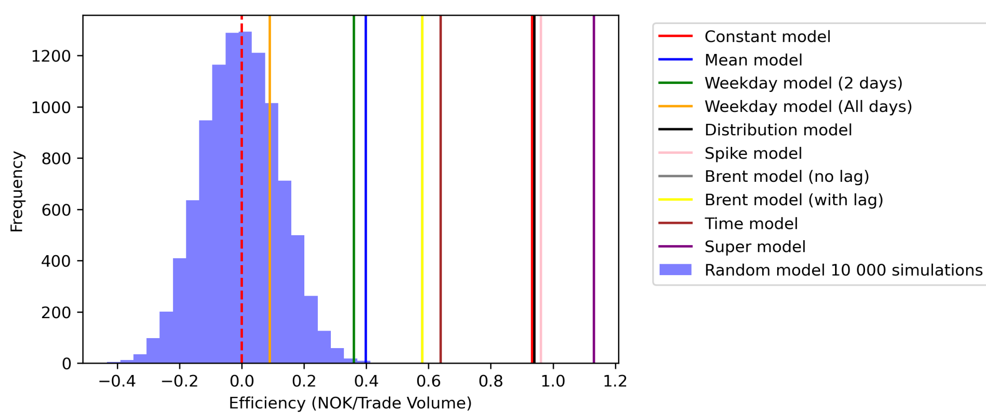


FIGURE 36. Comparing test models with random model efficiency with the gasoline prices at Circle K Haugesundsgata 3 in the 2020 data set.

The test models give a significant indication that the retail fuel market in Stavanger is not following a Markov process and is therefore not an efficient market, however, what would happen if these models were used on an efficient market such as the oil market? Using the same test models and only adjusting some tipping points, is it possible to algorithmically make a profit of Brent crude oil using the same constraints? The only added constraint is that Brent crude oil prices are converted to kr/l like gasoline using USD-NOK exchange rates from the Methodology section. Table 10 shows that none of the test models are particularly efficient. Even the models that are historically maximizes is not performing well. Some of the worse models like the Weekday model are losing money. This does not prove that the Brent crude oil market is an efficient market or that retail fuel market is not one, but it is an indication that the test models are performing well and not arbitrarily in the retail fuel market in Stavanger.

| Model | Profits (NOK) | Volume (liter) | Efficiency (Profits/Volume) |
|---|---|---|---|
| Constant model | 9 111 | 25 080 | 0.3633 |
| Mean model | 854 | 19 440 | 0.0439 |
| Weekday model (2 days) | 266 | 5 880 | 0.0453 |
| Weekday model (all days) | -1 321 | 16 920 | -0.0780 |
| Distribution model | 445 | 14 398 | 0.0309 |
| Spike model | 8 307 | 28 560 | 0.2909 |
| Super model | 8 283 | 28 680 | 0.2888 |

Table 10. Algorithmic trading model returns of Brent crude oil prices in NOK/liter in the 2020 data set.

Using the test models for the validation set from the 2021 data seen in Table 11 and 12. One can see that the Super model is indeed the most efficient model of them all. It was originally tweaked for a Circle K gas station in 2020 data set and since there are several gas stations in the 2021 data set, there is inevitably going to be some variation in performance across the different gas stations, however, the Super model outperformed every other test model again, meaning it is indeed the most efficient and cost saving refueling model. It is peculiar that the Weekday model loses money in the 2021 data set. This could be an indication that the price pattern has changed from 2020 to 2021. The other consistent models, the Distribution and Spike model also performed well with the validation data, whereas some of the inconsistent models such as the Brent and Time models performed much worse with the validation set. The Time model was supposed to work better here than in the 2020 data set, but since prices follow Edgeworth cycles most of the time, the model is not going to profit of smaller decreases, but only at price spikes, making it little effective most of the time. The Mean model also performed significantly better in 2021 compared to 2020. While it is one of the more effective models, its 2021 performance could be somewhat arbitrary given than it does not do anything different in the 2020 data set where it performed significantly worse. The Station model performs relatively well, meaning there is an opportunity for arbitrage across gas stations, however, it does not perform so well that it becomes one of the better models.

| 11.01.21-20.05.21 | Shell (Madla) | | | Esso | | | Shell (Haugås | | |
|---|---|---|---|---|---|---|---|---|---|
| | Profits | Volume | Efficiency | Profits | Volume | Efficiency | Profits | Volume | Efficiency |
| Constant model | 10 795 | 14 040 | 0.7688 | 11 105 | 13 560 | 0.8190 | 11 125 | 13 560 | 0.8204 |
| Mean model | 10 316 | 12 000 | 0.8597 | 10 066 | 12 000 | 0.8389 | 10 075 | 11 760 | 0.8567 |
| Weekday model (2 days) | -1 178 | 4 320 | -0.2728 | -1 274 | 4 200 | -0.3033 | -1 678 | 4 200 | -0.3996 |
| Weekday model (all days) | -485 | 16 200 | -0.0300 | -1 465 | 16 080 | -0.0911 | -2 235 | 16 080 | -0.1390 |
| Distribution model | 10 116 | 11 307 | 0.8946 | 10 071 | 11 149 | 0.9032 | 10 133 | 11 268 | 0.8993 |
| Spike model | 17 786 | 20 040 | 0.8875 | 17 779 | 19 680 | 0.9034 | 17 042 | 19 800 | 0.8607 |
| Brent model (no lag) | 2 191 | 23 280 | 0.0941 | 4 502 | 22 800 | 0.1974 | 4 823 | 22 680 | 0.2127 |
| Brent model (with lag) | 1 377 | 18 240 | 0.0755 | 3 043 | 18 240 | 0.1668 | 3 391 | 18 240 | 0.1859 |
| Time model | 3 011 | 12 720 | 0.2367 | 2 509 | 12 480 | 0.2010 | 1 779 | 12 600 | 0.1412 |
| Station model | 11 362 | 18 360 | 0.6189 | 11 362 | 18 360 | 0.6189 | 11 362 | 18 360 | 0.6189 |
| Super model | 16 930 | 17 804 | 0.9509 | 16 532 | 17 325 | 0.9542 | 15 408 | 16 702 | 0.9226 |

TABLE 11. Algorithmic trading model returns at the gas stations monitored in the 2021 data set.

| 11.01.21-20.05.21 | Uno X | | | Circle K | | | YX | | |
|---|---|---|---|---|---|---|---|---|---|
| | Profits | Volume | Efficiency | Profits | Volume | Efficiency | Profits | Volume | Efficiency |
| Constant model | 9 781 | 17 160 | 0.5700 | 9 082 | 15 000 | 0.6054 | 9 002 | 21 600 | 0.4168 |
| Mean model | 8 969 | 12 360 | 0.7257 | 9 208 | 12 480 | 0.7378 | 6 794 | 13 560 | 0.5011 |
| Weekday model (2 days) | -1 501 | 4 200 | -0.3574 | -713 | 4 200 | -0.1699 | -359 | 4 200 | -0.0854 |
| Weekday model (all days) | -1 897 | 16 200 | -0.1171 | 252 | 16 080 | 0.0157 | -1 211 | 16 440 | -0.0736 |
| Distribution model | 9 225 | 11 218 | 0.8223 | 9 041 | 11 333 | 0.7978 | 8 949 | 14 430 | 0.6202 |
| Spike model | 14 889 | 20 040 | 0.7430 | 16 031 | 19 800 | 0.8096 | 25 001 | 21 840 | 1.1448 |
| Brent model (no lag) | 4 046 | 22 800 | 0.1774 | 1 044 | 22 680 | 0.0460 | 3 559 | 24 360 | 0.1461 |
| Brent model (with lag) | 2 538 | 18 240 | 0.1391 | 635 | 18 240 | 0.0348 | 2 855 | 18 240 | 0.1565 |
| Time model | 2 084 | 12 720 | 0.1638 | 2 352 | 12 600 | 0.1867 | 5 269 | 16 680 | 0.3159 |
| Station model | 11 362 | 18 360 | 0.6189 | 11 362 | 18 360 | 0.6189 | 11 362 | 18 360 | 0.6189 |
| Super model | 13 770 | 17 014 | 0.8093 | 15 056 | 17 292 | 0.8707 | 24 203 | 21 031 | 1.1508 |

TABLE 12. Algorithmic trading model returns at gas stations monitored in the 2021 data set.

7.2.4. *Refueling model.* Since the retail fuel market in Stavanger is not following a Markov process, there is a way to beat the market reliably. Using the Super model as a basis, the Refueling model is a practical mathematical model for private and commercial consumers to use for refueling their vehicles economically. Due to the retail fuel market in Stavanger having unpredictable Edgeworth price cycles, this model could be used to save money over time. Consumers who use their vehicles often, might have to refuel every other week. This model gives a refueling indication once every other week to simulate when the consumer should refuel their vehicle.

This model uses the Super model to calculate price spikes, how many days since last price spike, mean price, GARCH(1,1) estimated volatility and price distribution. If the current price of fuel is above the mean, the model will not refuel, however, if it is below the mean, it calculates whether to refuel or not. When the model has given an indication, the model will not prompt the consumer to refuel before the next two weeks. After the two weeks, it will give a comparison of what the most expensive and cheapest prices you could have refueled at, so the consumer can see how much money was saved. This model gives a refueling indication only based off historical prices, which means it can be used practically as it does not rely on future price analyses to maximize profits.

$$\frac{spikedays}{7} + 2 * \frac{min_{price}}{price_{today}} * volatility_{modifier} > Refueling_{threshold} \tag{11}$$

If this equation is above the $Refueling_{threshold}$, the consumer should refuel their vehicle. The model is more accurate the more prices are put into it. In the data sets used for input there are some periods where not many prices are recorded. If the model does not find a price that is above the $Refueling_{threshold}$, it will simply output the last price recorded in those two weeks, meaning the model has not had enough data to find a more suitable price, but since vehicles need refueling, it will give a price regardless. Therefore, the model is dependent on having data put into it for it to be efficient. Analyzing the 2020 data set, $Refueling_{threshold} = 2$ is a good threshold. This value ensures that the model outputs economical refueling prices and often enough where even though prices are not recorded each day, it will still manage to give an indication every other week.

Using the model on both data sets, there is a substantial amount of money to be saved each month, and the model does so reliably (see Table 13). The Mean refueling is the mean price the model refuels at in the given data set. The Mean min price is the mean of the cheapest prices the model could have refueled at and the Mean max price is the mean of most expensive prices the model could have refueled at. The savings are relative to the Mean max price. The Mean refueling price is often less than 1 krone from the theoretical best price possible. In some cases, like with YX, it is 0.31 kr from the best price possible on average. Without using any form for saving algorithm, getting this close on average when being careful is not easy to do reliably.

| Gas station | Mean refueling (kr/l) | Mean min (kr/l) | Mean max (kr/l) | Volume (liter) | Money saved per 2 weeks (kr) |
|---|---|---|---|---|---|
| Circle K (Kjelvene - 2020) | 13.08 | 12.54 | 15.69 | 60 | 157 |
| Shell (Madla) | 15.15 | 14.15 | 17.42 | 60 | 136 |
| Esso | 15.13 | 14.12 | 17.39 | 60 | 136 |
| Shell (Haugås) | 15.02 | 14.14 | 17.40 | 60 | 143 |
| Uno X | 14.91 | 13.85 | 17.02 | 60 | 127 |
| Circle K (Mariero - 2021) | 14.87 | 14.10 | 17.21 | 60 | 140 |
| YX | 14.82 | 14.51 | 17.48 | 60 | 160 |

TABLE 13. Money saved every 2 weeks using the Refueling model at gas stations monitored in the 2020 and 2021 data set for gasoline.

## 8. Conclusions

Gas stations in Norway have a dynamic pricing system that lets them adjust fuel prices in an instant and they do so several times a day. Throughout the week, prices decrease incrementally until price spikes occur. Price spikes occur because of gas station headquarters sending out recommended prices that franchisees must follow. This characteristic price pattern is called Edgeworth cycles. Many gas stations in the world follow this pattern, however, what makes Norway unique is that Edgeworth cycles here tends to restart because of timing, not prices. What used to be characteristic of gas stations in Norway, was that gas stations used to restart cycles on specific days of the week. After analyzing data from 2020 and 2021, this is no longer the case. It has become unpredictable when cycles restart since they are not decided by a specific price or day of the week anymore. There is still about one spike a week occurring on average. This unpredictability makes it difficult for consumers to choose an optimal time to refuel their vehicles. Therefore, consumers could benefit from having a model that can tell them when it is a good time to refuel. Tanken is the only gas station chain monitored in this thesis whose prices do not follow an Edgeworth cycle as they only update prices once a week. While this gas station chain tend to be more expensive compared to other gas stations in general, it is always cheaper to refuel at Tanken stations when price spikes occur.

Even though some sources like SSB [24] claim that the volatility in the retail fuel market is lower than in Brent crude oil, the findings in this thesis show otherwise, at least when analyzing shorter time periods of days or weeks. SSB shows that Brent crude oil prices are more volatile than retail fuel prices in Figure 21, which is a comparison between pump price gasoline and diesel and Brent crude oil prices monthly returns. Taking taxes and administrative cost into consideration, using this thesis' data, gasoline and Brent crude oil prices have about the same volatility seen in Figure 24. GARCH(1,1) is a statistical method of estimating volatility in assets. This method also shows that gasoline prices are more volatile than Brent crude oil prices seen in Figure 25. Klaus Mohn is technically correct when he explains that big price fluctuations in Brent crude oil prices, does not equal big price fluctuations in gasoline prices [24]. After calculating fuel cost prices, this thesis was unable to establish a strong correlation between Brent crude oil and gasoline prices, which is strange, considering gasoline is primarily made of Brent crude oil.

To develop a refueling model, algorithmic trading models, also called test models, are developed. Test models that attempt to simulate price sensitive consumers such as buying on specific days of the week (Weekday model) and on specific times a day (Time model), tend to perform worse than more sophisticated models such as the Spike model and Distribution model. After testing many different factors for algorithmic trading models, the most efficient model, the Super model, incorporates the best elements from the previous test models which includes calculating mean tipping point for buying and selling fuel, spike analysis and trading on a distribution. It also incorporates new factors such as volatility modifiers calculated from estimated volatility by GARCH(1,1), spike modifiers by calculating how many days since last price spike and added some longevity to the model by calculating new means, minimums and maximums over time that do not include outdated data for extended use over years. Using the same test models developed using the 2020 data set on the 2021 data set, the Super model was still unrivaled in performance. Some test models such as the Weekday model, Brent model and Time model performed significantly worse in 2021 than in 2020, and the mean model performed significantly better. This could be because their algorithms performs arbitrarily.

An average fuel dependent consumer that needs to refuel every other week could benefit from having a practical model that simply tells them when it is a good time to refuel. Using the basis of the most efficient test model, the Super model, a Refueling model was developed to take fuel prices as an input and outputs a refueling date, time and price once every two weeks. This algorithm proves to save a substantial amount of money across all gas stations that follow a form of Edgeworth cycles. This model saves between 127 kr to 160 kr every two weeks. This is a significant amount of money saved considering the average gasoline price is 15.57 kr/l, making a full tank, 60 liters, cost 934 kr.

The validation set performed quite well with the data collected for this thesis, however, it is no guarantee that it would work just as well for other local retail fuel markets as there is too little data collected from other gas stations in other retail fuel markets than Stavanger. Algorithms could be improved upon or generalized by analyzing a wider data set with more gas stations represented from different retail fuel markets in Norway. Data was collected from 20.03.20 to 20.05.21, which is somewhat longer than a year. The longevity of refueling algorithms could be tested by extending the monitor duration.

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# Appendices

## Appendix A. Appendix

### A.1. **Esso.** Email correspondence:

"Hei Ola,

Takk for at du kontaktet Esso Norge Kundeservice. Vi kan forsikre deg om at enhver henvendelse Esso mottar blir grundig behandlet og fulgt opp. Vi vil, for ordens skyld, informere deg om at stasjonenene eies av Certas Energy Norway AS og drives av Tiger AS (eid av NorgesGruppen). På denne stasjonen er Esso nå kun leverandør av drivstoff og har ingen direkte innflytelse på stasjonsdriften.

Vi vil informere deg at vi har videresendt din kommunikasjon - med dine personlige opplysninger - til NorgesGruppen kundeservice og Certas Energy Norway. Om du ønsker å ta opp din sak direkte med deres kundeservice, er deres kontaktinformasjon: NorgesGruppen: tlf 24 11 34 11, e-post post.tiger@norgesgruppen.no Certas Energy Norway: e-post kundeservice@certasretail.no

Takk for at du kontaktet oss om denne saken."

A.2. **Excel.** The Excel document with all data from the 2020 and 2021 data can be viewed and downloaded here or here.

A.3. **Python code.** Python codes developed for this thesis can be downloaded here (Main code) and here (Brent crude oil test functions), or here.

A.4. **Tanken.** Email correspondence:

"Fra: Joar Skorpe - Tanken AS <joar@tanken.one> Sendt: mandag 11. januar 2021 15:40 Til: the-o@live.no <the-o@live.no> Emne: Masteroppgave

Hei Ola,

Viser til henvendelsen din!

Ja, vi besluttet å ta bort prisene fra nettsiden, da vi fikk inntrykk av at konkurransetilsynet kunne mene dette var prissamarbeid ved å legge ut prisene offentlig.

Alle stasjonseide stasjoner priser seg likt fra uke til uke, men franchise stasjonene priser slik dei ønsker. Ofte ikke så ulikt det eg gjør, men det er forskjeller, da alle franchiseeier i Tanken er sin egen sjef, og bestemmer alt sjøl!

Ukens anbefalte priser er:

Bensin: 14,69 Diesel: 13,69 Farget: 9,69

(opp 20 øre fra forrige uke)

Nedenfor ser du innprisene forrige uke, tar vi diesel blir da fordelingen som følger

Salgspris ink mva 13,49 Salgspris eks mva 10,792 Innkjøpspris eks mva 9,87 = Avanse: 0,922

Avansen skal dekke nedbetaling av stasjon, driftsutgifter som internett, strøm, papir, reperasjoner og vedlikehold, lønn etc.

Du spør om avgifter, dette finner du her https://www.regjeringen.no/no/tema/okonomi-og-budsjett/skatter-og-avgifter/avgiftssatser-2021/id2767486/

Diesel er avgiften 3,58. I tillegg kommer mva. Det som er den største utviklingen i kostnad er bioavgift og etanol avgiften, skal nå være 22,5

Tanken AS Levert Frakkagjerdv 124, 5563 Førresfjorden, knr 985256

Produkt Blank diesel Farget diesel Bensin 95 Artikkelnr. 21600 21200 15050 Kode BADO FADO Bensin Basert på ADO 10 ppm (93Rapeseed (7Pris Enhet kr/ltr kr/ltr kr/ltr Pris til kunde m/avgift 9,088 6,415 9,811 Totalt påslag 0,782 0,743 0,903 Pris i perioden 9,870 7,158 10,714

Vinterkvalitetspåslag er inkludert i totalt påslag.

Alle priser er oppgitt eksl mva, inkl min.oljeavgift.

Prisene er å forstå inntil videre og gjelder til ny pris foreligger.

Transport er inkludert i totalt påslag.

Send gjerne spørsmål, så skal eg prøve å svare deg så fort eg kan!

Mvh JOAR SKORPE | DAGLIG LEDER | TANKEN AS | JS BUTIKKDRIFT AS | TANKEN EIENDOM AS | TANKEN ENERGI AS | JOARS AS M:+47 980 80 805 | A: TANKEN, LØKKEVEIEN 9, 4008 STAVANGER, NORWAY www.tanken.one

«Det er Tanken som Teller"

<image002.jpg>

SØR ROGALAND: LØKKEVEIEN TANKE SVILAND HØLE SOKNDAL FORSAND ØSTHUSVIK KLEPP/BRYNE (KÅSEN)

NORD ROGALAND: SPANNAVEIEN FRAKKAGJERD FLYPLASSVEIEN LANGÅKER VIKEDAL FIKSE NEDSTRAND VIKEBYGD

VESTLAND: LOFTHUS

AGDER: BORTELID SKISENTER GRIMSTAD LONGUMKRYSSET MYRENEVEIEN

TELEMARK: STATHELLE BRENNA (BØ I TELEMARK) PORSGRUNN

SUNNMØRE: BUSSTASJONEN ELLINGSØY AURE

PARTNERE: SLÅTTEVIK JELSA KVITSØY BUKTAMO

SØK PÅ KORT MED RABATT IDAG, ESSOCARD & TANKENKORT SØKNAD FINNER DU PÅ WWW.TANKEN.ONE"

A.5. **Uno X.** Email correspondence:

"Fra: Ola Nes <The-O@live.no>

Dato: 08.01.2021 17:01

Til: "automat@unox.no" <automat@unox.no>

Emne: Drivstoff priser

Hei

Jeg skriver en masteroppgave i matematikk om drivstoff, og jeg en av tingene jeg trenger å vite er hvordan dere bestemmer bensin- og dieselprisene. Hvor mye av prisen er avgifter, skatt, transport og profitt osv.? Takker så mye på forhånd.

Mvh Ola Nes"

"From: Uno-X kundestøtte Sent: 11 January 2021 09:53 To: Ola Nes Subject: (Sak:406) Drivstoff priser

Hei,

Takk for din henvendelse. Du kan lese om drivstoffprisens oppbygging her.

Lykke til med oppgaven din. Med vennlig hilsen/Best regards, Eirik Kundekontakt Uno-X Norge AS unox.no | unoxvask.no | Facebook"

A.6. **US Gasoline fluctuations.** Email correspondence:

From: Ola Nes To: US citizen Date: 31.05.2021

"...gasoline prices only change once a week in the US. Is this true for most gas stations in the US, or just your state or?"

From: US citizen To: Ola Nes Date: 01.06.2021

"... I can stay it is for my state (Illinois) as well as most of the country. It is rare that it changes from day to day. It can happen, but it is either weekly or at least every few days. Now that is starting to change with the current regime, but that is another story."

A.7. **YX.** Email correspondence:

"Fra: Ola Nes <The-O@live.no> Dato: Fri, 8 Jan 2021 16:02:54 +0000 Til: "kundeservice@yx.no" <kundeservice@yx.no> Emne: Drivstoffpriser

Hei

Jeg skriver en masteroppgave i matematikk om drivstoff, og en av tingene jeg trenger å vite er hvordan dere bestemmer bensin- og dieselprisene. Hvor mye av prisen er avgifter, skatt, transport og profitt osv.? Takker så mye på forhånd.

Mvh Ola Nes"

"From: kundeservice@yx.no Sent: 11 January 2021 17:55 To: The-O@live.no Subject: (YX-ID:351743) Drivstoffpriser

Hei,

For mest mulig nasjonal representativ oversikt over priskomponenter henviser vi oftest til Drivkraft, som er vår bransjeforening. Vårt søsterselskap, Uno-X har også en forenklet men svært aktuell oversikt på sin nettside.

https://unox.no/i/k/pris/drivstoffprisens-oppbyging Vi pleier ikke å uttale oss direkte om prinsipper for prissetting utover å si at det i drivstoffmarkedet konkurreres ekstremt hardt på pris og at vi gjør det vi kan for å være konkurransedyktige. Med vennlig hilsen Marius Nicolaysen Mobil +47 95003203 E-post: mn@yx.no www.yx.no Besøk: Lysaker Torg 35, 1366 Lysaker"