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ENERGY MARKETS AT WAR: THE EFFECT OF THE RUSSIAN INVASION OF UKRAINE ON REFINERY MARGINS

Leonard Gregor and Justus Haucap

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Economists for Ukraine (Econ4UA)

Website: https://econ4ua.org/ Email: info@econ4ua.org

ABSTRACT

Energy Markets at War: The Effect of the Russian Invasion of Ukraine on Refinery Margins

This paper evaluates the effect of the Russian invasion of Ukraine in February 2022 on refinery margins, i.e. the difference between wholesale prices for road fuels (gasoline and diesel) and oil prices in Europe and Germany in particular. Following the Russian invasion of Ukraine, wholesale road fuel prices net of taxes rose by more than 50 cents per liter, whereas crude oil prices increased by only about 30 cents per liter. Using a difference-in-differences framework, we compare refinery margins in Germany with those on the Amsterdam-Rotterdam-Antwerp (ARA) spot market, which serves as a European benchmark price. The results indicate that refinery margins in Germany increased by approximately 5-6 cents per liter relative to the ARA region after the invasion. We attribute this differential primarily to Germany's strong dependence on Russian Ural crude oil imports and to the presence of regional market power among German refineries. We further document substantial heterogeneity in treatment effects across both time and regions. In addition, the invasion was associated with a significant decline in fuel demand, with gasoline consumption falling by about 13% and diesel consumption by approximately 9%.

JEL CLASSIFICATION: G14, H56, L13, L71, Q41
KEYWORDS: Event Study, Ukraine War, Fuel prices, Wholesale markets

Leonard Gregor
University of Duesseldorf
Duesseldorf Institute for
Competition Economics
Duesseldorf, Germany
gregor@dice.hhu.de

Justus Haucap
University of Duesseldorf
Duesseldorf Institute for
Competition Economics
Duesseldorf, Germany
haucap@dice.hhu.de

1 Introduction

In the wake of the global economy recovering from the COVID-19 pandemic and related lockdowns, Russia invaded Ukraine on 24 February 2022, significantly escalating the ongoing Russo-Ukrainian war beyond regional limits. The invasion had a significant effect on global and especially European energy markets, which intensified the 2021-2023 global energy crisis. In Germany, among many other European countries, retail prices for gasoline and diesel increased by more than 50 cents/liter (c/l) to over two Euro/liter. To ease consumer burdens many European countries temporarily reduced energy taxes, subsidized road fuels or alternative transportation or payed lump sums to households.[1]

This paper examines the effect of the Russian invasion of Ukraine on German energy markets, in particular the ex-refinery and wholesale markets for road fuels (gasoline and diesel). Descriptive data shows that prices for road fuels increase significantly stronger than crude oil prices, widening refinery margins substantially. We employ a difference-in-differences (diff-in-diff) framework comparing refinery margins for road fuels in Germany with those on the Amsterdam-Rotterdam-Antwerp (ARA) spot market. We find significant positive effects of the war on refinery margins in the short term, whereas effects become insignificant in the long term, beyond 2022. We also analyze the effect of the invasion on demand and find a significant decrease in demand in line with economic theory. We hypothesize that this effect reflects Germany's stronger dependence on Russian crude oil and diesel imports relative to the ARA region. In addition, the German wholesale market for road fuels is less competitive than the ARA spot market.

Given the importance of the institutional background of the market we begin the paper by examining the supply chain of German crude oil refineries. Germany crucially depends on crude oil imports from other countries. Even though Germany imports from various countries, single refineries often depend on crude oil from a single or very few origin countries. These constraints prevent refineries from switching easily between different crude oil types. We further state that the market for refined petroleum products, like gasoline and diesel is regionally limited as transportation costs are high. The market is, also, shaped by anti-competitive characteristics which have been investigated numerous times by antitrust authorities across various jurisdictions. Globally the market is controlled by a relatively small number of companies which control the entire vertical supply chain from exploration, extraction, transportation and refinement of crude oil to wholesale, transportation and retail of refined petroleum products. Moreover, these firms cooperate

[1] See, e.g. Gregor and Haucap (2025), Frondel et al. (2026), Dovern et al. (2023b), Kahl (2024), Schmerer and Hansen (2023), Bernhardt et al. (2023), Freitas and Syga (2022), Seiler and Stöckmann (2023), Montag et al. (2023).

at every level of the vertical supply chain by jointly owning essential infrastructure such as oil platforms, pipelines, and refineries. In addition, they maintain business connections along the vertical chain by buying and selling crude oil and refined petroleum products from one another.

For the empirical analysis, we use pricing and quantity data from all three levels of the supply chain, meaning the market for crude oil and the wholesale and retail markets for gasoline and diesel. We use daily pricing data for different crude oil blends, wholesale and retail prices for road fuels in Germany and the ARA spot market. We also use monthly and national quantity data on crude oil, gasoline and diesel from the Joint Organizations Data Initiative (JODI).

A descriptive analysis shows that after the Russian invasion of Ukraine wholesale and retail prices increased significantly. This increase is, however, only partially driven by crude oil prices. We show that after the Russian invasion of Ukraine the refinery margin (the difference between crude oil and wholesale gasoline and diesel prices) quadruples for gasoline and triples for diesel. This effect is visibly distinguishable throughout 2022, 2023 and 2024. We show that to a lesser extent this is also the case on the ARA spot market. Employing a diff-in-diff approach we find that the increase in German refinery margins caused by the Russian invasion of Ukraine is on average 5-6 c/l higher than those on the ARA spot market. An analysis of treatment heterogeneity over time shows an immediate effect, which further increases during a temporary energy tax cut in Germany in the summer of 2022 and fades towards the end of the year. We do not find a significant long term effect beyond 2022, as refinery margins on the ARA spot market are also elevated and those in Germany decrease in the long term. A regional heterogeneity analysis reveals that the treatment effect is driven by margins in eastern Germany. In the southern part of Germany the treatment effect is insignificant. In the western and northern part a significant treatment effect is measurable. Using the same diff-in-diff approach on demand in Germany and using the European Economic Area (EEA) as a control group shows that demand in Germany decreases by about 10% after the Russian invasion of Ukraine. This is in line with economic theory as absolute gross prices increase. The results do, however, not show the universal effect of the Russian invasion of Ukraine on German road fuel prices, as the control group the ARA spot market is treated by the invasion as well. We, therefore, rather show the differences in effects of the invasion on the German and the ARA spot market. These effects can then be attributed to the fact that the wholesale market for road fuels is less competitive and more dependent on Russian Ural crude oil and diesel imports. We, therefore, connect to multiple strands of literature as shown in the following.

First, and most broadly, we contribute to the literature on the response of fuel prices to changes in input costs. Bacon (1991) was the first to document the so-called "rockets and feathers" phenomenon, showing that retail fuel prices adjust more rapidly to input price increases than to decreases in the UK. This empirical result has since been confirmed by a large body of subsequent research (see, among others, Borenstein and Shepard (2002), Bachmeier and Griffin (2003), Chen et al. (2005), Grasso and Manera (2007), Blair and Rezek (2008), Meyler (2009), Honarvar (2009), Atil et al. (2014), Gautier and Le Saout (2015), Auer and Schoenle (2016), Blair et al. (2017), Sun et al. (2022), Kilian and Zhou (2024)). More specifically, we contribute to the literature that describes the effects of unexpected external shocks on prices for road fuels. Kendix and Walls (2010) use data from 2002 to 2008 to show that unexpected refinery outages have a statistically significant positive impact on refined petroleum products. Atkinson et al. (2014) shows that a refinery fire in southern Ontario led to a change in the equilibrium behavior of petrol stations in Toronto: Markets in which prices followed Edgeworth cycles before the shock, changed their equilibrium behavior and switched to fixed retail margins. Lewis (2009) investigated the pass-through of input cost shocks in the wake of Hurricane Rita. The author showed that high retail margins dissipated more quickly after the hurricane in cities where competition between stations tends to generate cycle retail price fluctuations. Haucap et al. (2017) account for heterogeneity across petrol stations and document high pass-through rates of crude oil price changes. However, only a limited number of studies explicitly account for multiple stages of the supply chain. Farkas and Yontcheva (2019) shows that with higher concentration along the vertical chain, pass-through of cost shocks becomes more asymmetrical. Severin et al. (1997) investigates possible reasons for the "rockets and feathers" phenomenon and finds that primarily inventory adjustment legs and the retailers market power explains most of it. Verlinda (2008) shows that brand identity, proximity to rival stations and local market features such as demographics determine the asymmetric response to input prices of a petrol station. Li and Stock (2019) adopt a different perspective by examining price transmission for bioethanol and shows that fuels with a higher bioethanol content such as E85 have a much lower pass-through of price changes compared to fuels with a lower bioethanol content like E10.

In response to the Russian invasion of Ukraine, many countries temporarily reduced energy taxes during the summer of 2022. A growing body of literature analyzes the effects of these tax reductions. For example, Jiménez et al. (2025) and Balaguer and Ripollés (2024) study a fuel subsidy of 20 c/l introduced in Spain in the summer of 2022 and document full pass-through for gasoline and partial pass-through for diesel. Similarly, Drolsbach et al. (2023) examines several energy tax reductions across Europe and finds consistently high pass-through rates. Most relevant to this paper are studies analyzing the German energy tax cut implemented in the summer of 2022. The majority of these studies report full or near-complete pass-through of the tax reduction to retail fuel prices. For instance, Fuest et al. (2020) employs France as a control group in a diff-in-diff framework and finds evidence of full pass-through. Schmerer and Hansen (2023) compares German prices with those in Austria and reports pass-through rates slightly exceeding

100%. Using multiple control groups, Kahl (2024) estimates pass-through rates close to 90% for both gasoline and diesel. Several studies apply synthetic diff-in-diff approaches. Bernhardt et al. (2023) and Dovern et al. (2023a) find high pass-through rates for gasoline but only partial pass-through for diesel, while Seiler and Stöckmann (2023) and Freitas and Syga (2022) report high yet incomplete pass-through rates. Particularly relevant are Montag et al. (2023), who finds higher pass-through for diesel than for gasoline, and Gregor and Haucap (2025), who compares wholesale market prices with the ARA benchmark and estimates pass-through rates of approximately 60–70%. They also find a significant increase in demand during the energy tax cut.

Second, we connect to the literature on the consequences of the Russian invasion of Ukraine. The Russo-Ukrainian war had extensive political, economical and individual effects, which go far beyond the scope of this paper. For example Blanchflower and Bryson (2023) studies the impact of the Russian invasion of Ukraine on individual subjective well-being in Europe, the U.S. and the four neighboring countries of Ukraine. Baumeister (2023) discusses the structural changes in each of the three main oil-producing countries as well as policy tools to stabilize energy markets from the demand side. Aizenman et al. (2023) use a daily event-based structural vector autoregression to estimate the effects of different events during the Russo-Ukrainian war in January 2022 and March 2024 on wheat, corn and European natural gas prices. Goyal and Steinbach (2023) estimate a 16% price increase in agricultural futures after the Russian invasion of Ukraine in their event-study. They also note that the Black Sea Grain initiative had little impact on future prices, but EU Solidarity Lanes did. Fang and Shao (2022) even propose a new index to measure the intensity of the Russo-Ukrainian war and then use it to measure the channels through which the war affects the volatility of commodity markets. They show that the higher the global market share of a commodity exported by Russia, the higher the volatility when the intensity of the war increases. They also show that investor panic and the monetary policy of major central banks amplifies the impact of the war on commodity markets.

More specifically, however, we connect to the literature on the effect of the Russian invasion of Ukraine on energy markets, in this case markets for road fuels. Meng and Yu (2023) use a regression discontinuity design and show that the Russian invasion of Ukraine leads to higher gasoline prices, as crude oil prices and inflation rates increase. They further show that the more a country depends on crude oil imports, the stronger this effect is. Colgan et al. (2023) estimate that European countries spend an extra 643 billion Euro in excess costs due to elevated fossil fuel prices from October 2021 until December 2022. Arndt et al. (2023) use national economywide models to measure near-term effects of price increases for fertilizer, food and fuel in the wake of the Russian Invasion of Ukraine. They find that the invasion leads to 27.2 million more people in poverty and 22.3 million people into hunger. Most notably Liu and Lee (2025) use a propensityscore matching diff-in-diff to estimate a 9% increase in energy prices in OECD countries. The authors do, however, note significant treatment heterogeneity in their results. They find no statistically significant effect in non-EU and non-NATO OECD countries, whereas prices in southern Europe increased by approximately 22% following the Russian invasion of Ukraine. Furthermore, Aizenman et al. (2023) and Liu and Lee (2025) both provide a very thorough list of all paper that investigate the effect of the Russian invasion of Ukraine on different financial markets.

In contrast to the aforementioned literature, our paper uniquely examines the impact of the Russian invasion of Ukraine on the German wholesale market for road fuels. We, therefore, explicitly account for the institutional and structural characteristics of the German wholesale market for road fuels. Most related studies either analyze the effects of various exogenous shocks on fuel prices or assess the consequences of the invasion on energy markets more broadly, including natural gas and electricity. These differences in scope directly inform our choice of control group, making our study the only one to employ the ARA spot market as a control. Moreover, we are the only study to explicitly analyze the effects of the Russian invasion of Ukraine on both prices and demand in the market for road fuels.

The rest of the paper is structured as follows: Section 2 describes the supply chain of German refineries as well as the ex-refinery and wholesale market for road fuels. Section 3 describes the data used in the empirical analysis. In Section 4 we explain our empirical strategy. Section 5 presents descriptive evidence, before Section 6 discusses our results. Lastly, Section 7 concludes.

2 Institutional Setting

This section examines Germany's dependence on crude oil imports and the reliance of refineries on specific crude oil blends. We also explain that fuel refining occurs as a joint production process, in which the output shares of different fuel types cannot be freely adjusted but are constrained by both the technical capabilities of the refinery and the characteristics of the crude oil processed. Last, this Section also addresses the significance of transportation costs and the pricing mechanisms in wholesale crude oil and fuel markets, including the role of specialized pricing information services.

2.1 Supply Chain

As only 2% of Germany's crude oil demand is met through domestic production, reliance on foreign imports is substantial (Energy Balances Group, 2022). Given the large volumes required and the high degree of product homogeneity, approximately 72% of crude oil imports are transported via pipelines, with the remainder arriving by ship (Federal Cartel

Office, 2022). Consequently, most German refineries depend on a specific pipeline and, by extension, on a particular origin region for their crude oil supply. Figure B.4 illustrates that crude oil supply in Germany can be classified into four regions, each defined by its primary source and associated supply pipeline.

Figure B.4 shows that refineries in southern Germany are predominantly supplied via the Transalpine Pipeline (TAL), which originates at the marine terminal in Trieste, Italy. The TAL traverses the Alps and connects Italy, Austria, the Czech Republic, and Germany. In addition to the Schwechat refinery near Vienna and two refineries in the Czech Republic, five refineries in Germany are supplied through the TAL: the OMV refinery in Burghausen at the Austrian-German border, the Gunvor refinery in Ingolstadt, the two Bayernoil refineries in Vohburg and Neustadt, which are represented as a single entity in the map, and the MiRo refinery in Karlsruhe, the largest refinery in Germany. MiRo is particularly dependent on the TAL, with only 1% of its supply sourced domestically from the Palatinate region. The crude oil transported through the TAL is predominantly Sahara Blend from North Africa, implying that the refineries supplied by the pipeline are specifically configured to process this type of crude (Orlen Unipetrol (2024a), Orlen Unipetrol (2024b), Transalpine Pipeline (2024), Bayernoil (2024), OMV (2016), OMV (2024), MiRo (2024)).

In western Germany, crude oil supply is predominantly secured via the Rotterdam–Rhine Pipeline, which links the marine terminal in Rotterdam to the Shell refinery in Cologne and the BP "Ruhr Oil" refinery in Essen. Both facilities are additionally connected to the Nord-West Ölleitung (NWO), originating at the marine terminal in Wilhelmshaven, as shown in Figure B.4 (Shell, 2024; BP, 2024). Consequently, these refineries primarily process Brent Blend crude oil sourced from the North Sea.

A similar supply structure exists for all three refineries in northern Germany. The "Holborn Europa Raffinerie" in Hamburg-Harburg is also supplied by the NWO, as is the BP refinery in Lingen, located in the Emsland region. The latter additionally processes domestic crude oil extracted from nearby oil fields. The Raffinerie Heide, operated by the Klesch Group, is connected to the marine terminal in Brunsbüttel by a 32 km pipeline and therefore likewise relies predominantly on Brent Blend crude oil. However, approximately 15% of its feedstock is sourced from nearby oil fields, which are directly linked to the refinery via dedicated pipelines.

The eastern part of Germany, the former German Democratic Republic (GDR), was historically connected to Russian and Kazakh oil fields via the Druzbha (Friendship) Pipeline, which is an extensive network of pipelines stretching over 9000km from western Siberia. In 2021, the year before the invasion, approximately 90% of the crude oil demand for the PCK Schwedt and the Total Energies Refinery Mitteldeutschland in Leuna came from the Druzbha pipeline. Residual demand was met by the APR Pipeline connecting the marine terminal in Rostock to the PCK Schwedt (Puls, 2022). Both refineries in eastern Germany therefore use an Ural blend. As Russian crude oil imports into the EU were, however, banned from 1 January 2023 onward, this supply stream ceased. Alternative supply via the APR pipeline from Rostock did only cover about 50 to 60 % of both refineries demand. Alternative supply chains were, therefore, established throughout 2023. Crude oil was imported via the marine terminal in Gdansk, Poland and small volumes came through the Druzbha pipeline from Kazakhstan. By the end of 2023, refinery utilization in the region increased to approximately 80% (Pfister (2022), Kimani (2022), Jamestown Foundation (2022), dpa (2022)).

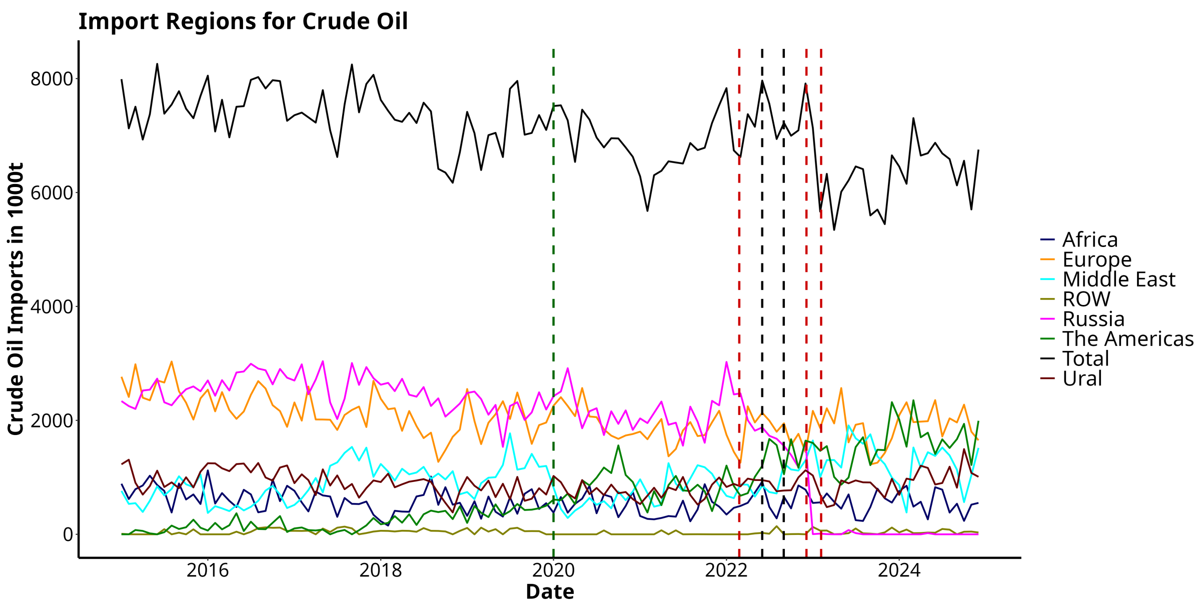

Figure 1: Crude Oil Imports into Germany by Country (Statistisches Bundesamt, 2025)

As explained above Germany's crude oil import structure is characterized by substantial diversification, both in terms of transport infrastructure and source countries. Figure 1 shows the total monthly volume of crude oil imports into Germany, measured in thousand metric tons, along with the corresponding regional import shares. Overall import volumes remain relatively stable over time and decline noticeably only during the COVID-19 pandemic. It is apparent that after the Russian invasion of Ukraine the total import volume of crude oil does not decrease significantly. A significant and persistent reduction in total import volumes does not occur until after the European sanctions on Russian crude oil import take effect in December 2022. From this point onward until the end of 2024, the total volume of crude oil imports stays below the levels from before the beginning of the sanctions.
Russia was, historically, the most dominant supplier of crude oil to Germany, followed by European countries, primarily those bordering the North Sea, including Denmark, the United Kingdom, the Netherlands, and Norway. Since 2018, the Americas, meaning the totality of North-, Central and South America have gained increasing importance as

supplier regions, a development largely driven by rising imports from the United States. North African and Middle Eastern countries have also remained consistently relevant sources over the sample period. In addition, we show imports from other Ural countries, namely Azerbaijan, Kazakhstan and Turkmenistan without Russia. Imports from these countries have been relatively stable over time and only increased in 2023 and 2024.

Figure 1 shows that Russian crude oil imports into Germany declined sharply following the Russian invasion of Ukraine. Nevertheless, Russia remained a major supplier of crude oil to Germany. Only after the European sanctions against Russian crude oil came into effect, did Russian crude oil imports stop. During 2022, it seems that imports from other European, Middle Eastern, and American countries were offsetting the decrease in Russian crude oil imports. Only in 2023 did the decrease in Russian crude oil imports affect the total import volume into Germany, as increases in imports from European and Ural oil countries did not offset the loss of Russian imports.

As shown above in Figures 1 and B.4 that Germany's crude oil supply system is highly diversified and relies on four largely independent transportation networks, as well as a broad set of exporting countries. At the refinery level, however, supply flexibility is significantly more constrained. Individual refineries depend heavily on specific transport routes due to physical infrastructure such as pipelines and terminals, as well as technical requirements related to the processing of particular crude oil types. Refineries located in eastern Germany, for instance, are optimized for Russian Urals crude and face substantial technical and economic barriers when switching to alternative crude oil blends, as discussed in the following section (Federal Cartel Office, 2022).

2.2 Refinery Production

Refineries operate under a joint production process, in which multiple output products are derived from crude oil through one integrated production process. The following section outlines the aspects of this process that are most relevant to the scope of this paper.

Figure 2 provides an overview of the crude oil refining process. Initially, crude oil is heated and mixed with water, after which an electric current is applied. This process removes dissolved salts, as they transfer from the oil into the water layer. Because oil and water separate into distinct layers, the saline water can then be separated. In the subsequent stage, the desalted crude oil is heated to approximately 400°C, causing it to vaporize. As the vapor cools, the components condense at distinct temperatures, enabling their separation into different fractions, as illustrated in Figure 2. This stage, known as atmospheric distillation, is conducted at normal atmospheric pressure and yields products such as gases, gasoline, petroleum, kerosene, diesel, and light and heavy fuel oils. The remaining residues are then subjected to vacuum distillation, which operates under reduced pressure, to produce heavier fractions including lubricants and bitumen.

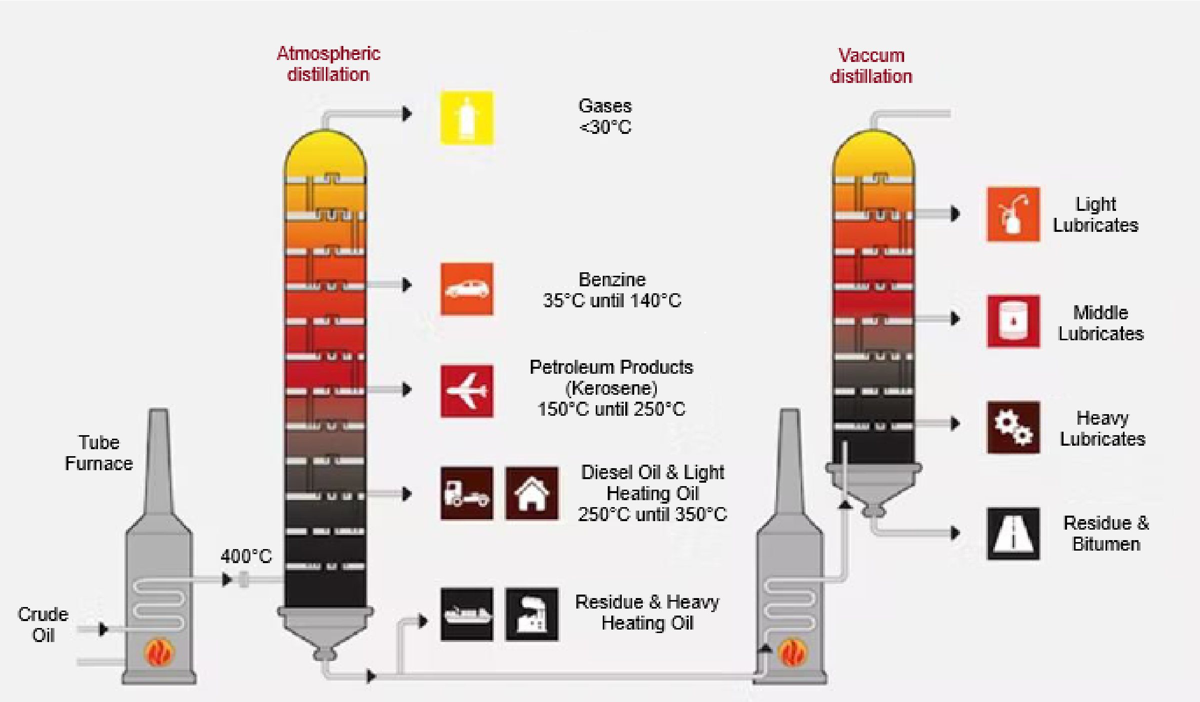

Figure 2: Joint-Product Production in a Refinery (Gunvor Raffinerie Ingolstadt, 2016)

Most refineries operate a range of supplementary processing units designed to enhance product quality, including desulfurization, cracking, catalytic reforming, pyrolysis, and blending facilities. Desulfurization plays a critical role in removing sulfur compounds from lubricants and heating oil, thereby enabling the production of lighter fractions such as light heating oil, diesel, and gasoline. Because demand for these lighter products is substantial, refineries frequently employ various cracking processes to break down heavy, long-chain hydrocarbons (e.g., heavy heating oil) into shorter-chain hydrocarbons such as gasoline, diesel, and light heating oil. Several distinct cracking methods exist, each exerting a specific influence on the resulting product composition (Federal Cartel Office, 2022).

Refinery operations are continuously adapted to the characteristics of the crude oil blend being processed, the configuration of the facility, and the targeted product output. Each refinery maintains a defined portfolio of crude oil blends it can process efficiently. Transitions between blends within this established portfolio incur minimal costs and can typically be completed within a few hours. By contrast, processing a crude oil type outside this repertoire is both costly and technically demanding, potentially requiring several years for full integration. As a result, a refinery's operational flexibility is largely determined by the set of crude oil blends it can handle. Blends within its established portfolio are readily processable, whereas those outside it are not. Consequently, the product yield and efficiency of individual refineries can vary considerably (Federal Cartel

Office, 2022).

Table 1 illustrates the average product yield of refineries in Europe and the United States (U.S.). In both regions, approximately 75% of production consists of road fuels, including gasoline and diesel, while all other products collectively account for the remaining 25%. Notably, 10% of the output is allocated to kerosene for aviation. The table further highlights that European refineries produce a significantly higher proportion of diesel compared to their U.S. counterparts. This difference is driven by comparatively higher gasoline demand relative to diesel in the United States than in Europe.

Products	Europe	U.S.
Diesel	∼ 40.2%	∼ 25%
Gasoline	∼ 18.7%	∼ 50%
Fuel oil	∼ 10%	∼ –
Naphta	∼ 6.9%	∼ –
Kerosene	∼ 7.7%	∼ 9%
LPG	∼ 2.5%	∼ 6%
Other	∼ 14%	∼ 10%

Table 1: Average Refinery Production (FuelsEurope, 2024; EIA, 2025)

2.3 Refinery Capacity

According to Federal Cartel Office (2022) and Federal Competition Authority (2022), the evidence on the availability of refining capacity is mixed. Media reports indicate a global reduction of refining capacity, primarily attributed to declining profitability, a development intensified by the demand shock during the COVID-19 pandemic and by the broader structural shift toward more sustainable consumption patterns.[2]

Nevertheless, Figure 3 shows that, in historical perspective, global refining capacity has continued to expand. Although Europe, and Germany in particular, has experienced a decline in capacity, this reduction has been moderate over the period under consideration (2017–2025). At the global level, refining capacity is still increasing. This apparent discrepancy can be explained by strategic adjustments undertaken by many refinery operators. In anticipation of a long-term decline in demand for crude oil products, firms have started to scale back conventional refining capacity and to reallocate resources toward renewable energy technologies, such as hydrogen and synthetic fuels. Since German and European refineries are, on average, older, more complex, and less efficient, they have been among the first to be shut down (Argus Media (2024a), World-Energy (2021)). These developments are consistent with the assessments in Federal Cartel

[2]See, for example, Deutsche Wirtschafts Nachrichten (2022), Sanicola (2022), The Washington Post (2022a).

Office (2022) and Federal Competition Authority (2022), which conclude that, despite the heterogeneous trends in refining capacity, refineries are generally not operating at full capacity and could, in principle, expand their output.[3] Overall, refinery capacity constraints therefore do not appear to constitute a binding limitation.

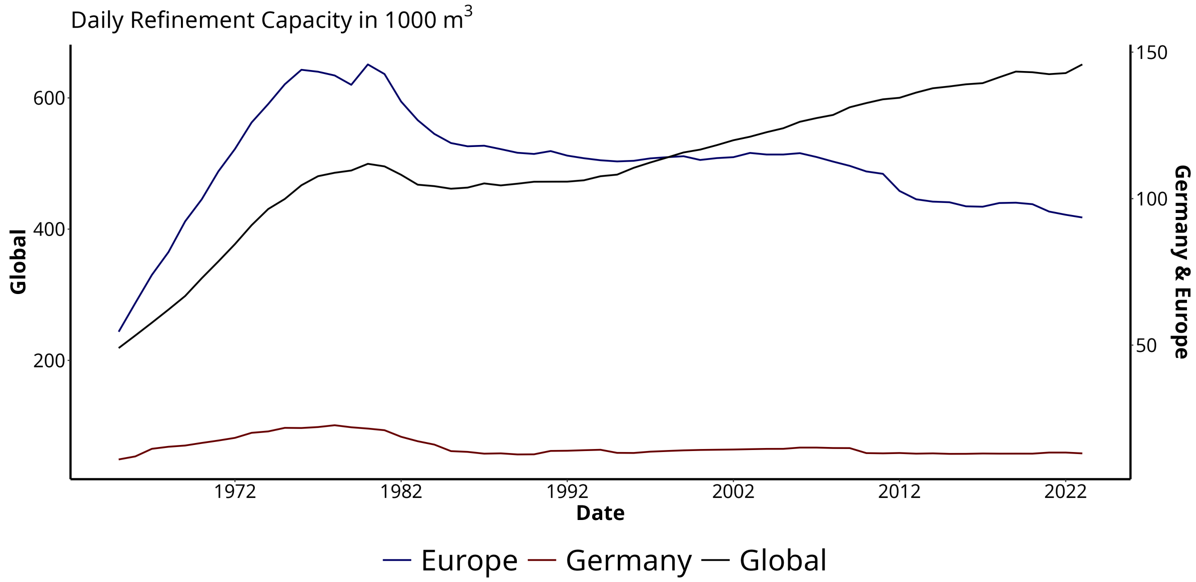

Figure 3: German, European and Global Refinement Capacity According to EIA (2025)

Persistent concerns remain that German refineries may be unable to fully satisfy domestic diesel demand, as Germany exhibits a negative trade balance in diesel while maintaining a positive trade balance in gasoline. As discussed in the previous section, refineries cannot arbitrarily adjust their output proportions. According to Federal Cartel Office (2022), it is not evident whether these limitations are attributable to binding capacity constraints. Against this background, the following subsection analyzes gasoline and diesel imports and exports in greater detail.

2.4 Ex-Refinery Transportation

The distribution network for refined petroleum products is considerably more complex than that of crude oil, primarily due to the heterogeneity of product types and end users. Refineries typically market their outputs in bulk to wholesalers, large retail chains, and industrial consumers. Certain specialized products, such as kerosene, lubricants, and intermediate chemical feedstocks, are usually traded directly with small purchasers, including airlines, chemical producers, and pharmaceutical firms. In contrast, diesel and gasoline are predominantly supplied to retail distributors (i.e., petrol stations), with wholesalers and large end users accounting for only a minor share of overall sales.

[3] See Figure 7 in Federal Competition Authority (2022) and p. 74 in Federal Cartel Office (2022).

As indicated in Figures Table C.1 and B.3, the boundaries between these vertical market segments are not rigid. Many firms are vertically integrated across several stages of the supply chain, while others operate within a single market tier. This overlap complicates the precise classification of transactions according to market level, as the same firm may act simultaneously as producer, distributor, and retailer.

The physical movement of refined products is similarly diverse, relying on multiple transportation modes. As depicted in Figure B.4, dedicated product pipelines link refineries to storage depots and export terminals, from which barges distribute large volumes along inland waterways. The final stage of delivery is typically conducted by road tanker. The allocation of transport responsibilities and costs varies by contractual arrangement and trading relationship (Federal Cartel Office (2022), Federal Competition Authority (2022)).

As transportation costs are a major cost factor, refined petroleum products are often sold in small region around the refinery. According to Table 2, approximately 90% of gasoline (diesel) sales occur within 300 km (350 km) of the producing refinery, whereas heating oil distribution is even more geographically restricted, with a typical delivery radius of roughly 200 km. The relevant market is therefore probably not national but regional, as transportation costs make far transportation inefficient. Hence, refineries have at least some form of regional market power around their location. The next section will further elaborate the competition and structure of the wholesale market for fuels.

Product	70% of Sales	80% of Sales	90% of Sales
Diesel	ca. 200km	ca. 250km	ca. 350km
Gasoline	ca. 150km	ca. 200km	ca. 300km
Heating Oil	ca. 100km	ca. 150km	ca. 200km

Table 2: Regional Extent of Refinery Sales according to Federal Cartel Office (2022)

2.5 International trade

Figure B.4 illustrates that most German refineries are located near national borders and are connected to at least one neighboring country via pipelines and waterways. These transportation networks are used both for crude oil supply and for the distribution of refined products, as they constitute the most cost-efficient modes of transportation. Figure 4 indicates that substantial volumes of diesel and gasoline are traded across Germany's borders. Approximately 10% of domestic gasoline production is supplemented by imports, while more than 20% of the production is exported. By contrast, Germany additionally imports around 20–25% of its domestic diesel production and exports only about 10%. This implies a pronounced import surplus for diesel and a smaller export surplus for gasoline. According to Federal Cartel Office (2022), these trade patterns do not necessarily reflect binding capacity constraints in diesel production but can instead be explained by factors such as regional price differentials and the cross-border allocation of refining capacity.

Owing to the importance of transportation costs, Germany primarily trades gasoline and diesel with its neighboring countries. This pattern is illustrated in Figures B.1 and B.2, which report regional import and export shares of gasoline and diesel. The bulk of gasoline exports is directed to Austria and Switzerland, likely supplied by the Burghausen refinery, which is owned by the Austrian company OMV and located directly on the Austrian border (see Figure B.4). Additional export destinations include the Benelux countries, France, and Poland, although the composition of export destinations varies substantially over time. The overwhelming majority of gasoline imports, by contrast, comes from the Benelux countries. Given Germany's persistent export surplus in gasoline, and the fact that there is no trade with Russia, gasoline supply shortages were not expected after the Russian invasion of Ukraine.

A comparable pattern is observed for diesel, as shown in Figure B.2. Export volumes vary considerably across neighboring countries, with Austria again receiving the largest share, most likely supplied by the Burghausen refinery. Further export flows are directed to the Benelux countries, Poland, and France. Germany does not export diesel to Russia. Simultaneously, Germany imports substantial quantities of diesel from the Benelux countries, reflecting both the cross-border allocation of refining capacity and established trade relationships. Historically about a third of all German diesel imports originated from Russia, and this did not change substantially after the Russian invasion of Ukraine. Only after the European sanctions against Russian crude oil products came into effect on 5 February 2023, did the import of Russian diesel cease. A domestic supply shortage directly after the invasion is therefore unlikely.

Although the wholesale market for road fuels is international in scope, transportation costs play a central role in the spatial allocation of gasoline and diesel, as discussed above. Figure B.3 shows that these fuels are predominantly traded on a regional basis. At the same time, Figure 4 indicate that these regional markets frequently extend beyond national borders and are shaped by the availability of waterways and existing pipeline infrastructure, as illustrated in Figure B.4. Consequently, regional market boundaries are more plausibly determined by proximity to individual refineries and their competitors rather than by national borders. In line with this perspective, we use price data from eleven German regions, as described in Section 3, to analyze regional treatment heterogeneity of the Russian invasion of Ukraine. In the following, we will further elaborate on the structure of the wholesale market for road fuels.

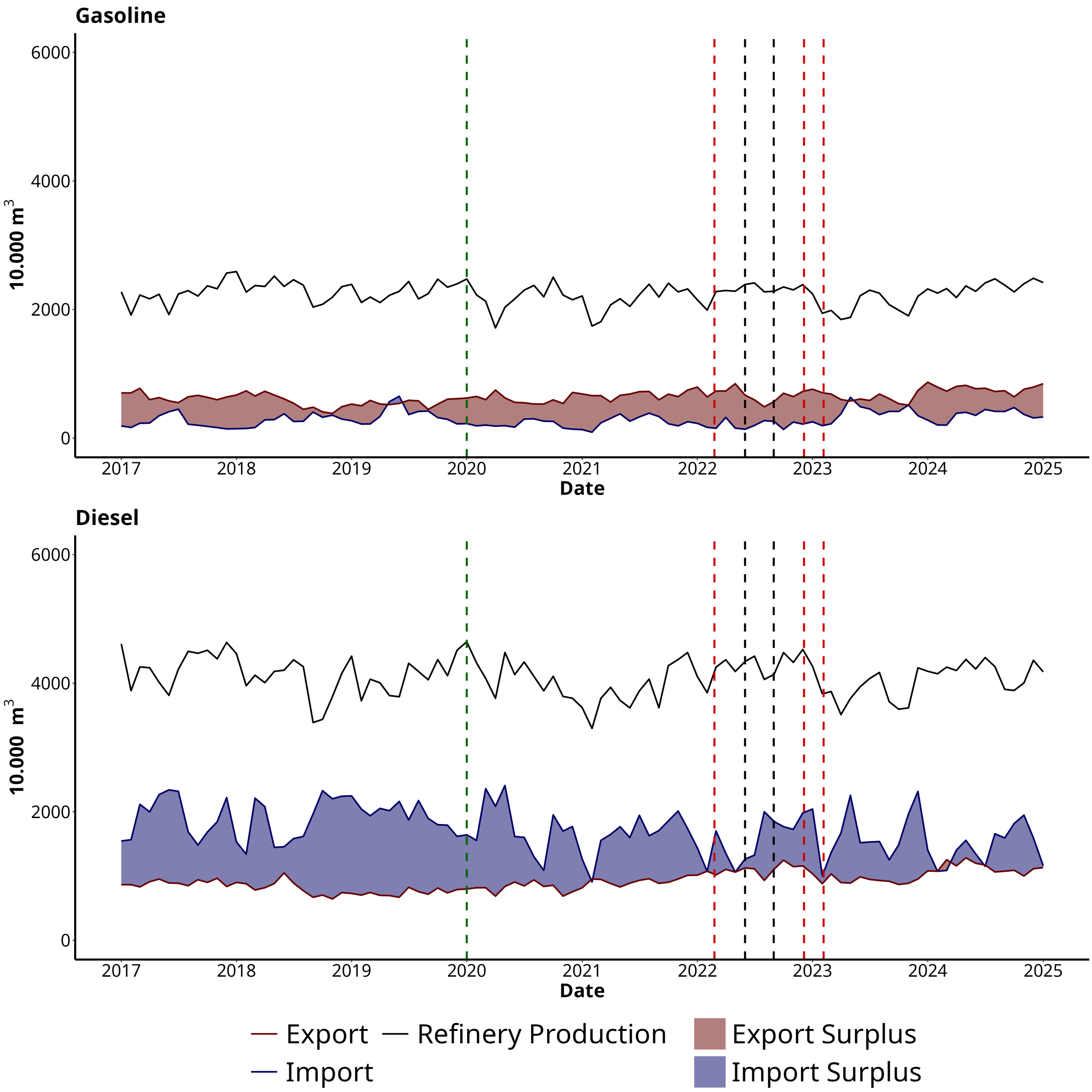

Figure 4: German Diesel and Gasoline Imports, Exports and Refinery Production

2.6 Wholesale Market Structure

As previously noted, the market for road fuels is shaped by anti-competitive characteristics that have repeatedly attracted the attention of antitrust authorities across various jurisdictions. First and foremost, the market is dominated by a small number of globally active firms that also partially control the German market. These firms are, or historically have been, fully vertically integrated, controlling the entire supply chain. This means they control the facilities to extract, transport and refine crude oil, while also selling the refined products at both the wholesale and retail levels.

Table C.1 lists all companies that own crude oil refineries in Germany. Historically, seven of these twelve firms have been fully vertically integrated, namely BP, Shell, ENI, Total-Energies, OMV, Esso, and Phillips 66. Since 2018, Esso, OMV, and Total-Energies have divested their petrol station networks, and Phillips 66 is currently offering its network for sale. In addition, three companies operate exclusively in refining and rely on other firms for crude oil supply and the marketing of refined products. Rosneft, which is majority-owned by the Russian state, have historically been involved in supplying and refining crude oil but they have never operated a petrol station network in Germany. Following the Russian invasion of Ukraine, the company's German assets have been placed under trust management by the Federal Network Agency (Bundesnetzagentur). The Oilinvest Group operates a refinery in northern Germany and maintains a petrol station network under the brand name Tamoil.

Moreover, these firms cooperate at multiple stages of the supply chain, as illustrated in Figure B.3. First, they jointly own and operate refineries, pipelines, and storage facilities. Second, although vertically integrated companies could theoretically supply their own refineries with crude oil, they do so only partially. To minimize transportation costs, they also procure and sell crude oil from and to third parties rather than exclusively within their corporate groups, resulting in mutual interdependence among firms. Independent companies or those without exploration capacity are fully reliant on external sources for crude oil supply. Finally, a system of swap agreements exists among most of the (formerly) fully vertically integrated companies. These firms operate, or historically operated, nationwide petrol station networks, despite lacking refinery capacity in all regions. They therefore engage in swap agreements to exchange refined products across regions, thereby reducing transportation costs. According to Federal Cartel Office (2011), approximately 25% of all fuel sold in Germany is traded under such arrangements.

Across the entire vertical market structure, more firms are active than the twelve listed refinery owners, for instance, those engaged in the exploration and extraction of crude oil, as well as the companies that have acquired the divested petrol station networks. As illustrated in Figure B.3, an additional layer exists within the vertical market structure covering import, export, and wholesale activities. This segment comprises a larger number of small and medium-sized enterprises operating at this market level. Other firms are active in transportation and storage services. According to Federal Cartel Office (2025b), however, these companies are generally small, and there are no indications of significant market power or competition impediments.

Although various stages of the supply chain in this sector have been examined repeatedly in Germany[4] the Federal Cartel Office has never concluded that significant joint market power can be definitively established. Nevertheless, all reports identify multiple factors with the potential to restrict competition across all levels of the market's vertical structure. This is partly because independent firms and potential entrants face substantial investment costs to establish their own supply chains or remain dependent on incumbents possessing

[4]See, for example, (Federal Cartel Office, 2011), (Federal Cartel Office, 2022), and (Federal Cartel Office, 2025b)

market power. Moreover, demand is highly fragmented: even the largest consumers purchase only a small fraction of the incumbents' output, and major wholesalers likewise lack buyer power. As a result, no effective countervailing buyer power exists.

2.7 Pricing Mechanism

The pricing and contracting mechanisms prevalent on the wholesale markets for crude oil and road fuels have been the subject of an ongoing investigation by the Federal Cartel Office (2025a). In the following, we provide an overview of these mechanisms, with particular emphasis on the role of price benchmarks.

Crude oil (products) are commonly traded on specialized exchanges such as the Intercontinental Exchange (ICE). Various contract types are available, differing in delivery terms for example locations, insurance conditions, product quality, and quantity. However, such standardized contracts are primarily traded globally and typically concern large shipment volumes at major logistical hubs such as seaports and terminals.

In Germany, by contrast, there is no formal exchange; instead, a more regional open spot market operates, characterized by smaller transaction volumes and shorter delivery periods. Refineries, wholesalers, and retailers generally rely on two main types of contracts to procure crude oil and road fuels. In the short term firms trade on over-the-counter markets directly with each other, meaning there is no exchange or broker as a middlemen. Over the longer term, firms commonly enter into annual contracts specifying delivery schedules, quantities, and product mixes to accommodate the demand at petrol stations. These contracts are usually negotiated in autumn for the following calendar year. Most of these agreements do not specify fixed prices, given the inherent uncertainty in fuel price developments. Instead, they reference price indices published by market information providers such as S&P Global Platts and Argus Media, which serve as benchmarks.

These benchmark prices are in turn derived from aggregated short-term spot market transactions described above. For example, Argus Media collects data on transactions involving product pick-up at refineries or storage facilities within a maximum of 28 days after contract conclusion. According to Argus Media, their assessments *"are informed by information received from a wide cross-section of market participants, including producers, consumers and intermediaries. Argus Media reporters engage with the industry by proactively polling participants for market data. Argus Media will contact and accept market data from all credible market sources including front and back office of market participants and brokers. Argus Media will also receive market data from electronic trading platforms and directly from the back offices of market participants. Argus Media will accept market data by telephone, instant messenger, email or other means."* Contracts often reference weekly or monthly averages of these benchmark indices. As reported by Federal Cartel Office (2022), firms vary considerably in their reliance on spot market transactions versus long-term supply contracts.

However, as noted by Federal Cartel Office (2025a), concerns have been raised regarding the reliability and objectivity of the benchmark data. The authority criticizes that "in some regions, the quoted prices were based on no or only very few transactions on many trading days." Moreover, the data appear to be asymmetrically reported, with sellers more frequently providing price information to Argus Media than buyers. Some firms have also stated to selectively reporting transactions, which could potentially introduce a systematic bias into the benchmark indices.

Our model therefore considers that Germany as a whole sources crude oil from a diverse range of countries. Yet individual refineries operate under more constrained procurement conditions determined by their geographic location due to infrastructure and technical capability to process particular crude oil types. Refining inherently produces multiple petroleum products jointly, and the ability of refineries to alter their product mix is limited. Consequently, the wholesale market for road fuels exhibits significant regional segmentation, with refineries likely exerting market power within their respective supply areas.

During the period under investigation, there is no evidence of supply shortages in the German road fuel market. Despite the termination of substantial diesel imports from Russia, suppliers successfully compensated for these losses between the onset of the invasion and the enforcement of the European Union's import bans on Russian oil products. Nevertheless, the oligopolistic market structure and the prevailing pricing mechanisms appear to restrict the intensity of competition in the wholesale fuel market.

3 Data

In this paper, we utilize a unique combination of pricing and quantity data covering all three market levels, as described in Section 2. In addition, we incorporate a range of control variables capturing demand- and supply-side characteristics as well as broader economic cycles.

Pricing Data We use crude oil prices from Argus Media and Refinitiv Datastream to control for crude oil input costs. Following Federal Cartel Office (2022), we specifically employ the "ICE Brent 1-minute month" indicator from Argus Media, which represents the daily settlement price at 16:30 London Time on the London ICE for a futures contract trading 1,000 barrels of Brent Blend for delivery in the month after next. This contract is particularly relevant as Brent Blend serves as the benchmark price for European crude oil trading. Moreover, its trading volume is high and it is not regionally limited unlike a spot price. For robustness, we also incorporate crude oil input prices from Refinitiv Datastream. First, we use prices for Brent Blend on the ARA spot market, which provide a more accurate input price for refineries located along the Rhine River. Second, we include prices for Sahara Crude Oil, which better reflect input prices for refineries in southern Germany. Finally, we use prices for Ural Blend, which more closely approximate input prices for refineries in eastern Germany.

Furthermore, we use data on the wholesale market for refined crude oil products in Germany and the ARA region. As discussed in Section 2, there is no commodity exchange for these products in Germany; instead, trading takes place on an open spot market. We use physical pricing data from Argus Media, a price information service that publishes daily "end-of-day price assessments" supposed to reflect prevailing spot market values. Specifically, we use price quotations for "95 Ron E5" and "Diesel EN590 10ppm", hereafter referred to as gasoline and diesel, respectively. Argus Media reports these prices for eleven German regions: South, Southwest, Southeast, East, Magdeburg, West, Rhine-Main, Seefeld, North, Emsland, and Cologne Lowland. Each region is associated with one or more trading locations, typically refineries, ports, or major storage facilities. Figure 5 depicts the geographical extent of these eleven regions within Germany, along with their corresponding trading spots. Each colored point on the map represents a petrol station, which is assigned to the nearest trading location and thereby to its respective regional market.

Figure 5 also highlights red triangles, which represent the locations used by Argus Media to compute so-called "ARA import parities". These correspond to the calculatory costs of importing gasoline and diesel from northwest Europe to German regional markets. They reflect the costs of procuring refined products in Germany without sourcing from domestic refineries. Argus Media calculates these import parities by combining ARA regional price quotations for gasoline or diesel with estimated freight costs. These prices are published for several German regions, including Dortmund, Duisburg, Cologne, Frankfurt, and Karlsruhe (Argus Media, 2024a).

Lastly, we use data on retail gasoline prices collected by the Market Transparency Unit for Fuels (MTU) at the German Federal Cartel Office, accessed via "tankerkoenig.de."[5] Since all German petrol stations are legally required to report every price change in real time, this dataset provides comprehensive coverage of virtually all fuel price changes in Germany. Consistent with the wholesale market data, we use retail prices for E5 gasoline and diesel.

Quantity Data We get Quantity Data from the *Joint Organizations Data Initiative* (JODI), which is an initiative of the international energy forum (IEF). JODI publishes monthly quantity data for nearly 100 countries, covering significantly more than 90% of the global supply and demand of crude oil (products). The data itself is reported by the government

[5] `https://tankerkoenig.de/` provides access to the full historical dataset published by the MTU.

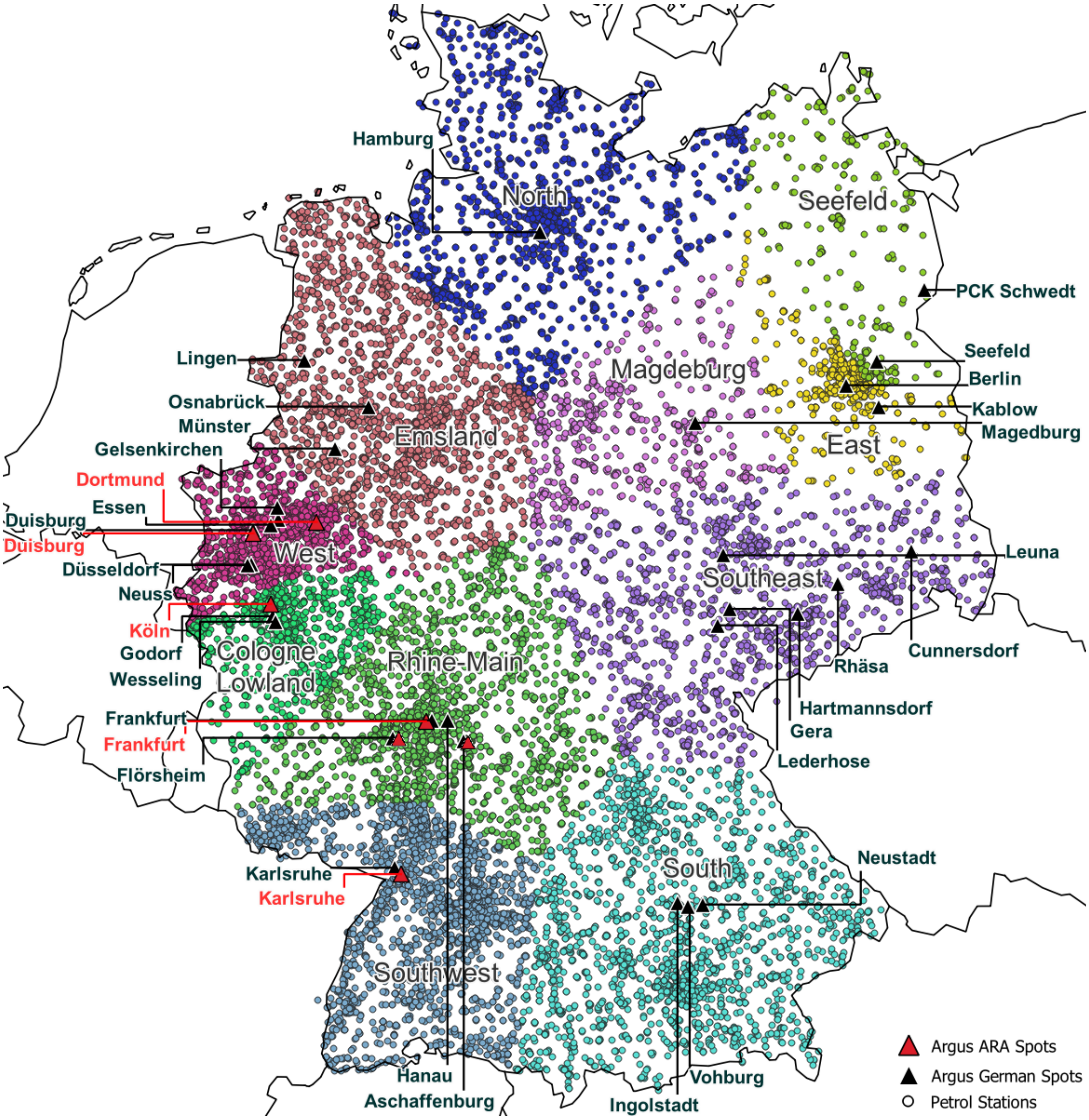

Figure 5: Argus Media Spots, Regions and Petrol Stations

of participating countries and send directly to JODI by filling out a standardized survey. JODI defines all quotas, definitions and insures the quality of the published data. The data, is however, only available on a monthly basis and at the national level.

The data itself repoprts monthly quantity data for thirteen different product categories, from which we use “crude oil”, “motor and aviation gasoline” and “gas/diesel oil”, hereafter referred to as crude oil, gasoline and diesel respectively. It includes the supply as well as the demand side and follows the following logic:

$$
\begin{aligned}
&Production + From\ other\ Sources + Products\ transferred/Backflows - Direct\ Use\\
&+ Imports - Exports - Stock\ Change - Statistical\ difference\\
&= Refinery\ Intake, \qquad (1)
\end{aligned}
$$

$$
\begin{aligned}
&Refinery\ Output + Receipts + Interproduct\ transfers - Products\ transferred\\
&+ Imports - Exports - Stock\ Change - Statistical\ difference\\
&= Demand. \qquad (2)
\end{aligned}
$$

Equation (1) outlines the structure of the crude oil data, while Equation (2) describes the structure of the data for refined oil products. In Equation (1), $Refinery\ Intake$ represents the observed refinery consumption within a country and thus captures the demand side of national crude oil use. *Production* refers to the marketable output of crude oil. *From other sources* denotes the input of additives such as biofuels and lubricants. $Products\ transferred/Backflows$ refers to returns from the petrochemical and pharmaceutical industries, as well as "imported petroleum products which are re-classified as feedstocks for further processing in the refinery, without delivery to final consumers" (JODI, 2025). $Direct\ Use$ denotes crude oil consumed within the refinery itself, for instance for electricity generation.

In Equation (2), *Demand* captures the total domestic deliveries or sales for consumption, including marine and aviation bunkers. $Refinery\ Output$ measures the marketable production of a specific product from refineries, while *Receipts* primarily refer to recycled products reintroduced into the supply chain. $Interproduct\ Transfers$ capture the re-classification of products, either due to changes in their specifications or because they have been blended into another product.

In both Equations (1) and (2), *Stock Change* denotes the net variation in inventory levels, reflecting additions to or withdrawals from stocks. *Import* and *Export* capture the quantities of crude oil or refined products entering or leaving a country, respectively. Finally, $Statistical\ Difference$ represents the residual discrepancy between *Demand* (for refined products) and $Refinery\ Intake$ (for crude oil), as well as all supply-side components described above. This difference primarily arises from inaccuracies or inconsistencies in data reporting to JODI (2025).

3.1 Timeline of Events

Figure 6 presents the timeline of our data. We utilize data from the beginning of 2017 until the end of 2024, thereby covering a sufficiently long period prior to the invasion and the COVID-19 pandemic as well as an extended period thereafter, enabling us to examine the effect of the invasion and subsequent war on fuel prices. Within this timeframe, however, several exogenous discontinuities have influenced fuel prices. First, an exceptional drought during the summer of 2019 led to a substantial decline in the water level of the Rhine, significantly constraining transport capacity and increasing barge prices along the river. Second, the COVID-19 pandemic and related lockdown measures led to a pronounced decline in fuel demand, resulting in a substantial decrease in prices. Third, as part of the pandemic response, the value-added tax (VAT) on fuels was temporarily reduced from 19 % to 16 %, from the beginning of July until the end of 2020. While we do not exploit these exogenous shocks, we account for them in the analysis that follows.

In 2022, the conflict between Russia and Ukraine, ongoing since at least 2014, escalated when Russia invaded Ukraine on 24 February 2022. The invasion was, however, to be expected, as a Russian military buildup along the Ukrainian border was observed since April 2021, with increasing efforts in October 2021 (The Washington Post, 2022b). In the aftermath of the invasion, crude oil prices rose, but fuel prices increased disproportionately, which is the effect we analyze in this paper. In response to the price surge, the German government introduced the so-called "Tankrabatt" (tax rebate), a temporary reduction in energy taxes on gasoline and diesel to the European minimum permitted levels. In reaction to Russian aggression against Ukraine, the European Union imposed numerous sanctions targeting Russia and its economy, including bans on the import of crude oil and crude oil products. Between 30–31 May 2022, the European Council agreed on the sixth sanctions package, which encompassed such bans. On 3 June 2022, it was officially announced that the EU is "prohibiting the purchase, import or transfer of crude oil and crude oil products from Russia into the EU." (Council of the EU, 2022b) These import bans took effect on 5 December 2022 for crude oil and on 5 February 2023 for crude oil products. An exception for pipeline-delivered crude oil remained in place until 23 June 2023 for Germany and Poland; only limited exceptions apply thereafter. According to the EU, 90 % of all Russian crude oil imports into the EU are prohibited under these sanctions. Additionally, the EU sanctioned all services related to the transportation of Russian crude oil if the price of crude oil exceeds 60 USD per barrel (Council of the EU, 2022a).

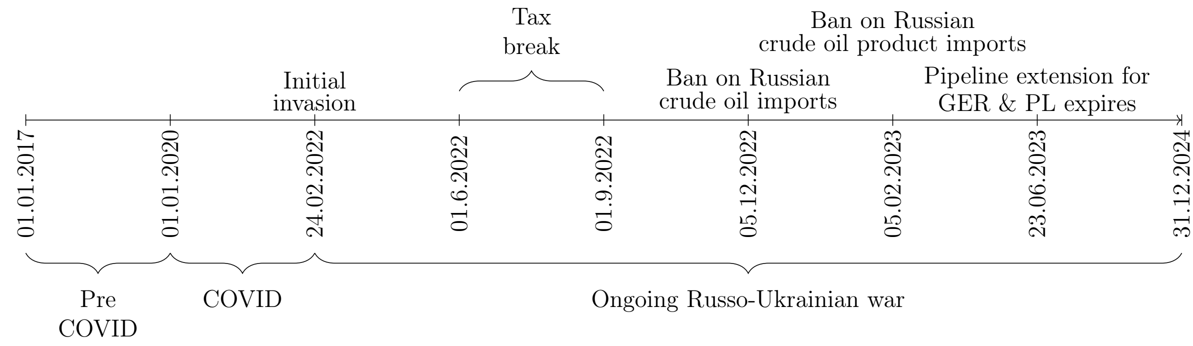

Figure 6: Timeline of Events

4 Empirical Strategy

We estimate a standard diff-in-diff model following Ashenfelter (1978) and Card and Krueger (1994), comparing refinery margins in Germany and the ARA region before and after the invasion. The empirical specification is as follows:

$$\Pi_{it} = \alpha + \lambda Invasion_t + \gamma Germany_i + \beta[Germany_i \times Invasion_t] + \rho X_{it} + \epsilon_{it}, \qquad (3)$$

where Π_{it} denotes refinery margins, defined as the difference between the wholesale price for gasoline (diesel) and the crude oil input price including freight costs. The variable $Invasion_t$ is a binary indicator equal to 1 for all dates after 24 February 2022. $Germany_i$ identifies whether an observation is from Germany or not. The interaction term coefficient, β, captures the ATT of the invasion on refinery margins in Germany, expressed in c/l of gasoline (diesel). X_{it} is a vector of control variables, described in Section 3.

To account for regional and temporal heterogeneity, we also estimate an extended specification that includes fixed effects for days and locations:

$$\Pi_{it} = \alpha \sum_{i=1}^{I} \lambda_i Region_i + \sum_{t=1}^{T} \gamma_t Period_t + \beta[Germany_i \times Invasion_t] + \rho X_{it} + \epsilon_{it}. \qquad (4)$$

Here, $\lambda Germany_i$ is replaced with a full set of region fixed effects $\sum_{i=1}^{I} \lambda_i Region_i$, and $\gamma Invasion_t$ with a set of time fixed effects $\sum_{t=1}^{T} \gamma_t Period_t$. This controls for unobserved heterogeneity across regions and over time. The coefficient of interest β remains the same.

Baseline Sample The markets for crude oil and road fuels underwent substantial changes prior to and during the Russian invasion of Ukraine, as detailed in Section 5. To isolate the baseline effect, we estimate the treatment effect using a restricted sample covering the period from 1 January 2022 to the announcement of import bans on Russian crude oil and refined fuels at the end of May 2022. This restriction yields a lower bound estimate, as wholesale prices had already begun responding to the anticipated invasion as early as January 2022. We relax this constraint in subsequent specifications.

Identification The causal interpretation of the treatment effects in Equations (3) and (4) relies on three main assumptions: (i) the treatment and outcomes in Germany do not influence those in the ARA region (corresponding to the stable unit treatment value assumption, SUTVA), (ii) the treated group did not anticipate the intervention and adjust behavior in the pre-treatment period accordingly, and (iii) in the absence of treatment, refinery margins in Germany and the ARA region would have evolved in parallel trends.

The first assumption is likely violated. It presumes that Germany is treated and the ARA region is not. However, given the global impact of the Russo-Ukrainian War on crude oil and fuel markets, refineries in the ARA region are also plausibly affected. Consequently, the ARA region does not constitute a pure control group. Therefore, our estimate reflects a lower bound of the true treatment effect on German refinery margins. Nonetheless, we expect margins in Germany to increase more than in the ARA region, primarily for two reasons. First, German refineries were more reliant on Russian crude and diesel imports, making them more vulnerable to the disruption. Second, refineries in the ARA region face stronger competitive pressures, as its prices are shaped by both European and global supply and demand conditions. The counterfactual in this diff-in-diff design is thus not a no-invasion scenario, but one in which the supply of German refineries was more diversified and the market for road fuels was more competitive.

The second assumption is also likely violated. As shown in Section 5, fuel and Ural crude oil prices began rising in October 2021 and January 2022, in response to Russia's military mobilization near the Ukrainian border. This suggests that the invasion was partially anticipated by market participants, resulting in earlier price adjustments. Again, the relative dependence of Germany on Russian imports implies that German refinery margins likely increased more than those in the ARA region. Hence, our pre-treatment period is already partially treated, leading to an upward bias in the control group. This means that the estimated treatment effect is biased downwards - again implying a lower bound. The counterfactual pre-invasion period is thus one in which the invasion was expected but had not yet occurred. This is especially true for the baseline sample beginning on 1 January 2022. When using the extended sample beginning in January 2017, the pre-treatment period includes years where the invasion was not anticipated, reducing the bias and improving identification.

To assess the plausibility of the third assumption, the parallel trends assumption, we follow Lichter and Schiprowski (2021) and extend the basic diff-in-diff model in Equation 3 to a dynamic specification that allows for time-varying treatment effects. The dynamic model is given by:

$$\Pi_{it} = \alpha + \sum_{t=1}^{T} \gamma_t Period_t + \lambda_i Germany_i + \sum_{t=1}^{T} \beta_i t(Period_t \times Germany_i) + X_{it} + \varepsilon_{it}. \quad (5)$$

Here, we replace the term $Invasion_t$ with $\sum_{t=1}^{T} \gamma_t Period_t$, which captures week or month indicators. The period directly preceding the invasion is excluded to avoid collinearity and serves as the baseline. The interaction coefficients β_k capture the differential in refinery margins between Germany and the ARA region relative to this baseline. Statistically insignificant coefficients in the pre-treatment period would support the parallel trends assumption.

This specification also enables examination of the invasion's dynamic effects on refinery margins throughout the post-treatment period. We estimate it thrice: once using weekly periods for the year 2022 to assess dynamic treatment effects, and once using monthly periods starting in 2017 to test for the validity of the parallel trends assumption over a longer horizon. We also estimate a dynamic model to analyze the long term effect of the Russo-Ukrainian war and subsequent sanctions on wholesale prices and quantities, using all available data until 2025.

Regional treatment heterogeneity To exploit the full regional variation in the dataset, we examine treatment heterogeneity across German regions. As outlined in Section 3, the data covers eleven distinct German regions. We therefore estimate the following specification:

$$\Pi_{it} = \alpha + \sum_{i=1}^{I} \lambda_i Region_i + \gamma Invasion_t + \sum_{i=1}^{I} \beta_i [Region_i \times Invasion_t] + \rho X_{it} + \epsilon_{it}, \quad (6)$$

In this model, we replace the binary indicator for Germany with a full set of region-specific dummy variables, $\sum_{i=1}^{I} Region_i$, capturing the eleven regions within Germany. The ARA region is excluded and serves as the reference category. The interaction terms β_i capture the differential impact of the treatment on refinery margins in each German region relative to the ARA benchmark.

Finally, we combine the regional and dynamic dimensions to assess how the treatment effect evolves over time across regions. The resulting model is specified as follows:

$$\Pi_{it} = \alpha + \sum_{i=1}^{I} \lambda_i Region_i + \sum_{t=1}^{T} \gamma_t Period_t + \sum_{i=1}^{I} \sum_{t=1}^{T} \beta_{it} [Region_i \times Period_t] + \rho X_{it} + \epsilon_{it}, \quad (7)$$

Here, we simultaneously replace $Invasion_t$ and $Germany_i$ with a full set of time dummies

$\sum_{t=1}^{T} \gamma_t Period_t$ and region dummies $\sum_{i=1}^{I} Region_i$. The ARA region is again omitted as the baseline region, and the final week prior to the invasion is excluded to avoid perfect multicollinearity. The coefficients β_{it} measure the time-varying treatment effect for each German region relative to the ARA region and relative to the last pre-invasion week. This allows us to track the temporal evolution of the invasion's impact on refinery margins at the regional level, with all coefficients interpreted relative to the ARA region and the baseline period.

Quantity Effects We further utilize the available quantity data to estimate the impact of both the invasion and the sanctions on fuel demand in Germany using a diff-in-diff approach. Before we have used ARA spot market prices as a control group, because they are an established benchmark price for trading crude oil products in Europe. The quantity data is, however, only available on a national basis and the Netherlands and Belgium are not representative for the whole of Europe. We therefore use the entire European Economic Area (EEA) as a control group. We apply the specifications in Equation 3 and adjust them, as following:

$$log(Q_{it}) = \alpha + \lambda Germany_i + \gamma Invasion_t + \beta[Germany_i \times Invasion_t] + \rho X_{it} + \epsilon_{it}, \quad (8)$$

where $log(Q_{it})$ is the relative change in quantity demand. As in the approach above the coefficient of interest i.e. the ATT compares demand in Germany and the rest of the EEA before and after the invasion or respective sanctions.

Following the approach from Equation 5, we also estimate dynamic treatment effects of the invasion and subsequent sanctions on demand of gasoline and diesel using the following estimation:

$$log(Q_{it}) = \alpha + \sum_{t=1}^{T} \gamma_t Germany_i + \lambda_i Period_t + \sum_{t=1}^{T} \beta_i t(Germany_i \times Period_t) + X_{it} + \varepsilon_{it}. \quad (9)$$

Results of these estimations will, however be very rough, as the quantity data at hand is only available on a monthly basis and thus are the interaction coefficients. We can therefore only look at less than 10 coefficients before the start of the sanctions in order to assess the effect of the invasion. Further, we only have quantity data on a national level, therefore no regional level analysis is possible.

5 Descriptive Statistics

Before we estimate the impact of the Russian invasion of Ukraine on refinery margins and quantity in Germany, we provide a detailed discussion of the available data in the following.

Price Data Figure 7 shows the development of prices per liter net of taxes for crude oil, as well as gasoline and diesel in both the wholesale and retail market, from 2017 until 2025. The first green dotted line indicates the start of 2020, marking the onset of the COVID-19 pandemic, which initially led to a sharp decline in crude oil and fuel prices in both wholesale and retail markets. The first red dotted line denotes the Russian invasion of Ukraine in February 2022. Prices for crude oil and fuels had already begun to rise in anticipation of the invasion, but following the event, wholesale and retail fuel prices increased sharply, while crude oil prices remained relatively stable. This divergence implies a substantial rise in refinery margins, approximately two to three times higher than pre-invasion levels. Figure 7 indicates that refinery margins remained elevated throughout 2022. In 2023 and 2024, following the implementation of European sanctions on Russian crude oil and fuel imports, marked by the final two red dotted lines, refinery margins appear to return to pre-war levels. The figure also shows that station margins, i.e. the difference between wholesale and retail prices for road fuels net of taxes stays remarkably constant over time.

Figure 8 presents the development of average refinery margins for gasoline and diesel in Germany and the ARA region. Refinery margins for both fuel types in Germany and the ARA region exhibit substantial volatility following the invasion. For gasoline, German margins peaked sharply immediately following the invasion and again after the beginning of the temporary tax cut. They decreased throughout 2022 before increasing again in 2023 and then returning to pre-war levels in 2024. In contrast, gasoline refinery margins in the ARA region remained relatively stable immediately after the invasion before increasing significantly by mid-2022. During the second half of 2022, ARA gasoline margins began to decline, increase again and then return to pre-war levels. Within 2023 margins in the ARA region increase slightly, but remained generally stable. The difference between gasoline refinery margins in Germany and the ARA region is mainly pronounced the first time immediately after the invasion, the second time around the end of the tax cut in Germany and last throughout 2023.

Diesel refinery margins show greater volatility in both Germany and the ARA region. In both regions, margins peak immediately after the invasion and remain elevated, though volatile, until the end of the year. Throughout 2022, diesel refinery margins in Germany are significantly higher than those in the ARA region. Over the course of 2023, German diesel margins decline and converge with ARA margins, with both remaining aligned for

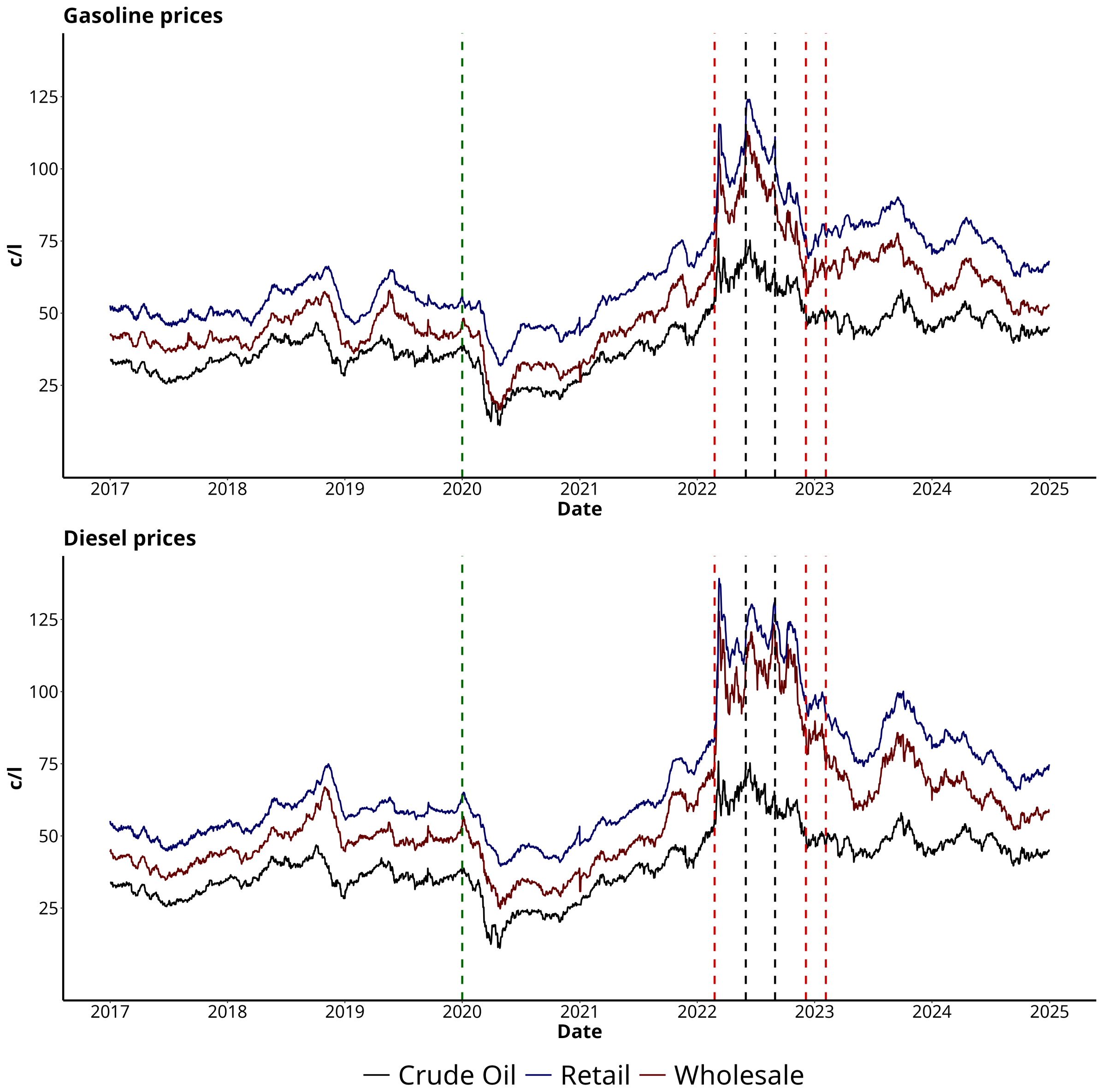

Figure 7: Crude Oil, Diesel and Gasoline Prices on the Wholesale and Retail Market

the rest of the observation period. The volatility of prices also decreases significantly. Overall, refinery margins in Germany increase significantly more than those in the ARA region immediately following the invasion. For gasoline, margins converge relatively quickly and diverge again toward the end of the year, while the gap in diesel margins remains relatively constant, narrowing only in 2023. This pattern highlights the possibility of heterogeneous treatment effects of the invasion across fuel types and over time.

Table C.2 confirms these results. Prices for Sahara and Brent crude oil blends double after the invasion from about 32-35 to 65-71 c/l. Ural crude oil blend prices already increased during the COVID-19 pandemic and stayed constant during the Invasion at 56 c/l. Wholesale prices for gasoline (diesel) in Germany increased from about 42 (45) to 99 (112) c/l during the peak, meaning that relative changes in crude oil and wholesale prices

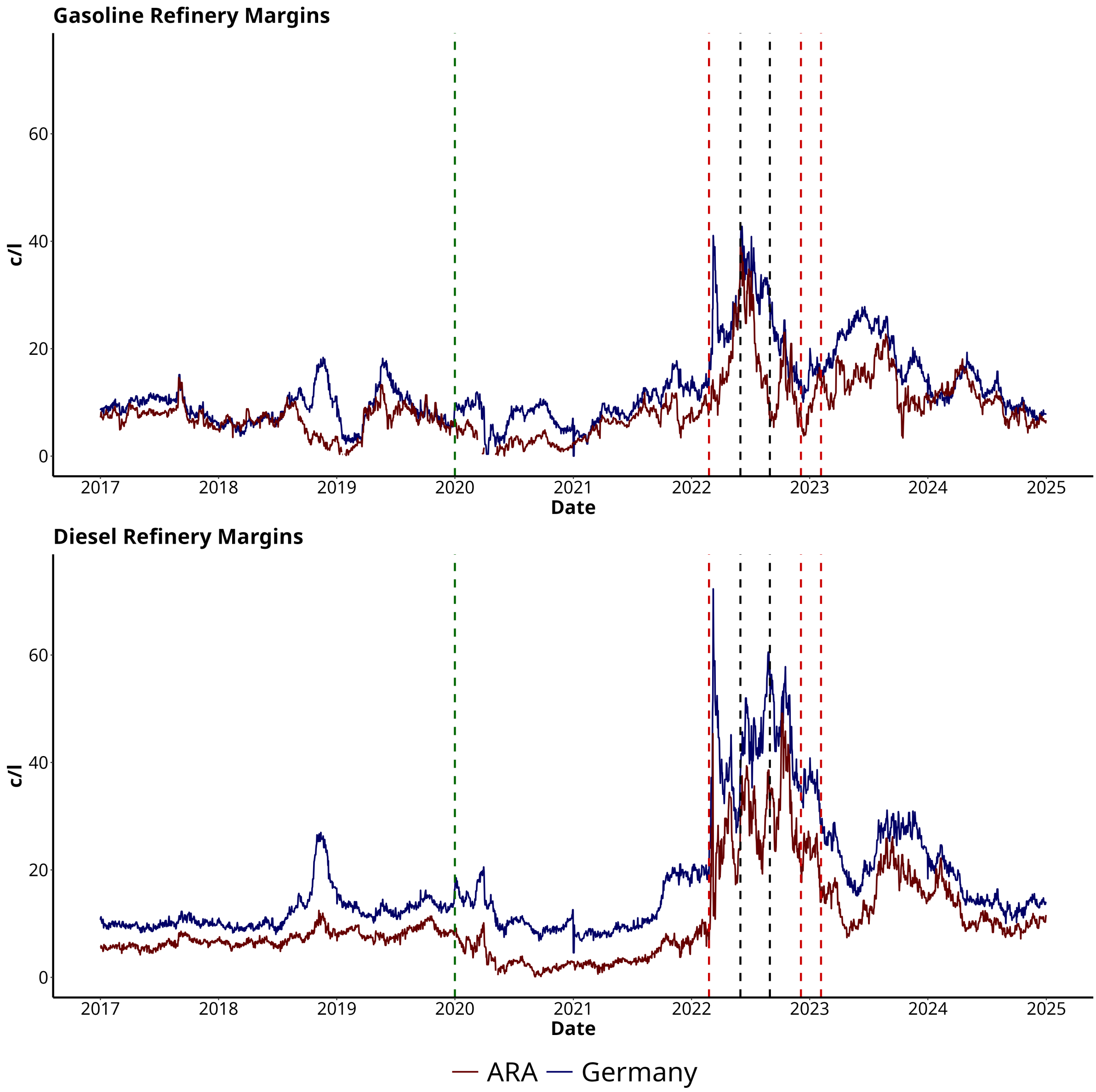

Figure 8: Refinery Margins for Gasoline and Diesel in Germany and on the ARA spot market

are comparable. Subsequently, however absolute refinery margins in Germany increased overproportionally: Margins for diesel nearly quadruple from 12 c/l to 47 c/l and for gasoline they more than triple from 9 to 34 c/l. In our control group the ARA region, refinery margins increase for gasoline (diesel) from 7 (7) to 23 (33) c/l, which is a lower increase in absolute terms, but in relative terms the increase is nearly identical. This preliminary evidence suggests that the relative increase is similar for crude oil (products) prices in Germany and the ARA region. However, as wholesale prices in Germany are higher than those in the ARA region, refinery margins in Germany subsequently increased more in absolute terms after the invasion.

Furthermore, Table C.2 also shows that freight costs, which are an important cost factor are more or less stable over the observed time period. Also station margins, the difference between wholesale and retail price, is remarkably stable and only increases from about 10 to 14 c/l within our observation period. Consequently, we will focus our primary analysis on wholesale markets, as the station margin shows limited variation.

Table C.3 shows that on average there is no significant regional variation in prices between different locations in Germany. As described above the table shows that in all regions prices double after the invasion and peak in the tax and posttax period, before returning to lower levels in the post sanctions period. The variation between locations in Germany is mostly within one standard deviation and therefore not significant.

Quantity Data Using monthly data from JODI, we analyze the development of aggregated demand for gasoline and diesel over time. Figure 9 shows normalized demand for gasoline and diesel in Germany and the EEA in percent. In this figure 100% is the average demand from 2016. The figure shows that demand for gasoline in Germany and the rest of the EEA follows a similar trend. In the period before the COVID-19 pandemic demand did however increase more significantly in Germany than it did in the rest of the EEA. Demand during the COVID-19 pandemic and subsequent lockdowns decreased significantly both in the EEA and Germany. However, during the recovery in the second half of 2021, demand for gasoline in the rest of the EEA is stronger than it is in Germany, compared to 2016. From 2022 onward the development of demand for gasoline in Germany and the EEA is very similar and mostly on a level above 2016 demand. A clear effect of the invasion and subsequent import bans on demand in Germany and the EEA is not distinguishable.

Figure 9 also shows the development of normalized demand for diesel. The variance of demand for diesel is much less than it is for gasoline and mostly fluctuates around the level of 2016 in the years preceding the pandemic. The effect of the pandemic is also a lot less pronounced than it is for gasoline.[6] Demand for diesel, however never fully recovers to pre-pandemic levels and is from then on about 10-20 % below 2016 levels. This is especially true for demand in Germany and less so for demand in the EEA. A distinct effect of the invasion and subsequent import bans is also not distinguishable.

In Table C.4 we show the components of the absolute quantity data from JODI, as explained in Equation 2 in more detail. We simplify the data so that the sum of Production, Import and Other minus Export is equal to the demand or refinery intake, which leads to limited deviations in the data. As the data is only available on a monthly basis, there are 36 observations per country or three years before the start of the COVID-19 pandemic, 26 months within the pandemic, three months after the invasion and before the start of the temporary tax cut, four months after and 25 months after the start of import bans on Russian crude oil in December 2022.

[6]This is to be expected as car traffic was significantly lower during the pandemic, whereas truck traffic was not as significantly affected (KCW, 2024).

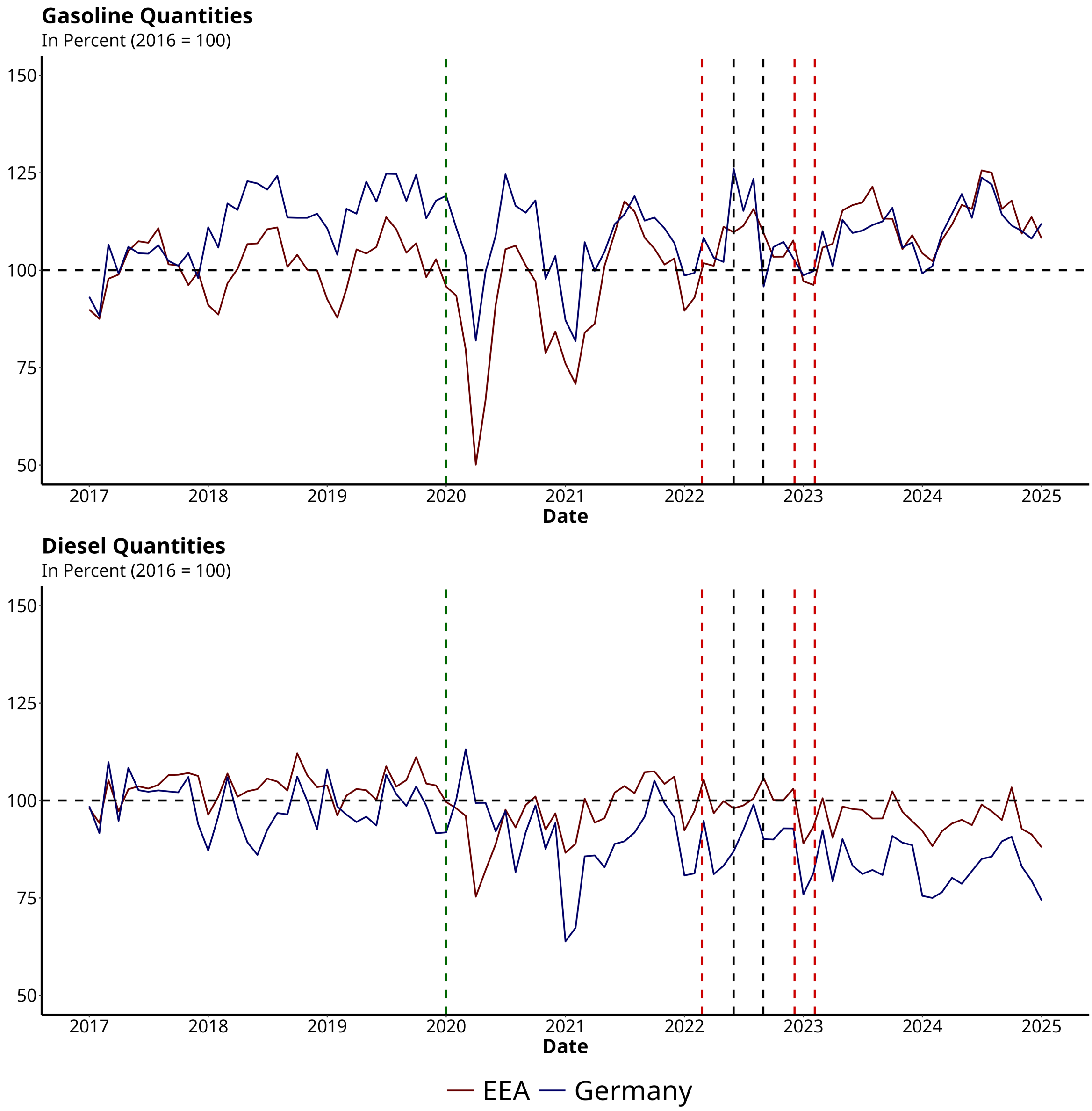

Figure 9: Normalized Development of Gasoline and Diesel Demand in Germany and the EEA

The table indicates that crude oil intake by German refineries is very stable over time, with observed fluctuations remaining well within one standard deviation. The same holds for the sources of crude oil supply: domestic production, the trade balance, and stock changes all exhibit only limited variation within one standard deviation. Refinery intake in the EEA declines during the COVID-19 pandemic, as expected, but subsequently recovers to a level slightly below its pre-pandemic average. These changes are almost entirely driven by variations in the EEA trade balance, while crude oil production within the EEA remains remarkably stable throughout the period.

The table shows that the crude oil intake of German refineries is very stable over time, as fluctuations are well within a standard deviation, so are the sources of the crude oil:

Production, trade balance and stock changes all fluctuate within a standard deviation. Refinery intake in the EEA decreases during the COVID-19 pandemic as expected, but recovers again to level slightly below pre-pandemic levels. These changes all come down to changes in the trade balance of the EEA. Production of crude oil in the EEA is very stable over time.

Gasoline demand in Germany is remarkably stable over time. A modest increase is observed only during the temporary tax cut, which may partly reflect seasonal patterns. Gasoline production in Germany increases following the Russian invasion of Ukraine, while the trade balance increases slightly, indicating a rise in net exports. In contrast, gasoline demand in the EEA declines significantly during the COVID-19 pandemic and subsequently increases to levels exceeding those observed prior to the pandemic. Over the same period, gasoline production in the EEA declines, which is accompanied by a corresponding reduction in the EEA's export surplus. Diesel demand in Germany declines during the COVID-19 pandemic and falls further in the three months following the Russian invasion of Ukraine. Although demand temporarily recovers during the tax cut period, it subsequently decreases again over time. In contrast, diesel production in Germany increases over the sample period, leading to a gradual reduction in the country's diesel import surplus. A broadly similar pattern is observed for the EEA. Diesel demand declines during the pandemic and does not fully recover thereafter. However, diesel production in the EEA decreases even more strongly over time, resulting in a further deterioration of the trade balance and implying an increasing reliance on diesel imports at the aggregate EEA level.

Overall, the data provide no indication of gasoline or diesel shortages in either Germany or the EEA, consistent with anecdotal evidence. For gasoline in Germany, production grows more strongly than demand, while the trade balance declines over time, implying an increasing export surplus. In the control group, the trade balance also decreases but remains clearly negative, indicating that the EEA continues to export substantial gasoline volumes. Additionally, these quantity changes are generally small and not statistically significant.

For diesel, the opposite pattern emerges. In Germany, production increases while demand declines, possibly reflecting rising prices, following the loss of Russian imports and a decreasing import surplus. A similar development is observed at the EEA level, suggesting that the control group is also affected. Again, changes in quantities are modest and largely insignificant. Overall, shortages appear unlikely, and a clear demand-side effect of the Russian invasion of Ukraine is not evident. The results nonetheless highlight the need to account for major external shocks, such as the COVID-19 pandemic, when evaluating pre-trends in the subsequent analysis.

6 Results

We exploit the Russo-Ukrainian war as an exogenous shock within a diff-in-diff framework. Specifically, we compare refinery margins in Germany and the ARA region before and after the full-scale Russian invasion of Ukraine in early 2022, whereas we calculate refinery margins as the difference between wholesale prices for road fuels and crude oil plus freight costs. The increased geopolitical uncertainty surrounding the invasion is expected to raise import prices for crude oil and road fuels. We do, however, hypothesize that wholesale prices for road fuels increased disproportionately to crude oil prices, therefore increasing margins for refineries. We also expect German refinery margins to increase disproportionately to margins in the ARA region, resulting in a positive ATT. As discussed in Section 5 the Russian invasion of Ukraine has a significant positive impact on refinery margins within 2022, which seems transitory. Therefore, we will first analyze the transitory shock by using data from 2022. Second, we will investigate the long term effect of the ongoing Russo-Ukrainian war on refinery margins in Germany compared to those in the ARA region. Additionally, we incorporate quantity data to estimate the ATT of the invasion and the war on demand, employing the same identification strategy.

6.1 Effects of the Russian Invasion of Ukraine on Refinery Margins

In this section we will investigate the short and medium term effects of the Russian invasion of Ukraine before the start of the European import sanctions against Russian crude oil and crude oil products.

Baseline Results In Section 5 we show that the market for crude oil and road fuels has undergone significant changes within the period of our analysis. Therefore, we estimate a diff-in-diff model over a very limited period of time from 1 January 2022 until the announcement of the Russian crude oil import ban in Europe on 30 May 2022, spanning 149 days: 55 days before the invasion (control) and 94 days after (treatment). We cluster standard errors at the level of Argus regions and ARA import parity spot markets (see Section 3).

	Gasoline	Gasoline	Diesel	Diesel
Germany:Invasion	9.977***	9.977***	8.274***	8.274***
	[7.928; 12.025]	[7.870; 12.083]	[6.579; 9.969]	[6.531; 10.018]
Germany	3.514***		11.178***	
	[1.672; 5.357]		[10.202; 12.153]	
Invasion	−0.059		11.689***	
	[−0.337; 0.220]		[11.374; 12.005]	
Location FE		✓		✓
Date FE		✓		✓
Num. obs.	2682	2682	2682	2682
R^2	0.326	0.828	0.645	0.866
Adj. R^2	0.325	0.817	0.645	0.857
Num. Dates		149		149
Num. Locations		18		18

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

Table 3: Diff-in-Diff Estimation Results of the Russo-Ukrainian War on Gasoline and Diesel Refinery Margins

Table 3 presents the baseline estimation results based on the models specified in Equations (3) and (4). A positive coefficient indicates an increase in German refinery margins following the Russian invasion of Ukraine, relative to refinery margins in the ARA region. In other words, it suggests that refinery margins for road fuels in Germany rose compared to those in the ARA region after the Russian invasion of Ukraine in early 2022.

The baseline estimates indicate that the Russian invasion of Ukraine had a strictly positive effect on German refinery margins. On average, gasoline (diesel) refinery margins increased by approximately 10 (8.3) c/l relative to the ARA region after the invasion. The 95% confidence intervals imply a true effect ranging from 7.9 to 12 (6.6 to 10) c/l. Given that the ATT is both strictly and statistically significant, the null hypothesis that refinery margins were stable following the invasion can be rejected. Hence, refinery margins for road fuels in Germany rose significantly relative to those in the ARA region after the Russian invasion of Ukraine. Nonetheless, the validity of these results is limited due to the restricted control- and treatment- observation periods.

Extended Sample In the following, we employ the same model as above but extend the sample period to include data from 1 January 2017 up to the introduction of the European sanctions on Russian crude oil and oil product imports on 5 December 2022. This extension serves two purposes. First, it allows us to control for seasonal effects such as holiday-related traffic fluctuations, as well as demand-side variables that are only available on an annual basis, including inflation rates and disposable income. Second, it provides a robustness check for the previous estimation by assessing whether the results remain stable when both the control and treatment periods are expanded.

Tables 4 and 5 confirm the earlier findings that the Russian invasion of Ukraine in early 2022 had a strictly positive and significant impact on refinery margins in Germany compared to those in the ARA region. The tables further show that, as expected, the estimated ATT is biased upwards before accounting for the temporary energy tax cut during the summer of 2022 and the effects of the COVID-19 pandemic. We control for these externalities by introducing interaction terms between the regional fixed effects (distinguishing between the ARA region and Germany) and time fixed effects for the tax cut and pandemic periods. This approach allows the influence of the tax cut and the pandemic to differ between the treatment and control group. As anticipated, the treatment coefficient declines once these controls are included.[7] In the final specification, we additionally include demand-side variables as discussed in Section 3.

The results reported in Tables 4 and 5 with all controls in place, closely resemble those in Table 3, although the estimated effects are slightly smaller in magnitude. We estimate an ATT of 6 (5.1) c/l for gasoline (diesel). The corresponding 95% confidence intervals suggest that the true effect likely lies between 4 and 7.9 (3.5 and 6.7) c/l. These results show that our findings remain largely robust even when the control and treatment periods are extended substantially beyond the temporary tax cut and COVID-19 pandemic. Nonetheless, controlling for external shocks is essential to obtain these results. In the following we will therefore, use a dynamic diff-in-diff model to first investigate the robustness of the parallel trends assumption and second to investigate heterogeneous treatment effects over time.

	Gasoline Refinery Margins in c/l				
Germany:Invasion	11.437***	11.437***	12.068***	8.584***	5.949***
	[6.464; 16.411]	[6.320; 16.555]	[6.685; 17.452]	[6.291; 10.876]	[4.019; 7.878]
Germany	2.054*				
	(1.123)				
Invasion	6.280***				
	(0.079)				
Location FE		✓	✓	✓	✓
Date FE		✓	✓	✓	✓
Tax Cut FE			✓	✓	✓
COVID FE				✓	✓
Demand controls					✓
Num. obs.	38934	38934	38934	38934	38934
R^2	0.066	0.577	0.593	0.628	0.637
Adj. R^2	0.066	0.552	0.568	0.606	0.615
Num. Locations		18	18	18	18
Num. Dates		2163	2163	2163	2163

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

Table 4: Diff-in-Diff Estimation of the Russo-Ukrainian War on Gasoline Refinery Margins

[7]Because the tax cut occurred within the treatment period and it has a positive effect on refinery margins, failing to control for it biases the treatment effect upwards in earlier estimations. A similar logic applies to the COVID-19 pandemic, which negatively affected German refinery margins relative to those in the ARA region. However, since the pandemic period falls within the control period, it temporarily decreased margins in the control period, again biasing the estimated treatment effect upwards.

	Diesel Refinery Margins in c/l				
Germany:Invasion	13.805***	13.805***	14.518***	11.380***	5.108***
	[9.277; 18.334]	[9.146; 18.465]	[9.632; 19.403]	[9.502; 13.258]	[3.552; 6.664]
Germany	5.647***				
	[3.142; 8.151]				
Invasion	15.235***				
	[15.047; 15.422]				
Location FE		✓	✓	✓	✓
Date FE		✓	✓	✓	✓
Tax Cut FE			✓	✓	✓
Covid FE				✓	✓
Demand controls					✓
Num. obs.	38934	38934	38934	38934	38934
R^2	0.144	0.736	0.748	0.766	0.777
Adj. R^2	0.144	0.720	0.733	0.753	0.764
Num. Locations		18	18	18	18
Num. Dates		2163	2163	2163	2163

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

Table 5: Diff-in-Diff Estimation of the Russo-Ukrainian War on Diesel Refinery Margins

Dynamic Diff-in-Diff Figure 10 presents the estimated coefficients from a dynamic diff-in-diff specification as described in Equation (5). We estimate monthly coefficients, which measure the difference between refinery margins in Germany and the ARA region to investigate the pre-trend. To avoid the dummy variable trap, the month preceding the invasion is omitted; all coefficients are therefore interpreted relative to that reference month. We use a relatively long pre-trend as we have reliable data from 2017 onward. If the parallel trends assumption would be fulfilled, the coefficients should vary insignificantly around zero. The figure does, however, indicate the presence of differential trends in the development of refinery margins across Germany and the ARA region, potentially violating the parallel trends assumption.

The first spike in late 2018, shows a severe drought in Germany, which led to extremely low water levels in Germany, especially in the Rhine. This disrupted the transportation of crude oil and crude oil products along rivers. Even though, we calculate the refinery margins by deducting crude oil and freight costs from wholesale prices for fuel, we cannot fully control for this extreme weather event, as transportation capacity constraints became binding during this period, causing a supply shortage in parts of Germany. During the COVID-19 pandemic, prices for crude oil (products) decreased globally, due to significantly lower demand. This also affected the ARA region and Germany. Figure 10 shows decreasing coefficients, meaning that refinery margins decreased more significantly in Germany than they did in the ARA region. The figure does, however, also show that the variance of coefficients increase significantly, which implies that the coefficients are only just significantly different from zero.

Lastly, it is apparent that during the control period in January 2022 is already at an increased level. Therefore, the benchmark period, which is normalized to zero is already at an higher level than the pre-trend. This is not surprising, as the invasion of Ukraine was to be expected at least since late 2021, when Russia massively increased their military presence along the Ukrainian border, as described in Section 2. This is especially true for diesel, leading us to underestimate the true effect.

For our results, this has two implications: First, the parallel trends assumption should be fulfilled, as we can rule out another drought or pandemic. Second, our results show a lower bound of the true treatment effect of the invasion. Especially the results in Table 3 use a control period that has already been partially treated by the expectation of the invasion, increasing wholesale prices and refinery margins.

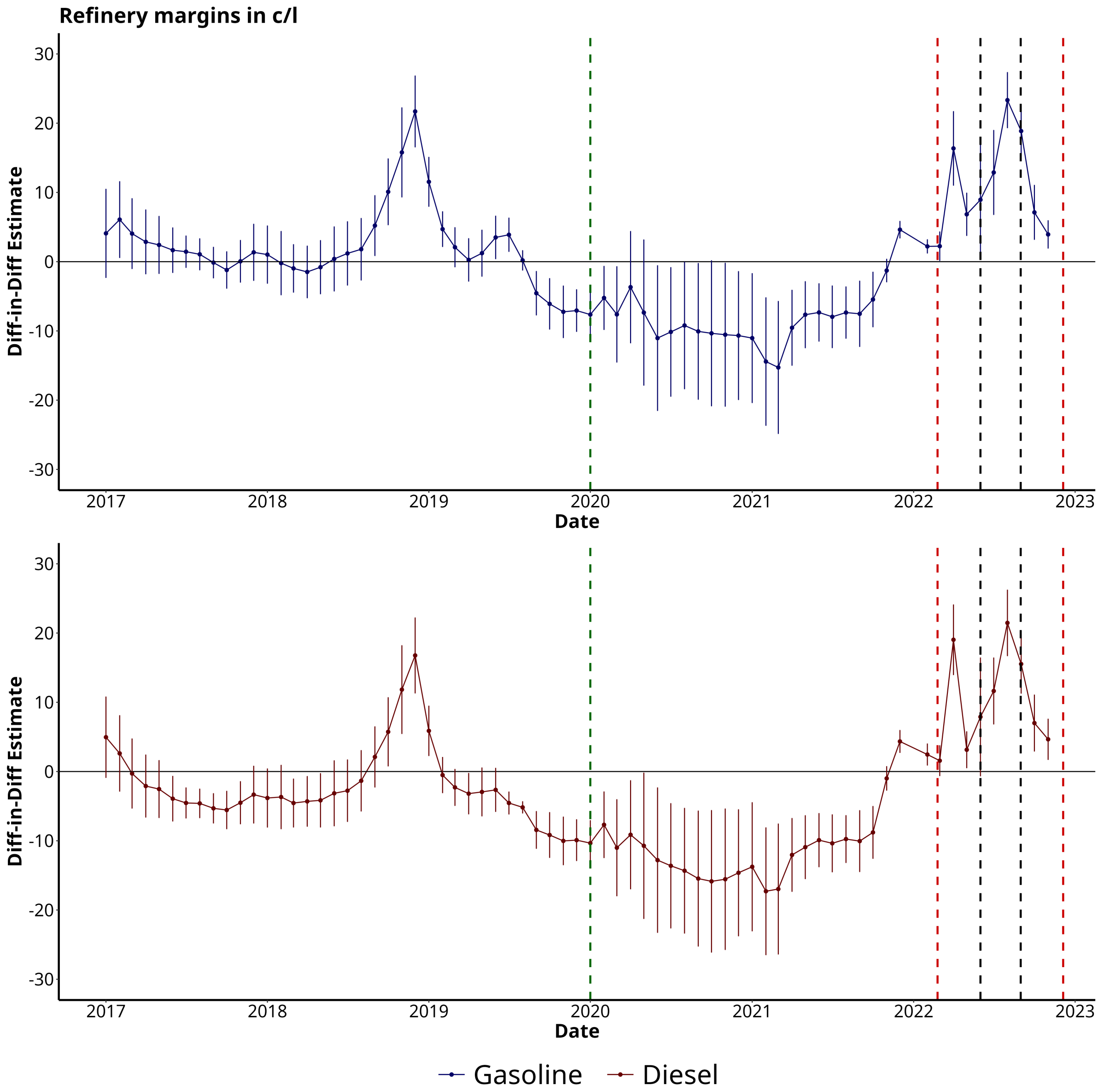

Figure 10: Monthly Coefficients of a Dynamic DID on Refinery Margins

Treatment Heterogeneity over time Figure 11 presents the estimated coefficients from a dynamic diff-in-diff specification as described in equation (5). We examine how the treatment effect evolved over time, by estimating weekly coefficients with data from 2022, which measure the difference between refinery margins in Germany and those in the ARA region. To avoid the dummy variable trap, the week preceding the invasion is omitted; all coefficients are therefore interpreted relative to that reference week. A positive coefficient indicates that German refinery margins exceeded those in the ARA region during the corresponding week. The figure suggests that the week before the invasion was already partially treated, as coefficients for earlier weeks lie below zero. The figure further shows that refinery margins in Germany rose sharply within three weeks after the invasion, peaking at approximately 25 (35) c/l for gasoline (diesel) relative to the ARA region.

Although coefficients declined during April and May, they remained positive, indicating persistently elevated German refinery margins. Variation increased during this period, as reflected in the fluctuations of the coefficients and the large 95% confidence intervals. During July and August, coinciding with the temporary energy tax cut, coefficients rose again to levels comparable to those observed immediately after the invasion. As Figure 8 illustrates, this increase appears primarily driven by declining refinery margins in the ARA region, while German margins remained relatively stable. In September and October 2022, the coefficients decreased once more, approaching but still exceeding pre-invasion levels. The estimation period ends before the first European import sanctions against Russia took effect.

These results indicate that the earlier findings reported in Tables 3, 4, and 5 are largely driven by two dynamics: An immediate surge in German refinery margins following the invasion and a subsequent decline in ARA refinery margins during late summer that did not occur in Germany. The initial increase in coefficients likely reflects heightened uncertainty regarding short-term fuel supply in Germany. The reason for the second increase in July and August remains ambiguous. It is unclear why lower refinery margins in the ARA region were not transmitted to the German market. The tax reduction may have influenced demand, yet such an explanation would imply an unusually persistent effect, as coefficients did not return to pre-war levels until October. Transportation and crude oil input costs, which we control for in the model, showed no indication of price increases during this period. The following section demonstrates that this second peak was not uniformly distributed across regions.

Treatment Heterogeneity across regions Unlike the previous analysis, which employed a group fixed effects estimator distinguishing only Germany and the ARA region, we now apply an estimator that accounts for all eleven German regions and the ARA region, as specified in Equation (6). The ATTs for all regions is then derived from the interaction between these regional fixed effects and a time dummy variable indicating the pre- and post-invasion periods. To avoid the dummy variable trap, the ARA region is omitted and serves as the benchmark, so that all estimated effects are interpreted relative to it.

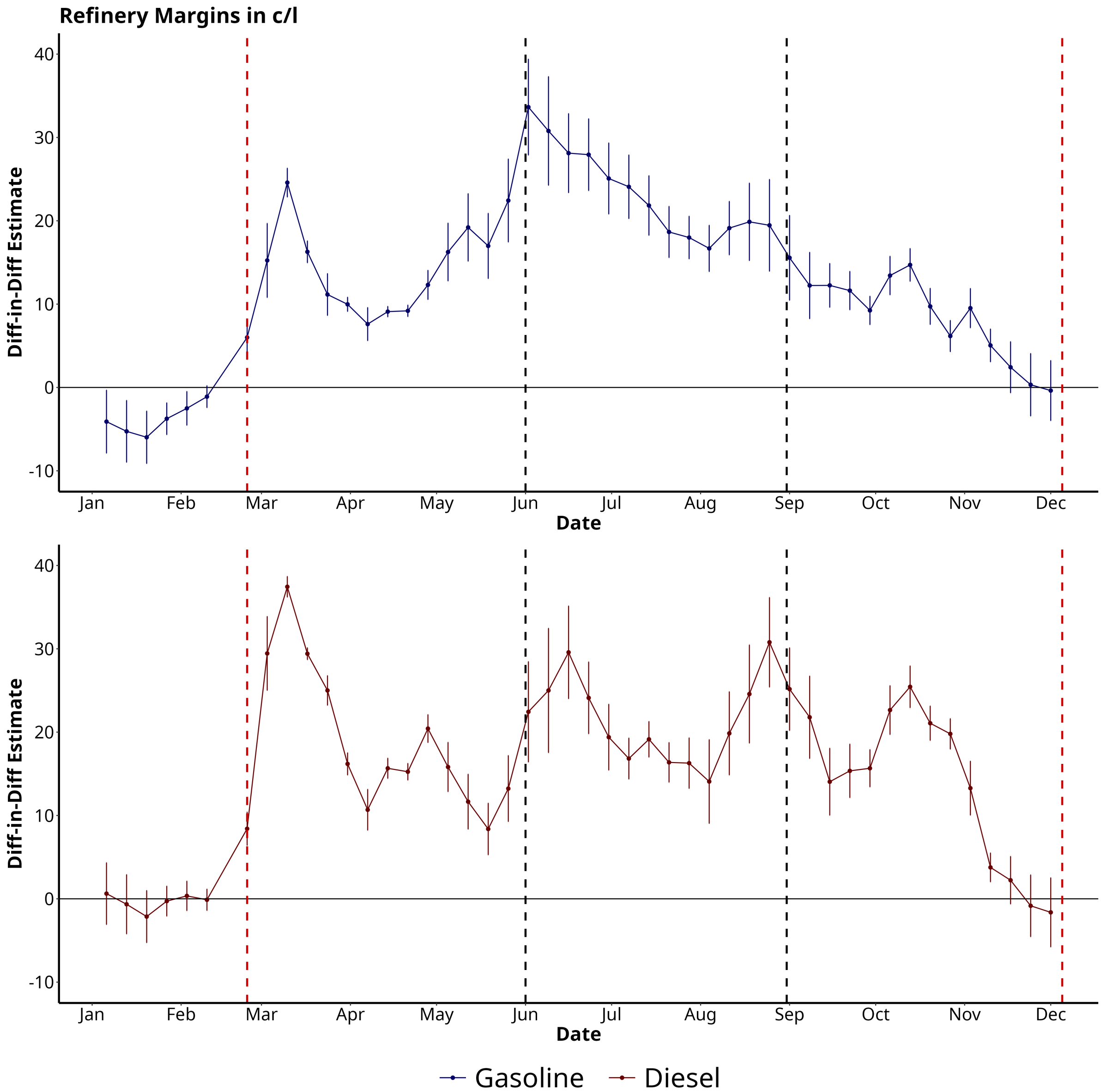

Figure 11: Weekly Coefficients of a dynamic DID on refinery margins

Figure 12 presents the estimated ATT for each of the eleven German regions. The figure shows significant heterogeneity across regions but surprisingly little variation between fuel types. The lowest treatment effects are observed in the three southern regions: Southwest, Rhine-Main, and South, where coefficients are slightly negative for both gasoline and diesel but generally not significantly different from zero. In contrast, the North, Cologne, West, and Emsland regions exhibit modestly positive effects of approximately 0-5 c/l for both fuel types. The highest ATT occur in the Seefeld, East, Magdeburg, and Southeast regions, with estimated coefficients of around 15 c/l.

These results are noteworthy for several reasons. First, within regions, the differences between gasoline and diesel are negligible. Although the aggregate German estimates presented earlier indicated significantly different ATT for the two fuel types, regional

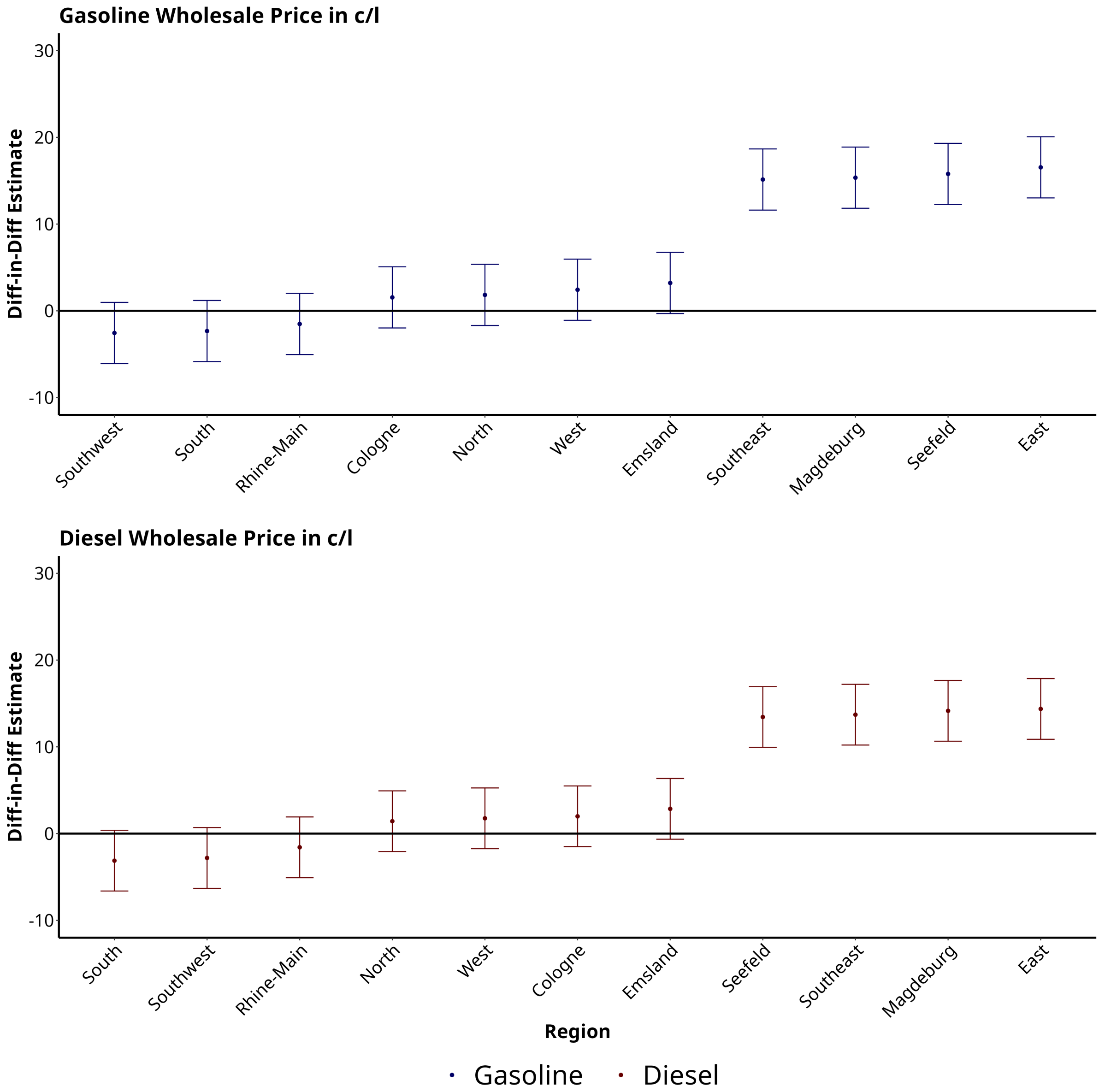

Figure 12: Regional Diesel and Gasoline Treatment Effects

results suggest that these differences are not statistically significant within regions. Second, regional heterogeneity is substantial, reaching nearly 20 c/l for both types of fuels. This variation can partly be attributed to differences in crude oil input costs, which, as shown in Section 3, display a similar spatial distribution. However, such large disparities are somewhat unexpected, given that competition tends to exhibit a regional structure, as discussed in Section 5. Notably, the regions with the highest and lowest estimated effects, South and Southeast, are geographically adjacent. Moreover, structural differences in regional demand, as documented in Montag et al. (2023), may have reinforced these effects. Finally, the largest ATT are observed in eastern regions, consistent with the fact that refineries located there depend heavily on Russian crude oil and diesel imports. The anticipation of capacity constraints in diesel and crude oil supply may therefore have contributed to widening margins, an issue examined further in the following section.

Treatment Heterogeneity over Time in Different Regions This approach combines the two preceding empirical models, enabling us to investigate the treatment heterogeneity over time across all eleven regions in Germany. Equation (9) illustrates that we employ group fixed effects for all eleven regions and time fixed effects for all weeks in 2022. The treatment effect coefficients are derived from the interaction of these two sets of fixed effects. In line with our earlier specifications, we omit the ARA region and the final week preceding the invasion, so that all treatment coefficients are interpreted relative to the ARA region and compared to the week immediately before the invasion.

Figures 13 and 14 show the estimation results for each German region. At the onset of the Russian invasion of Ukraine, the ATT is positive and statistically significant across all regions and for both fuel types, as expected. The timing of the shock, however, varies across regions. In the eastern regions, East, Magdeburg, Seefeld, and Southeast, refinery margins increased significantly even before the invasion, as indicated by pre-trends that lie clearly below the benchmark week. In contrast, for the remaining regions, Cologne, Emsland, North, Rhine-Main, South, Southwest, and West, the treatment effect becomes apparent only after the invasion, with a lag of up to two weeks. This pattern suggests that expectations surrounding the invasion had a stronger anticipatory effect in regions more dependent on Russian crude oil and diesel imports. Notably, this holds for both gasoline and diesel, despite Germany's independence from Russian gasoline imports. Nevertheless, the peak effect is substantially more pronounced for diesel than for gasoline.

Although the ATT subsequently levels off in nearly all regions, it fails to return to pre-war levels anywhere and rises again toward the introduction of the temporary energy tax cut in the summer of 2022. The subsequent progress of the ATT differs across regions and fuel types. For gasoline, the eastern regions experience an increase to levels exceeding those observed during the initial invasion, before declining toward the end of the observation period. In the remaining regions, the ATT for gasoline rises prior to the tax cut, declines during its implementation, increases again before the end of the tax cut, and decreases thereafter until the end of 2022. The variation of the ATT increases significantly after the expiration of the tax cut in all regions, potentially reflecting heightened uncertainty in anticipation of the European sanctions on Russian crude oil imports. Nevertheless, the ATT across all regions roughly returns to pre-war levels.

For diesel, the ATT exhibits substantially greater regional variation and distinct patterns are much harder to identify. Overall, the ATT tends to increase both before and at the end of the energy tax cut, though the magnitude differs across regions. In the eastern regions the increase is particularly pronounced at the beginning of the tax cut but less so toward its end. In contrast, the Cologne, Emsland, North, and West regions display only modest increases. In the southern regions, Rhine-Main, South, and Southwest, the ATT rises during the tax cut, reaching its peak at the end of the measure. Although the ATT declines in all regions toward the end of the observation period, another increase occurs in the autumn of 2022, possibly reflecting the impending implementation of European sanctions on Russian crude oil imports. However, this effect is not limited to the eastern regions, and it should be noted that the import ban on refined crude oil products such as diesel only came into effect in February of the following year.

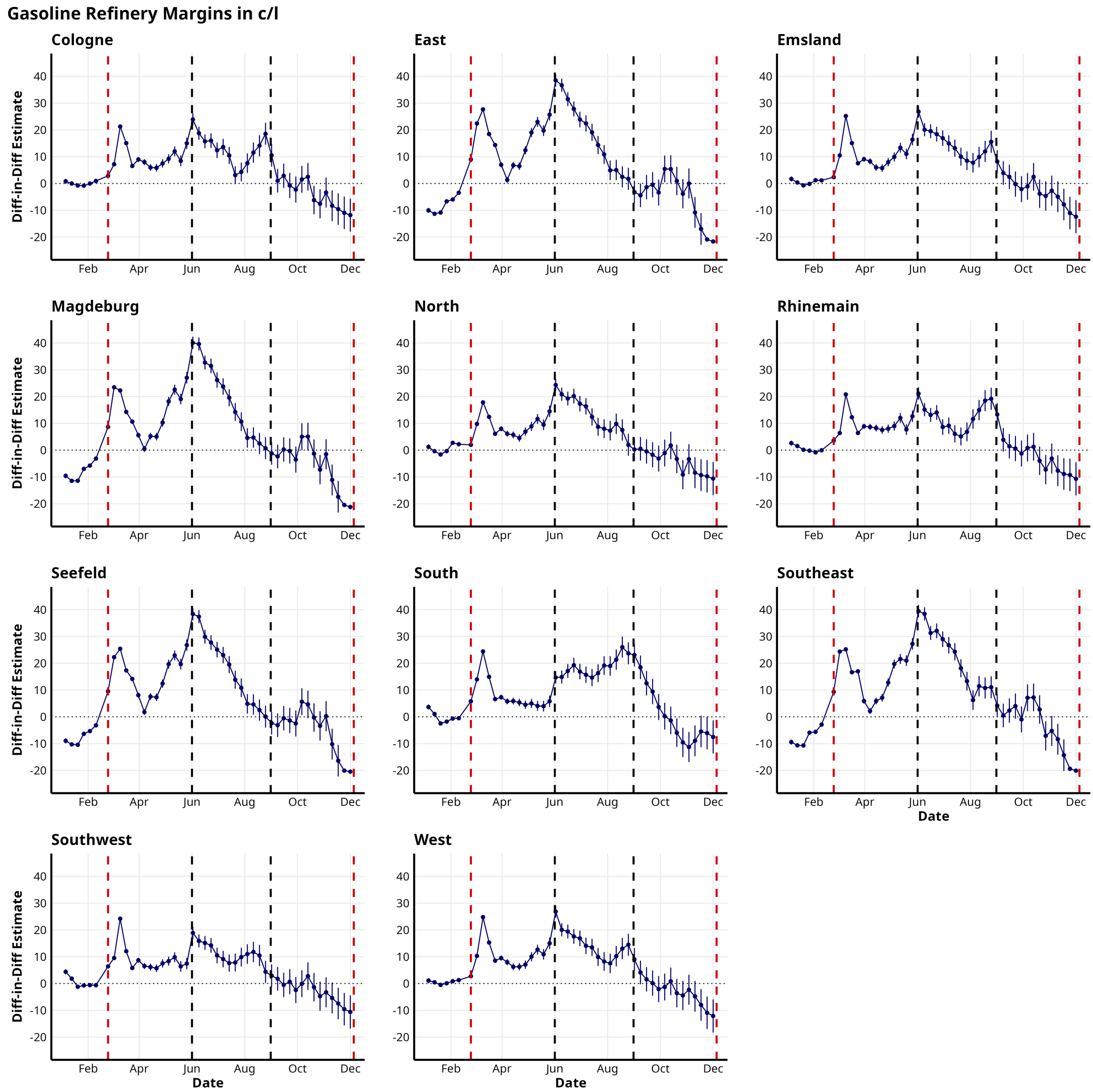

Figure 13: Regional Gasoline Treatment Effects over Time

Long-term Effects of the Russo-Ukrainian War Lastly, we examine the long-term effects of the Russo-Ukrainian war on refinery margins in Germany. Figure 15 presents the results from the same dynamic diff-in-diff framework as before, outlined in Equation (5), but now applied to the full sample period from the beginning of 2017 through the end of 2025. As before, we include monthly interactions between time and group fixed effects.

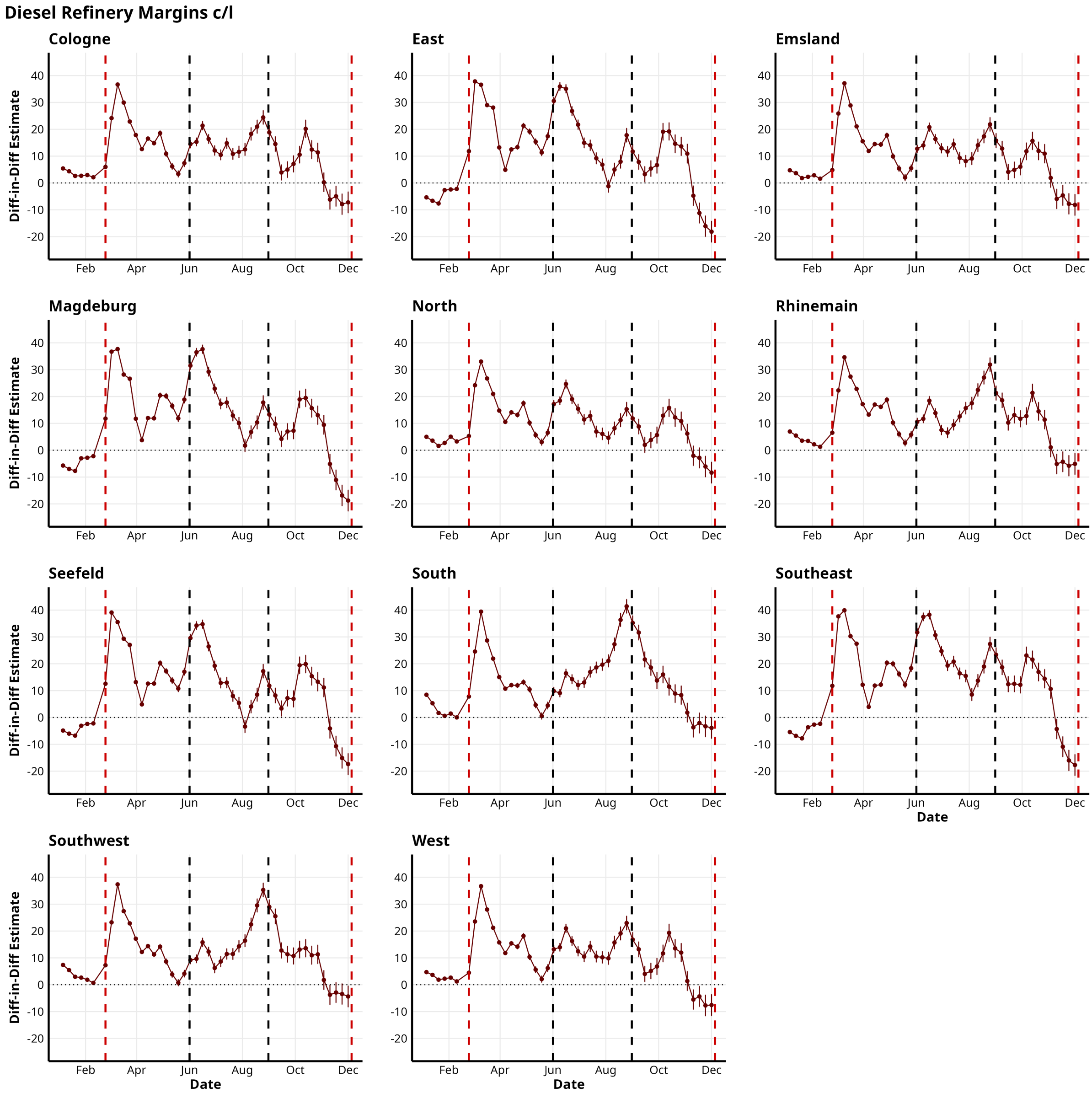

Figure 14: Regional Diesel Treatment Effects over Time

We have already discussed the pre-trend behavior and the immediate impact of the Russian invasion of Ukraine on refinery margins up to the point when European sanctions on Russian crude oil imports took effect in December 2022. In February 2023, additional sanctions against imports of refined petroleum products such as diesel were implemented. Consequently, from this point onward, it becomes impossible to disentangle the direct effects of the war from those of the sanctions.

Figure 15 shows that after the implementation of the import sanctions, the coefficients for gasoline refinery margins remain largely stable, exhibit a modest increase toward the end of the year, and then decline throughout 2024 until the end of the observation period. The pattern of coefficients on diesel refinery margins is similar: Coefficients decrease immediately after the import ban on Russian diesel took effect than show a mild uptick at the end of 2023, followed by a decline during 2024. These results are surprising, given that Germany historically imported around 15% of its diesel demand, with approximately 15% of these imports previously sourced from Russia, as discussed in Section 2. We would, therefore, expect an increase in refinery margins after the start of import sanctions against Russian crude oil (products).

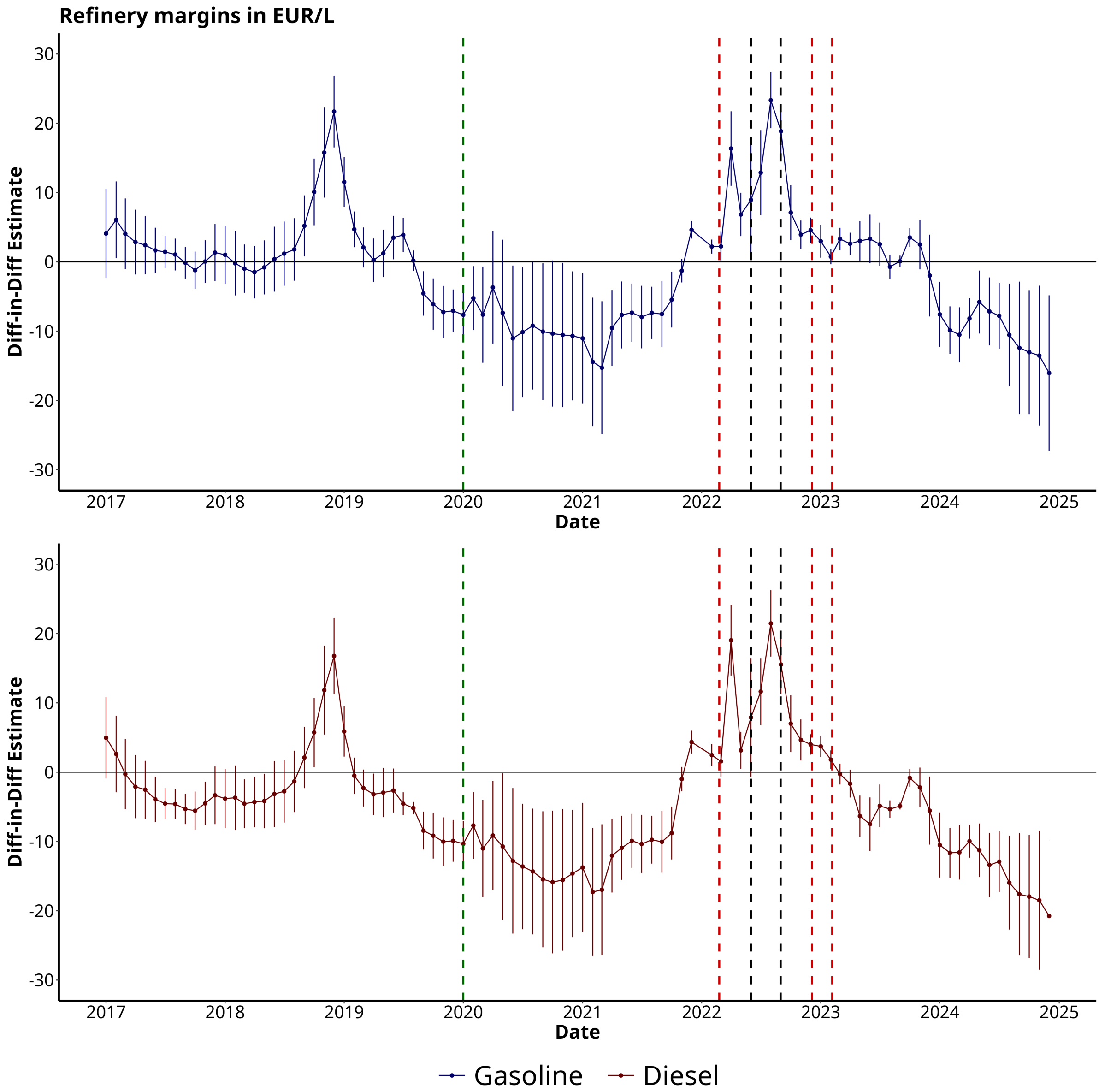

Figure 15: Long-term Treatment Effects of the Russo-Ukrainian War

These developments can be partly explained by Figure 8, which illustrates the evolution of refinery margins for both gasoline and diesel in Germany and in the ARA region. For gasoline, the period of stable treatment effects during 2023 coincides with a moderate increase in refinery margins in both Germany and the ARA region. The subsequent increase in coefficients at the end of 2023 can be attributed to a sharp decline in ARA refinery margins that was only gradually passed through to the German market. Throughout 2024, no major trends are apparent, and refinery margins converge toward levels slightly above those observed prior to the war.

For diesel, the decline in estimated coefficients corresponds to a real decrease in refinery margins in both Germany and the ARA region, though the decline in Germany is disproportionately larger. The brief recovery in late 2023 follows a similar pattern to the one of gasoline coefficients, before margins again decrease to levels marginally higher than those before the war.

Overall, our results demonstrate a substantial and statistically significant increase in refinery margins in both Germany and the ARA region following the onset of the war. The increase in Germany was considerably more pronounced in the short run, with refinery margins rising by approximately 5-10 c/l relative to the counterfactual. This effect is particularly notable given that the control group was also indirectly affected, though to a lesser extent. Within Germany, heterogeneity is also visible: eastern regions, which were historically more dependent on Russian crude oil and refined product imports, experienced stronger effects. In the long run, however, these differences diminish. In absolute terms, refinery margins remain above pre-war levels across all regions, but the relative effect between treatment and control groups becomes statistically insignificant.

6.2 Effects of the Russian Invasion of Ukraine on Demand

In the following, we investigate the impact of the Russian invasion of Ukraine and the ensuing Russo-Ukrainian war on gasoline and diesel demand in Germany. As previously noted, we used ARA spot market prices as a benchmark for the European wholesale market for both fuel types. The JODI data are, however, reported at the national level. Using only data from Belgium and the Netherlands would therefore be insufficient to capture broader European trends; instead, we use all member states of the EEA as the control group. This control group is, however, also affected by the Russo-Ukrainian war, though to a lesser extent. Consequently, our estimates should be interpreted as identifying a lower-bound effect on a less competitive market in Germany. Given the significant positive impact on refinery margins and the drastic increase in retail prices shown in Figure 7, we expect fuel demand in Germany to decline, consistent with standard economic theory.

Extended Sample For consistency, we continue to refer to this section as the extended sample, even though no baseline was estimated, as the available quantity data are only recorded at a monthly frequency. Accordingly, we employ the extended sample covering the period from 2017 through December 2022 and estimate the diff-in-diff model specified in Equation (8). The treatment coefficient represents the ATT of the Russian invasion of Ukraine on logarithmized fuel demand in Germany, relative to the average demand across the EEA. A negative treatment coefficient thus indicates that road fuel demand in Germany declined following the invasion, compared to the rest of the EEA.

Tables 6 and 7 show the estimation results for gasoline and diesel demand in Germany, while incorporating different sets of control variables step by step. Overall, the findings indicate that the Russian invasion of Ukraine had a clearly negative impact on gasoline demand in Germany relative to the rest of the EEA. The baseline diff-in-diff specification shows a −5.6% decline in demand for both gasoline and diesel. After including country and time fixed effects to account for regional and temporal variation, the estimated effect becomes slightly larger in magnitude, at −6.1% for gasoline and −5.9% for diesel.

	Log Gasoline Quantity					
Invasion:Germany	-0.056^{**}	-0.061^{***}	-0.058^{**}	-0.068^{**}	-0.129^{***}	-0.136^{***}
	[−0.099; −0.013]	[−0.104; −0.019]	[−0.111; −0.004]	[−0.121; −0.015]	[−0.170; −0.088]	[−0.183; −0.089]
Country FE		✓	✓	✓	✓	✓
Months FE		✓	✓	✓	✓	✓
Tax Cut FE			✓	✓	✓	✓
COVID FE				✓	✓	✓
Demand controls					✓	✓
Crude Oil						✓
Freight Costs						✓
Num. obs.	2055	2055	2055	2055	2055	2055
R^2	0.172	0.987	0.987	0.987	0.987	0.987
Adj. R^2	0.171	0.986	0.986	0.986	0.986	0.987
Num. Countries		29	29	29	29	29
Num. Months		71	71	71	71	71

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

Table 6: Diff-in-Diff Estimation of the Russo-Ukrainian War on Gasoline Demand in Germany

	Log Diesel Quantity					
Invasion:Germany	-0.056^{**}	-0.059^{**}	-0.083^{**}	-0.080^{**}	-0.058^{**}	-0.090^{***}
	[−0.101; −0.011]	[−0.103; −0.014]	[−0.152; −0.013]	[−0.151; −0.009]	[−0.112; −0.003]	[−0.147; −0.032]
Country FE		✓	✓	✓	✓	✓
Months FE		✓	✓	✓	✓	✓
Tax Cut FE			✓	✓	✓	✓
COVID FE				✓	✓	✓
Demand controls					✓	✓
Crude Oil						✓
Freight Costs						✓
Num. obs.	2057	2057	2057	2057	2057	2057
R^2	0.136	0.984	0.984	0.984	0.984	0.984
Adj. R^2	0.135	0.983	0.983	0.983	0.983	0.983
Num. Countries		29	29	29	29	29
Num. Months		71	71	71	71	71

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

Table 7: Diff-in-Diff Estimation of the Russian Invasion of Ukraine on Diesel Demand in Germany

Because several external shocks occurred during the observation period, such as the temporary fuel tax reduction and the COVID-19 pandemic, these estimates are potentially biased, as previously discussed. To mitigate this, we include time fixed effects for these events and interact them with a group fixed effect, allowing German demand to respond differently than the rest of Europe during such periods. Controlling for the temporary tax cut has almost no impact on the estimated treatment coefficient for gasoline demand (−5.8%) but results in a more pronounced negative effect for diesel (−8.3%). Incorporating a control for the COVID-19 pandemic further strengthens the negative impact on gasoline (−6.8%) while leaving the diesel estimate essentially unchanged (−8%).

Lastly, we add demand-side control variables such as population density, inflation, and disposable income. Including these variables results in a notably larger negative ATT for gasoline (−12.9%) and a somewhat smaller negative effect for diesel (−5.8%). When we additionally control for refinery input costs, specifically crude oil and freight prices, the ATT for gasoline remains the same (−13.6%), whereas the ATT for diesel becomes more negative (−9%). However, these input-cost variables may introduce endogeneity, so these results should be interpreted with caution.

Dynamic Diff-in-Diff We further estimate a dynamic diff-in-diff model using logarithmized road fuel demand to examine pre-trends and heterogeneous treatment effects over time. Following the specification presented in Equation (9), we estimate monthly coefficients that capture the differential demand between Germany and the EEA. Consistent with our previous analyses, we omit the month preceding the invasion (January 2022) and interpret all estimated effects relative to this baseline. The estimation sample covers the period from January 2017 to December 2024.

Figure 16 presents the results. The figure clearly indicates that the pre-trends are not flat; rather, they exhibit substantial variation that cannot be attributed to identifiable external shocks, with the notable exception of the first COVID-19 lockdown.[8] Consequently, a causal interpretation of this model is not possible, as the presence of significant unexplained heterogeneity likely biases the estimated treatment effects. Nonetheless, a descriptive interpretation remains informative for understanding market dynamics.

According to Figure 16, the estimated treatment coefficients for gasoline demand decline modestly following the invasion, rise temporarily during the period of the temporary tax cut, and subsequently stabilize at levels comparable to those observed before the war. A clear long-term effect is not discernible. Notably, fluctuations in the pre-trend coefficients appear larger in magnitude than the post-invasion decline itself. The treatment coefficients for diesel demand exhibit a similar temporal pattern: a decrease after the invasion, an increase during the tax cut, and a return to roughly pre-war levels thereafter. In the longer run, coefficients appear somewhat lower, suggesting a persistent though moderate reduction in demand.

In summary, road fuel demand in Germany appears to have declined following the Russian invasion of Ukraine, consistent with the substantial increase in retail fuel prices observed

[8]The corresponding effect appears significantly positive, likely because fuel prices declined sharply before the pandemic began to affect Germany substantially.

during this period. The estimated decline is more pronounced for gasoline than for diesel, which contrasts with the findings of Montag et al. (2023), who report higher demand elasticity for diesel. In the long run, demand seems to be lower than before the invasion.

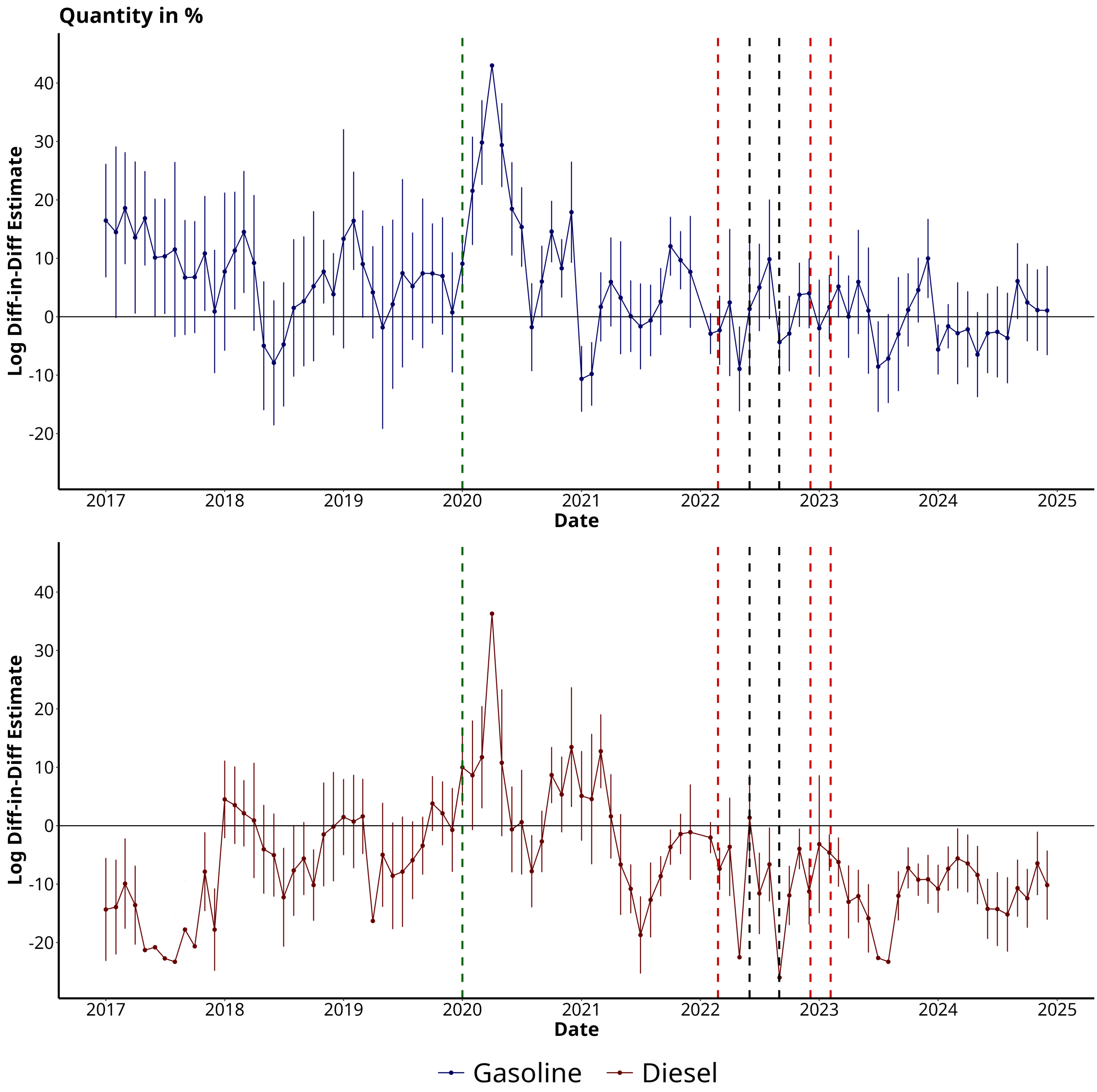

Figure 16: Monthly Coefficients of a Dynamic Diff-in-Diff on Gasoline and Diesel Demand

7 Conclusion

This paper examines the effects of the Russian invasion of Ukraine on refinery margins and the demand for gasoline and diesel in Germany. Following the invasion, retail prices for road fuels increased by roughly 50 c/l and temporarily exceeded 2 Euro/liter. Descriptive evidence indicates that this price surge cannot be explained solely by developments in

crude oil prices. Instead, it was largely driven by a substantial increase in refinery margins, while station margins remained comparatively stable over time.
A comparison of refinery margins in Germany with those observed on the ARA spot market shows that margins increased strongly in both markets, rising by roughly a factor of four after the invasion. In absolute terms, however, the increase in refinery margins was considerably larger in Germany than in the ARA region.
Using a diff-in-diff approach, we estimate the effect of the invasion on refinery margins in Germany relative to the ARA spot market. The estimated ATT amounts to approximately 6 c/l for gasoline and 5 c/l for diesel. The results further reveal substantial heterogeneity across time and regions. The estimated treatment effect is primarily driven by pronounced increases immediately after the invasion and during the summer of 2022, while no evidence of persistent long-run effects emerges. In addition, the effect is concentrated mainly in eastern Germany, whereas estimates for other regions fluctuate insignificantly around zero.
We also estimate a statistically significant negative association between the invasion and fuel demand. This relationship should not be interpreted causally because the parallel-trend assumption is violated. Nevertheless, the descriptive evidence remains informative and consistent with economic theory, given the sharp increase in fuel prices. In particular, the results suggest that gasoline demand responds more strongly to price changes than diesel demand.
We conclude by discussing potential explanations for the increase in refinery margins following the invasion. One plausible hypothesis is that crisis-related supply constraints in the German fuel market generated temporary scarcity of gasoline and diesel. Germany historically relied heavily on Russian crude oil to supply refineries in eastern Germany. In the wake of the Russian invasion of Ukraine, the PCK Schwedt refinery and the Total refinery in Leuna reduced production to roughly 50 percent of capacity at the beginning of 2023. Consistent with this narrative, the estimated treatment effect is concentrated in eastern German regions—Southeast, Magdeburg, Seefeld, and East—which lie within the catchment area of these refineries. At first glance, these patterns suggest that disruptions in crude oil supply may have contributed to the observed price increases.
Several pieces of evidence, however, contradict the hypothesis that a crude oil shortage was the primary driver of higher refinery margins. Most importantly, the timing of declining Russian crude oil imports and the increase in wholesale prices and refinery margins does not align, as shown in Figure 1. Although imports from Russia gradually declined during 2022, Russia remained an important supplier of crude oil to Germany for most of that year. The majority of imports ceased only toward the end of 2022. Our estimates, however, do not show any price effects associated with the import ban, despite its clear impact on import volumes. Moreover, formal restrictions on Russian crude oil imports only came into effect on 5 December 2022, implying that earlier reductions in

imports reflected voluntary decisions by refinery operators. For example, TotalEnergies, the owner of the Leuna refinery near Magdeburg, announced that its supply contracts for Russian Urals crude would expire at the end of 2022 and would not be renewed, meaning that any supply limitations during 2022 were largely self-imposed (Total Energies, 2022). Finally, Table C.4 indicates that the crude oil intake of German refineries declined only after sanctions against Russian crude oil came into force. Taken together, these observations suggest that a shortage of crude oil was unlikely to be the main driver of rising refinery margins.

A second possible explanation is that refinery capacity constraints limited the domestic supply of gasoline and diesel. Although reductions in Russian crude oil imports were partially offset by increased imports from other regions, eastern German refineries are specifically optimized to process Urals crude. Alternative crude grades, such as Brent Blend from the North Sea or Arab Light from the Middle East, cannot perfectly substitute for Urals, which could in principle reduce effective refining capacity in Germany. This mechanism would also be consistent with the stronger effects observed in eastern Germany. However, the timing again does not support this explanation, as the decline in Russian crude oil imports occurred primarily at the end of 2022 rather than immediately after the invasion. In addition, if significant shortages of gasoline or diesel had emerged in eastern Germany, firms would likely have increased shipments from refineries located in other regions, leading to higher transportation costs. The data does not support this scenario, as transportation costs remained stable after the invasion.

A third potential explanation is a reduction in imports of refined products. This channel should primarily affect diesel prices, as Germany is a net exporter of gasoline but imports roughly 15 % of its diesel consumption. Approximately 15 % of these diesel imports previously originated from Russia. However, neither the estimated treatment effects nor the descriptive evidence indicate substantially different impacts for gasoline and diesel. Furthermore, data on diesel trade flows shows that Russia continued exporting significant quantities of diesel to Germany until February 2023, when EU sanctions on Russian refined petroleum products came into effect. Hence, the timing of import restrictions again does not correspond to the observed price dynamics.

After ruling out these potential sources of supply shortages, the precise causes of the sharp increase in refinery margins remain uncertain. One plausible explanation is that heightened market uncertainty following the invasion increased risk premia in fuel markets. Concerns about future availability of crude oil and refined products may have led market participants to anticipate potential shortages, thereby raising margins in the short run. This interpretation is consistent with the broader policy debate on energy security that emerged in Germany and across the European Union after the invasion. It is also consistent with the observation that many energy companies reported exceptionally high profits in 2022 and 2023, suggesting that firms were able to expand profit margins during

this period of crisis. These so-called windfall profits became a central topic in the public and political discussion surrounding the economic consequences of the war.
These hypotheses, however, hold for both ARA and German markets for road fuels. They therefore do not, by themselves, explain why price increases in German markets have been more pronounced than in the ARA region. To account for this difference, we posit that competition in the German wholesale market for road fuels is less intense than in the ARA market. One possible explanation lies in the presence of regional market power among German refineries. In contrast, refineries supplying the ARA spot market face competition not only from each other, but also from the global supply of refined products. This broader competitive environment may exert stronger competitive pressure on margins in the ARA region, whereas more limited competitive constraints in Germany could allow refinery margins to increase more substantially.

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A Data Preparation

To make the data comparable along the supply chain we follow this procedure: First, all prices are expressed in cents/liter and all quantities in units of 10,000 m^3. Prices reported in metric tons or other weight-based units are converted to volume-based prices using fixed densities of 0.775 kg/liter for gasoline and 0.845 kg/liter for diesel.

Second, we net out all taxes and fees from German retail and wholesale prices. Retail prices are first adjusted for value-added tax, applying a rate of 19, or 16 % for the period from 1 July to 31 December 2020. From retail prices net of VAT and from wholesale prices, we subtract the German energy tax, amounting to 65.45 c/l for gasoline and 47.04 c/l for diesel. During the fuel tax reduction from 1 June to 31 August 2022, these rates are replaced by 35.9 and 33 c/l, respectively. We additionally deduct the carbon tax, which equals 7 and 8 c/liter in 2021, 8.4 and 9.5 c/l in 2022 and 2023, and 12.7 and 14.2 c/l in 2024 for gasoline and diesel. Finally, we subtract fees paid to the Erdölbevorratungsverband, amounting to 2.7 c/l for gasoline and 3 c/l for diesel. In contrast, ARA import parity prices already incorporate energy taxes and EBV fees only.

Third, we harmonize regional wholesale price coverage over time. Since Argus Media began reporting prices for the East and Emsland regions only in June 2020, earlier observations for these regions are imputed using the average prices of three adjacent regions. For East, we use North, Magdeburg, and West; for Emsland, we use Seefeld, Magdeburg, and South. This procedure yields a balanced panel of wholesale prices for all eleven German regions from 2017 through 2024.

Fourth, we align the three market levels geographically. Each German region is linked to a specific crude oil benchmark reflecting its supply chain. Brent crude is assigned to the West, Cologne, Emsland, and North regions; Sahara Blend to Southwest, South, and Rhine-Main; and Ural oil to Southeast, East, Magdeburg, and Seefeld. Because ARA import prices serve as the counterfactual for wholesale gasoline and diesel prices, Brent crude is used as the input cost for the control group. Petrol stations are then assigned to one of the eleven Argus Media regions based on proximity. Using the reference locations specified in the Argus Media methodology, we compute straight-line distances from each station to all regional reference points and assign each station to the nearest one. Figure 5 displays the full set of petrol stations in Germany and their regional assignments, with black triangles indicating Argus Media reference locations and red triangles denoting ARA import parity locations.

B Figures

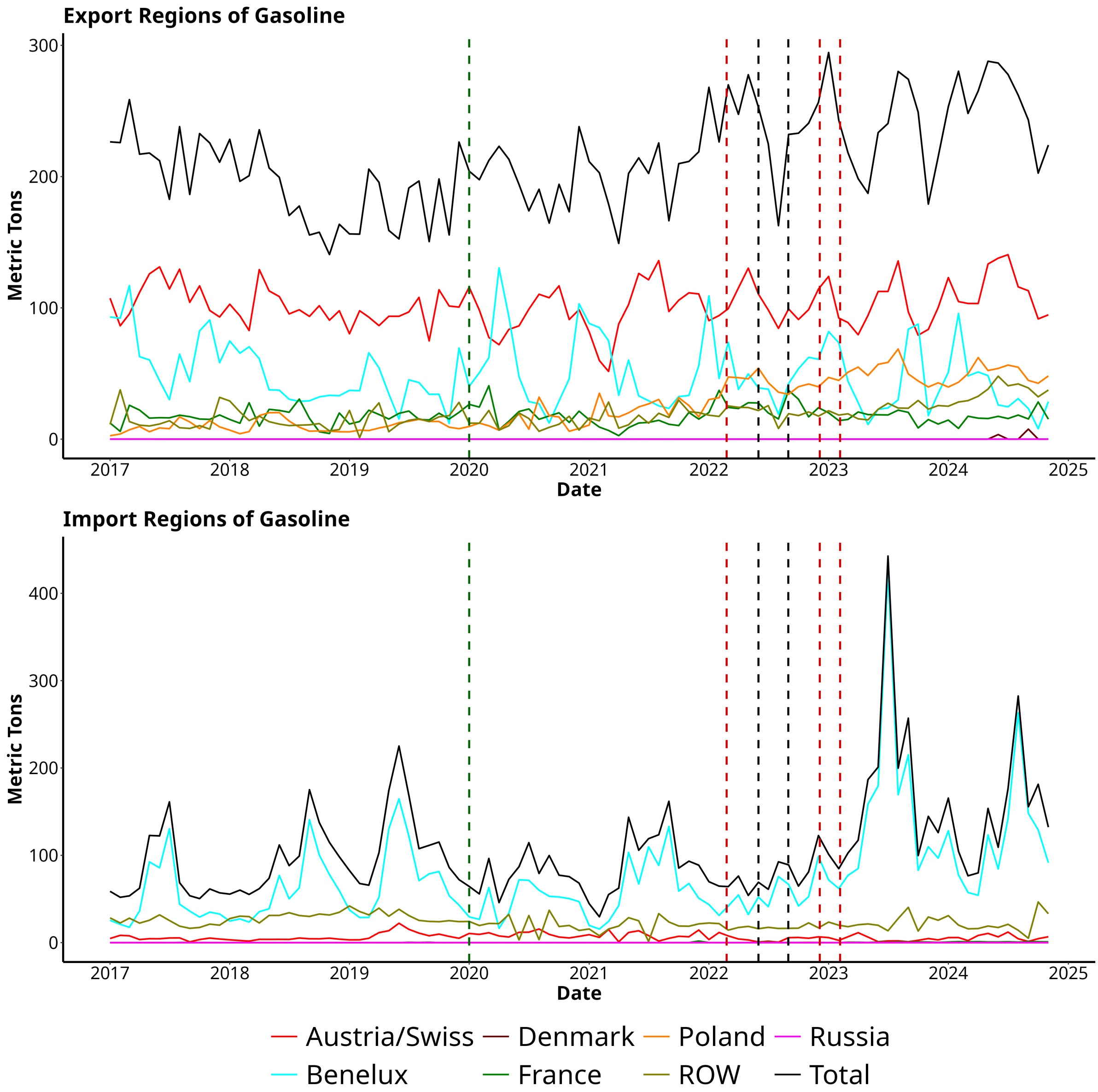

Figure B.1: German Gasoline Imports and Exports by Country (Statistisches Bundesamt, 2025)

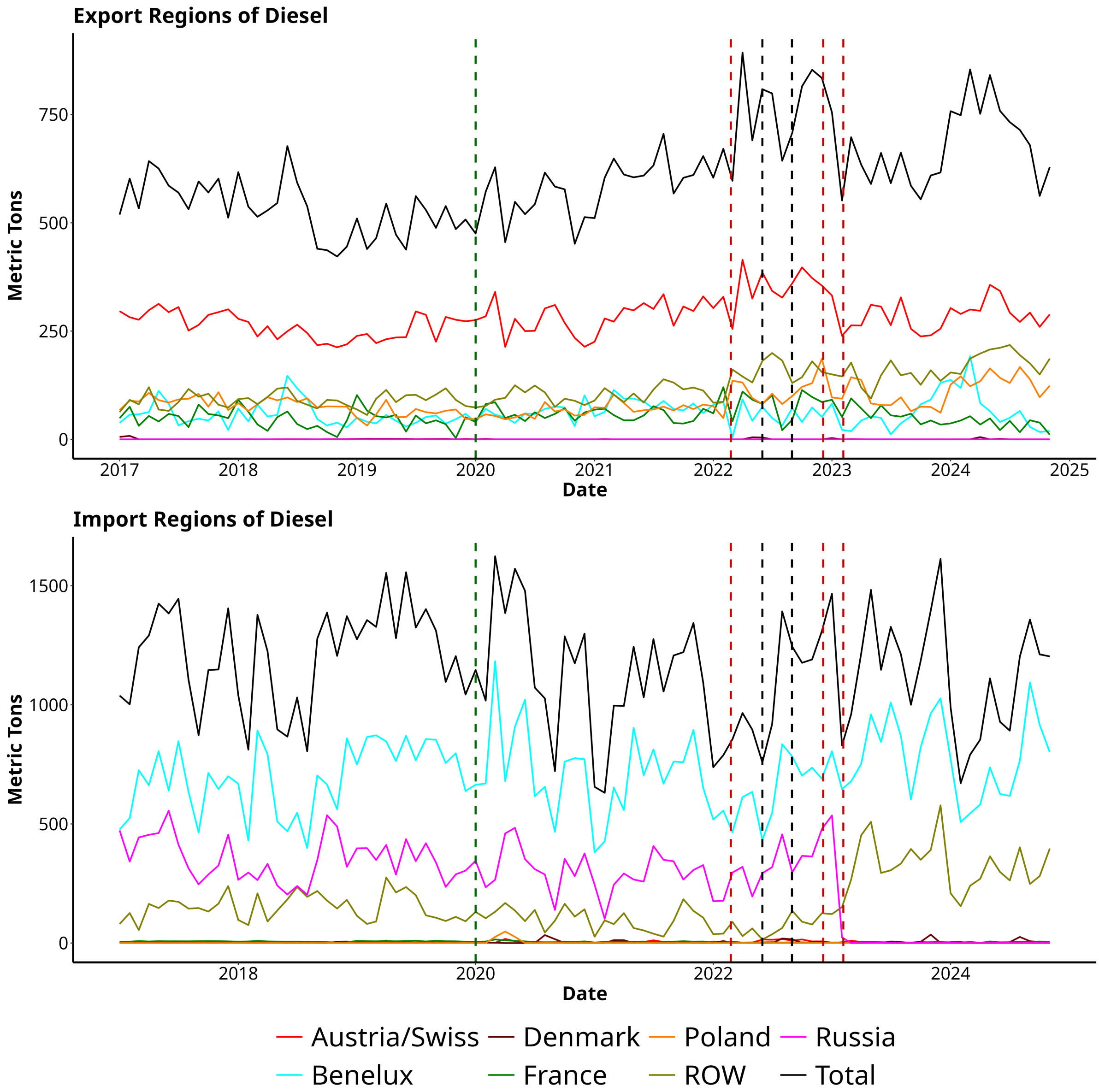

Figure B.2: German Diesel Imports and Exports by Country (Statistisches Bundesamt, 2025)

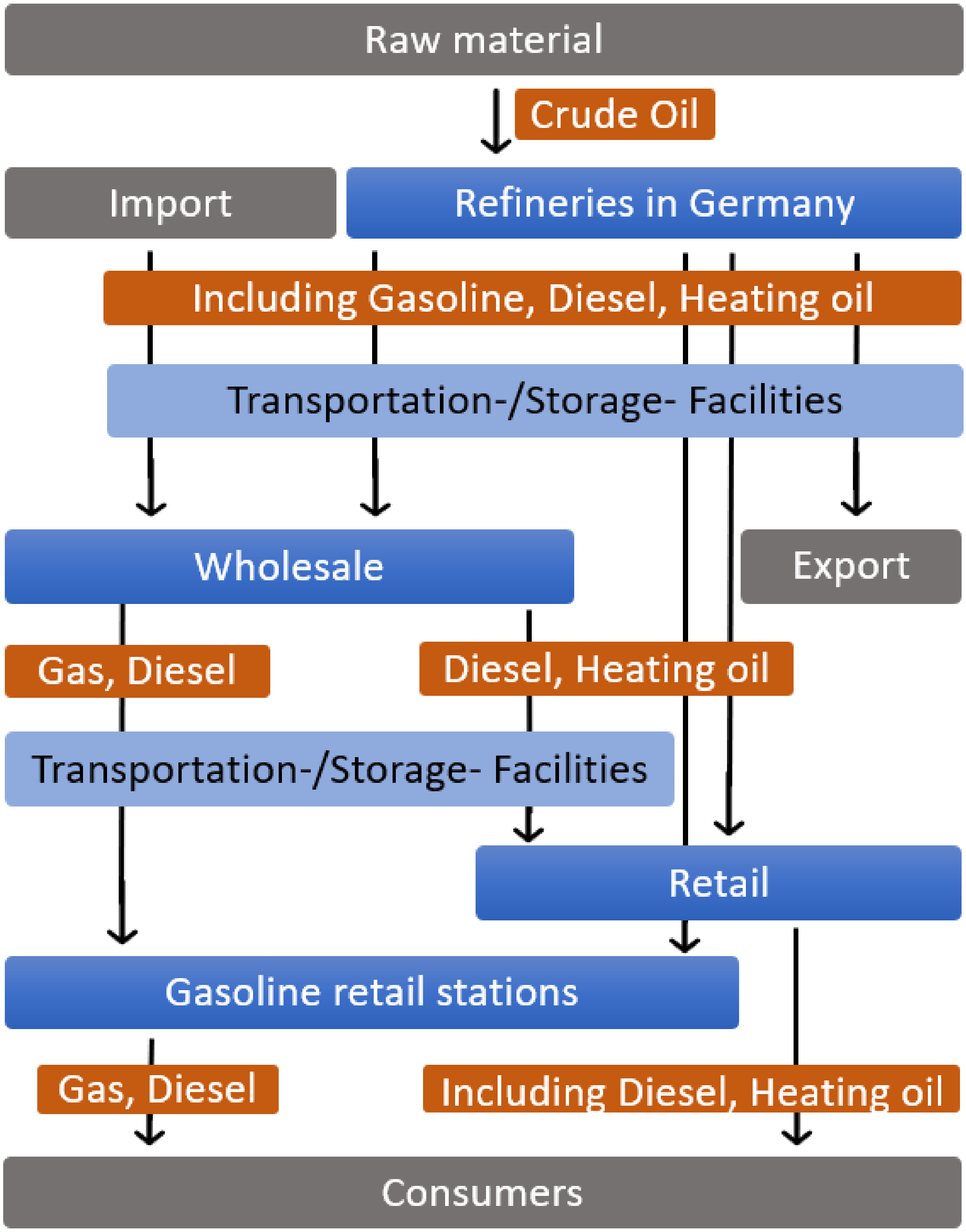

Figure B.3: Vertical Market Structure according to Federal Cartel Office (2022)

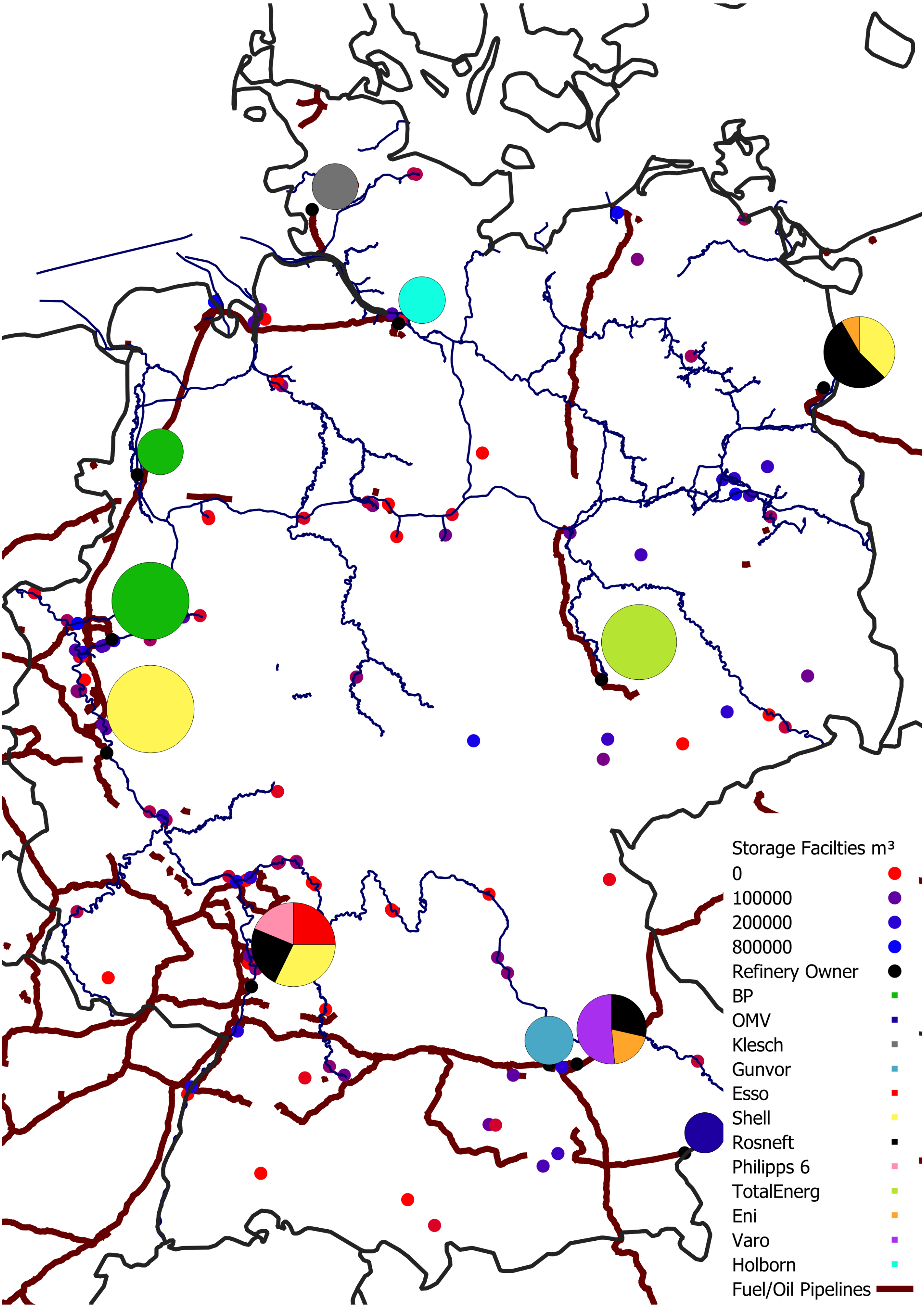

Figure B.4: Refineries, pipelines, facilities and waterways in Germany

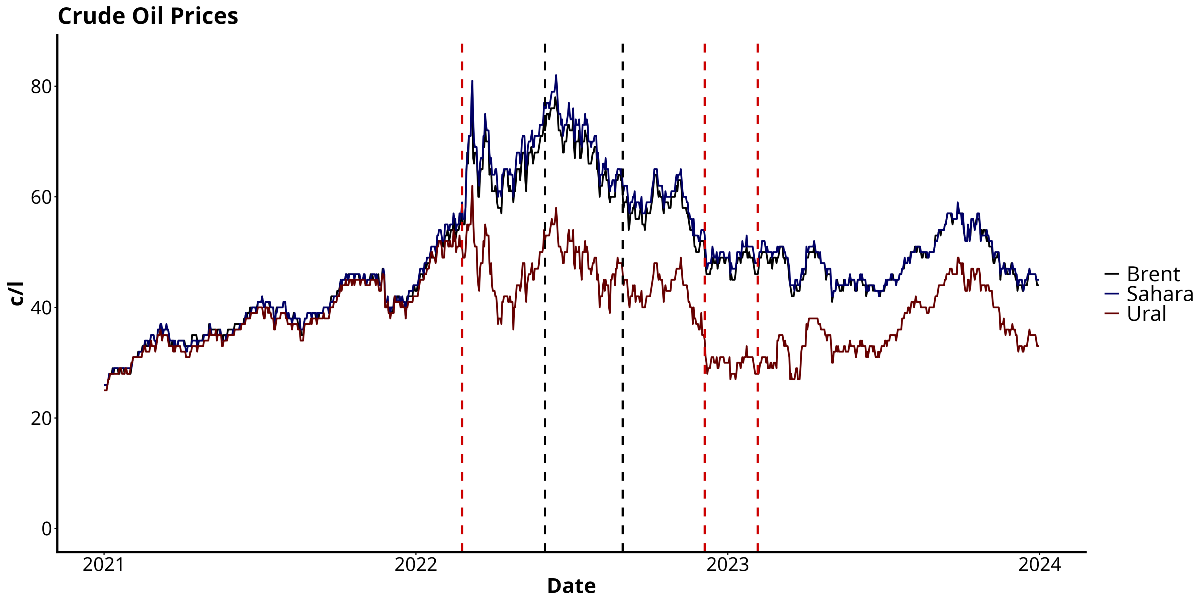

Figure B.5: Brent, Sahara and Ural Crude Oil Prices

C Tables

Company	Level of vertical integration	Refineries
BP	Fully integrated	Gelsenkirchen Lingen
Shell	Fully integrated	Rheinland MiRO (partially) PCK (partially)
ENI	Fully integrated	Bayernoil (partially) PCK (partially)
Total Energies	From exploration to refinery (German petrol stations sold in 2023)	Leuna
OMV	From exploration to refinery (German petrol stations sold in 05/2022)	Burghausen
Esso	From exploration to refinery (German petrol stations sold in 10/2018	MiRO (partially)
Philipps66	Refinery and petrol stations (German petrol stations offered for sale)	MiRO (partially)
Rosneft	From exploration to refinery Under trust management by the German Bundesnetzagentur since 09/2022	PCK (partially) MiRO (partially) Bayernoil (partially)
Oilinvest Group	Refinery and petrol stations	Holborn Europa
Varo Energy	Only Refineries	Bayernoil (partially)
Gunvor	Only Refineries	Ingolstadt
Klesch	Only Refineries	Heide

Table C.1: Companies Active in German Fuel Production, Table According to Federal Cartel Office (2022); OMV (2022); TotalEnergies (2024); German Federal Ministry for Economic Affairs and Climate Action (2022); EG Group (2018); Argus Media (2024b)

	Pre COVID	COVID	Invasion	Tax Cut	Post Tax Cut	Post Sanctions
Observations (Days)	1094	785	97	92	95	758
A. Crude Oil Prices						
Brent	34.74	31.88	63.60	64.84	57.25	46.92
	(4.43)	(9.61)	(4.10)	(4.27)	(3.26)	(3.43)
Sahara	34.75	31.84	67.35	70.72	59.29	47.94
	(4.66)	(10.73)	(4.73)	(5.41)	(3.29)	(3.60)
Ural	32.57	57.16	57.09	57.43	56.22	65.56
	(8.57)	(4.81)	(4.03)	(3.82)	(2.40)	(8.89)
B. Wholesale Prices						
Gasoline	43.86	40.64	88.99	98.89	77.04	62.88
	(5.29)	(12.21)	(7.56)	(7.02)	(6.31)	6.93
Diesel	46.88	44.11	102.25	111.67	103.41	68.18
	(6.25)	(12.25)	(10.72)	(5.61)	(9.22)	9.05
Gasoline (ARA)	41.67	36.73	80.51	87.89	69.51	58.86
	(4.82)	(12.69)	(9.35)	(12.55)	(7.16)	6.09
Diesel (ARA)	42.18	35.91	87.16	95.68	90.16	61.58
	(5.06)	(11.19)	(8.91)	(7.89)	(10.37)	7.39
C. Retail Prices						
Gasoline	53.40	53.46	100.51	111.94	88.94	76.25
	(5.28)	(11.75)	(7.73)	(7.05)	(6.00)	(6.60)
Diesel	56.59	55.90	115.36	123.12	114.68	82.53
	(6.10)	(11.87)	(10.69)	(4.68)	(8.44)	(8.84)
D. Refinery Margins						
Gasoline	9.12	8.76	25.39	34.05	19.79	15.96
	(3.15)	(3.46)	(5.75)	(3.76)	(4.20)	(5.61)
Diesel	12.14	12.23	38.65	46.83	46.16	21.25
	(3.38)	(4.29)	(9.70)	(5.59)	(6.68)	(7.03)
Gasoline (ARA)	6.93	4.86	16.91	23.05	12.26	11.94
	(2.53)	(3.38)	(6.59)	(8.95)	(4.76)	(4.00)
Diesel (ARA)	7.44	4.03	23.56	30.84	32.91	14.66
	(1.48)	(2.41)	(6.44)	(5.10)	(7.78)	(5.02)
E. Station Margins						
Gasoline	9.54	12.83	11.52	13.05	11.90	13.37
	(1.02)	(1.72)	(3.22)	(2.17)	(1.90)	(1.50)
Diesel	9.71	11.79	13.11	11.45	11.26	14.36
	(1.04)	(1.23)	(5.62)	(2.91)	(2.75)	(1.44)
F. Cost of Freight						
Gasoline	1.51	1.08	1.77	3.40	3.06	1.56
	(1.04)	(0.40)	(0.41)	(1.91)	(0.96)	(0.50)
Diesel	1.67	1.14	1.93	3.77	3.39	1.68)
	(1.18)	(0.46)	(0.46)	(2.17)	(1.09)	(0.56)

Table C.2: Daily Prices and Margins in c/l

	Pre COVID	COVID	Invasion	Tax Cut	Post Tax Cut	Post Sanctions
Observations (Days)	1094	785	97	92	95	758
A. Gasoline Prices						
Cologne	43.98	40.89	88.77	97.33	77.30	62.47
	(5.26)	(11.99)	(7.40)	(8.09)	(7.72)	(6.38)
East	43.71	41.48	90.73	98.11	76.95	64.30
	(4.87)	(12.09)	(7.85)	(8.06)	(5.83)	(6.97)
Emsland	43.01	41.33	90.47	99.80	78.63	63.54
	(4.57)	(12.31)	(8.65)	(8.23)	(6.88)	(6.54)
Magdeburg	43.71	41.11	89.90	99.65	77.45	64.12
	(4.87)	(12.44)	(7.71)	(9.24)	(6.06)	(7.37)
North	43.01	40.97	88.82	98.39	76.88	63.33
	(4.57)	(12.40)	(7.66)	(9.30)	(5.95)	(6.99)
Rhine-Main	45.00	41.45	89.60	99.73	77.24	63.26
	(5.85)	(11.97)	(7.43)	(6.50)	(7.60)	(6.49)
Seefeld	42.98	39.94	88.88	96.06	75.35	62.16
	(5.39)	(12.26)	(7.28)	(8.40)	(5.57)	(7.60)
South	43.31	38.85	85.73	102.81	77.67	61.04
	(6.33)	(12.19)	(7.90)	(2.73)	(10.47)	(8.59)
Southeast	45.20	41.70	90.50	101.73	78.54	64.62
	(5.32)	(12.13)	(7.92)	(7.06)	(6.40)	(7.50)
Southwest	43.63	38.77	85.76	95.14	73.46	60.27
	(6.18)	(12.30)	(7.36)	(7.22)	(5.88)	(7.43)
West	43.91	40.87	89.74	98.99	77.94	62.61
	(4.99)	(12.26)	(8.16)	(8.14)	(6.83)	(6.45)
B. Diesel Prices						
Cologne	46.68	43.89	102.77	111.24	101.75	67.37
	(6.28)	(12.26)	(10.51)	(5.52)	(10.21)	(8.97)
East	46.53	44.58	102.25	108.43	102.77	69.22
	(5.63)	(12.08)	(10.63)	(7.33)	(8.80)	(8.90)
Emsland	45.57	43.86	102.94	110.74	102.25	67.72
	(5.43)	(12.31)	(11.27)	(5.62)	(9.48)	(9.07)
Magdeburg	46.53	44.22	102.41	110.97	103.51	68.57
	(5.63)	(12.23)	(10.63)	(6.66)	(8.88)	(9.06)
North	45.57	43.72	101.74	109.34	101.82	67.65
	(5.43)	(12.30)	(10.24)	(7.63)	(8.94)	(9.18)
Rhine-Main	47.52	44.32	103.23	114.30	103.62	68.07
	(6.77)	(12.32)	(10.59)	(5.88)	(10.14)	(9.12)
Seefeld	46.02	43.58	100.39	105.85	101.84	68.17
	(5.96)	(12.10)	(10.47)	(7.69)	(8.58)	(8.85)
South	48.09	44.74	102.30	118.35	106.62	69.11
	(7.36)	(12.53)	(11.61)	(7.49)	(11.73)	(9.77)
Southeast	47.37	44.68	102.74	114.74	107.10	69.28
	(6.04)	(12.27)	(10.98)	(6.04)	(10.17)	(9.05)
Southwest	47.58	43.68	101.54	113.55	103.78	67.30
	(7.37)	(12.44)	(11.23)	(6.64)	(10.10)	(9.28)
West	46.52	43.74	102.42	110.87	102.49	67.47
	(6.20)	(12.18)	(10.66)	(5.56)	(9.98)	(9.10)

Table C.3: Daily Regional Wholesale Prices for Gasoline and Diesel in c/l

	Pre COVID	COVID	Invasion	Tax Cut	Post Tax Cut	Post Sanctions
Observations (Months)	36	26	3	3	4	25
A. Crude Oil Quantities in Germany						
Oil Production	201.03	180.35	168.77	162.91	164.96	148.75
	(14.56)	(11.90)	(3.10)	(4.23)	(2.00)	(22.87)
Oil Trade Balance	8525.00	8017.74	8620.06	8577.48	8868.82	7884.04
	(615.69)	(599.83)	(303.72)	(253.37)	(492.90)	(567.80)
Oil Stock Change	-10.74	-9.47	46.88	-62.12	-2.64	-22.03
	(254.25)	(262.86)	(491.82)	(89.42)	(390.00)	(269.03)
Oil Other	-18.69	-1.89	-78.13	55.87	-85.85	36.85
	(78.58)	(112.97)	(266.31)	(60.15)	(150.39)	(231.96)
Oil Refinery Intake	8718.05	8205.85	8663.03	8858.76	8950.56	8091.68
	(623.50)	(576.73)	(293.90)	(279.41)	(121.24)	(491.65)
B. Crude Oil Quantities in the EEA						
Oil Production (EEA)	13591.68	13989.08	13333.06	12480.24	12979.61	12993.78
	(814.70)	(810.00)	(462.50)	(1202.82)	(662.88)	(601.13)
Oil Trade Balance (EEA)	36133.35	28500.34	31064.64	34455.63	32148.25	31821.11
	(2167.46)	(2924.59)	(2912.34)	(1184.36)	(2652.33)	(1812.31)
Oil Stock Change (EEA)	43.82	-146.77	622.33	-199.24	167.01	-86.40
	(1364.74)	(1634.53)	(724.68)	(944.95)	(1962.88)	(1022.39)
Oil Other (EEA)	151.22	-289.39	517.63	45.71	0.29	138.39
	(568.60)	(755.52)	(648.65)	(704.45)	(1163.15)	(616.97)
Oil Refinery Intake (EEA)	49829.11	42346.25	44294.57	47177.30	44962.90	45040.38
	(2512.48)	(2829.23)	(1856.76)	(1708.94)	(1830.89)	(1984.20)
C. Gasoline Quantities in Germany						
Gasoline Production	2279.74	2172.82	2286.00	2358.90	2331.11	2216.27
	(158.95)	(201.49)	(8.25)	(73.77)	(46.59)	(193.59)
Gasoline Trade Balance	-293.62	-408.74	-560.70	-381.15	-444.15	-336.69
	(182.32)	(107.42)	(140.64)	(158.64)	(113.87)	(180.93)
Gasoline Stock Change	-3.75	-3.89	49.50	-157.50	116.78	-21.22
	(156.02)	(166.90)	(45.31)	(162.69)	(109.06)	(132.09)
Gasoline Other	304.12	420.94	419.40	519.30	228.15	381.94
	(150.65)	(150.34)	(161.27)	(193.25)	(168.20)	(149.81)
Gasoline Demand	2290.31	2184.92	2146.05	2495.70	2114.78	2261.30
	(192.42)	(226.68)	(67.89)	(116.20)	(104.95)	(137.48)
D. Gasoline Quantities in the EEA						
Gasoline Production (EEA)	11597.59	10040.31	10874.25	11182.05	10524.60	11170.12
	(676.25)	(1063.64)	(283.19)	(567.46)	(664.72)	(650.38)
Gasoline Trade Balance (EEA)	-6299.21	-5429.03	-6076.80	-6021.90	-5567.74	-5361.88
	(574.01)	(781.33)	(645.11)	(237.58)	(630.48)	(534.11)
Gasoline Stock Change (EEA)	-15.30	14.49	-158.85	-108.00	-51.30	65.07
	(664.00)	(718.40)	(488.91)	(428.58)	(291.32)	(529.11)
Gasoline Other (EEA)	1850.81	1981.28	2847.15	2938.50	2630.14	2193.97
	(955.75)	(969.49)	(754.66)	(313.58)	(825.21)	(647.96)
Gasoline Demand (EEA)	7405.61	6779.60	7653.60	8207.55	7750.35	8162.96
	(511.03)	(1163.02)	(409.57)	(223.73)	(223.24)	(552.88)
E. Diesel Quantities in Germany						
Diesel Production	4143.95	3999.33	4265.25	4271.58	4365.37	4037.48
	(304.87)	(323.79)	(92.34)	(190.15)	(174.26)	(258.91)
Diesel Trade Balance	1093.72	783.44	311.92	473.61	667.12	512.64
	(355.06)	(401.98)	(346.89)	(517.69)	(140.32)	(413.82)
Diesel Stock Change	-15.06	-31.79	52.18	-190.55	163.67	20.45
	(345.14)	(411.11)	(271.70)	(147.93)	(193.07)	(476.76)
Diesel Other	92.15	129.37	94.48	273.18	-85.98	-70.31
	(358.36)	(380.59)	(286.42)	(80.80)	(190.34)	(448.61)
Diesel Demand	5329.92	4912.05	4672.05	5019.55	4946.21	4479.95
	(330.61)	(578.87)	(397.31)	(325.89)	(87.68)	(299.55)
F. Diesel Quantities in the EEA						
Diesel Production (EEA)	21781.68	19335.91	19313.22	20399.20	19872.62	19151.10
	(1041.68)	(1098.98)	(250.40)	(1122.94)	(1102.37)	(795.18)
Diesel Trade Balance (EEA)	1721.02	1894.59	2531.71	1726.03	3649.03	2158.52
	(831.35)	(898.07)	(751.43)	(465.74)	(548.51)	(768.17)
Diesel Stock Change (EEA)	-124.53	-112.94	-456.21	43.09	549.41	120.55
	(1424.99)	(1389.40)	(1293.56)	(987.71)	(1796.66)	(1290.41)
Diesel Other (EEA)	1036.53	1720.16	2108.71	1449.29	807.96	1288.52
	(1544.88)	(1921.74)	(1313.37)	(849.64)	(1622.33)	(1222.25)
Diesel Demand (EEA)	24616.52	22951.70	23950.48	23575.70	24333.16	22596.67
	(921.69)	(1829.45)	(1042.61)	(308.05)	(648.32)	(969.91)

Table C.4: Monthly Quantity Data in 1.000 m^3