A Statistical Analysis of the Impact of the Russia-Ukraine War on Gas Prices

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Abstract

During the five-month period between January and June of 2022, the price of gasoline in the United States increased by 49%, while diesel prices increased by 55% [1]. Some individuals have attributed the price increase to the Russia-Ukraine War. To delve deeper into the issue, I will examine the sources of price changes in the United States gasoline market by using ordinary least squares and fixed effects regressions to analyze gasoline price data between January 2004 and March 2022. Additionally, I will distinguish between two key impacts on gasoline prices in 2022: the beginning of the Russia-Ukraine conflict in February and the implementation of sanctions limiting the import and export of petroleum products to Russia in March. The results of my study suggest that the sanctions enacted had a significant impact on gasoline prices in the United States, and had more gravity compared to the start of the war.

Section I - Introduction

The ongoing Russia-Ukraine war has resulted in 5,916 civilian casualties as of September 18, 2022 [2]. Numerous western officials have condemned the insurgency and claimed that it may be the most consequential war in Europe since World War II. On February 24, 2022, the day Russia initiated the invasion, Russian President, Vladimir Putin, characterized the act of aggression as an attempt to "demilitarize and denazify Ukraine" [3]. Putin has expressed disdain for western civilization and its role in the collapse of the Soviet Union several decades ago. In a speech given in April of 2005, Putin said, “[Russians] should acknowledge that the collapse of the Soviet Union was a major geopolitical disaster of the century, as for the Russian nation, it became a genuine drama.” Some hypothesize Putin's decision to invade Ukraine is the first stage in his plan to reestablish the Soviet Union. Aligning with the European Union (EU) and The Group of 7 (G7), the United States imposed sanctions against Russia in response to the insurgency. Since Russia is the third-largest exporter of gasoline to the United States, many believe that the ongoing war caused an increase in gas prices.

Due to the non-renewable nature of gasoline, the use of it for fuel has generated controversy in recent years. After the industrial revolution in the twentieth century, gasoline became a relatively cheap and effective source of energy. As of 2022, gasoline “currently supplies around 80% of the world’s energy.” [4] With the use of electric cars becoming more prevalent, the consumption of coal to generate electricity has decreased by more than half over the fourteen-year period from 2005 to 2019—from 50% to 23% [5]. The California Air Resources Board approved a regulation prohibiting the sale of gasoline-powered vehicles by 2035 in an effort to reduce carbon emissions. This new California legislation has been adopted by more than 15 states, including New York, Virginia, Washington, and Oregon. Additionally, the regulation will incentivize automakers to create more electric cars beginning in 2026. To ensure they have a competitive market, automakers will establish a market for their product and start developing high end electric vehicles prior to 2035.

Despite the initiative to reduce nonrenewable sources of energy for fuel, the United States imported over 245 million barrels of crude oil from Russia in 2021 alone. Intuitively, if the third-largest supplier of petroleum stopped exporting to the United States, there would be a

supply shortage. Such a supply shortage, as caused by the sanctions implemented against Russia, led to an increase in gasoline prices in the United States.

To dive deeper into the implicit and explicit effects of the war, my study will answer three main questions. Did the start of the war have an impact on gas prices? Did the implementation of sanctions have an impact on gas prices? And, was the impact of the sanctions on gas prices greater than the impact of the war on gas prices? To answer these questions I use ordinary least squares (OLS) regressions to analyze the behavior of gas prices as the war commenced and compare the results to when the sanctions were implemented. Since some of the variation in gas prices can be attributed to the discrepancies between states, I add fixed effects to the regressions to reduce the influence of state-level differences. Utilizing ordinary least squares regression and fixed-effects regressions, I propose that the increase in gas prices can be attributed to sanctions that restricted the imports and exports of Russian oil.

Section II - Literature Review

Various empirical studies have been conducted on the direct and indirect consequences of wars on economies. While examining the basis for price fluctuations of commodities, the most common methodologies are time series models, specifically structural and ordinary vector autoregressive models (VAR). To investigate the variability in crude oil pieces, Gong et al. employed a five variable Markov switching VAR approach [6]. The VAR model in this study was constructed based on oil prices, aggregate supply and demand, global oil inventory, and oil speculative demand. While their research emphasized the broader determinants of oil price fluctuations, my study will concentrate on the influence of the Russia-Ukraine war on gasoline prices. Ji et al.used data-driven directed acyclic graphs to explain natural gas price variations [7]. When determining the causal influence on natural gas prices, their study considers storage and seasonality factors. Adding to these papers, I will analyze the impact of the Russia-Ukraine war and diplomatic sanctions on gasoline prices, something that has not yet been researched.

Hailemariam and Smyth used a structural heterogeneous VAR model while accommodating structural breaks in both the coefficient and volatility [8]. While this study uses structural VAR methods to analyze significant changes in the price of natural gas, my study will employ panel data and OLS regressions to determine which event increased the price of gas. Liu et. al used power spectrum analysis to study the volatility of price fluctuations. While their study analyzed the S&P 500 to fund the root cause of price volatility, my study has a narrower scope and will focus on a single commodity and utilize panel data methods to do so, as opposed to spectrum analysis [9].

Closely related to my study, Nick et al. used a structural VAR model to analyze supply interruptions caused by diplomatic disputes specifically in the Russia-Ukraine geographic area [10]. While their study looked at the natural gas market in Europe, I will focus on the gasoline market in the United States. Because this study was conducted in 2014, it did not account for the recent insurgency by Russia in Ukraine which my paper will address.

Section III - Empirical Design

My study will use two types of regressions: ordinary least squares regressions, and fixed effects regressions. The ordinary least squares regression equation is given by

$$\Delta G_{it} = \beta_0 + \beta_1 w_t + \varepsilon_{it} \quad (1)$$

where ΔG represents the difference in gas prices, the subscripts i and t indicate individual states during a given year, respectively, and ε represents the observed uncertainty in the regression. In Eq. (1), β_0 represents the constant in the least squares model. The coefficient of interest is β_1, which represents the change in gas prices that happens in years with either war or sanction restrictions. This equation is used to run two regressions:: one that calculates the gas price difference after Russia initiated the offensive on Ukraine on February 24, 2022, and another that calculates the gas price difference after the United States placed restrictive sanctions on the import of Russian petroleum products on March 8, 2022. To clarify, ΔG is the gas price of the week of February 24th minus the gas price of the prior week in state i and year t for the war regression. For the second regression, the difference is between the week of March 8th and the previous week.

Since there are likely state-level differences that influence changes in gas prices, I also include fixed effects regression. The fixed effects regression can be modeled by the equation

$$\Delta G_{it} = \beta_0 + \beta_1 w_t + \gamma_s + \varepsilon_{it} \quad (2)$$

where ΔG still represents the difference in gas prices, and the subscripts i and t indicate individual states and a particular year, respectively. The difference between Eq. (1) and Eq. (2) is in the γ term, which is a vector representing the fixed effects with the subscript s indicating different states. By adding nine additional components to the regression, one for each state, I limit the amount of gas price fluctuation attributable to state differences. Additionally, I use HuberT's norm with a 'H3' covariance matrix to account for the heteroscedasticity of the data. Since fixed effects reduces the variability attributable to state differences, I expect this method to provide the most accurate outcomes.

To interpret these regressions as causal and unbiased, I made the following assumptions. First, no significant economic, political, or diplomatic events occurred during the weeks containing February 24th and March 8th from 2004 to 2022, with the exception of the start of the war on February 24th, 2022 and the implementation of sanctions on March 8th, 2022. I also assume that Russia declaring war and the United States enforcing sanctions are independent from state-by-state characteristics from 2004 until 2022. Finally, it is necessary for me to assume that anything affecting gas prices does not affect the start of the war or implementation of sanctions, and vice versa.

The two assumptions needed for me to interpret my OLS regressions as causal and unbiased are the following: the average error of the regressions (ε_{it}) given if it is a war year or not (w_t) is equal to zero, and the covariance of the war year and error terms are equal to zero: $E[\varepsilon_{it}|w_t] = 0,\ Cov[w_t, \varepsilon_{it}] = 0$. There are likely challenges to these assumptions, however, comparing the estimates from the war and sanction regressions could still shed light on which effect is more important for gas prices.

Section IV - Data, Calculations, & Graphs

From The Energy Information Administration of the United States I gathered weekly data regarding the average gasoline price from California, Colorado, Florida, Massachusetts, Minnesota, New York, Ohio, Texas, and Washington from 2004 until 2022. I compare the change in prices in response to expectations of war and to the implementation of sanctions. The war began on February 24th, so I subtract the average price of gasoline the week before

February 24th from the average price of the week after. Similarly, the most significant sanction on the import and export of Russian oil went into effect on March 8, so I do the same with the average price before and after March 8th. While reviewing the data, I noticed a significant spike in prices in the first week of March only in 2022.

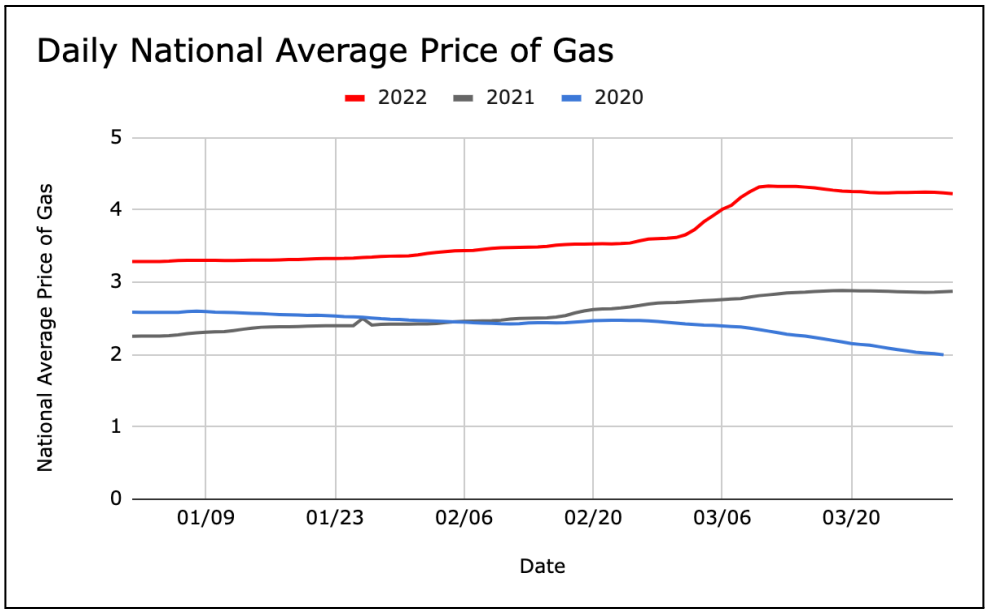
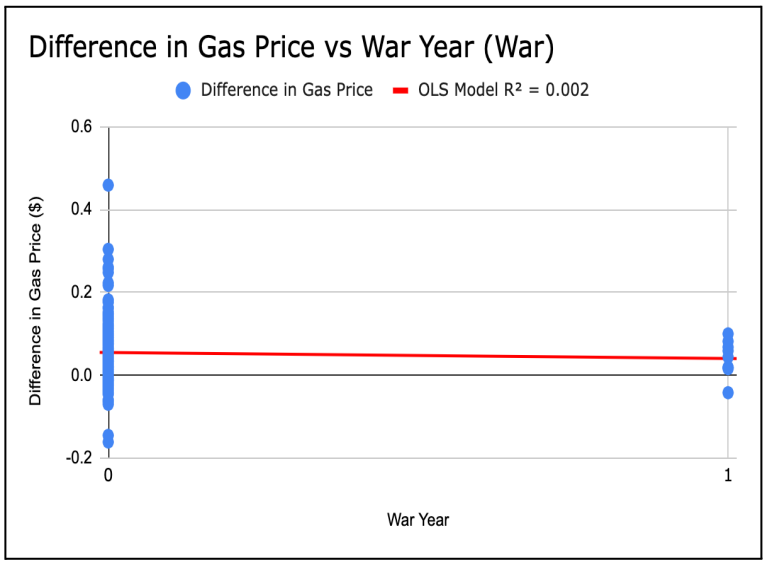


Figure (1): plots the date with the corresponding average price of gas for 2020, 2021, and 2022.

Looking at the data for all three years, as seen in figure 1, there isn't any significant increase around February 24th, the day the war started. However, there is a sizable increase in gas prices, roughly 19%, surrounding March 8, the day the United States enacted sanctions against Russia.



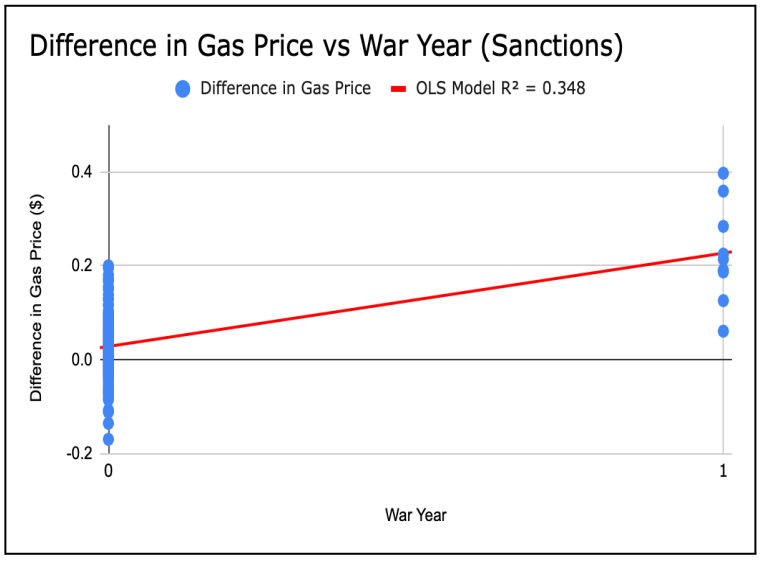


Figure (2)

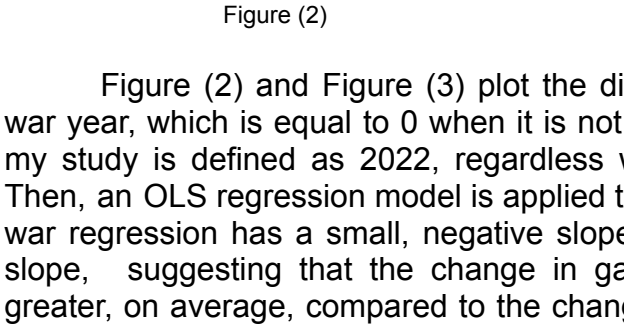


Figure (3)

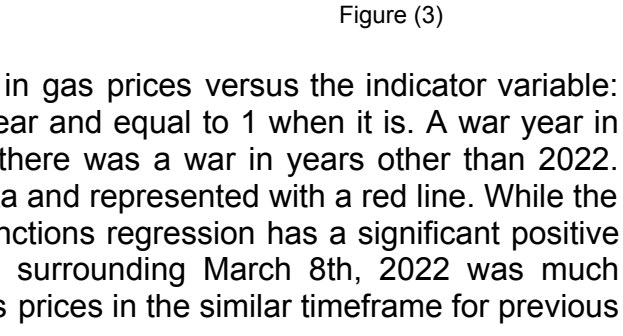


Figure (2) and Figure (3) plot the difference in gas prices versus the indicator variable: war year, which is equal to 0 when it is not a war year and equal to 1 when it is. A war year in my study is defined as 2022, regardless whether there was a war in years other than 2022. Then, an OLS regression model is applied to the data and represented with a red line. While the war regression has a small, negative slope, the sanctions regression has a significant positive slope, suggesting that the change in gas prices surrounding March 8th, 2022 was much greater, on average, compared to the change in gas prices in the similar timeframe for previous years.

	War		Sanctions	
	Coefficient		Coefficient	
	Column 1	Column 2	Column 3	Column 4
Constant	0.0488***	0.0444	0.0275***	0.0251
Std. Error	0.005	8.29e+05	0.004	1.17e+06
War Year	-0.0082	-0.0087	0.1925***	0.1961***
Std. Error	0.020	0.020	0.030	0.033
Fixed Effects	No	Yes	No	Yes
R-squared	0.002	0.055	0.348	0.403
Observations	171	171	171	171

Table (1)

*** represents significance at the 0.01 level
Column 1 is the war regression without fixed effects. Column 2 is the war regression with fixed effects. Column 3 is the sanctions regression without fixed effects. Column 4 is the sanctions regressions with fixed effects.

Table (1) compares the coefficients of four regressions. There are combinations of war regressions with and without fixed effects, and the same war versus sanction regressions and OLS versus fixed effects regressions. The independent variable is the gas price difference, while the dependent variable is an indicator variable that would equal 0 if it was not a war year, and 1 if it was a war year. A war year, in my study, is defined as the year 2022, regardless of if there was a war in other years from 2004 until 2022.

Looking at the war regressions, the slope of the OLS regression is -0.0082 with a standard error of 0.020. The negative slope indicates the difference in gas prices decreased after the start of the war. The fixed effects estimate is similar, with a slope of -0.0087 and a standard error of 0.020. Since both regressions had small, non-significant negative slopes, I infer that there was not a significant increase in gas prices following the start of the war.

Considering the sanction regressions, the slope of the OLS regression is 0.1925 with a standard error of 0.030 and the β_1 value in the fixed effects regression is 0.1961 with a standard error of 0.033. Contrary to the war regressions, the positive slope indicates the difference in gas

prices increased after the sanctions. In both regressions, the coefficient of the war year variable is positive and significant at the 0.01 level, which tells us that there was a significant increase in gas prices following the sanctions.

The total number of observations in all four regressions is 171, meaning the regression accounted for weekly gas price data for 171 weeks since 2004. In the war regressions, the r^2 value for the OLS regression is 0.002 while it is 0.055 for the fixed effects regression. Both the OLS and fixed effects model only explained 0.2% and 5.5% of the variation in the change in gas prices, respectively. For the sanction regressions, the r^2 for the OLS regression is 0.348 while it is 0.403 for fixed effects. The OLS model accounts for 34.8% of the variation in gas price difference and the fixed effects model accounts for 40.3% of the variation in gas price difference.

For both the war and sanction regressions, adding fixed effects increased the r^2 and β_1 values by reducing the variation attributable to state differences. Furthermore, including robust instead of non robust standard errors helped with the heteroscedastic nature of the data. Taking into account these elements, fixed effects is the preferred methodology for analyzing the data.

Section V - Conclusion

In March 2022, the United States experienced roughly a 16% increase in the price of gas in the span of less than two weeks according to AAA (2022). Since Russia was America's third largest supplier of petroleum products and crude oil, the sanctions stopping the trade between the countries impacted the supply chain of gasoline in the United States and as a result, increased gas prices.

Referring back to the introduction, my study intended to answer three questions: Did the start of the war have an impact on gas prices? Did the implementation of sanctions have an impact on gas prices? And, was the impact of the sanctions on gas prices greater than the impact of the war on gas prices? Based on the evidence presented in this paper, the data shows that sanctions affected gas prices more than the war did since the sanction regressions had a positive slope, contrary to the war regressions. Despite the sanctions being a direct result of the war, the regressions can still tell us the relative importance of each of these events regarding price fluctuations in the gasoline market.

While some consider the increase in prices a major financial setback, others are looking at it as an opportunity to switch to an electric vehicle. As of October 1 2022, the average price of one kilowatt-hour of electricity is $0.20, while the average price of one gallon of gasoline is $3.80 in the United States. With the California Air Resources Board and over 15 other states on a collective mission to reduce carbon emissions by banning the sale of gasoline cars by 2035, electric powered vehicles will inevitably be the status quo in years to come. Consequently, the demand for gasoline will take a hit if similar legislation is passed in the near future.

Despite my study analyzing and differentiating between the causes of gas price fluctuations, there is much more to be uncovered surrounding this topic. Based on the results and methods of my study, future research should be done to delve deeper into the Russia-Ukraine war, or broader topics on analyzing historical sanctions that the United States implemented and its impact on the prices of commodities. Furthermore, one can also look into instrumental variables that are related to wars or sanctions. Such issues are important to understand due to the significantly relevant effects that foreign conflicts have on our daily lives.

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