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Investigating the Relationship Between Fuel Price Disparities and Traffic Flow on Border Roads

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Abstract

This paper aims to investigate the relationship between differences in fuel prices across neighboring countries and the amount of traffic on cross-border roads. Without direct data on smuggling rates, our study proposes that there may be a link between disparities in fuel prices and the activity of smuggling fuel, which could be reflected in the volume of traffic along these border roads. Without relying on complex statistical techniques, we'll be analyzing the patterns and trends in the data to understand how changes in fuel prices might affect the flow of traffic. By uncovering this connection, our research seeks to shed light on indirect indicators of smuggling, providing valuable insights into cross-border activities.

Introduction

Border regions are vital hubs for economic activities and exchanges between neighboring countries. One significant aspect of this dynamic is the difference in fuel prices between these countries. In this article, we will delve into how these fuel price disparities influence the flow of traffic on border roads, focusing on the Iran-Turkey border, where notable differences in fuel prices are observed.

These fuel price differences also impact potential illicit activities such as smuggling. Understanding the relationship between price disparities and smuggling elasticity—how responsive smuggling activity is to changes in price differences—is crucial.

We hypothesize that there is a positive correlation between fuel price disparities and traffic flow on border roads. Specifically, as the difference in fuel prices between neighboring countries increases, we expect to observe a corresponding increase in the volume of traffic on border roads. This is based on the assumption that significant price differentials create financial incentives for individuals or groups to engage in cross-border activities, including potential fuel smuggling. Therefore, Iran-Turkey cross-border routes are likely to experience higher levels of traffic as individuals seek to take advantage of these price differentials.

Fluctuations in the Iranian Rial (RIAL) compared to gas prices in Turkey can widen the price gap between the two countries. A weaker Rial benefits Iranian gas sellers in Turkey, potentially increasing cross-border activities like fuel smuggling. This highlights the importance of considering both gas prices and currency exchange rates in analysis. Additionally, Iran's fixed gas price ensures consistent costs for sellers, potentially magnifying the impact of currency fluctuations on price differentials.

Data Collection

Comprehensive and current traffic data are essential for transportation studies, yet obtaining it from governmental sources poses challenges due to diverse formats and access restrictions. To overcome this, we developed an automated approach for accessing traffic data from the country's road management center website. Moreover, we extended this method to collect historical USD price data in Rial from [1]. We also collected gasoline price history data from Turkey via [2].

To automate data collection, we utilized Python scripting with Selenium for web scraping. Initially, we developed a script for [3], navigating through the traffic data section by authenticating with session cookies and downloading files by interacting with webpage elements.

Following a similar approach, another script was created for [1] to extract historical USD price data in Rial.

Both scripts effectively handled website variations, monitored downloads, and organized data into CSV files for analysis.

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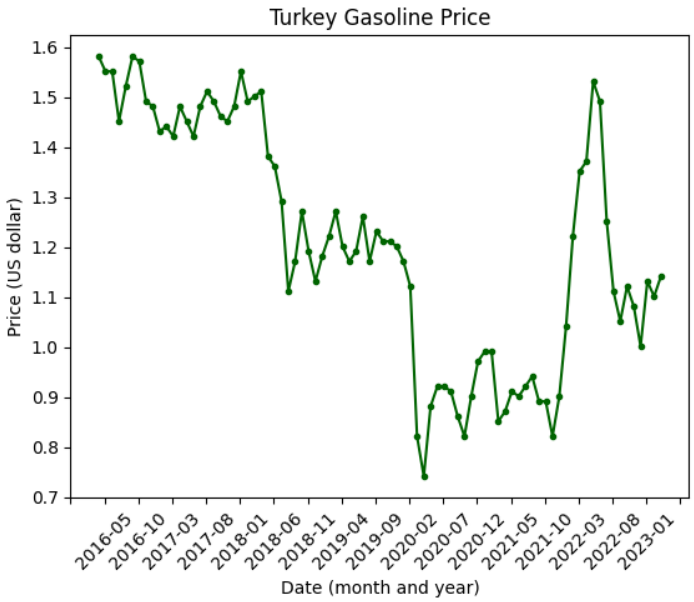

Figure 1: Turkey Gasoline Price in USD

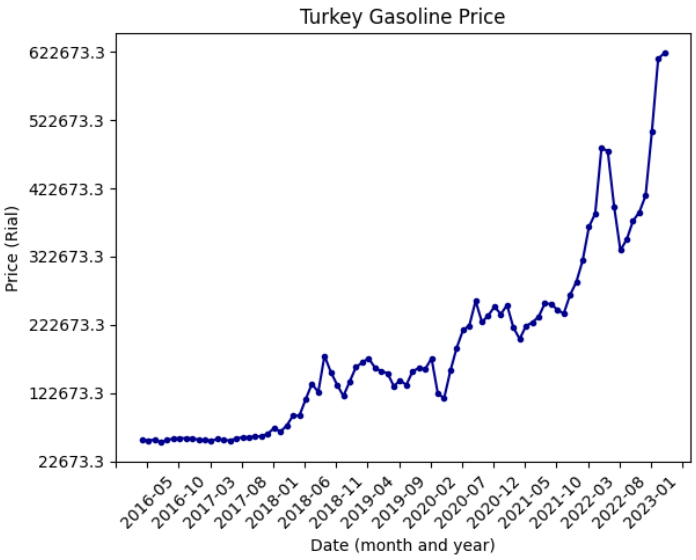

Figure 2: Turkey Gasoline Price in RIAL

Table 1: Sample table of Traffic volume on Iran-Turkey cross-border roads

DateTime	Price	Bazargan	Sarv	Razi	Total
2016-04	54525	55898	287927	50681	394506
2016-05	53707	58716	213369	50864	322949
2016-06	54699	56205	275561	46368	378134
2016-07	51156	53352	320694	50340	424386
2016-08	54066	58006	341838	51209	451053
⋮	⋮	⋮	⋮	⋮	
2022-11	387590	14480	115912	18584	148976
2022-12	411740	55443	434579	64290	554312
2023-01	505155	52830	407568	62737	523135
2023-02	612161	47767	346801	52320	446888
2023-03	620809	43172	311430	49758	404360

* Prices are in RIAL

The gas prices provided correspond to the closing prices recorded on the final day of each month. This reporting methodology may potentially obscure or underestimate the occurrence of daily high resonances in gas prices when interpreting the charts.

To note, it's important to acknowledge that the traffic data collected from the website of the country's road management center may contain small gaps. These gaps can arise due to the nature of machine-generated data, which may occasionally encounter technical issues or inconsistencies in reporting.

Due to sensor location and name mismatch at the "Sarv" border, an alternative sensor further from the border was used. This may impact analysis efficiency due to potential differences in data accuracy and reliability.

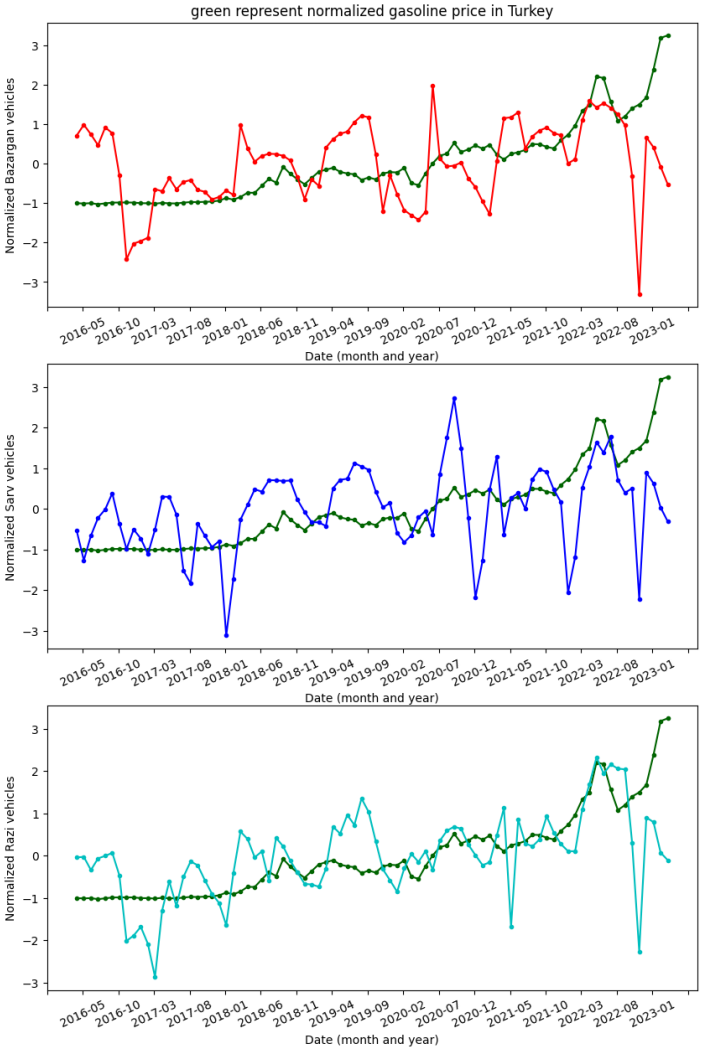

Figure 3: Comparison of Traffic volume Along Three Cross-Border Routes

Correlation is a statistical measure that quantifies the strength and direction of the relationship between two variables. It indicates how changes in one variable are associated with changes in another variable. Correlation values range from -1 to 1, where:

- 1 indicates a perfect positive correlation (both variables increase or decrease together),
- -1 indicates a perfect negative correlation (one variable increases as the other decreases), and
- 0 indicates no correlation (there is no apparent relationship between the variables).

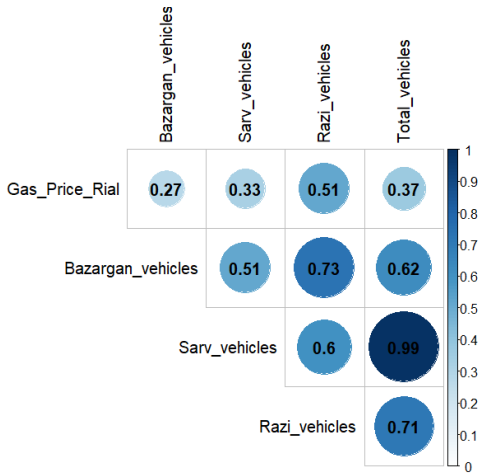

Figure 4: Correlation Matrix: Turkey borders and Gas prices

Our Contribution

The correlation matrix analysis provides evidence of a significant and meaningful association between the fluctuations in gas prices within Turkey and the observed traffic flow along cross-border routes. This statistical examination offers valuable insights into the interconnections of these two variables, indicating a potential causal relationship or shared influencing factors.

By employing a 95% confidence interval in our analysis, we establish a solid foundation for the observed correlation, enhancing the reliability and validity of our findings. This rigorous statistical approach not only highlights the strength of the relationship between gas prices and cross-border traffic but also underscores the confidence level in our conclusions.

The ”Razi” route exhibits a stronger correlation with gas price differentials compared to other routes. This suggests that there is a significant relationship between gas price disparities and traffic flow on this road. Given the higher correlation, there is a strong indication that fuel smuggling activities may be more prevalent on this route, as fluctuations in gas prices motivates smuggling across borders.

Additionally, it’s worth to say that in ”Total”, the majority of the data is attributed to the ”Sarv” road. Therefore, the overall correlation in the ”Total” will be heavily influenced by the correlation number of the ”Sarv” road, as it has more weight in determining the Total number due to the higher volume of cars on this route.

To validate the robustness of our previous findings and to ensure that the observed high correlations were not merely coincidental, we deliberately selected two additional roads located far from the border area, Urmia-Tabriz (Urmia) and Tabriz-Urmia (Tabriz). This strategic choice aimed to assess whether the strong correlations observed in our initial analysis were unique to border regions or if they could be replicated in distant areas.

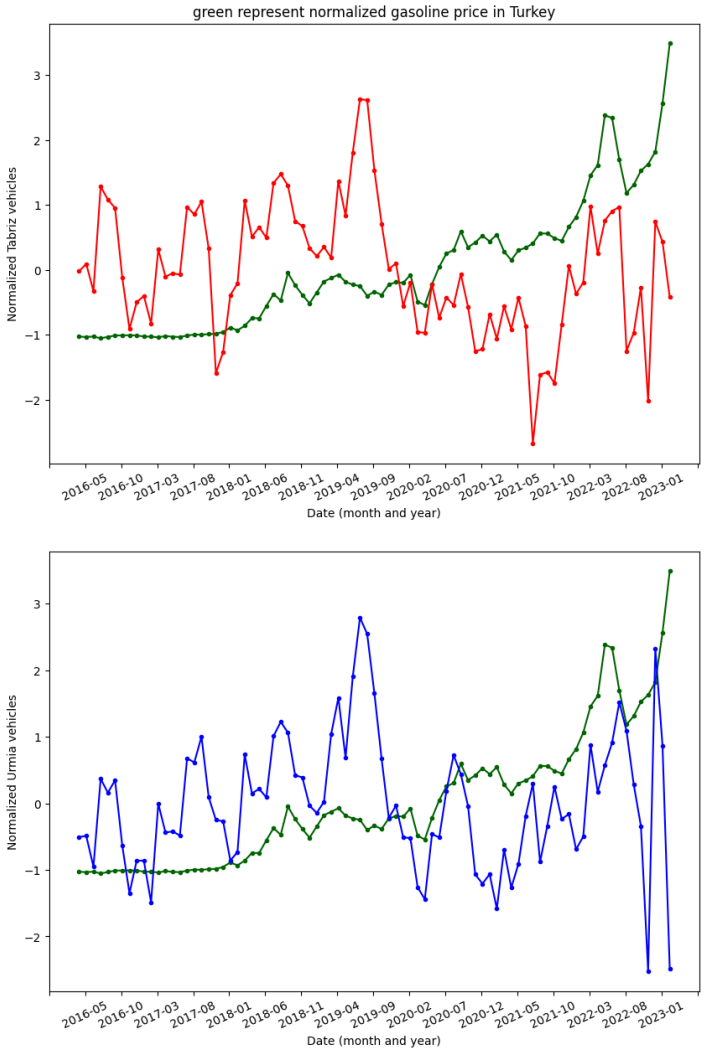

Figure 5: Comparison of Traffic volume Along Two Distant roads

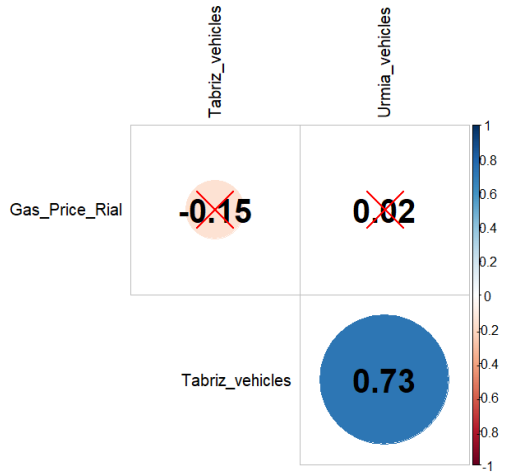

Figure 6: Correlation Matrix: Distant roads and Gas prices

The correlation matrix for distant roads revealed significantly low correlations between traffic volume and gas prices in Turkey, contrasting with previous findings. This suggests that the high correlations observed initially were not due to chance but indicated meaningful relationships specific to border regions. Coupled with a 95% confidence interval calculation, this analysis offers valuable insights into the interplay between gas prices and cross-border traffic dynamics, benefiting both research and practical applications.

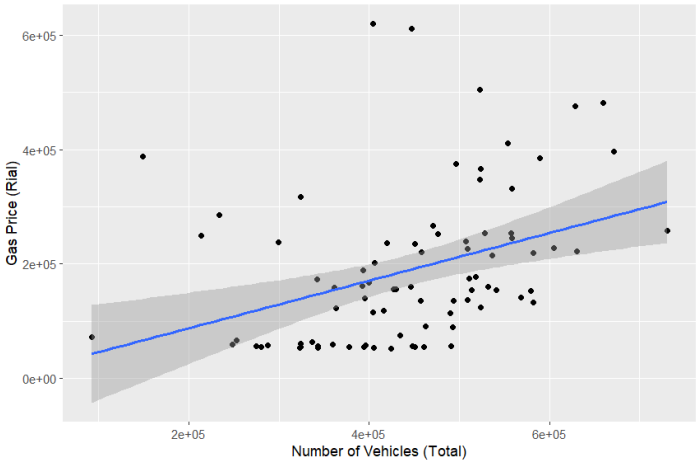

Figure 7: Simple Linear Regression: Gas prices and Total Trrafic volume

The simple linear regression analysis shows a moderate positive correlation (correlation coefficient: 0.37) between gas prices and traffic flow on cross-border roads. This suggests that as gas prices rise, there's a tendency for traffic volume to increase along these routes. Subsequently, regression plots for the main cross-border roads ("Razi", "Sarv", and "Bazargan") are presented, illustrating the relationship between gas prices and traffic flow for each road separately. These plots offer insights into the unique dynamics observed in each border region.

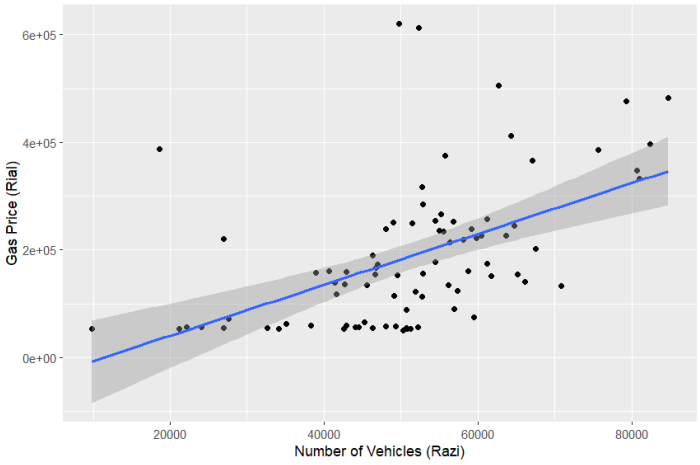

Figure 8: Simple Linear Regression: Gas prices and Razi Traffic volume

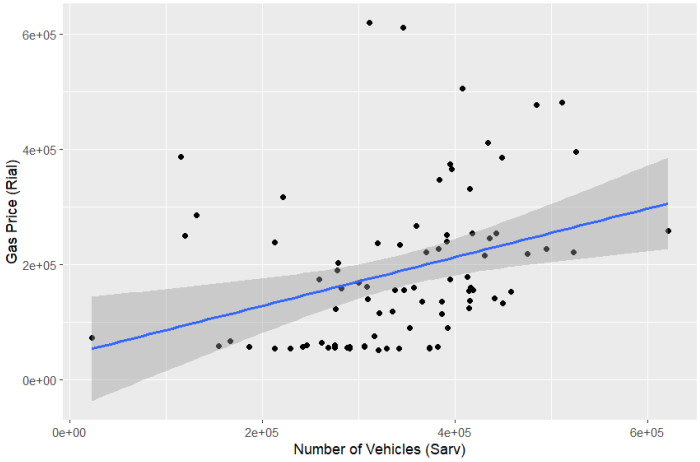

Figure 9: Simple Linear Regression: Gas prices and Sarv Traffic Volume

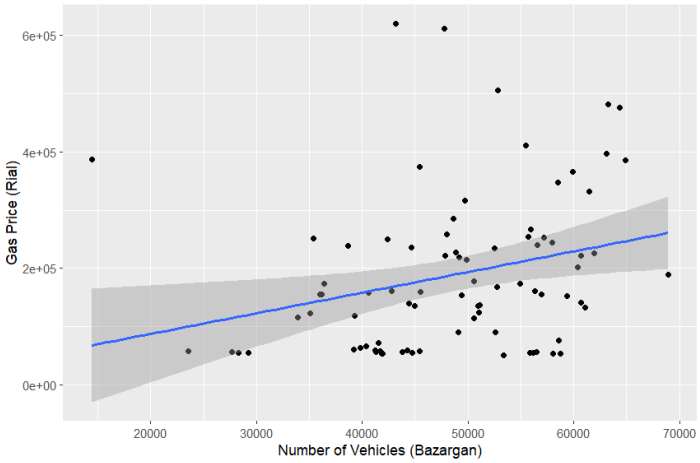

Figure 10: Simple Linear Regression: Gas prices and Bazargan Traffic volume

Table 2: P-values

Road	P-value
Sarv	0.00256
Bazargan	0.0116
Razi	6.71e-07
Tabriz	0.173
Urmia	0.859

The table shows that low p-values indicate a strong statistical significance, implying a reliable relationship between gas prices and traffic flow, particularly for closer borders like Sarv, Bazargan, and Razi. Conversely, higher p-values suggest weaker statistical significance, indicating that the observed relationship may be less reliable, especially for more distant borders such as Tabriz and Urmia.

While the correlation is statistically significant, it's important to note that correlation does not imply causation. In other words, we can't say for certain that changes in gas prices directly cause changes in traffic flow; other factors may also be at play. For example:

1. **Economic conditions:** Overall economic health, including factors such as employment rates, GDP growth, and consumer spending, can impact travel patterns and demand for cross-border transportation.

2. **Seasonal variations:** Seasonal changes, such as holidays, vacation periods, or weather conditions, may affect travel behavior and traffic volumes along border routes.

3. **Regulatory policies:** Changes in regulations related to trade, immigration, or transportation infrastructure can influence cross-border traffic patterns and logistics operations.

4. **Political events:** Political instability, border disputes, or changes in diplomatic relations between countries can impact cross-border travel and trade flows.

5. **Infrastructure development:** Investments in transportation infrastructure, such as new roads, bridges, or border crossings, can affect the efficiency and capacity of cross-border transportation networks.

6. **Demographic factors:** Population growth, urbanization trends, and migration patterns can shape travel demand and traffic volumes along border regions.

Overall, the simple linear regression analysis highlights the importance of considering gas price differentials as a potential factor influencing cross-border traffic flow.

Further Discussions

1. **Interpretation of Results**: While the findings of our study shed light on the relationship between gas prices and traffic flow on cross-border roads related to Iran-Turkey border, it's important to acknowledge the limitations that may have affected the accuracy of our analysis. Due to time constraints, we were unable to explore alternative structures of comparison or conduct more in-depth investigations into the nature of the relationship. As a result, our analysis may not fully capture the complexities of the phenomenon under study.

2. **Potential for Future Research**: Moving forward, there is an opportunity to address these limitations and enhance the robustness of our analysis. Exploring different methodologies or analytical frameworks could provide deeper insights into the dynamics of cross-border transportation and energy markets. Additionally, leveraging data from neighboring countries such as Pakistan and Azerbaijan (which were collected for this research) could offer a broader perspective and enable a more comprehensive analysis of the factors influencing traffic flow and gas prices in the region.

   However, for a deeper analysis of the price elasticity of gasoline smuggling, we recommend referring to the work of Nima Rafizadeh [4], which offers a comprehensive examination of smuggling patterns and their economic implications.

3. **Policy Implications**: Despite the limitations of our study, the findings have important implications for policymakers and stakeholders involved in cross-border trade and transportation. For example, you can read Mehrnews report on this topic.

Appendix

Traffic Data Organization

Our dataset includes detailed information on traffic volume, categorized by day, month, and hour, for each of the three border roads. We examined this data for each month, spanning from the year 1395 to 1401, for all three roads.

Cleaning the data is an important process that improves the quality and usability of the data. In this project, the following steps were taken to clean the data:

1. **Correction of Estimated Counts:** In all datasets, except for the first two months of 1395, there was a column named "Estimated Count" which corrected the traffic count based on the vehicle operating time.

These corrections were applied using an R script titled `fix_missing_1395.R`.

2. **Standardization of Column Names:** Some column names, such as "Operating Time (minutes)" or "Number of Speed Violations", contained spaces in some datasets and were missing in others. To merge the datasets using R functions, all column names were made consistent. These changes were implemented using an R script named `modify_columns.R`.

3. **Additional Clarifications:** For ease of use, column names were translated into English, Persian dates were converted to Gregorian, and some columns were removed.

Normalization Process

To standardize the gas prices and traffic volume data, we applied the following formula:

$$\frac{\text{column\_data} - \text{column\_data.mean()}}{\text{column\_data.std()}}$$

1. **Column Data:** Refers to the original data values in the column that you want to normalize.

2. **Column Data Mean:** Represents the mean (average) value of the data in the column.

3. **Column Data Standard Deviation:** Represents the standard deviation of the data in the column.

This process ensures that both variables are scaled to have a mean of 0 and a standard deviation of 1, facilitating fair comparison and analysis.

P-Value definition

The p-value, or probability value, in statistical hypothesis testing, represents the probability of observing a test statistic as extreme as, or more extreme than, the one calculated from the sample data, under the assumption that the null hypothesis is true. In summary, the p-value helps researchers make decisions about the null hypothesis based on the observed data. A smaller p-value provides stronger evidence against the null hypothesis, while a larger p-value suggests weaker evidence against it.

Datasets and Code

The datasets used in this project can be found in the "Datasets" folder, and the Python and R codes can be found in the "Codes" folder, both located next to this file.

Additionally, the datasets and codes are also available on GitHub at the following link.

References

[1] Gold and C. I. Network. "Dollor-rial prices." (2024), [Online]. Available: `https://www.tgju.org/profile/price_dollar_rl/history`.

[2] T. Economics. "Turkey gasoline prices." (2024), [Online]. Available: `https://tradingeconomics.com/turkey/gasoline-prices`.

[3] C. R. M. Center. "Iran's traffic data." (2024), [Online]. Available: `https://141.ir/`.

[4] N. Rafizadeh. "Price elasticity of gasoline smuggling: A semi-structural estimation approach." (2018), [Online]. Available: `https://www.sciencedirect.com/science/article/abs/pii/S0140988318300665?via%3Dihub`.