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Research Article

Determinants of fuel smuggling in Türkiye (1990-2023)[1]

Türkiye'de akaryakıt kaçakçılığının belirleyicileri (1990-2023)

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Abstract

Smuggling activities have long been debated in economics due to their potential positive and negative externalities. Fuel smuggling is a significant issue that requires attention, as Türkiye has limited fuel and natural gas reserves, while its neighbouring countries possess abundant resources. The loss of tax revenue from fuel smuggling results in substantial revenue declines for governments. This study aims to analyse the factors influencing fuel smuggling in Türkiye from 1990 to 2023. Unlike other research, it uses a dataset that includes the quantities of seized smuggled fuel and the corresponding tax revenue loss over this period. The potential causal relationships among nine independent variables believed to be related to fuel smuggling were examined using the Toda-Yamamoto causality test. The results show bidirectional causality between tax revenue loss from fuel smuggling and actual tax revenues. Additionally, there is a causal link from tax loss due to fuel smuggling to the energy dependency ratio, and a unidirectional causality from dealer profit margins to tax revenue loss from fuel smuggling. The findings also indicate that smuggling activities declined during the period when Unmanned Aerial Vehicles were effectively used to combat smuggling in Türkiye.

Keywords: Fuel Smuggling, Tax Loss, Time-Series Analysis, Türkiye

Jel Codes: C32, H26, K42

Öz

Kaçakçılık faaliyetleri, neden olabileceği olumlu ve olumsuz dışsallıklar nedeniyle ekonomide her zaman tartışma konusu olmuştur. Akaryakıt kaçakçılığı, Türkiye için yeterli petrol ve doğalgaz rezervlerinin olmaması ve komşu ülkelerdeki kaynakların bolluğu nedeniyle ele alınması gereken önemli bir konudur. Akaryakıt kaçakçılığı nedeniyle oluşan vergi kaybı, devletlerin büyük miktarda gelir kaybına uğramasına neden olmaktadır. Bu çalışmanın amacı, Türkiye'de 1990-2023 dönemi için akaryakıt kaçakçılığının belirleyicilerini incelemektir. Çalışmada diğer çalışmalardan farklı olarak, 1990-2023 dönemi için ele geçirilen kaçak akaryakıt miktarları ve bunun sonucunda oluşan vergi kaybını içeren bir veri seti kullanılmıştır. Akaryakıt kaçakçılığı ile ilişkili olduğu düşünülen dokuz bağımsız değişken arasındaki olası nedensellik ilişkisi Toda-Yamamoto Nedensellik testi yardımıyla araştırılmıştır. Analiz sonuçlarına göre, Türkiye'de akaryakıt kaçakçılığı nedeniyle oluşan vergi kaybı ile vergi gelirleri arasında iki yönlü bir nedensellik ilişkisi tespit edilmiştir. Ayrıca akaryakıt kaçakçılığından kaynaklanan vergi kaybından enerjide dışa bağımlılık oranına doğru nedensellik ilişkisinin olduğu ve bayi kâr marjından akaryakıt kaçakçılığı nedeniyle oluşan vergi kaybına doğru olmak üzere tek yönlü nedensellik ilişkisinin olduğu tespit edilmiştir. Ayrıca çalışmada elde edilen uzun dönem katsayı sonuçları Türkiye'de İnsansız Hava Araçlarının kaçakçılıkla mücadelede etkin olarak kullanıldığı dönemde kaçakçılık faaliyetlerinin azaldığını işaret etmektedir.

Anahtar Kelimeler: Akaryakıt Kaçakçılığı, Vergi Kaybı, Zaman Serisi Analizi, Türkiye

JEL Kodları: C32, H26, K42

Introduction

The informal economy generally includes any economic activity outside the reach of legal public authorities. Smuggling, which involves illegally bringing goods into a country without paying taxes, is a core part of this economy. Specifically, illegal border crossings and the market for high-tax products like cigarettes, alcohol, and fuel are significant smuggling activities. Among these, fuel smuggling is widespread and plays an essential role in shaping the informal economy.

The two primary methods of fuel smuggling are the illegal importation of unregulated fuel into the country without customs checks and the production of fuel through illicit blending within the country. Fuel smuggling, which employs various tactics, can cause numerous financial, economic, political, and social problems. The most damaging aspect of fuel smuggling is the loss of tax revenue for the government. There are two primary types of taxes on fuel: indirect taxes, VAT, and SCT. Since indirect taxes are a key source of government income, the tax loss from fuel smuggling is a significant issue. In addition to financial harm, fuel smuggling can also harm society. It disrupts fair income distribution between the tax-paying seller and the trader using smuggled fuel. It also compromises tax integrity and may foster moral decline in society. Vehicles using improperly produced fuel may also experience mechanical problems and damage.

The government has established specific legal practices and laws to regulate the fuel market, combat smuggling, and set legal and fiscal regulations. Various regulations and circulars, mainly the Petroleum Market Law and the Anti-Smuggling Law, aim to prevent fuel smuggling and define criminal penalties. Additionally, the "national marker" system, introduced in 2007, makes it easier to distinguish legitimate from illegal fuel. One of the most notable technological innovations is the use of uncrewed aerial vehicles. Used in our country since 2014, with capabilities increasing daily, UAVs play an essential role in fighting smuggling by monitoring land and sea routes. On the other hand, fuel smuggling, operating in an informal environment, can create employment opportunities for many and, by providing cheap fuel, can help alleviate poverty. However, due to the negative externalities it causes, governments will inevitably need to develop comprehensive policies on the issue. Factors such as the country's financial situation, geographic location, role in counter-terrorism, fuel reserve capacity, and public awareness of taxes can all influence the development of these policies.

The literature review on the subject shows that the informal economy and its causes have been the focus of many studies. However, the factors influencing fuel smuggling and their effects on public finances, including tax revenue loss from fuel smuggling, have not been examined. This study aims to address that gap in the literature. The first section discusses the concept of fuel, its uses, and the global status of petroleum resources. The second and third sections define fuel smuggling and explore the reasons for fuel smuggling in Türkiye, along with the methods used. The fourth section reviews the historical development of fuel taxes in Türkiye and the role of fuel taxes in the economy. Additionally, the fifth section compares fuel taxes collected in other countries with those in Türkiye, providing graphical analyses, especially with EU and OECD countries. The sixth section examines the impact of the sliding-scale mobile system, a policy implemented by the government to combat fuel smuggling. The seventh section provides a brief literature review of studies on the determinants of fuel smuggling and the informal economy. Finally, the eighth section analyses the determinants of fuel smuggling through time series analysis using data from 1990 to 2023.

Literature review

Smuggled fuel is defined as fuel that has a national marker applied but is below the level set by the Energy Market Regulatory Authority or has no marker at all. Additionally, it is observed that smuggled fuel, also known as number ten fuel, which is obtained through various processes from mineral, vegetable, animal, and waste fuels other than fuel, is illegally sold on the market. Smuggled fuel impacts society financially, economically, and socially. The primary harm caused by fuel smuggling is the loss of revenue to the government through the shadow economy it fuels. The income lost between those who sell legally taxed fuel and those who sell illegally produced or imported fuel also negatively affects income equality in society. The main goal of fuel smuggling is to evade the heavy tax burden on fuel. Today, it is inevitable that government policies include combating fuel smuggling. Analysing the factors that drive fuel smuggling shows that the heavy tax burden is the leading cause. However, many financial, economic, political, and social factors can also influence the level of fuel smuggling.

The literature shows that many studies have been conducted specifically on the informal economy and its determinants. Additionally, the reasons for tax evasion and the financial losses resulting from it have been the focus of numerous studies. However, the impact of tax revenue loss caused by fuel smuggling on the structure of public finances has not yet been explored in the literature. In this sense, it is believed that this topic will fill a gap in the research, and the studies on this subject are as follows;

Giles and Johnson (1999) studied the link between the tax rate and the shadow economy in New Zealand using data from 1968 to 1994 and non-parametric regression analysis. They discovered that the shadow economy's sensitivity to simple changes in the tax burden dropped significantly when the effective tax rate fell below about 20%.

Friedman et al. (2000) examined the determinants of the shadow economy in 69 countries using data from 1969 to 1993 and panel data analysis. They found that the shadow economy is linked to higher tax rates, increased tax revenues, a stronger legal environment, and less informal activity. Excessive tax regulations can lead to corruption and bribery, thereby encouraging the growth of the shadow economy.

Additionally, Roscovan (2004) examined the relationship between tax evasion and tax rates on petroleum products in Moldova, using data from 1988 to 2003 and a demand model. His study revealed a close connection between tax evasion and tax rates. He highlighted that one reason for petroleum smuggling is the high VAT applied to petroleum, which leads to tax losses caused by the informal economy generated through petroleum smuggling.

Thießen (2010) studied the link between economic indicators and the informal economy using data from 1991-2007 and panel data analysis for 38 countries. His 26-year study found that short-term interest rates, the tax wedge, taxes, social security contributions, subsidies, and transfer expenditures all contributed to the growth of the informal economy. Conversely, improvements in public administration quality and the democratisation process reduced the informal economy.

Mara (2011) examined the drivers of the informal economy and their relationship with the informal economy in 27 EU countries. He questioned causality in his study using the MIMIC model and 20 years of data. As a result, he found that the most critical factors affecting the informal economy are corruption and tax morality. Alm and Embaye (2013) investigated the relationship between interest, inflation, and tax rates and the informal economy in 111 countries using 22 years of data from 1984 to 2006 and panel data analysis. They concluded that increases in interest, inflation, and tax rates expand the shadow economy, while increases in per capita income, urbanisation level, and institutional quality reduce it.

Karamıklı (2019) aimed to identify the determinants of the informal economy in 11 EU transition economies from 2000 to 2015, using panel regression analysis with data from that period. He explored the relationship between economic growth, trade freedom, financial recovery, the legal system, and property rights, as well as improvements in the regulatory framework and the informal economy. He found that positive changes in all these variables have a suppressive effect on the informal economy. Additionally, his study showed that inflation, unemployment, and the tax burden negatively impact and expand the informal economy.

Rentschler and Hosoe (2022), in their study "Illicit Schemes: Fossil Fuel Subsidy Reforms and the Role of Tax Evasion and Smuggling," developed a general equilibrium model that attempts to analyse the relationship between smuggling and fuel smuggling activities in Nigeria and tax evasion. They emphasise that fuel smuggling can be prevented by lowering price differences with neighbouring countries through fuel subsidy reform in the country. This approach will reduce informality in the energy sector and help prevent tax evasion.

Gökmenoğlu and Amir (2023) examined the relationship between tax burden, financial development, institutional development, rule of law, political stability, and the informal economy in Estonia, Latvia, and Lithuania using panel data analysis (ARDL) from 2000 to 2019. Their study found that increases in tax burden, financial development, and institutional development led to an expansion of the informal economy. However, they also discovered that the establishment of the rule of law and political stability reduced the size of the informal economy.

Based on the studies summarised above, the factors influencing the informal economy and its sub-sectors have been discussed throughout history. According to these studies, as a country's level of development increases, the size of the informal economy tends to decrease. Especially in developing and underdeveloped countries, the informal economy plays a much larger role compared to developed ones. Numerous studies have investigated the factors that influence the informal economy. These variables may vary depending on a country's unique dynamics. However, all studies agree that improving public administration, increasing the efficiency of public institutions, developing the judicial system, and enhancing democratisation help reduce the informal economy. Additionally, having a fair and effective tax system, as well as higher per capita income, are identified as key factors in minimising the informal economy.

Oil: Its history, use, and discovery

Hydrocarbons, also called fossil oils, form when living tissues—such as plants, animals, and bacteria—undergo chemical reactions over many years. The most common oil products are fuel, coal, and gas. (Kaya, 2016: 4).

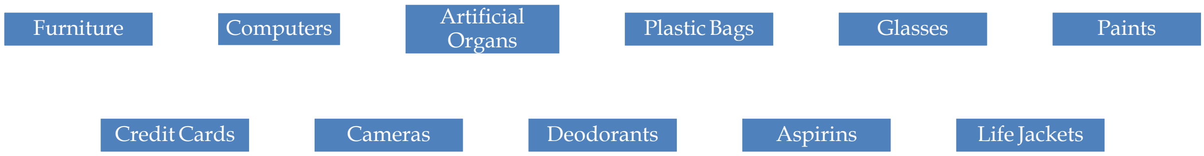


Figure 1: Products Derived from Crude Oil

Source: Kaya, 2016

Crude oil, the most valuable type of fossil oil, is a natural substance that produces energy through chemical reactions and combustion. After the necessary refining processes, products such as gasoline, diesel, fuel, and LPG are produced. The remaining fuel is used for asphalt, medicine, fertiliser, and textiles. Some of the products derived from crude oil are listed in the table above. As you can see, oil products are used in nearly every part of our daily lives, from credit cards to deodorants, from hair dye to computers (Kaya, 2016: 8).

The importance of petroleum products grew with the discovery of the internal combustion engine in the mid-1800s and the rise of the automobile industry during the Industrial Revolution that followed. States and large global corporations started competing for oil (black gold), whose strategic importance increased along with the Industrial Revolution (Üret, 2024: 2).

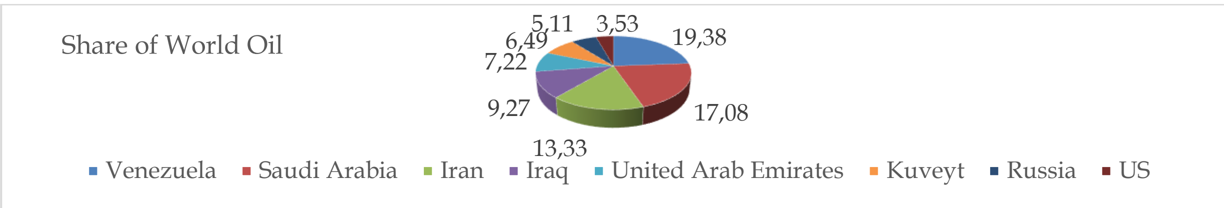


Figure 2: Distribution of World Oil Resources by Country

Source: Üret, 2024

Oil is found in different parts of the world at varying rates as the chemical process of formation continues. The world's officially proven oil reserves increased in 2021 and 2022 as discoveries were made, despite high consumption. While total reserves were 1 trillion 544 billion barrels at the start of 2021, total recoverable oil reserves grew to 1 trillion 564 billion barrels by mid-2023 (Üret, 2024: 4). The Middle East is the world's most important oil region, containing over 50% of reserves. Saudi Arabia, Iraq, and the United Arab Emirates have the largest reserves in the area. Until 2012, Saudi Arabia held the record for the largest oil reserves in the world. However, with new resources discovered in Venezuela in 2012, Venezuela became the world's leading oil-rich country starting in 2013 (Üret, 2024: 3).

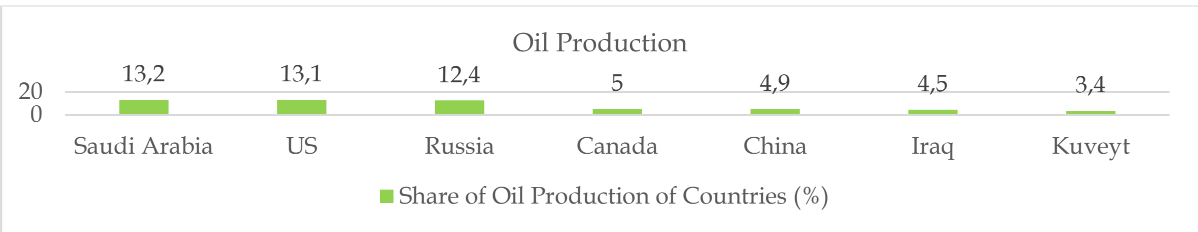
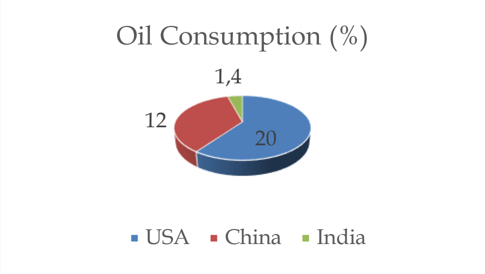


Figure 3: Distribution of World Oil Production by Country

Source: World Energy Forum, 2023

Although Venezuela leads in oil reserves, the ranking shifts when oil production is considered. Looking at global oil output, Saudi Arabia produces about 13 million barrels daily, making up 15% of world oil production.



On the other hand, the United States is the largest consumer of oil in the world. Since the global consumption is about 90 million barrels per day, the United States accounts for approximately one-fifth of this intake. Following the U.S., China and India—two of the most populous countries—are the next largest consumers. (World Energy Forum, 2023: 6).

Figure 4: Distribution of World Oil Consumption by Country

Source: World Energy Forum, 2023

Türkiye is ranked 52nd in the world with about 350 million barrels of oil reserves. Türkiye, which produces over 50,000 barrels per day, ranks 62nd in oil production. In terms of oil consumption, Türkiye ranks 25th globally with around 800 million barrels per day (OPEC, 2023: 14).

Causes and methods of fuel smuggling in Türkiye

The Petroleum Market Act defines "oil" as all types of petrol, feedstock (naphtha), kerosene, jet fuel, diesel, and petroleum oils. In simple terms, fuel smuggling involves importing or producing any of these products within the country in ways that violate laws and regulations. All products resulting from these illegal activities are considered "smuggled fuel" (Emniyet Genel Müdürlüğü, 2021: 6). The rules specifying what constitutes a smuggling offence and how it is committed are outlined in the Smuggling Act. According to the law, "fuel that is subject to the application of the national marker and contains the national marker below the level determined by the Energy Market Regulatory Authority or does not contain any national marker is defined as smuggled fuel." Additionally, "a person who produces, possesses, transports, offers for sale, or sells for commercial purposes and purchases with this characteristic knowingly and for commercial purposes" is considered to have committed the crime of fuel smuggling (Emniyet Genel Müdürlüğü, 2021: 7). Under the Customs and Smuggling Law, fuel smuggling is defined as failing to pay or underpaying taxes on the import, export, and transit transactions of all petroleum derivatives, or conducting transactions that violate regulations such as prohibitions, restrictions, permits, and licenses. It also includes illegal addition of various chemicals to fuel domestically or obtaining fuel through mixing, as well as producing fuel from such mixtures. Furthermore, smuggling involves adding different chemicals to fuel domestically or creating fuel from mixtures of various chemicals. The act of mixing imported chemicals—intended for use in the paint, chemical, and textile industries—subject to different special consumption taxes depending on their purpose—with fuel after importation is also considered smuggling (Emniyet Genel Müdürlüğü, 2024: 7).

Causes of fuel smuggling

Existence and size of the informal economy

When defining the scope of the informal economy, activities that are not legally permitted by the government come first. All legal but unregistered (undocumented) economic activities can also be considered part of these. (Erdinç, 2016: 14).

Similar patterns can also be seen when analysing regional rates of the informal economy worldwide. However, African and Latin American countries tend to have higher informal economy rates than other nations. Core issues such as the economic condition of countries, the level of democratisation, the judicial system, and other factors influence the informal economy. The financial factors that influence the size of the informal economy include economic policies, business size, inflation, the prevalence of the cash economy, income distribution, and unemployment rates. (Erdinç, 2016: 15).

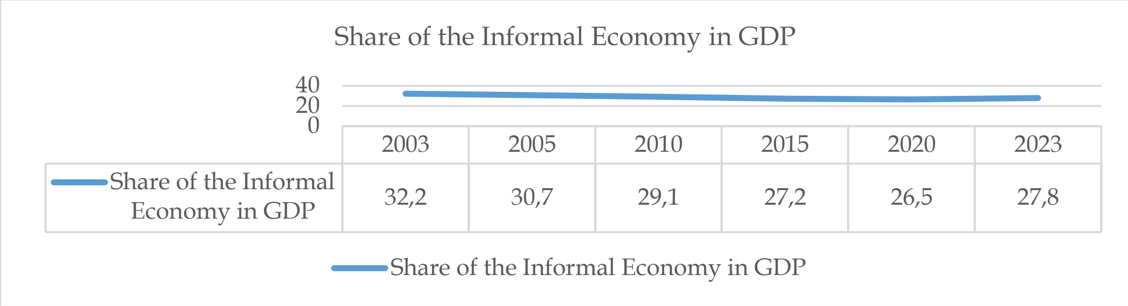


Figure 5: Unregistered Economy Rates in Türkiye in the Last 20 Years

Source: Schneider, 2015

In Türkiye, due to key reasons such as rising tax burdens, inadequate oversight, and limited social awareness, the informal economy—and therefore, tax losses and evasion—has become increasingly significant. Studies estimate that around 30% of the country's economy operates informally. The smuggling of fuel products and derivatives is also a substantial part of the informal economy. As is well known, fuel products and derivatives comprise a significant portion of energy needs across all sectors, particularly in manufacturing. (Kargı & Güven, 2017: 7).

Tax burden on fuel

One of the indirect taxes collected is the fuel tax. Regarding tax revenue in the budget, the Special Consumption Tax (formerly known as the Petroleum Consumption Tax) collected from fuel has increased as a percentage over the years.

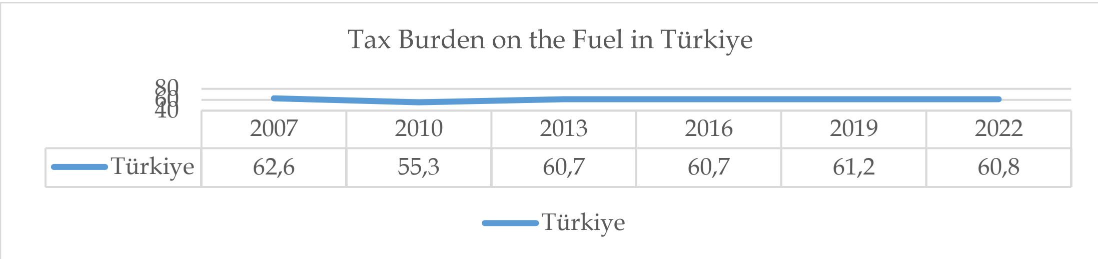


Figure 6: Tax Burden on Fuel

Source: TUIK, 2023

Throughout our recent history, especially before the Arab Spring, items like tea, sugar, tobacco, and alcoholic beverages have been popular smuggling products due to heavy taxes. Fuel and its derivatives have also become key smuggling items for the same reason. It can be observed that the tax policies enacted by the government contribute to increasing the demand for smuggled goods.

Local and regional exemption practices

The local population, especially in the east and southeast of the country, has faced various economic hardships due to terrorist attacks. Additionally, due to disrupted income distribution and limited commercial space, residents have begun to view smuggling as a means of generating income. Throughout this challenging period, the government has used border trade as part of its social policy. As part of this border trade, the local population has been allowed to import fuel from neighbouring countries "within certain limits" (Doğu Anadolu Kalkınma Ajansı, 2020: 4).

Furthermore, as part of a government policy to support the local economy, permission was granted to use old model vehicles that were not allowed in the transportation sector for transport purposes in border provinces. For example, official figures show that the number of cars registered with government agencies for fuel imports at the Habur border gate during the border trade period (1997-2002) exceeded 60,000. (İbiş, 2015: 54).

Additionally, there is a direct connection between a society's level of development, per capita income, education, and tax awareness. In our country, there remains a lack of sufficient social and individual awareness about the trade conducted through smuggling, which involves evading taxes (Ibiş, 2015: 66). Furthermore, the state supported border trade to provide economic support to local communities. However, terrorist organisations benefited the most from trade with border countries. It was found that the period of border trade played a significant role as a domestic funding source for the separatist terrorist organisation. (İbiş, 2015: 66).

An excessive number of authorised institutions in customs areas and fields

Customs administrations are the primary agencies responsible for implementing customs activities. However, there are also units within various ministries and organisations authorised to conduct customs operations under relevant legislation. Depending on the type of customs transaction at our border gates, many administrative and civil units may be involved, including those from agriculture, health, finance, energy, interior, transport, industry, TSI, gendarmerie, and intelligence agencies. The involvement of numerous different administrative and civil units makes coordination challenging. (İbiş, 2015: 64). Furthermore, the difficulties encountered during the transition to automation in customs registration, control, monitoring, and coordination systems have increasingly contributed to smuggling issues (İbiş, 2015: 67).

Differences in special consumption tax between petroleum products

Examining the special consumption tax regulation for petroleum products, it is evident that petroleum products, mineral fuels, and natural gas are listed in the (I) category of the law.

Table 1: Amounts of Special Consumption Tax on Certain Petroleum Products

No	Product	Tax Amount (Lira)	Unit
1	Gasoline	11,29 TL	Liter
2	Diesel	10,59 TL	Liter
3	Liquefied Petroleum Gas (LPG)	8,67 TL	Liter
4	Solvent	9,34 TL	Liter
5	Other Mineral Oils	6,46 TL	Kilogram
6	Gas Oil	4,90 TL	Liter
7	Others	3,51 TL	Kilogram

Source: Special Consumption Tax Law (Access Date 11.07.2024)

One of the factors contributing to fuel smuggling is the differences in special excise tax rates and exemptions established by law. In particular, tax exemptions and rebates on non-fuel products to promote industry and production have been one of the issues fueling the production of illegal fuel. Because of these SCT differences between fuel and its derivatives, individuals and companies turn to producing illegal fuel products (İbiş, 2015: 74).

Historical development of fuel taxes in Türkiye

As state structures evolve and change with globalisation, so do the roles and responsibilities of states. While the financial and economic responsibilities of states have increased over the years, it has become necessary for them to use scarce resources most effectively and efficiently to fulfil these responsibilities. Of course, creating new financial resources and developing and managing existing ones have become one of the most fundamental tasks of states. Except for countries rich in natural resources and energy, taxes have become the primary source of financing for most countries. Therefore, proper planning of taxes, which have many financial, economic, and social effects, and the development of an effective tax system are vital for the continued sustainability of countries. In addition, tax revenues from fuel account for a large share of indirect tax revenues. Additionally, high fuel prices have long been a significant topic of discussion in our country (Türkiye İstatistik Kurumu, 2024: 2).

Table 2: Historical Development of Fuel Taxes in Türkiye

Year	Type of Tax Considered as a Fuel Tax
1926	Umumi İstihlak Vergisi (General Consumption Tax)
1927	Toplu Muamele Vergisi (Bulk Transaction Tax)
1948	Dâhili İstihlak Vergisi (Internal Consumption Tax) (It is the first law to tax fuel products. A tax of 8 kurus was levied per kilogram of diesel produced or imported.)
1956	Gider Vergileri Kanunu (Expenditure Tax Law) (20% tax was levied on imported fuel products)
1981	Akaryakıt Resmi (Fuel Fund) (As Municipality Revenue, not Central Government Budget Revenue)
1984	Akaryakıt Tüketim Vergisi Kanunu (Fuel Consumption Tax Law) (From fuel products at a rate of 6%). This rate was increased to 9% in 1985, 26% in 1988, 31% in 1989, 70% in 1990, 85% in 1991, 290% in 1998, and 500% in 1999. With this law, tax revenues from fuel products are no longer just municipal revenues.
1985	Value Added Tax
2000	In 2000, it was decided to collect a lump sum tax based on the type of fuel, rather than a rate.
2002	The Special Consumption Tax has come into force, and the Fuel Consumption Tax has been abolished.
2003	VAT and SCT

Source: It is the author's compilation using relevant laws.

The first significant regulation concerning the taxation of petroleum products in our country was the General Consumption Tax enacted in 1926. Taxation of petroleum products continued to evolve, with the Collective Transaction Tax enacted the following year. The initial law to tax petroleum products in our country was the Internal Consumption Tax, passed in 1948. Under this regulation, a tax of 8 Kuruş was levied per kilogram of diesel produced or imported. Additionally, the Expenditure Tax Law of 1956 introduced a 20% tax on imported fuel products. Meanwhile, a practice that began in 1981 involved collecting fuel tax on fuel products, lasting approximately three years. Until 1984, revenue from fuel products was collected as municipal revenue rather than as part of the central government budget. However, the Fuel Consumption Tax Law of 1984 marked a turning point, removing fuel tax revenues from municipal funds. This law established a fixed 6% tax on all fuel products, which was periodically increased in subsequent years. Starting at 6%, the rate reached 500% in 1999 due to successive hikes. Furthermore, a decree the following year altered the tax system, determining a fixed tax based on the type of fuel product. In 2002, a significant overhaul of the Turkish tax system was introduced with the implementation of the Special Consumption Tax. This replaced the previous fuel consumption tax. Over the following two decades, VAT and the Special Consumption Tax continued to be levied on petroleum products. Today, VAT and SCT remain the primary taxes applied to petroleum products.

The special consumption tax is charged only once on the goods specified in the law. One of its main features is that it is applied in addition to VAT. Furthermore, the goods subject to the special consumption tax are those in the economic stages (production, consumption, manufacturing, or import) specified by law and listed in the relevant lists of the law (numbered 1, 2, 3, and 4). The first list includes petroleum products. The tax on petroleum products applies to the import (for goods produced abroad) or delivery (for goods produced domestically) of petroleum products listed in number 1 (Koşar, 2015: 6).

The share of taxes on fuel in our economy

Like other taxes, the primary purpose of taxes on fuel (VAT and SCT) is to raise funds for public goods and services. However, VAT also helps regulate the informal economy. Similarly, the SCT serves an essential purpose beyond its fiscal goal of protecting domestic production.

The demand for fuel products such as gasoline, diesel, and LPG is relatively inelastic. In countries like ours, which blend Middle Eastern and Mediterranean cultures, urbanisation and the use of public transportation are not widespread, and the education system is not sufficiently developed. As a result, people tend not to give up using private cars despite steep increases in fuel prices. Therefore, it is crucial to protect citizens from sudden fuel price swings. Additionally, the cost of fuel products is a key component in the production of many goods and services.

Looking at the development of fuel taxes over the years, their share in overall tax revenues has been increasing since the early 1990s. The tax share, especially since 1996, when it reached 13.54%, peaked in 1999 at 15.19%. Over the past ten years, the share of fuel taxes in the budget has nearly tripled. Moreover, the growth rate of fuel tax revenues as a percentage of gross national product (GNP) was more than five times higher during the same period. However, due to the low demand elasticity, increases in fuel excise taxes during those years did not significantly impact total tax revenues (Tosun, 2016: 3).

It is well understood that certain key elements must be considered when setting the pump price of fuel. Specifically, when determining the refinery price (excluding VAT), the SCT and EPDK shares are added to the duty-free refinery price, resulting in the refinery selling price (excluding VAT), calculated as: duty-free refinery price + SCT + EPDK share (Enerji Piyasası Düzenleme Kurulu, 2023: 2).

Table 3: The Place of Fuel Income in the Economy

Years	Fuel Income/ Central Government Income %	Fuel Income/ Total Tax %	Fuel Income/ VAT and SCT %
2002	14,15	18,62	33,90
2003	14,94	18,30	32,77
2004	12,81	15,69	27,51
2005	12,70	16,22	28,66
2006	11,85	14,95	26,26
2007	11,58	14,43	26,76
2008	11,42	14,24	27,02
2009	11,85	14,80	28,17
2010	12,47	15,05	26,45
2011	11,31	13,23	23,51
2012	10,81	12,89	23,44
2013	11,59	13,85	24,25
2014	10,73	12,94	23,56
2015	10,52	12,47	19,76
2016	9,09	10,76	19,67
2017	10,48	14,82	22,24
2018	11,02	11,18	20,36
2019	10,64	11,31	20,12
2020	9,98	10,35	19,84
2021	11,02	13,36	22,24
2022	11,85	17,84	24,25
2023	10,24	13,05	19,60

Source: Türkiye İstatistik Kurumu, 2024.

Tax revenues from petroleum products make up more than 10% of central government revenues, and their share of total tax revenues is roughly 15%. Additionally, tax revenues from fuel products account for over a quarter of VAT and special excise tax revenues. The ratios between general budget revenues and fuel tax revenues indicate that income from fuel products is an essential source of revenue (Tosun, 2016: 15).

Comparison of taxes on fuel in Türkiye with EU and OECD countries

The taxes countries impose on fuel products vary. Whether a country is a fuel producer (with fuel reserves) or not is a key factor that directly influences tax policy. In this context, all countries with the cheapest fuel products in the world are exporters of fuel resources. Some of these countries (especially in the Arabian Peninsula), which essentially float on fuel fields, have not imposed taxes for many years, not only on fuel products but also on all other goods and services. In summary, the presence of fuel reserves, proximity or distance to these regions, supply and demand balance, and the country's economic conditions are among the main factors that determine a country's fuel prices (OPEC, 2023: 3).

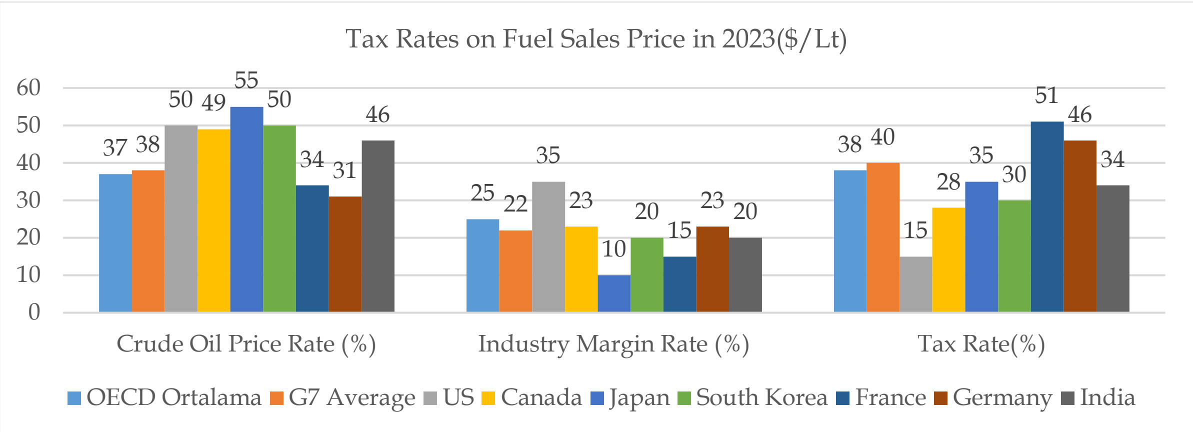


Figure 7: Tax Rates on Fuel Sales Price

Source: OPEC, 2023.

Examining the table prepared using 2023 data, we observe that the average price per litre of fuel in G7 and OECD countries varies by country. It is clear that these differences mainly result from the level of taxation, which depends on fuel consumption. While high rates are standard in the Asia-Pacific and Europe, such as in Türkiye, the US has relatively low rates because it mostly meets its consumption through domestic production (Tosun, 2016: 12).

The European Union Member States are working on a standard transnational energy policy in response to rising global tensions, economic issues, and environmental pollution. In this context, all products and activities that cause environmental pollution are taxed under the ecological tax. The main goal here is to internalise negative externalities, rather than financial ones. Additionally, tax policy is also used as a tool to guide consumers toward using alternative clean energy sources (Tosun, 2016: 14).

Table 4: VAT Rates on Fuel Products for European Union Countries and Türkiye

EU Countries	Gasoline	Diesel	LPG
Germany	19	19	19
Denmark	25	25	25
Finland	24	24	24
Croatia	25	25	25
England	20	20	20
Italya	22	22	22
Hungary	27	27	27
Malta	18	18	18
Luxembourg	17	17	8
Greece	23	23	23
EU Average	21,46	21,46	21,46
Türkiye	20	20	20

Source: European Union, 2025

Examining the table showing the VAT rates applied to fuel products (petrol, diesel, and LPG) by some European Union countries and our country, it is evident that all other countries, except Luxembourg, apply the same VAT rate to these three products. Hungary has the highest VAT rate among EU member states at 27%, followed by Croatia with 25%. Like other EU countries, Türkiye applies the same VAT rate to all three fuel products. Although Türkiye had an 18% VAT rate on fuel products for many years, the current rate is 20%. The VAT rate in Türkiye is the third highest after Malta and Germany. Therefore, the VAT rate on fuel products in Türkiye is below the average of many EU countries and the EU overall.

In EU countries, SCT on fuel products primarily aims to influence consumer behaviour and encourage them to adopt more environmentally friendly alternatives. In European Union nations, the principle of applying minimum rates has been widely adopted, thereby achieving "tax harmonisation". As part of this harmonisation, all energy products are exempt from taxation when used as raw materials or in chemical processes. However, energy products are taxed if they are used for fuel and heating purposes (European Union, 2025: 3).

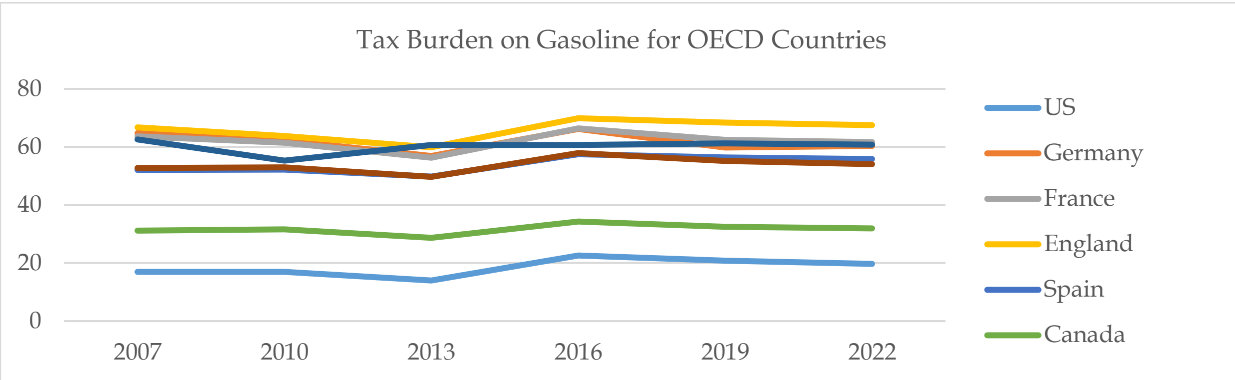


Figure 8: Tax Burden on Gasoline for OECD Countries

Source: OECD Tax Revenue Statistics, 2025

Examining OECD countries from 2007 to 2022, the petrol tax burden in six countries shows variation across nations. On average, the lowest tax burdens are found in the USA and Canada. It is also evident that the tax burden on petrol in France, Germany, the United Kingdom, and Türkiye exceeds 60%. Over the past 15 years, Türkiye's tax burden on gasoline has been above the OECD average but below that of the United Kingdom (Ubay, 2012: 6).

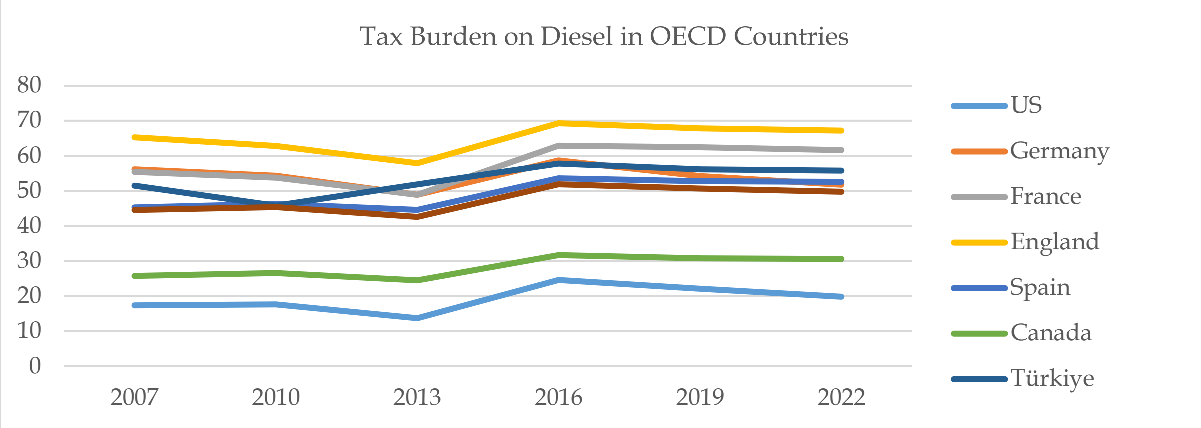


Figure 9: Tax Burden on Diesel in OECD Countries

Source: OECD Tax Revenue Statistics, 2025

Looking at the graph showing the tax rates applied to diesel in some selected OECD member countries, we see that, similar to petrol, the lowest tax burdens are in the USA and Canada. While the highest tax burden appears to be in the UK, it is also around 50% in Türkiye, Spain, and Germany. On the other hand, when specifically examining Türkiye, we observe that the tax burden on diesel there exceeds the OECD average.

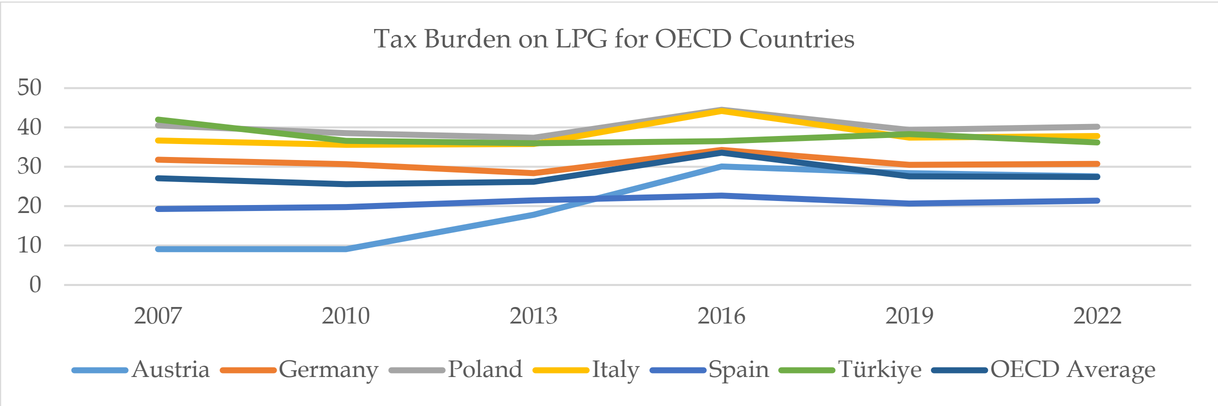


Figure 10: Tax Burden on LPG

Source: OECD Tax Revenue Statistics, 2025

Looking at the graph showing the tax burden on LPG in OECD member countries, it is evident that the tax burden on LPG is lower than that on diesel and gasoline. The main reason for this difference is that LPG is considered more environmentally friendly than other fuel products. The graph indicates that Australia has the lowest tax burden. Conversely, the highest tax burdens among countries using LPG are observed in Poland, Italy, and Türkiye (OECD, 2025: 4).

Sliding scale system period (17.5.2018-22.12.2021)

The sliding scale system is a mechanism introduced to control the rise in fuel prices. This system automatically manages increases in fuel prices and provides consumers with a stable pricing policy. Regarding fuel prices, it helps protect consumers' purchasing power.

Some European Union countries, such as Belgium, Denmark, Luxembourg, and France, have used the sliding scale system or a similar method to regulate energy product prices. For example, Belgium adopted the sliding scale system in 2009. In this system, a minimum price is set, and when fuel prices exceed or fall below this threshold, adjustments such as taxes or subsidies are made to help balance prices (World Bank, 2023: 2).

Table 5: Special Consumption Tax Amounts in Fuel

Date	Type of Goods (SCT Amount)		
	Gasoline	Diesel	LPG
27.3.2018	2,3765	1,7945	1,7780
22.5.2018	2,1241	1,5679	1,6501
26.6.2018	2,1842	1,6210	1,2152
17.7.2018	2,0604	1,6210	1,2152
08.11.2018	2,3765	1,5227	1,4177
20.11.2018	2,3765	1,7399	1,4177
13.03.2019	2,3765	1,7945	1,6844
27.09.2019	2,3765	1,7276	1,7780
01.12.2020	2,5265	2,0094	1,1121
07.01.2021	2,4957	1,9728	0,5273
02.03.2021	1,7292	1,3650	0,1875
23.03.2021	1,4261	1,4912	0,1875
26.03.2021	1,3340	1,1950	0
20.04.2021	1,1682	0,9947	0
20.05.2021	1,3313	1,2931	0,8107
25.06.2021	0,8387	0,7177	0,4479
17.07.2021	0,6726	0,7177	0,8599
27.07.2021	0,7840	0,8156	0
11.08.2021	0,7840	1,0339	0
30.09.2021	0,4849	0,1226	0
08.10.2021	0,2285	0	0
16.10.2021	0	0	0
20.11.2021	0	0	0
24.12.2021	1,6260	1,6481	0
25.12.2021	2,0376	2,0559	1,7780
01.03.2022	2,5265	2,0559	1,7780
16.07.2023	7,5265	7,0559	5,7780
03.01.2024	9,4540	8,8629	7,2577
03.07.2024	11,2965	10,5902	8,6722

Source: Gelir İdaresi Başkanlığı, 2024

In Türkiye, the sliding scale system for fuel, which was introduced on May 17, 2018, and then removed at the end of that year, was reintroduced on April 10, 2019. Under this system, increases in fuel prices were covered by the special consumption tax collected by the government. The sliding scale system was abolished when the rate of the special consumption tax on fuel reached zero.

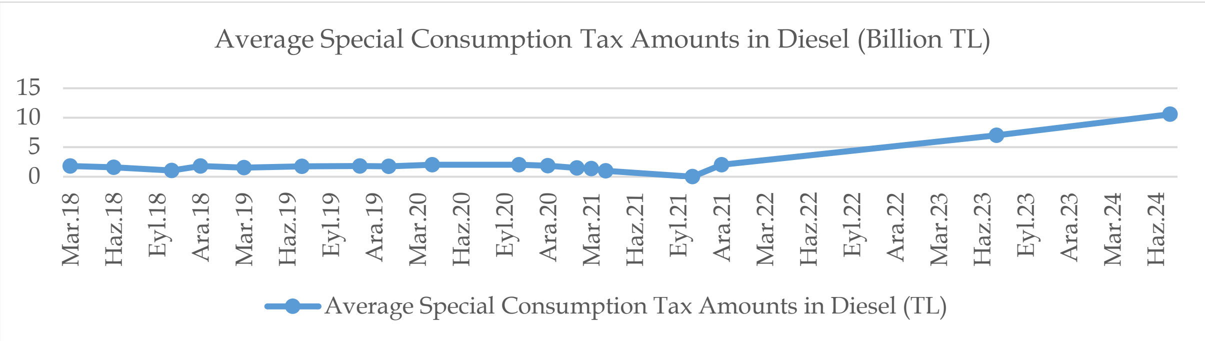


Figure 11: Average Special Consumption Tax Amounts in Diesel

Source: Gelir İdaresi Başkanlığı, 2024

The application of the Sliding Scale System, which started in May 2018 with the rise in Brent crude fuel prices, aimed to offset the increase in fuel prices caused by higher costs such as exchange rates and fuel prices through a lump sum special consumption tax rebate. It is estimated that approximately 46 billion liras in VAT and SCT revenues were foregone in 2021 due to the application of the sliding scale system.

Data and method

Data

When determining the data set used in the study, the seized smuggled fuel (measured in litres) between 1990 and 2023 served as the primary data source. To identify the seized smuggled fuel, public databases from the Turkish Police, the Coast Guard Command, and the Anti-Smuggling and Organised Crime Directorates of the Gendarmerie General Command were utilised. Additionally, data gaps were filled through correspondence with the Gendarmerie General Command regarding non-public information.

In this context, the tax loss was calculated based on the quantities of smuggled fuel seized. This calculation used the pump prices of fuel products for the relevant years. The value of the smuggled fuel was determined by multiplying the amount seized each year by the fuel product's price. The tax loss on fuel products was then estimated using the applicable tax rates on these products. Finally, the calculated tax loss was proportionally applied to that year's GDP.

This study aimed to identify the factors that influence fuel smuggling. The dependent variable was the tax loss caused by fuel smuggling. The independent variables included tax burden, tax audit rate, tax revenue, external energy dependence rate, economic growth, inflation rate, unemployment rate, dealers' profit margin, and trade openness rate. Additionally, dummy variables represented the period when the Sliding Scale System was implemented and the period after 2014, when uncrewed aerial vehicles began to be used in the fight against smuggling as a technological advancement. The study utilised a long-term data set spanning 2000-2023, with data on inflation rate, unemployment rate, economic growth, tax burden, and trade openness obtained from the official website of the Turkish Statistical Institute. Tax audit rates were sourced from the Ministry of Finance, and external energy dependence rates from the Ministry of Energy. All data were expressed as percentage changes. The collected data were analysed using Eviews 11 software. The variables used in the analysis are shown in Table 6.

Table 6: Variables and Their Sources

Variable	Symbol	Source
Tax Loss from Fuel Smuggling to GDP	YKAYVK	GENDARMARIE and POLICE DATA
Tax Burden	VY	TSI
Tax Audit Rates	VDO	FINANCE MINISTRY
Tax Revenues/GDP	VG	TSI
Inflation Rate	TUFE	TSI
Trade Openness	TA	TSI
Dealer Margin	KM	Energy Market Regulatory Authority
External Dependency in Energy	EDB	ENERGY MINISTRY
Economic Growth	EB	TSI
Unemployment Rate	ISZ	TSI
Eşel Mobile System	EMS	Dummy Variable
Technological Developments	TG	Dummy Variable

Descriptive statistics of the series examined in the model are reported in Table 7.

Table 7: Descriptive Statistics

Variable	Mean	Median	Standard Deviation	Skewness	Kurtosis	Jarque-Bera (JB)	Probability (JB)
YKAYVK	-0.836	-0.432	1.199	-0.981	2.848	10.972	0.004
VY	4.048	4.107	0.180	-0.973	3.008	10.722	0.005
VG	2.835	2.845	0.191	-1.423	8.939	122.904	0.000
VDO	0.960	0.952	0.541	-1.036	6.325	43.492	0.000
TUFE	3.162	2.917	1.011	0.123	1.342	7.956	0.019
TA	1.350	1.581	0.365	-0.491	1.461	9.444	0.009
KM	2.654	2.639	0.190	-0.007	1.911	3.362	0.186
EDB	4.201	4.240	0.111	-0.976	2.606	11.243	0.004
EB	4.755	5.850	4.526	-1.020	3.362	12.164	0.002
ISZ	2.223	2.242	0.195	-0.136	2.664	0.530	0.767

Table 7 presents the descriptive statistics for various variables, including their mean, median, standard deviation, skewness, kurtosis, Jarque-Bera (JB) test statistic, and associated probability. The variable YKAYVK has a mean of -0.836 and a standard deviation of 1.199, exhibiting negative skewness (-0.981) and a kurtosis of 2.848, with a significant JB statistic of 10.972 and a probability of 0.004, indicating nonnormality. VY shows a mean of 4.048 and a standard deviation of 0.180, also with negative skewness (-0.973) and a JB statistic of 10.722 (p = 0.005). VG, with a mean of 2.835 and a higher standard deviation of 0.191, displays considerable negative skewness (-1.423) and kurtosis (8.939), resulting in a highly significant JB statistic of 122.904 (p < 0.001). VDO has a mean of 0.960 and a standard deviation of 0.541, with negative skewness (-1.036) and a JB statistic of 43.492 (p < 0.001). TUFE shows a mean of 3.162, a standard deviation of 1.011, and a slight positive skewness (0.123), with a significant JB statistic of 7.956 (p = 0.019). TA has a mean of 1.350 and a standard deviation of 0.365, exhibiting negative skewness (-0.491) and a JB probability of 0.009. KM, with a mean of 2.654 and a standard deviation of 0.190, shows minimal skewness (-0.007) and a non-significant JB statistic (p = 0.186). EDB has a mean of 4.201 and a standard deviation of 0.111, with negative skewness (-0.976) and a significant JB statistic of 11.243 (p = 0.004). EB presents a mean of 4.755, a high standard deviation of 4.526, negative skewness (-1.020), and a significant JB statistic of 12.164 (p = 0.002). Finally, ISZ has a mean of 2.223 and a standard deviation of 0.195, displaying minimal skewness (-0.136) and a non-significant JB statistic (p = 0.767).

The model to be examined within the scope of the study is as follows:

$$YKAYVK_t = \beta_0 + \beta_1 VY_t + \beta_2 VDO_t + \beta_3 VG_t + \beta_4 EDB_t + \beta_5 EB_t + \beta_6 TUFE_t + \beta_7 ISZ_t + \beta_8 KM_t + \beta_9 TA_t + \beta_{10} EMS_t + \beta_{11} TG_t + e_t$$

β_0 is the constant term and v_t is the error term. The echelon mobile system (implemented period 17.05.2018-22.12.2021) and technological developments (Unmanned Aerial Vehicles after 2014) variables were included in the model as dummy variables.

Method

In the presented study, the determinants of fuel smuggling were analysed. Since a specific time period from 2000 to 2023 was examined, the determinants of fuel smuggling in Türkiye were studied using time series analysis. The stationarity of the data was assessed with the Extended Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. Subsequently, the Toda-Yamamoto Causality Test was employed to explore the relationship between the tax loss caused by fuel smuggling and other factor variables.

ADF unit root test

The ADF (1981) unit root test was developed because the traditional Dickey-Fuller (DF) (1979) test ignores autocorrelation. In the DF unit root test, autocorrelation appears in the error terms. This issue is addressed by adding the lagged value of the dependent variable to the right side of the equation, which removes the autocorrelation problem (Dickey & Fuller, 1979: 427).

In the ADF unit root test, as with the DF unit root test, there are three equation patterns considered (constant and trended, constant and trendless, trendless only). By including the lagged values of the dependent variable in the equation, the ADF equations are written as follows (Dickey & Fuller, 1981, 107):

$$\Delta Y_t = \delta Y_{t-1} + \sum_{j=2}^{k} \delta_j \Delta Y_{t-j+1} + \varepsilon_t \quad (2)$$
$$\Delta Y_t = \alpha + \delta Y_{t-1} + \sum_{j=2}^{k} \delta_j \Delta Y_{t-j+1} + \varepsilon_t \quad (3)$$
$$\Delta Y_t = \alpha + \beta t + \delta Y_{t-1} + \sum_{j=2}^{k} \delta_j \Delta Y_{t-j+1} + \varepsilon_t \quad (4)$$

ADF (1981) the hypotheses for the unit root test are as follows:

$$H_0 : \ \delta = 0$$
$$H_A : \ \delta < 0$$

The critical values to be used for the ADF test are the essential values of the DF test. The calculated Tau test statistics are compared with the critical values to examine the presence of a unit root (Dickey & Fuller, 1979: 430).

PP unit root test

Phillips and Perron (1988) generalised the DF test by relaxing the assumptions about the error terms and proposed a non-parametric method for determining the unit root. The following regression equations are used for PP (Phillips and Perron, 1988: 338):

$$y_t = \hat{\mu} + \hat{\alpha} y_{t-1} + \hat{u}_t \quad (5)$$
$$y_t = \tilde{\mu} + \tilde{\beta}\left(t - \tfrac{1}{2}T\right) + \tilde{\alpha} y_{t-1} + \tilde{u}_t \quad (6)$$

In equations (5) and (6), the parameters ($\hat{\mu}$, $\hat{\alpha}$) and ($\tilde{\mu}, \tilde{\beta}, \tilde{\alpha}$) are the OLS regression coefficients, and T is the number of observations. The t-statistics of these coefficients are as follows (Phillips and Perron, 1988: 338):

$$t_{\hat{\alpha}} = (\hat{\alpha} - \alpha)\{\sum(y_{t-1} - \bar{y}_{-1})^2\}^{\frac{1}{2}}/\hat{s}$$
$$t_{\hat{\mu}} = (\hat{\mu} - \mu)\{\sum(y_{t-1} - \bar{y}_{-1})^2\}^{\frac{1}{2}}/\hat{s}$$
$$t_{\tilde{\mu}} = (\tilde{\mu} - \mu)/(\tilde{S}^2 C_1)^{\frac{1}{2}}$$
$$t_{\tilde{\beta}} = (\tilde{\beta} - \beta)/(\tilde{S}^2 C_2)^{\frac{1}{2}}$$
$$t_{\tilde{\alpha}} = (\tilde{\alpha} - \alpha)/(\tilde{S}^2 C_3)^{\frac{1}{2}} \tag{7}$$

$\hat{S}$ and $\tilde{S}$In these equations, the standard errors represent the standard errors of the relevant regressions. C_i variable $(X'\,X)^{-1}$ is the ith diagonal element of the matrix and $\bar{y}_{-1} = T^{-1}\sum y_{t-1}$ in the form.

Phillips and Perron (1988) defined the following Z statistics by applying simple transformations to the test statistics obtained from equations (5) and (6). The test statistics derived for equation (5) are as follows. (Phillips and Perron, 1988: 341):

$$Z(\hat{\alpha}) = T(\hat{\alpha} - 1) - \hat{\lambda}/\bar{m}_{yy}$$
$$Z(t_{\hat{\alpha}}) = (\hat{S}/\hat{\sigma}_{Tl})t_{\hat{\alpha}} - \hat{\lambda}'\hat{\sigma}_{Tl}/\bar{m}_{yy}^{\frac{1}{2}}$$
$$Z(t_{\hat{\mu}}) = (\hat{S}/\hat{\sigma}_{Tl})t_{\hat{\mu}} - \hat{\lambda}'\hat{\sigma}_{Tl} m_y/\bar{m}_{yy}^{\frac{1}{2}} m_{yy}^{\frac{1}{2}}$$

The test statistics obtained for equation (6) are as follows (Phillips and Perron, 1988: 341):

$$Z(\tilde{\alpha}) = T(\tilde{\alpha} - 1) - \hat{\lambda}/M$$
$$Z(t_{\tilde{\alpha}}) = (\tilde{S}/\tilde{\sigma}_{Tl})t_{\tilde{\alpha}} - \tilde{\lambda}'\tilde{\sigma}_{Tl}/M^{\frac{1}{2}}$$
$$Z(t_{\tilde{\mu}}) = (\tilde{S}/\tilde{\sigma}_{Tl})t_{\tilde{\mu}} - \tilde{\lambda}'\tilde{\sigma}_{Tl} m_y/M^{\frac{1}{2}}(M + m_y^2)^{\frac{1}{2}}$$
$$Z(t_{\tilde{\beta}}) = (\tilde{S}/\tilde{\sigma}_{Tl})t_{\tilde{\beta}} - \tilde{\lambda}'\tilde{\sigma}_{Tl}(\tfrac{1}{2}m_y - m_{ty})/(M/12)^{\frac{1}{2}}\bar{m}_{yy}^{\frac{1}{2}} \tag{8}$$

In this eqation; $m_{yy} = T^{-2}\sum y_t^2$, $\bar{m}_{yy} = T^{-2}\sum(y_t - \bar{y})^2$, $m_y = T^{-3/2}\sum y_t$, $m_{ty} = T^{-5/2}\sum t y_t$, $M = (1 - T^{-2})m_{yy} + 12m_{ty}^2 + 12(1 + T^{-1})m_{ty}m_y - (4 + 6T^{-1} + 2T^{-2})m_y^2$, $\hat{\lambda} = \frac{1}{2}(\hat{\sigma}_{Tl}^2 - \hat{S}^2)$, $\hat{\lambda}' = \hat{\lambda}/\hat{\sigma}_{Tl}^2$, $\tilde{\lambda} = \frac{1}{2}(\tilde{\sigma}_{Tl}^2 - \tilde{S}^2)$, $\tilde{\lambda}' = \tilde{\lambda}/\tilde{\sigma}_{Tl}^2$ is expressed like this.

The hypotheses for the unit root test of Phillips and Perron (1988) are as follows (Phillips and Perron, 1988: 339-340);

$$H_0 : \ \alpha = 0$$
$$H_A : \ \alpha < 0$$

The calculated test statistics are compared with the critical value produced by Phillips-Perron (1988) (Phillips and Perron, 1988: 344).

ARDL bounds test analysis

Using the ARDL bounds test, it is possible to identify both short-term and long-term cointegration relationships between variables, even if the variables are integrated at different levels. The ARDL bounds test has a key advantage over other cointegration tests: there are no restrictions on the error correction model used in the test. As a result, more reliable and accurate results are obtained with the ARDL bounds test. In applying this test, three different equations are considered. The first is the bounds test equation, which is used to examine the cointegration relationship. The other two equations analyse the long-term and short-term relationships, respectively. The ARDL bounds test equation is expressed as follows. (Pesaran et al., 2001: 291);

$$y_t = \alpha_0 + \sum_{i=1}^{k}\alpha_{1i}\Delta y_{t-i} + \sum_{i=0}^{k}\alpha_{2i}\Delta x_{t-i} + \delta_1 y_{t-1} + \delta_1 x_{t-1} + e_t \tag{9}$$

Here Δ is the difference operator, y_t is the dependent variable, x_t is the independent variable, βi is the short-term coefficient, δi is the long-term coefficient, et is the error term, k is the optimal lag length.

The following hypotheses are tested for both F and t tests by Pesaran et al. (2001) for cointegration (Pesaran et al., 2001: 296).

$H_0 : \delta_1 = \delta_2 = 0$ (There is no long-term relationship.)
$H_1 : \delta_1 \neq \delta_2 \neq 0$ (There is a long-term relationship.)

To test the hypotheses, the F value is compared with the asymptotic critical values. If the F value is greater than the upper limit value, it is concluded that the coefficients. δ_1 and δ_2 are different from each other and zero. Thus it is said that there is a cointegration relationship.

$$y_t = \alpha + \sum_{i=1}^{m} \beta_1 y_{t-i} + \sum_{i=1}^{m} \beta_2 x_{t-i} + e_t \quad (10)$$

By using a lagged residual ($\lambda_3 ECM_{t-i}$) value of the equation expressing the long-term relationship, the following equation showing the short-term relationship is obtained (Pesaran et al., 2001: 292):

$$\Delta y_t = \alpha_0 + \sum_{i=1}^{m} \beta_1 \Delta y_{t-i} + \sum_{i=1}^{m} \beta_2 \Delta x_{t-i} + \lambda_3 ECM_{t-i} + e_t \quad (11)$$

The cointegration relationship between the variables and the long-term and short-term interaction coefficients are calculated with the equations.

Toda-Yamamoto causality test

Toda-Yamamoto's (1995) causality analysis allows the series to be used with level values without taking differences. This prevents information loss in the series and makes the analysis more sensitive. For Toda-Yamamoto (1995) causality analysis, a VAR model must first be established, and the lag length (k) must be determined. Then, the highest degree of integration (d max) is added to the determined lag length. The VAR model used for the test is shown below. (Toda and Yamamoto, 1995: 245):

$$Y_t = \overline{w} + \sum_{i=1}^{k} \alpha_{1i} X_{t-i} + \sum_{i=1}^{k} \beta_{1i} Y_{t-i} + \sum_{j=m+1}^{d_{max}} \delta_{1i} X_{t-i} + \sum_{j=m+1}^{d_{max}} \theta_{1i} Y_{t-i} + \varepsilon_{1t}$$
$$X_t = \partial + \sum_{i=1}^{k} \alpha_{2i} X_{t-i} + \sum_{i=1}^{k} \beta_{2i} Y_{t-i} + \sum_{j=m+1}^{d_{max}} \delta_{2i} X_{t-i} + \sum_{j=m+1}^{d_{max}} \theta_{2i} Y_{t-i} + \varepsilon_{2t} \quad (12)$$

k is the appropriate lag length, $d_{max}$is the maximum degree of integration. The mean of the error terms ε_{1t} and ε_{2t} is assumed to be zero, and the covariance matrix is constant.

Findings

The results of the ADF and PP unit tests used for the analysis of unit root tests in this study are shown in Table 8.

Table 8: ADF ve PP Unit Root Test Results

		Constant Model		Constant ve Trend Model	
Test	Variable	Level	First Difference	Level	First Difference
ADF	$YKAYVK$	-1.878 [0]	-9.210 [0]	-2.753 [0]	-9.205 [0]
		(0.340)	(0.000)***	(0.219)	(0.000)***
	VY	-1.045 [0]	-8.053 [0]	-2.329 [0]	-8.429 [1]
		(0.732)	(0.000)***	(0.4125)	(0.000)***
	VDO	-2.919 [0]		-2.963 [0]	-7.881 [0]
		(0.048)**		(0.150)	(0.000)***
	VG	-2.316 [0]	-7.976 [1]	-2.791 [0]	-8.291 [1]
		(0.170)	(0.000)***	(0.205)	(0.000)***
	EDB	-2.632 [2]	-3.514 [1]	-0.384 [0]	-6.286 [1]
		(0.091)*	(0.010)**	(0.986)	(0.000)***
	EB	-6.286 [1]		-6.349 [1]	
		(0.000)***		(0.000)***	
	$TUFE$	-1.092 [0]	-7.563 [0]	-0.241 [0]	-7.779 [0]
		(0.714)	(0.000)***	(0.990)	(0.000)***
	ISZ	-2.298 [2]	-4.626 [1]	-1.302 [2]	-4.611 [1]
		(0.175)	(0.000)***	(0.074)*	(0.002)***
	KM	-0.649 [2]	-9.795 [1]	-1.463 [2]	-10.134 [1]
		(0.851)	(0.000)***	(0.832)	(0.000)***
	TA	-1.879 [0]	-8.775 [0]	-0.487 [0]	-9.285 [0]
		(0.340)	(0.000)***	(0.981)	(0.000)***
PP	$YKAYVK$	-1.419 [4]	-10.2209 [15]	-2.5228 [3]	-12.4954 [18]
		(0.567)	(0.000)***	(0.316)	(0.000)***
	VY	-0.8026 [4]	-8.285 [9]	-2.040 [6]	-9.559 [15]
		(0.811)	(0.000)***	(0.568)	(0.000)***
	VDO	-3.070 [2]		-3.162 [2]	-7.879 [2]
		(0.033)**		(0.100)	(0.000)***
	VG	-2.421 [1]	-8.620 [11]	-2.684 [3]	-11.047 [18]
		(0.139)	(0.000)***	(0.246)	(0.000)***
	EDB	-2.871 [3]	-7.54 [4]	-0.318 [1]	-8.850 [1]
		(0.054)*	(0.000)***	(0.998)	(0.000)***
	EB	-4.537 [7]		-4.518 [7]	
		(0.000)***		(0.002)***	
	$TUFE$	-1.133 [1]	-7.548 [3]	-0.128 [4]	-7.780 [6]
		(0.698)	(0.000)***	(0.993)	(0.000)***
	ISZ	-2.155 [3]	-11.732 [0]	-3.151 [0]	-11.661 [0]
		(0.224)	(0.000)***	(0.103)	(0.000)***
	KM	-1.689 [12]	-9.078 [65]	-1.990 [18]	-12.213 [33]
		(0.432)	(0.000)***	(0.596)	(0.000)***
	TA	-1.879 [0]	-8.748 [1]	-0.352 [1]	-9.262 [1]
		(0.340)	(0.000)***	(0.987)	(0.000)***

Note: ***, **, and * indicate stationarity at the significance levels of 1%, 5%, and 10%, respectively. The values in parentheses represent the appropriate lag lengths determined by the Schwarz information criterion for the ADF test, and the bandwidth determined by the Bartlett kernel and Newey-West method for the PP test.

The unit root test results shown in Table 8 indicate that the dependent variable YKAYVK is non-stationary at the level but becomes stationary at first differences at the 1% significance level in both the constant and constant+trend models, confirming its I(1) property. Among the independent variables, VY, VG, TUFE, ISZ, KM, and TA display similar I(1) characteristics as they are non-stationary at the level but stationary in first differences at 1% significance. VDO shows level stationarity at 5% significance in the constant model (but not in the trend model), with its first differences being stationary in both models at 1% significance. EDB exhibits marginal level stationarity (10% significance) only in the constant model. EB is the clear exception, remaining stationary at the level in both models at 1% significance, indicating I(0) properties. These consistent findings from both the ADF tests (using Schwarz Information Criterion for optimal lag selection) and PP tests (employing Bartlett kernel and Newey-West methods for bandwidth selection) reveal a mixed integration order, where the dependent variable is I(1) and the independent variables are either I(0) or I(1). This provides a solid basis for applying the ARDL bounds testing approach, which effectively handles such mixed-order integration when examining long-run relationships. Consequently, following these unit root tests, the ARDL bounds test was performed to explore cointegration relationships, with detailed results presented in Table 9.

Table 9: Bound Test Results

Dependent Variable	F Statistic Value	Lower Bounds Critical Values		
		1%	5%	10%
$YKAYVK$	43.972***	2.54	2.06	1.83
		Upper Bounds Critical Values		
		1%	5%	10%
		3.86	3.24	2.94

Note: *** symbol indicates 1% significance level.

Table 9 shows the results of the cointegration analysis from the ARDL bounds test performed on the specified ARDL (1, 0, 3, 3, 3, 0, 1, 2, 2, 3, 3, 3) model with the dependent variable D(LNYKAYVK) under Case 3 (unrestricted constant and no trend). The test provides strong evidence of cointegration, with a computed F-statistic of 4.135 that clearly exceeds all critical value bounds at the 1% significance level (lower bound = 2.54, upper bound = 3.86). This finding - where the F-statistic is above the highest critical value - confirms the existence of cointegration among the variables, regardless of whether they are I(0) or I(1). It allows us to confidently reject the null hypothesis of no cointegration at the most stringent significance level. These results indicate that the variables share a stable long-term relationship despite their different orders of integration. As shown in Table 10, which presents the long-run coefficient estimates from the ARDL long-run form, this established cointegration allows for a comprehensive analysis of both the long-term equilibrium and short-term dynamic adjustments through the estimated ARDL model. The model's specific lag structure and unrestricted constant were carefully selected to represent the data best and ensure statistical reliability.

Table 10: Long-run Coefficient Estimates

Dependent Variable: $YKAYVK$			
Variable	Coefficient	t-Statistic	Probability
VY	-1.366	-2.277174	0.030**
VG	-9.368	-5.998274	0.000***
VDO	-1.460	-5.472984	0.000***
$TUFE$	-2.516	-7.709580	0.000***
TA	-12.729	-7.399162	0.000***
KM	0.112	0.227510	0.821
EDB	26.850	7.144832	0.000***
EB	-0.094	-4.858701	0.000***
ISZ	-5.304	-4.740849	0.000***
EMS	1.908	4.487846	0.000***
TG	-2.653	-9.375465	0.000***

Note: *** indicates statistical significance at the 1% level, while ** denotes significance at the 5% level.

The long-run coefficient results from the ARDL (1, 0, 3, 3, 3, 0, 1, 2, 2, 3, 3, 3) model in Table 10 show that the most substantial adverse effect on the dependent variable YKAYVK comes from the TA variable with a coefficient of -12.729 (p<0.01), while VG (-9.368, p<0.01) and the TG dummy variable (-2.653, p<0.01) also show significant adverse effects. Other negative effects are observed from TUFE (-2.516, p<0.01), VDO (-1.460, p<0.01), and VY (-1.366, p<0.05). The EB growth rate has a statistically significant but relatively weak adverse effect (-0.094, p<0.01). Positive effects are created by EDB (26.850, p<0.01) and the EMS dummy variable (1.908, p<0.01), while the KM variable (0.112, p = 0.821) does not show a statistically significant effect. These results reveal that the variables in the model have substantial differences in both direction and magnitude of their impact on the dependent variable.

The findings obtained with the ARDL error correction model applied for short-term estimation of the variables in the model are reported in Table 11.

Table 11: Short-Run Estimation Results

Dependent Variable: ΔYKAYVK			
Variable	Coefficient	t Statistic Value	Probability
ΔVG	-3.649	-8.1927	0.000***
ΔVG(-1)	4.133	8.9003	0.000***
ΔVG(-2)	-2.323	-6.9232	0.000***
ΔVDO	-0.555	-5.5611	0.000***
ΔVDO(-1)	0.900	8.4260	0.000***
ΔVDO(-2)	0.296	2.9710	0.005***
ΔTUFE	-0.701	-5.6654	0.000***
ΔTUFE(-1)	1.564	10.4220	0.000***
ΔTUFE(-2)	0.380	3.0286	0.005***
ΔKM	-0.827	-2.0826	0.046**
ΔEDB	27.022	9.7904	0.000***
ΔEDB(-1)	5.640	2.5368	0.016**
ΔEB	-0.066	-7.9587	0.000***
ΔEB(-1)	0.023	3.2590	0.002***
ΔISZ	-2.595	-5.9618	0.000***
ΔISZ(-1)	2.500	5.9720	0.000***
ΔISZ(-2)	1.487	3.5395	0.001***
ΔEMS	0.026	0.1602	0.873
ΔEMS(-1)	-1.549	-7.1507	0.000***
ΔEMS(-2)	-0.887	-4.0848	0.000***
ΔTG	-0.622	-2.5356	0.016**
ΔTG(-1)	2.259	8.1564	0.000***
ΔTG(-2)	0.625	2.2814	0.030**
Constant	-42.274	-16.8368	0.000***
ECM(-1)	-0.992	-16.7980	0.000***

Note: *** and ** indicate statistical significance at the 1% and 5% levels, respectively. Δ denotes the first-order difference operator. The values in parentheses represent the number of lag periods.

The ARDL error correction model's short-run estimation results, presented in Table 11, reveal significant short-run relationships among the variables affecting the dependent variable ΔYKAYVK. Notably, ΔVG exhibits a substantial negative impact in the current period (-3.649) but shows both positive and negative effects in lagged periods. Similarly, ΔVDO and ΔTUFE demonstrate significant adverse effects with positive lagged influences, indicating delayed responses. ΔKM also negatively influences ΔYKAYVK, while ΔEDB stands out with a substantial positive coefficient (27.022), suggesting that increases in EDB significantly boost the dependent variable. Other variables like ΔEB and ΔISZ show consistent adverse effects, whereas ΔEMS has a non-significant current value but notable adverse lagged effects. The constant term and the error correction term (ECM(-1)) are both significantly negative, highlighting the importance of adjustments over time. Overall, these findings highlight the intricate relationships among the variables, providing valuable insights for policymakers and researchers.

Residual diagnostics statistics for the ARDL ((1, 0, 3, 3, 3, 0, 1, 2, 2, 3, 3, 3)) model are given in Table 12.

Table 12: Diagnostic Statistics

	Test	Test Statistic	Probability
Otocorelation	Breusch-Godfrey Serial Correlation LM (AR1)	0.678	0.410
Heteroscedasticity	Breusch-Pagan Godfrey	34.099	0.511
Normality	Jarque-Bera	0.225	0.893

The residual diagnostics statistics for the ARDL ((1, 0, 3, 3, 3, 0, 1, 2, 2, 3, 3, 3)) model presented in Table 12 indicate that there are no autocorrelation and heteroscedasticity issues within the model. The Breusch-Godfrey Serial Correlation LM test reveals an absence of autocorrelation with a value of 0.678 and a probability of 0.410. In contrast, the Breusch-Pagan Godfrey test indicates no heteroscedasticity problems, with a value of 34.099 and a corresponding probability of 0.511. The Jarque-Bera test results demonstrate that the model has a regular distribution feature. According to the CUSUM and $CUSUM^2$ graphs provided below, it is understood that the established ARDL model is stable.

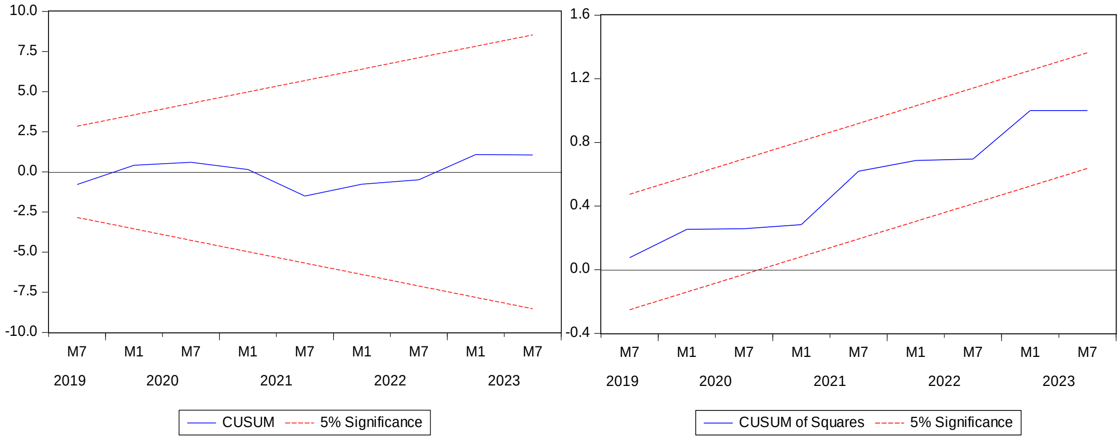


Figure 12: Cusum Graphs

Source: The author's own compilation.

In this study, the Toda-Yamamoto causality test based on Vector Autoregressive models (VAR($k + d_{max}$)) was utilised to investigate potential causal relationships among the examined variables. Here, the appropriate lag-length of the VAR model (k) and d_{max})) represent the maximum integration orders of the variables for which the causal relationship is being investigated. Therefore, selecting the appropriate lag length for each VAR model is of great importance. The Akaike Information Criterion (AIC) was used to determine the suitable lag length. The results of the Toda-Yamamoto causality test obtained in the study are presented in Table 13.

Table 13: Toda-Yamamoto Causality Test Outcomes

Null Hypothesis	$k + d_{max}$	χ^2 Statistic	Probability	Conclusion
$YKAYVK \nrightarrow VY$	2	4.267	0.118	No causality
$YKAYVK \nrightarrow VY$	2	2.245	0.325	No causality
$YKAYVK \nrightarrow VDO$	2	2.324	0.312	No causality
$VDO \nrightarrow YKAYVK$	2	1.072	0.585	No causality
$YKAYVK \nrightarrow VG$	6	32.424	0.000***	Significant causality (1%)
$VG \nrightarrow YKAYVK$	6	13.069	0.041**	Significant causality (5%)
$YKAYVK \nrightarrow EDB$	2	6.291	0.043**	Significant causality (5%)
$EDB \nrightarrow YKAYVK$	2	2.335	0.311	No causality
$YKAYVK \nrightarrow EB$	2	2.899	0.407	No causality
$EB \nrightarrow YKAYVK$	2	0.539	0.910	No causality
$YKAYVK \nrightarrow TUFE$	2	3.675	0.159	No causality
$TUFE \nrightarrow YKAYVK$	2	1.556	0.459	No causality
$YKAYVK \nrightarrow ISZ$	4	2.537	0.637	No causality
$ISZ \nrightarrow YKAYVK$	4	2.334	0.674	No causality
$YKAYVK \nrightarrow KM$	4	1.334	0.855	No causality
$KM \nrightarrow YKAYVK$	4	10.397	0.034**	Significant causality (5%)
$YKAYVK \nrightarrow TA$	2	2.975	0.225	No causality
$TA \nrightarrow YKAYVK$	2	1.438	0.487	No causality

Note: *** and ** indicate statistical significance at the 1% and 5% levels, respectively. The appropriate lag-length determined by the Akaike Information Criterion for the k VAR model is denoted as d_{max}, which represents the maximum order of integration of the time series. $\nrightarrow$ Indicates that there is no causal relationship.

The results of the Toda-Yamamoto causality test indicate significant causality relationships between YKAYVK and some other variables: YKAYVK causes VG at the 1% significance level (χ^2=32.424, p=0.000). In comparison, the causality relationship from VG to YKAYVK is significant at the 5% level (χ^2=13.069, p=0.041). There is a unidirectional causality relationship from YKAYVK to EDB that is significant at the 5% level (χ^2=6.291, p=0.043. There is a unidirectional causality relationship from KM to YKAYVK at the 5% significance level (χ^2=10.397, p=0.034). No statistically significant causality relationship is detected between YKAYVK and other variables (VY, VDO, EB, TUFE, ISZ, TA). As a result, a bidirectional relationship is established between YKAYVK and VG. In contrast, unidirectional causal relationships are identified from YKAYVK to EDB and from KM to YKAYVK, with no significant connections to other variables.

Conclusion

Smuggling activities involve illegally bringing various goods and products into our country to avoid paying customs duties, then selling them in the domestic market. These activities also include the illegal production of tobacco products, alcoholic beverages, and fuel outside legal conditions, along with unauthorised trade and export of our cultural and natural assets. The primary goal of smuggling is to generate unlawful income. Additionally, the profits from smuggling often serve as a financial resource for other criminal groups, especially terrorist organisations, helping them sustain their operations.

Fuel smuggling, which employs various methods and techniques, can have numerous financial, economic, political, and social consequences. The most serious issue with fuel smuggling is the loss of tax revenue for the government. There are two main types of taxes applied to fuel: indirect taxes, such as VAT and excise duties. While indirect taxes account for approximately 50% of total tax revenue in developed countries, they comprise around 70% in developing countries, such as Türkiye. The portion of taxes on petroleum products within indirect tax revenue typically ranges from 20 to 25%. Additionally, excise duties on fuel products constitute roughly 50% of total excise tax revenue. Therefore, the loss of indirect tax revenue caused by fuel smuggling, a primary source of government income, is a significant concern. Besides the financial loss, fuel smuggling can also negatively impact society by disrupting income fairness between the legally taxed seller and the trader using illegal fuel. It undermines the principle of the importance of taxes and may lead to moral decline in society. Vehicles using illegally produced fuel may also suffer mechanical damage.

The State has established specific legal practices and laws to regulate the fuel market, take measures to combat smuggling, and set legal and fiscal regulations. Various regulations and circulars, mainly the Petroleum Market Law and the Anti-Smuggling Law, aim to prevent fuel smuggling and specify criminal penalties. Additionally, the "national marker" application, introduced in 2007, facilitates the distinction between legitimate and illegal fuel. Moreover, with technological advancements, fuel entering the country can be tracked to the end user using more advanced tracking and tracing devices.

This study aims to examine the determinants of fuel smuggling in Türkiye from 1990 to 2023. Unlike other studies, this research utilises a dataset on the quantities of smuggled fuel seized and the resulting tax losses over this period. The study aims to identify the factors that influence fuel smuggling. The relationship between fuel smuggling and 11 independent variables believed to be related was tested using the Toda-Yamamoto Causality Analysis. The findings reveal a bidirectional relationship between tax losses from fuel smuggling and tax revenues. Additionally, there is a unidirectional link between tax losses and the energy dependency ratio, as well as dealer profit margins. Moreover, the results suggest that smuggling activities declined during the period when Unmanned Aerial Vehicles were effectively deployed to combat smuggling in Türkiye.

As a result, the informal economy deprives the state of a vital revenue source, harms society's tax awareness, encourages illegal associations, and can weaken the social fabric. This is why fighting the informal economy, especially fuel smuggling, is so important. Combating fuel smuggling not only lessens health and environmental dangers but also stops illegal profits and boosts the country's economy. To do this, it is crucial to purchase products only from fuel stations licensed by the Energy Market Regulatory Authority, report any issues such as price changes and failure to provide receipts or invoices, and target individuals and companies selling smuggled products to law enforcement. Additionally, coordination among law enforcement and other public agencies, along with the use of advanced technology for border security, is essential. Furthermore, efforts to stabilise the nation's tax policy and increase tax awareness and ethics in society are key parts of the fight against fuel smuggling.

Furthermore, potential increases in fuel prices could lead to higher costs for many goods and services. This ripple effect can negatively affect market price stability. Therefore, it is crucial to implement a flexible tax system that can be fully adjusted to protect price stability in the market from sudden fluctuations. Instead of applying a proportional tax to fuel products, a flexible system with a fixed tariff could be used. In this system, the fixed rate can be adjusted (raised or lowered) in response to changes in fuel prices, effectively maintaining fuel price stability.

However, it should not be forgotten that the main reason for fuel smuggling is the high tax burden on fuel products. Efforts should be made to reduce this burden on society alongside economic development. Additionally, global influences on fuel prices should be mitigated using systems similar to the sliding scale system. Finally, recognising that Türkiye's most significant current deficit is due to its energy dependence, increasing efforts to find and develop new reserves that will reduce the country's external reliance, along with expanding renewable energy facilities, will also help decrease dependence on fuel smuggling.

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