



## ORIGINAL ARTICLE

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## Estimation of the price elasticity of petroleum products' consumption in Ukraine

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### Abstract

**Research background:** The analysts of the petroleum product markets of industrial countries believe that the elasticity of demand varies at different periods, which gave rise to the hypothesis that behavioral and structural factors have changed the consumers' reaction during the last few decades, with a change in prices of petroleum products.

**Purpose of the article:** The purpose of this article is to study the elasticity of demand and prices in order to identify changes in consumer behavior in the oil market after significant socio-economic shocks and to establish a correlation between changes in elasticity and price volatility, with the Ukrainian petroleum products market as an illustrative example.

**Methods:** Based on the time series of the petroleum product market of Ukraine, static and dynamic models for assessing the demand elasticity were constructed. It was found that the time series of demand for petroleum products is non-stationary but then the time series of the first differences is stationary according to the extended Dickey-Fuller test; further, the fact of co-integration between time series of consumption, income, and prices was established by the Johansson test. This made it possible to construct co-integration dependence, allowing, in turn, the development of models for assessing the elasticity of demand for petroleum products, on the basis of which objective assessments of changes in consumer behavior were established. Analysis of the monthly calculation of petroleum products' price volatility during the period 2008 to 2018 has showed that the values of volatility increased abnormally in the period between the beginning of 2014 and the middle of 2015. The estimates of price and demand elasticities obtained for the two periods up to the beginning of 2014 and the second half of 2015 differ significantly from the values of the corresponding elasticities between the beginning of 2014 and the middle of 2015.

**Findings & Value added:** Assessments of income elasticities and price elasticities for petroleum products in the Ukrainian market were obtained by three co-integration models, both short and long term, for each of the three previously defined time intervals. In one of them, characterized by a high level of price volatility conditionally referred to as a crisis, the value of elasticities differed markedly from the corresponding values in the other two periods, in particular, -0.383 for price elasticity and 1.068 for a long-term bond. In the other two periods, these were, respectively, 0.543 for price elasticity and 0.274 for long-term pre-crisis elasticity, and -0.470 for price elasticity and 0.235 for long-term post-crisis elasticity. Appropriate elasticity estimates were obtained for both the short-run and the dynamic model, for the same defined intervals. A comparison of these estimates showed the closeness of the values of elasticities for the pre-crisis and post-crisis intervals and a marked difference from the estimates of the elasticities in the crisis interval. Thus, it was found that a significant change in elasticities is accompanied by an increase in price volatility.

## Introduction

Fuel is an important factor of production in transport, industry and agriculture. The behavior of prices in this market has an impact on the pace of general price increases in the economy, thus endowing them with a significant influence on the course of economic growth. The central issue in the study of this market is pricing. Researchers from all continents, including Valadkhani (2010), Akinboade *et al.* (2008), Alves and Bueno (2003), Baranzini and Weber (2013), Nicol (2003), Lin and Zeng (2013) and many others, have contributed significant efforts to the research on pricing mechanisms in this market.

One of the most important issues of pricing in the petroleum product market is the estimation of elasticity. Understanding the sensitivity of consumption of petroleum products to changes in prices and incomes is an important element of energy policy for all countries and has indirect implications for various aspects of socio-economic policy, such as avoiding excessive consumer losses, climate change threats, taxation, and national security.

In many countries in the world where the petroleum product market is operating and statistics are available, in particular in the United States, short-term price elasticity of petroleum product prices began to be studied since the 1970s. In the course of these studies, analysts from the petroleum products market and the related transportation industry found that demand elasticity differs in different periods. This has led to the hypothesis that behavioral and structural factors have changed the response of US and other consumers to changes in petroleum product prices over the last few decades.

In particular, comparing the periods 1975–1980 and 2001–2006, it was found that the short-run price elasticity of gasoline in these two periods is

relatively different from other periods: from -0.034 to -0.077 during 2001-2006, versus from -0.21 to -0.34 for 1975-1980, when prices were much lower. To catalogue a comprehensive list of factors that affect elasticity is quite problematic. In each of the national markets, it is necessary to take into account both the global trends and the peculiarities of the national realities in which the relevant product's market operates. In some countries where gasoline consumption was seen as a subsidized benefit, this created significant socio-economic problems. In particular, excessive government consumption of gasoline due to its low cost caused a serious crisis in Iran in 2006 (Ghoddusi *et al.*, 2018), as it exceeded the production levels and even led to gasoline imports. It not only caused economic damage by reducing the balance of payments surplus but also politically threatened the country with increasing energy dependency. Excessive gasoline consumption also increases pollution, which generally reduces social well-being (Ghoddusi *et al.*, 2018, p. 72). As a remedial measure, the government of Iran increased the price of gasoline significantly, eliminating the subsidy in 2007. Higher prices led to a drop in consumption, but not to the extent envisaged. The policy can reduce consumption, but it is unclear how effective it is. One can reduce placement, but it's unclear what this is about. The peculiarities of the national petroleum products markets in different countries can have a significant impact on pricing, especially where there is a strong state influence as in Turkey, or there is serious competition for alternative fuels. However, there is also a noticeable influence of external factors on the price elasticity of petroleum products.

Turkey has experienced a significant reduction in petroleum products consumption in 2009–2009 (Erdogdu, 2014) as a result of the global crisis. This is despite the pricing of the Turkish petroleum products market being specific due to the levy of two taxes: the value-added tax (VAT) and special consumption tax (SCT). The price in the market — the price of fuel before tax — is determined by free market forces and does not exceed 40% of the contribution to the total price of fuel.

The Brazilian petroleum products market also has a significant specificity and is significantly different from other markets, because of the availability of a variety of alternative fuels. There are four major fuels in this market: gasoline, ethanol, compressed natural gas (CNG), and diesel. Gasoline is still the main fuel but it competes strongly with two substitutes: ethanol and CNG. However, studies (Santos, 2013) have shown the impact of the growing ethanol market on the elasticity of demand for gasoline in Brazil, and the results showed a significant increase in price elasticity and cross elasticity with ethanol.

Even in a stable economy, like Switzerland, research on a solid basis of statistics reflected the OPEC oil shocks of 1973 and 1979 and the increase in the tax on mineral oils in 1993 was an additional impact on fuel consumption, affecting the elasticity of consumption more than their direct impact through the price increase. In addition to the increase in prices caused by the increase in the oil tax, the demand for fuel actually decreased by about 3%, while the demand for gasoline decreased by 3.5% (Baranzini & Weber, 2013, p. 676). However, this did not last long. The Swiss government is aware that price increases should be significant to reduce fuel consumption and reduce CO<sub>2</sub> emissions.

Though there are many examples, we will focus on the study of price elasticity and elasticity of demand on the petro-products revenue of Ukraine. The petroleum product market of Ukraine has been operating according to the rules of free competition only since 2005, and besides, it does not have such a rich statistical database as the USA. However, in the relatively short period of its existence, the market has passed through many dramatic events, such as the political turmoil in Ukraine in late 2013 and in early 2014, which raised quite a few questions about the behavior of the market participants. . One of the effects, which finally can be assessed from the point of view of the changing demand for petroleum products, is the elasticity of petroleum products consumption. Several factors exert significant influence on the petroleum product market. They have different natures, but can be seen from the same point of view. The emergence of such a factor entails a certain destabilizing effect, which is manifested in the change of price elasticity and elasticity of demand in the short and medium-term periods and accompanied by greater variability of petroleum product prices. Here, we should mention the pioneering work of Lin and Prince (2013), in which attention was first drawn to the presence of simultaneous fluctuations of growth and changes in price elasticity of the petroleum products market of the United States of America. Taking into account the peculiarities of pricing in the petroleum products market, elasticity is now being evaluated as short-run elasticity and long-run elasticity. The tools for this assessment are the static model, in which the demand for petroleum product  $D$  depends on the real price of petroleum product  $P$  and the real income  $INC$ , as well as a dynamic model, which must take into account the adaptation of consumers to changes that requires time. If income or prices change over one period, and some consumers postpone their reaction to a later period, then today's consumption will not only depend on today's income and price structure but also on previous income and prices. This leads to another approach to modelling this dynamic dependence.

The simplest and most widespread representation of a dynamic model is a partial adjustment model. It expresses the amount of petroleum product  $D$  consumed as a function of the real price of petroleum product  $P$ , the real income  $INC$  and the amount of petroleum product consumed in the last period,  $D_{t-1}$ . The following variants are possible: the ECM error correction model, static model, and dynamic model. We accept the hypothesis that the volatility of gasoline prices is a mediated indicator of the influence of political, socio-economic and other non-economic events on consumer behavior, which leads to changes in price elasticity at times when volatility values change significantly.

The purpose of this article is to investigate price elasticity and income elasticity of demand in the Ukrainian petroleum product market, based on its performance statistics from 2008 to 2018, and to establish the relationship between changes in elasticity values and changes in volatility values.

## **Literature review**

The petroleum product market has long attracted the attention of researchers, which continues to sustain mainly due to the strategic role the fuel sector occupies in the national economy, and the issue of elasticity of petroleum product consumption, which is one of the key problems in the petroleum products market. Examples of such studies are Leszkiewicz-Kędzior (2011), Liu (2014), Havranek *et al.* (2012) and Goodwin *et al.* (2004). In the literature, there is an opinion that the price of petroleum products is considered exogenous (Archibald & Forbes, 1980; Hausman & Newey, 1995; Wadud *et al.*, 2010). These authors believe that the price of petroleum products (primarily gasoline) is determined mainly by the price of crude oil in the world market, and not by demand. However, this formulation leads to the well-known problem of estimating demand when price and quantity are determined jointly through changes in both demand and supply, which in turn leads to biased and inconsistent parameter estimates.

In world literature, there are many studies on estimates of consumption of petroleum products by different methods and in three different decades, and authors have also classified important studies of models and assessments (Dahl & Sterner, 1991; Dahl, 2012; Espey, 1998). These works marked the beginning of the direction of meta-analyses to study the problems of elasticity in the petroleum products market. Initial studies were related mainly to problems of availability, resource depletion and security challenges caused by shocks and disruptions of oil supplies in the 1970s. Later, they covered the environmental consequences of gasoline consump-

tion, particularly in relation to emissions of greenhouse gases (Kayser, 2000). Environmental and political reasons cover the politicians' interest in determining the impact of changes in gasoline taxes and all sorts of sudden price changes on demand; thus, a study of the demand for gasoline has always attracted special attention. Since then, statistical and econometric methods have gained currency to examine issues of demand, consumption and the behavior of the prices of petroleum products.

The understanding of the determinants of gasoline demand was strongly motivated by the 1973 energy crisis, leading to an increasing number of studies aimed at modelling gasoline demand. A quantitative relationship between price and gas demand is needed to evaluate the impact of pricing.

Studies have shown that the market for petroleum products in the United States is quite heterogeneous and estimates of elasticity differ significantly in different states of America, as well as in different countries. It was necessary to find a methodology that could generalize numerous variations in estimation methods, model specifications and other empirical results. This methodology is meta-analysis.

Meta-analysis is a quantitative research synthesis technique that uses statistical and econometric methods to investigate, summarize, or integrate an array of research data to investigate and report on the size and characteristics of a specific effect. As such, meta-analysis can be used to estimate the true magnitude of the baseline effect, as well as to investigate and explain the variation in effect size estimates found in the literature.

Dahl and Sterner (1991) conducted a meta-analysis of price elasticity of demand for gasoline on the basis of a significant number of preliminary assessments to 1989. With more than ten different models, these authors found sufficient similarity of the price elasticity, particularly that it falls within a certain cluster. They believe that price elasticity is in the range of -0.2 for short-term and -0.31 for the medium term, and long-term elasticity is -0.8 to -1.01. Results (Espey, 1998) are based on meta-studies of hundreds of estimates obtained for the period 1929–1993. Price elasticities can range from 0 to -2.72, with the average value of -0.58.

It should be noted that evaluation of price elasticity and elasticity that depends on the income from consumption of petroleum products, is a complex problem due to the influence of external factors and oligopolistic nature of competition, resulting in corresponding time series being chaotic and, as a rule, not being a stationary time series. The technique of meta-analysis of the consumption of petroleum products has found its development in several works (Bronson *et al.*, 2008; Nelson & Kennedy, 2009; Labandeiraz-Otero *et al.*, 2017).

The literature on the demand for gasoline can be divided into two main areas from the perspective of the assessment approach. As consumption, price, and income, as a rule, are non-stationary variables, one approach uses co-integration for non-stationary variables and considers the long-term and short-term relationships between consumption and price in the model of error correction.

In the case where all variables are non-stationary, the combination of co-integration and ECM can be used to estimate the elasticity of demand for gasoline in the short- and long-term and short-term forecasts (Engle & Granger, 1987). In the case when all variables are stationary, the PAM is a reliable methodology to assess short-term and long-term elasticity. However, the cases of stationarity are rare enough, and the cases with time series variables in the petroleum product market being non-stationary were recorded a lot more in scientific publications, by many researchers around the world.

Therefore, the problem of estimation of price elasticity and the demand elasticity of income on petroleum products requires analysis of appropriate time series for this market. Over the last two decades, there have been hundreds of such studies, and a vast majority identified the non-stationary series, including time series showing the functioning of the petroleum product market of Ukraine (Galchynsky, 2013). Based on these results, the evaluation of price elasticity and the elasticity of demand for income in the market of motor fuel of Ukraine were obtained for 2008–2013 on the basis of a simplified static model, the results of which are generally consistent with models of meta-analysis conducted by researchers in other countries (Svy'denko, 2015).

While the estimates of elasticity should be done through more advanced models, on the other hand, in 2014–2015, Ukraine suffered a major political turmoil that affected the petroleum product market. It is obvious that this would have led to a change in price elasticity and the demand elasticity of income relating to petroleum products. Therefore, it was necessary to make a proper assessment. As stated in the introduction to this article, the petroleum product markets of many countries that have been hit by all kinds of turmoil, but this does not deny them the attention of researchers. An example is the data for the petroleum product market of Lebanon, a country that has experienced many dramatic political events in its recent history. The petroleum product market has undergone several upheavals, accompanied by sharp changes in the values of the elasticity model, involving, in turn, sharp changes in the elasticity (Sita *et al.*, 2012). By its form, it is an econometric model that does not describe the internal market mecha-

nism of the jump in the elasticity, but shows those possible changes of values of elasticity.

Lin and Prince (2013) not only estimated the elasticity of demand for gasoline in the United States until 2012, but also took into account the effect of fluctuations in gasoline prices on consumer behavior, which in their view further influences gasoline demand. The authors not only indicated the tendency of changes in demand for petroleum products to be accompanied by increased volatility, but also suggested that changes in elasticity depend on changes in volatility. In addition, an econometric model was formulated, in which variability acted as an exogenous variable. In my opinion, the validity of this rather original idea has not been proven and it is still a little early to apply this approach to building a model of elasticity.

Based on this analysis, it can be argued that the elasticity of petroleum products, in particular gasoline, may change under the influence of both external influences and internal ones inherent in a given national market. Moreover, if the nature of these internal influences can be country-specific, the methodology of elasticity research is of a general nature.

Based on the results of these publications, we will analyze the elasticity of petroleum products in the Ukrainian market and the volatility at a certain historical interval, which includes a period when the effects of the political turmoil in 2013–2014 had a significant impact on the market.

## **Research methodology**

In this section, we will carry out statistical processing of data for obtaining estimates of the elasticity of gasoline consumption and calculate the price volatility of the petroleum products market of Ukraine during the period 2008–2018. Accordingly, it is possible to envisage four stages:

1. Assessment of the stationarity of the time series;
2. Selection of models estimating the elasticities;
3. Computation and analysis of price volatility;
4. Estimation of elasticities of consumption at the intervals where price volatility is significantly different.

For assessment and analysis, we used data on the monthly consumption of petroleum products in Ukraine, presented on the website of the State Statistics Service of Ukraine, for 2008–2018 (State Statistics Service of Ukraine, 2014, 2018), the data on the average monthly price of a major brand of gasoline between 2008 and 2018, presented by the analytical Agency "Psyche" (Service Psychea Fuel, 2014, 2019), which monitors the petroleum products market of Ukraine. The income level of the population



of Ukraine was provided by data of monthly real wages (State Statistics Service of Ukraine, 2013, 2018). Daily price values were used to assess the volatility of the prices of petroleum products, as furnished by analytical Agency "Psyche" (Service Psychea Fuel, 2019).

Previous analysis focussed on the features of pricing in the petroleum products market demand to estimate elasticities in the short interval (short-run elasticity) and long interval (long-run elasticity). This leads to estimates for the static model, when the demand for the petroleum product ( $D$ ) depends on the real price of petroleum product ( $G$ ) and real income ( $INC$ ) and a dynamic model, which should take into account the adaptation of consumers to changes, which takes time. This approach allows reckoning the changes within one period, for which some consumers delay their response to a later period. That is, today's consumption depends not only on the current structure of income and prices but also on previous income and prices.

The simplest, yet the most common representation of dynamic behavior is the partial adjustment model. It expresses the amount of petroleum product  $D$  consumed as a function of the real price of petroleum product  $P$ , the real income  $INC$  and the amount of petroleum product consumed in the last period  $D_{t-1}$ . This model has the following options: ECM correction models, static model, and dynamic model. We consider these approaches for the Ukrainian petroleum products market. Estimates of elasticities based on these models were calculated using the statistical package EViews 11.

### *Estimation of the stationarity of the time-series of petroleum product consumption data*

But first, we shall do a time-series study that describes the behavior of petroleum product consumption, with an example of a gasoline time series. Figure 1 shows graphs of logarithms of consumption and prices and incomes in Ukraine for the period from 01/01/2008 to 30/06/2018. There is a clear tendency for consumption to decrease and prices and incomes to increase. But what is the characteristic of  $\ln(D)$  as a time series?

Previously, analysts have determined the stationarity of time series by the type of correlograms. In this case, it is likely that these series are non-stationary because the auto-correlation and partial auto-correlation functions decline slowly. However, to obtain a more objective estimation of stationarity, we apply the Dickey-Fuller test procedure to the time series of the logarithm of monthly gasoline consumption values for the period from 01/01/2008 to 30/06/2018. Testing of the hypothesis of non-stationarity of the time series is reduced to checking the presence of unit root in the autoregressive equation AR (1). The case of a root value greater than one for

this test is not considered since such series are rather indicative of the catastrophic state of the process and are not subject to Dickey-Fuller testing. The test is one-sided, that is, the alternative hypothesis is that the coefficient is less than zero.

In other words, if the presence of a single root is set, then the row is non-stationary, if not installed, the row is accordingly stationary. Test statistics (DF statistics) are statistics for checking the significance of linear regression coefficients, which, however, have a distribution different from the classical distribution of statistics (Student's distribution or asymptotic).

The distribution of DF statistics is expressed through the Wiener process and is called the Dickey-Fuller distribution. At one time, Dickey and Fuller (1979) calculated the reference values of statistics to determine the presence of a single root for different levels of statistical significance. Table 1 shows the results of estimating the non-stationarity of the time series  $\ln(D)$  according to this test.

As we can see, the value of DF statistics is -0.247. It turns out that even for the level of 10%, the value of DF statistics is to the left of the reference value of DF statistics for the presence of a unit root. This means that the time series  $\ln(D)$  is guaranteed to be non-stationary. However, according to the Dickey-Fuller test reveals (ADF) applied to the time series of the first differences in retail prices for petroleum products as stationary (Table 2).

DF Stats Value is -7.143. Therefore, even for a significance level of 1%, the DF statistic value is to the right along the true axis of the DF statistic reference value for a unit root. It turns out that the time series of the first differences  $\ln(D)$  is guaranteed stationary. The corresponding test for the series  $\ln(INC)$ , the results of which are shown in Table 3, shows that this time series is also non-stationary.

The values in this table indicate that this series is guaranteed to be non-stationary. And the results for the series of the first differences in Table 5 show that it is stationary even below the 1% level.

Testing of the series  $\ln(P)$  showed that it is non-stationary. However, for the first differences of the series  $\ln(P)$ , the test results show that it is stationary, albeit with slightly different levels of probability than the previous two: the test boundary for the null hypothesis is slightly more than the 1% confidence level and is guaranteed to be higher at the 5% confidence level. It is difficult to obtain a more accurate assessment of the level of trust but it is not very necessary. The test results are shown in Table 6.

It can be argued that the 2-3% level of confidence there is almost ensured, providing the basis to build a model of co-integration, as it is established that the time series are of the same order of integration  $I(1)$  with

a high-level front. This is a necessary condition for the production model of dynamic regression.

However, an equal level of integration of the time series is not sufficient to justify the assessment model of elasticity, for it requires proof whether series  $\ln(D)$ ,  $\ln(INC)$  and  $\ln(P)$  are in the cointegration. This is one of the most difficult problems of econometric analysis. The best solution is the methodology of Johansen, which is based on the relationship between the rank of the matrix of co-integration vectors and its characteristic roots. The test of the characteristic roots is compared with the critical values calculated by Johansen for the hypothesis about the evolution of the non-stationary process, with the inclusion of lags (Johansen, 1995).

Moreover, it is necessary to consider the presence of a deterministic trend, which is easy to see by visual inspection. The peculiarity of this method is there are several co-integrational combinations of vectors. In the specification between the dependent variable with lag 2 identified two cointegration equations at the level of statistical significance of 1%. The test results confirm a stable long-term relationship between the variables, which allows their use in the model to correct errors. However, by applying the Johansen test on co-integration series  $\ln(D)$ ,  $\ln(INC)$  and  $\ln(P)$  for 2008–2018, we obtain only one co-integrational combination that confirms a sustainable long-term relationship between the variables and allows their use in models for estimating the elasticity. The test results are shown in Table 7.

The trace test indicates 1 co-integrating eqn (s) at the 0.05 level.

### *Static model*

According to previous studies, a static model, also called a "log-linear model" or a long-term linkage model is used to measure the price and revenue elasticity of a petroleum product, which is still the same.

$$\ln(A) = a_0 + a_1 \ln(Pt) + a_2 \ln(INC_t) + \varepsilon_t \quad (1)$$

where  $\ln$  is the natural logarithm,  $D$  is the demand,  $P$  is the real price,  $INC$  is the income,  $\varepsilon_t$  is the residual term with the usual classical characteristics  $\varepsilon_t \sim \text{NID}(0, G, u)$ , and  $t$  is the period. In addition,  $a_0$  is a free term,  $a_1$  is long-term price elasticity, and  $a_2$  is a long-term of income elasticity of demand  $\varepsilon_t$  is a residual term.

Based on the Engle-Granger (1987) approach, co-integration regression indicates a long-term relationship between variables. Provided that all regression variables have the same degree of integration  $p$ , it will be a co-

integration regression if the residual series have a lower degree of integration than  $R$ . In this case, the parameter  $a_1$  in the equation is treated as the price elasticity of petroleum product demand and  $a_2$  as the elasticity of consumer income. The short-run elasticity of petroleum products is estimated by another model, the short-run model known as the Error Correction Model (ECM), which is as follows:

$$\Delta \ln(D_t) = \beta_0 + \beta_1 \Delta \ln(P_t) + \beta_2 \Delta \ln(INC_t) + \varepsilon_t \quad (2)$$

where  $\Delta$  is the first difference,  $\beta_0$  is the free term,  $\beta_1$  is the short-term price elasticity,  $\beta_2$  is the short-term income elasticity, and  $\varepsilon_t$  is the residual term. Since the stationarity of a number of first differences was established, the variables with one degree of integration are stationary.

### *Dynamic model*

A dynamic model called the "partial control model" or "endogenous delay model" is used to verify the results of the static model. The dynamic model looks like this:

$$\ln(D_t) = \theta_0 + \theta_1 \ln(P_t) + \theta_2 \ln(INC_t) + \theta_3 \ln(D_{t-1}) + \varepsilon^* \quad (3)$$

where  $D_{t-1}$  is the demand for petroleum product for the previous period,  $\theta_0$  is the free term,  $\theta_1$  is the short-term price elasticity,  $\theta_2$  is the short-term elasticity of income,  $\theta_3$  is the coefficient of demand for the petroleum product for the previous period,  $\varepsilon^*$  is the residual term.

In this model, the long-run price and revenue elasticities are  $\theta_1/(1-\theta_3)$  and  $\theta_2/(1-\theta_3)$ , respectively.

### *Volatility calculation*

Calculating the value of volatility in petroleum product prices is a much simpler problem that does not require estimating the stationarity of the time series. Generally speaking, the concept of volatility is given a great deal of attention in financial markets, where it is seen as a measure of investment uncertainty. In the simplest representation, volatility is considered as a normally distributed random variable with a variance equal to the variance of the yield over the interval. This method is also called SMA (Simple moving average). In accordance with the Basel Committee on Banking Supervision requirements, volatility and correlation coefficients of future periods should be estimated using at least equal-weighted volatility values

over the previous year. The volatility standard is the standard deviation of this value, calculated on a historical sample:

$$\bar{\sigma}_\varepsilon = \sqrt{\sum_{t=1}^T \frac{(r_t - \frac{1}{T} \sum_{i=1}^T r_i)^2}{T-1}} \quad (4)$$

where:

$\sigma_\varepsilon$  – volatility estimation;

$r_t$  – is the current value of a member of the series;

$T$  – is the value of the time interval.

Given that the time series under study is not normally distributed, this is a somewhat simplified model of volatility. However, for us, the value of volatility will act only as a specific indicator of market for petroleum product, not a model for calculating the risk for an investor.

Thus, the proposed methodology will allow us to estimate the values of the elasticities and volatility of petroleum products.

## **Results**

### *Calculation of price volatility*

Using the formula (4) to calculate the volatility of the price of gasoline, the volatility calculations for the years 2008 to 2018 are presented in Table 8 and Figure 2.

The results of the volatility calculations for the period 2010–2018 provided in Table 9 and the graph in Figure 2 clearly show a sharp increase in volatility from early 2014 to mid-2015 compared to 2008–2013 and 2016–2018. For a more accurate definition of the interval where petroleum product price volatility has increased significantly, we refer to Table 9, in which volatility data are provided monthly from 01/01/2010 to 01/06/2019. This allows us to determine the interval of significant increase in price volatility more accurately.

The analysis of this table shows that the interval of significantly increased volatility is between 01/01/2014 and 01/04/2015, just during the period of the acute crisis in Ukraine. This result provides a basis for calculating the elasticities during these periods for further comparison and evaluation.

### *Calculation of elasticities*

Based on the established properties of the time series and models studied, set out in the previous section, we estimate the values of elasticities for the three periods: 2011–2013, 2014–2015, and 2016–2018, and will continue to refer to these periods as pre-crisis, crisis and post-crisis periods. We estimate the long- and short-term elasticities in these three different periods on the basis of the static co-integration dependence model, as well as through the dynamic dependence calculated by the VAR model using the Eview statistical package. The results of the calculations of the elasticity estimates are given in the summary table of Table 10.

Table 11 lists the criteria for statistical significance for one of the dependencies obtained.

The values of these criteria indicate that this dependency can be trusted, although it would be desirable to raise this level of confidence, for example, to have  $R^2 = 0.95$  rather than  $R^2 = 0.73$  at significance level = 0.05, this requires more data. All other dependencies obtained have similar criteria values.

### *Estimation of price elasticity*

The estimation of long-term price elasticity for all three periods as a whole fits into the general context of meta-analysis for petroleum product markets in the world. However, it should be noted that the estimates of price elasticity in the pre-crisis and post-crisis periods are quite close, while the assessment of price elasticity in the crisis period differs markedly.

The same can be said about the estimation of values of short-term elasticity, albeit to a lesser extent. It is not easy to make unambiguous estimates of price elasticity in a dynamic model. Zero-lag price elasticity in a crisis period exceeds the corresponding estimates in the pre-crisis and post-crisis period and, conversely, the price elasticity estimate with a lag of 1 is less than the corresponding estimates of the pre-crisis and post-crisis periods.

### *Estimation of income elasticity of demand*

Like the price elasticity estimates, the long-run elasticity of demand estimates for all three periods also falls within the range of meta-analysis estimates for the Ukrainian petroleum products market. And here, there is a certain pattern: the value of income elasticity of demand during the crisis is greater than in the pre-crisis and in post-crisis periods.

This statement is also true of the estimates obtained on a dynamic model; that is, the values of income elasticity of demand in a crisis period are greater than in the pre-crisis and post-crisis periods. A value of long-term price elasticity of about -0.5 and short-term price elasticity close to it means that the demand for gasoline in Ukraine can be considered moderately elastic in relatively stable times, while the value of income elasticity of demand in the same conditions has less impact on demand in the opposite direction. The estimation of the elasticity of income according to the dynamic model confirms the tendency found by the two previous models: the impact of the decrease in income is more significant than the change in prices. Figure 3 shows the simultaneous increase in volatility and changes in elasticities.

Consumption rules are clearly changing during the crisis: lowering of consumers' income has a more significant effect on lowering demand, than potentially increasing fuel prices. Thus, we consider it established that during the crisis, the value of elasticities, both in price and income, as well as the value of price volatility, changes significantly.

## **Discussion**

Evaluating the results obtained, it can be argued that the estimation of the price and income elasticities, in general, is in line with the results obtained by previous authors and reflected in the totality of literature sources that investigate the elasticity of petroleum products in different markets and at different times. There is a clear correlation between changes in price and of income elasticity of demand, with a significant increase in the volatility of petroleum product prices in the period of exacerbation of the crisis caused by political events. It should be noted that there were no reasons other than the effects of political upheaval in this period in Ukraine. There were no natural disasters, man-made disasters or pandemics. There were also no significant shifts in the consumption of renewable motor fuels or a significant increase in tax burden.

The construction of econometric models of elasticity estimates based on the ideas of co-integration was made reasonably since the stationarity of some first-time series differences was proved, and the Johansen co-integration established. Although the degree of reliability of the statistical dependencies obtained needs to be improved, the fact is that three different models pointed to the same trend, including a negative value for price elasticity, a positive value for income elasticity; and the presence of a negative consumption trend for all the three periods reinforces the result that the demand for gasoline in Ukraine can be considered moderately resilient for

relatively stable intervals. At the same time, the value of elasticities changes under the influence of crisis factors, and the change in prices has less impact on consumption than the change in income.

It has been established that the volatility of gasoline price volatility is significantly increased during the crisis period, and the working hypothesis of the article is confirmed. The question, however, is how they are bound up. There is a hypothesis which posits a direct relationship between changes in volatility and changes in elasticity (Lin & Prince, 2012), i.e. a change in the value of price fluctuations in the petroleum products market affects the behaviour of market participants, so that elasticity also changes. However, there is no direct evidence for this hypothesis. In my opinion, both the change in elasticity and the change in volatility are a manifestation of the modification of the behaviour of market participants, due to the influence of circumstances caused by the crisis.

The existence of a certain linkage between the change of volatility and change of price elasticity of petroleum products is not excluded. However, this is a topic for future research, for which a different methodology should be employed, which would reveal the market mechanisms through which changes in elasticities and volatility occur.

## **Conclusions**

This paper has investigated the impact of significant socio-economic disturbances on the behavior of oil market participants, which is expressed in changes in price elasticities and changes in price volatility in these time series of petroleum products in the Ukrainian market for the period from 2008 to 2018.

By analyzing the distribution of volatility values by price, three intervals were distinguished: pre-crisis, during crisis and post-crisis, within which estimates of the elasticity of petroleum products were obtained, both by price and by income, based on econometric co-integration dependencies. Estimates of elasticities showed moderate elasticity at intervals in the pre-crisis and post-crisis periods and a significant change in the values of elasticities during the crisis period, where a significant increase in price volatility was previously established. However, the conditionality of changes in elasticity due to changes in volatility and *vice versa* has not been established. In order to ascertain the reason for this kind of correlation, it is necessary first to carry out additional research, in studying the pricing mechanisms in changing conditions for petroleum product market participants during crises. It may be noted that the methodology of such studies requires



more behavioral aspects of petroleum product market participants than purely econometric ones. In practical terms, the results of this study can be used for moulding government policy on the petroleum product market, particularly in times of crisis.

The study of changes in the price elasticities of petroleum products, based on the example of the Ukrainian market during the crisis, is, in my opinion, international in nature, as shown by the analysis of publications on this topic. However, the establishment of elasticity estimates requires the construction of models that take into account the specifics of the market in a particular country.

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## Annex

**Table 1.** Estimations of the non-stationarity of the series ln (D) by the DF test

<b>Indicator</b>	<b>Value</b>	
The value of Dickey-Fuller's t-statistics		-0.247
Critical values:	1%	-3.521
	5%	-2.901
	10%	-2.588
Log		3
$R^2$		0.077
Adjusted $R^2$		0.024
Average value		-0.013
Standard deviation		0.082
The sum of squares of residuals		0.457

**Table 2.** Estimations of the non-stationarity of the first differences of the series ln (D) by the DF test

<b>Indicator</b>	<b>Value</b>	
The value of t-statistics	: DF	-7.143
Critical values:	1%	-3.534
	5%	-2.906
	10%	-2.591

**Table 3.** Stationarity estimation of the ln (INC) series by the DF test

<b>Augmented Dickey-Fuller test statistics</b>		<b>1.469555</b>	<b>0.9979</b>
Test critical values:	1% level	-4.004425	
	5% level	-3.098896	
	10% level	-2.690439	
R-squared	0.346092	Mean dependent var	-0.027717
Adjusted R-squared	0.149919	S.D. dependent var	0.063696
		Akaike info	
S.E. of regression	0.058728	criterion	-2.596856
Sum squared resid	0.034489	Schwarz criterion	-2.414269

**Table 4.** Stationarity estimations of the first differences of the ln (INC) series by the DF test

<b>Augmented Dickey-Fuller test statistic</b>		<b>-5.268</b>	<b>0.001</b>
Test critical values:	1% level	-3.9598	
	5% level	-3.081	
	10% level	-2.681	
R-squared	0.681	Mean dependent var	-0.001
Adjusted R-squared	0.656	S.D. dependent var	0.105
S.E. of regression	0.061	Akaike info criterion	-2.604
Sum squared resid	0.049	Schwarz criterion	-2.510

**Table 5.** Stationarity estimation of the ln (P) series by the DF test

		<b>t-Statistic</b>	<b>Prob.*</b>
<b>Augmented Dickey-Fuller test statistic</b>		<b>-1.851</b>	<b>0.344</b>
Test critical values:	1% level	-3.920	
	5% level	-3.065	
	10% level	-2.673	
R-squared	0.197	Mean dependent var	0.041
Adjusted R-squared	0.139373	S.D. dependent var	0.067923
S.E. of regression	0.063012	Akaike info criterion	-2.574503
Sum squared resid	0.055588	Schwarz criterion	-2.477929

**Table 6.** Stationarity estimations of the first differences of the series ln (P) by the DF test

		<b>t-Statistic</b>	<b>Prob.*</b>
<b>Augmented Dickey-Fuller test statistic</b>		<b>-3.8410</b>	<b>0.013</b>
Test critical values:	1% level	-4.004	
	5% level	-3.098	
	10% level	-2.690	
R-squared	0.591	Mean dependent var	-0.008
Adjusted R-squared	0.517	S.D. dependent var	0.090
S.E. of regression	0.062	Akaike info criterion	-2.514
Sum squared resid	0.043	Schwarz criterion	-2.377

**Table 7.** Co-integration test of the series ln (D), ln (INC), and ln (P)

<b>No. of CE(s)</b>	<b>Eigenvalue</b>	<b>Statistic</b>	<b>Critical Value</b>	<b>Prob.**</b>
None *	0.331964	50.31629	42.91525	0.0077
At most 1	0.176288	22.48079	25.87211	0.1249
At most 2	0.123548	9.099284	12.51798	0.1743

**Table 8.** Volatility by years

<b>Years</b>	<b>Volatility</b>	<b>Years</b>	<b>Volatility</b>
2011	4.139	2015	18.009
2012	2.824	2016	4.618
2013	1.546	2017	3.500
2014	9.488	2018	5.143

**Table 9.** Volatility values monthly

<b>Date</b>	<b>Volatility</b>	<b>Date</b>	<b>Volatility</b>	<b>Date</b>	<b>Volatility</b>
01.08.2013	0.148	01.04.2014	4.397	01.12.2014	3.571
01.09.2013	0.122	01.05.2014	0.567	01.01.2015	0.718
01.10.2013	0.172	01.06.2014	0.198	01.02.2015	11.273
01.11.2013	0.908	01.07.2014	0.513	01.03.2015	9.414
01.12.2013	0.263	01.08.2014	2.740	01.04.2015	0.180
01.01.2014	0.746	01.09.2014	1.676	01.05.2015	0.688
01.02.2014	2.870	01.10.2014	2.170	01.06.2016	0.696
01.03.2014	2.724	01.11.2014	3.646	01.07.2016	0.319

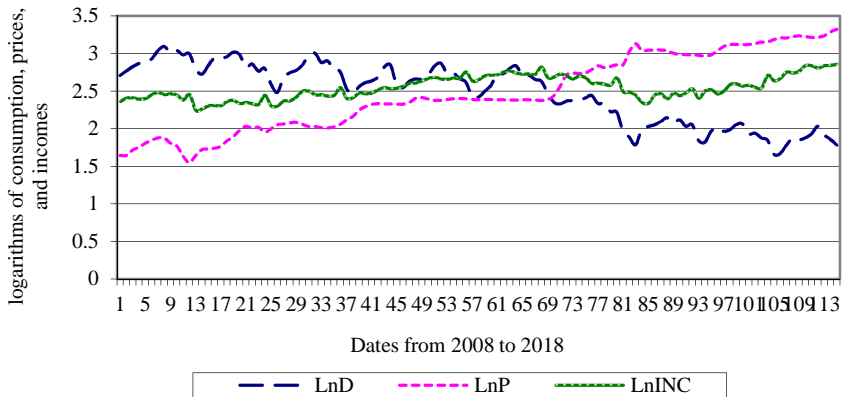
**Table 10.** Summary of elasticity estimates for different models for three periods

Models of estimation of elasticity	Pre-crisis period			Crisis period			Post-crisis period		
	Value	Std. Dev.		Value	Std. Dev.		Value	Std. Dev.	
Static model	$a_0$	5.527	0.436	0.564	0.601		9.787	1.975	
	$a_1$	-0.543	0.145	-0.383	0.415		-0.470	0.331	
	$a_2$	0.274	0.257	1.068	0.590		0.235	0.166	
Error correction model	$\beta_0$	0.636	1.078	0.409	2.098		-0.006	0.013	
	$\beta_1$	-0.391	0.271	-0.337	0.335		-0.486	0.272	
	$\beta_2$	0.853	0.187	1.067	0.481		0.203	0.182	
Dynamic model	$\theta_0$	0.943	0.317	-0.931	0.640		0.669	0.751	
	$\theta_1$	-0.146	0.052	-0.847	0.389		-0.538	0.224	
	$\theta_2$	0.131	0.083	0.815	0.402		0.011	0.065	
	$\theta_3$	0.811	0.054	0.476	0.226		0.933	0.047	

**Table 11.** Criteria for statistical significance for long-term dependence in the post-crisis Period

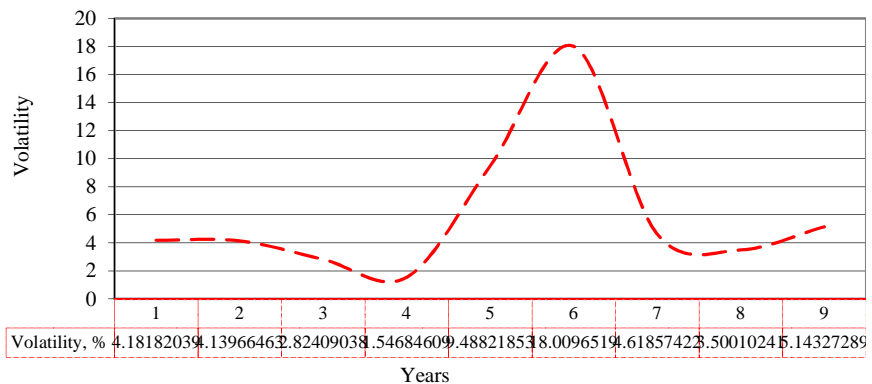
Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNP_95	-0.470	0.331	-1.418	0.163
LNREAL_W	0.203	0.182	2.230	0.031
C	9.787	1.975	4.955	0.000
@TREND	-0.011	0.005	-1.690557	0.0982
R-squared	0.733	Mean dependent var		11.236
Adjusted R-squared	0.715	S.D. dependent var		0.209

**Figure 1.** Graphs time-series logarithms of consumption, prices, and incomes



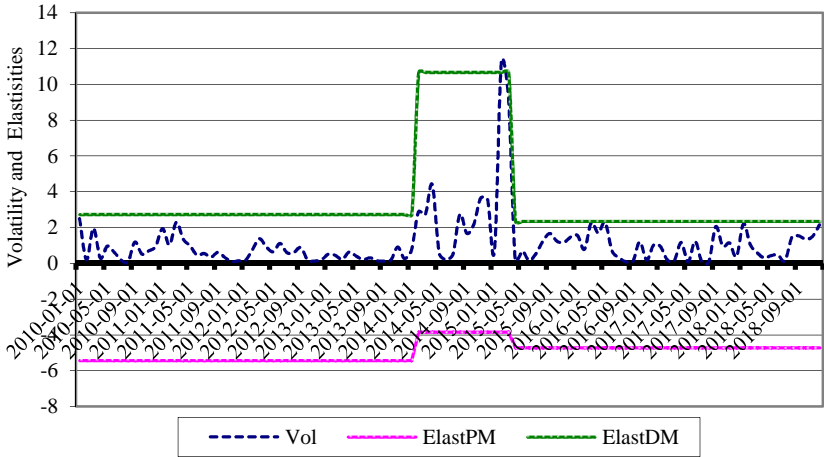
Note: LNDG – ln (D), LNINC – ln (INC), and LNP – ln (P)

**Figure 2.** Price volatility (%) for the period 2010–2018 by year (each period means a year beginning in 2010)





**Figure 3.** Superimposing graphs of elasticities and volatility monthly



Note: Volatility – Vol, Price elasticity – ElastPM, Elasticity of income – ElastDM).