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Pro-Inflationary Impact of the Oil Market—A Study for Poland

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Abstract: The economic activity of businesses and the living standards of the population are largely dependent on inflation. Here, energy prices are of particular importance. Energy is what offers a competitive edge to economies. Therefore, many energy sectors still remain under state control. However, the fuel market is free although highly concentrated. The primary objective of this study was to determine the impact of fuel price changes on inflation in Poland. The research was based on causality models and regression models including asymmetry correction. The flow path was analyzed of price impulses from the basic raw material (i.e., crude oil) through wholesale diesel prices to inflation. The study demonstrates that with each successive stage of raw material processing, price volatility proves to be weaker. However, the final effect is still significant: inflation is largely shaped by energy carriers and, here, specifically by fuel prices. Such results have serious implications for the state's economic policy. On one hand, they point to the limitations of this policy and, on the other hand, they raise questions about the legitimacy of the reforms that free up energy markets.

Keywords: oil prices; inflation; exchange rate; causality

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1. Introduction

Energy is one of the fundamental concepts in physics, and it is also an important factor in overall economic growth, which is why it is given special importance in economics. In physics, energy refers to the ability of a system to do work or produce heat. In economics, energy refers to any raw material and resource containing significant amounts of physical energy, thus enabling work to be performed [1]. The economic analysis of production is not oriented toward energy flows and the performance of work in the physical sense, but toward the process of value creation.

When analyzing the relationships between the economy and energy, the following facts can be noted:

- cheap energy, and even more so, energy efficiency, are crucial for economic growth [2];
- from a historical perspective, the increase in energy consumption due to the supply of a relatively cheap source of energy such as coal is considered as a key factor in the industrial revolution in Great Britain, and later worldwide [3];
- there is a clear, long-term relationship between the volume of the domestic product and the volume of energy consumption in the economy. This relationship is significant, especially for countries with lower energy consumption levels and it clearly weakens for countries with medium and high levels of energy consumption. This is because highly developed countries use energy more efficiently. Due to technological progress, there has been faster growth in domestic product than in energy production. In the 20th century, the volume of the product per one unit of energy consumption roughly doubled [4]; and

– there is a clear short-term relationship between changes in energy consumption and changes in GDP. This relationship is almost proportional, being strictest on the level of the global economy. However, the positive income elasticity of energy demand is gradually declining.

The determinants of energy consumption and changes in energy consumption in the national economy may be represented using a simple identity:

$$E = L \cdot GDP/L \cdot E/GDP, \tag{1}$$

This leads to three simple conclusions:

– population growth (L) increases energy consumption E in the economy,
– an increase in product per capita (GDP/L) raises energy consumption in the economy, and
– a decrease in specific energy consumption (E/GDP) and, therefore an increase in energy efficiency, results in a reduction in energy consumption in the economy.

However, the formula presented above does not specify any quantitative relationships between variables and, above all, it does not rely on any theoretical premises that could provide grounds for modeling the relationship between the economy and energy consumption. Attempts may be taken to derive these from economic growth models. In this context, what remains controversial is whether to treat energy as a factor of production, just like human labor and capital. However, regardless of the differences between the different versions, economic growth models do not consider raw materials including energy as a separate variable. Mainstream economic models decouple economic growth from raw materials including energy [5], which in practice could lead to their depletion and welfare falling to zero [6,7].

A useful theoretical approach to account for the interaction between energy, environment, and economic growth is the models proposed by Cass [8] and Koopmans [9]. In these, the future-oriented behaviors of producers and consumers are combined with the past-derived linkages between investments and capital resources. Alternative growth paths do not directly depend on energy and environmental policies, but this is indirectly through their impact on medium-term changes [10].

Increasing importance is being attached to the issue of ecology. In particular, the use of non-renewable energy sources—coal, oil and gas—is being critically viewed from an ecological perspective. Differences between traditional and ecological approaches to energy and economic growth include the following issues, among others [11,12]:

– identifying the main source of productivity growth. Traditionally, this is assumed to be technical progress, while in the green approach, this is an increasing availability of high quality energy;
– possibilities for a substitution of inputs. In the traditional approach, these can be determined by a flexibility of substitution at the sectoral level, while in the green approach, the flexibilities estimated in this manner were assumed to be overestimated as they did not take energy into account; and
– the marginal productivity of energy inputs. In the traditional approach, this is proportional to the share of energy in the value of the product, while in the ecological approach, it is greater than this share.

In models proposed by ecological economists, increases in energy inputs are crucial in explaining economic growth [13,14].

The long-term connections between energy consumption and economic growth are two-way connections as a rule, and this was only the methodology adopted and the research sample as well as the degree of economic development of the country that determines which direction will prove to be stronger [15–18]. Apart from long-term studies, the analyses have also covered short-term relationships between the economy and energy, primarily in the context of cyclical fluctuations. The focus has primarily been on the effect of shocks that are taken into account in short-run equilibrium models [19]. The vulnerability of the economy to supply shocks has decreased markedly over the past 200 years as the economy shifted from coal to oil [20,21].

In the past few decades, the greatest number of analyses have been conducted to assess the impact of oil shocks on the economy [22–24]. Detailed analyses have focused on the impact of energy prices, especially oil prices, on the macro economy in the post-World War II period. Many studies have found a significant negative effect of oil price increases on GDP [25–27], although net positive effects were found for energy importers [28,29].

Several studies have found an asymmetric relationship between the domestic product and oil prices. The effect for price increases was stronger than for price decreases [30,31]. In some studies, the results obtained indicated that, after taking into account other macroeconomic variables, the impact of oil prices on changes in the domestic product was insignificant [32]. Much of the recessionary impact of oil price increases may be due not to oil price changes as such, but due to endogenously determined effects on the part of monetary policy [33,34]. The rise in oil prices caused inflation to rise, prompting central banks to tighten monetary policy.

An important area related to energy production and consumption is the problem of energy market regulation and the state energy policy. Energy policy focuses on three main areas [35]:

- energy security, understood as the ability to meet the current and future energy demand and to withstand any potential systemic shocks in relation to energy supply at the level of a national economy and/or a group of countries;
- energy justice, understood as an ability to ensure common access to energy at affordable and fair prices that ensure the competitiveness of the economy and its stable growth; and
- environmental sustainability, understood as a transition of the energy system toward mitigating and avoiding potential environmental damage and climate change impacts.

These goals can be formulated on the level of the national policies of individual countries, but also on the level of economic and political groupings and on the global level. In the conditions of a multiplicity of goals and participants in the decision-making process, a conflict between these is quite natural, and a mechanism for resolving these disputes and decision making needs to constitute a component of the energy policy. In the energy policy of the European Union, these are supplemented by the creation of an internal energy market.

Energy policy makes use of various instruments of influence. Among these, we can distinguish regulatory and market-based instruments. Examples of the former include quality standards, quotas, and prohibitions. The second group includes fiscal and non-fiscal instruments. A well-known proposal in economic theory to internalize external costs (the costs are borne by the issuer) is the Pigou tax. This tax should be equal to the full marginal cost/loss resulting from the emission. As a result, the volume of pollutant emissions is reduced to a level at which the marginal benefits of the emitter are equal to the marginal social costs of the emissions. The advantages of this tax, in addition to those outlined above, are that it offers producers a high degree of flexibility in their operations, relatively low administrative costs, and it stimulates the development of low-carbon technologies [36]. Nevertheless, the rationale and applicability of the Pigou tax are subject to theoretical and practical controversies. Theoretical arguments point to the assumed determinants of the efficiency of the tax. The interaction with other taxes causes the size of the optimal tax to be below the optimum based on the marginal cost criterion of emissions [37]. In turn, the cross elasticity between energy prices and leisure time may lead to the conclusion that the optimal tax should be higher in relation to this criterion [38]. Practical problems arise from the difficulty of estimating the marginal social costs of emissions and their variation depending on, among others, the type of emissions and the location of the issuer. What might be an alternative proposal under these conditions is a criterion based on environmental objectives [39]. Under such an approach, the objective could be to limit emissions to a certain level. Regulations based on such a principle could reduce the marginal costs of emissions and provide an incentive to develop innovations that reduce emissions. The efficiency of such regulations is enhanced by a system of tradable emission rights [40]. Distortions in the functioning of markets that are due, for example, to price and wage rigidity, undermine the effectiveness of general tax instruments. As a result, energy policy should also include other instruments (e.g., those that take into account differentiation of taxes according to products and raw materials, subsidies, etc.) [41].

Despite the high politicization of the energy market, economic instruments play a fundamental role in its regulation. According to the traditional classification, they can be divided into fiscal and non-fiscal instruments. In economic policy, regulation of the energy sector has largely been subordinated to the achievement of macroeconomic objectives including control of inflation, balance of payments, and technological development [42]. The apogee of these actions was during the oil crises of the 1970s. The ban on oil exports in the USA was a spectacular, but not the only example of such a policy. Energy companies were the main target of the policy, and they incurred costs, but also had some benefits [43]. The source of the latter was primarily regulations protecting domestic companies from international competition.

In many countries, what was an instrument for achieving the primary objectives had a direct influence on energy sector companies, often state-owned ones as well as direct interventions to limit competition in the industry [44]. The experience of the past decades shows that the hierarchy of objectives in the energy policy has changed and, consequently, the instruments preferred by states to influence the sector have also changed. First of all, energy is no longer perceived as a good of social necessity, which was used to justify state support and interference in the past; external costs undermine the idea of always available, cheap energy; they question the idea of the economies of scale underlying the preference for large, centralized electricity systems and energy policy.

At the same time, however, this policy continues to emphasize the importance of technological progress to counteract the scarcity of resources and to enable the supply of energy to meet the expected growth in demand. A review of energy policy goals is also evident in China and in the European Union [45]. There is a stronger emphasis on increasing energy efficiency and reducing the environmental impact of emissions.

In empirical studies carried out for various countries, a statistically significant impact of energy prices on inflation has most frequently been revealed. However, conclusions were often drawn on the basis of primary energy prices including oil prices [46–50], while from the point of view of households and businesses, it is petrol and diesel prices that they observe directly and make decisions on the basis of these prices [51,52] and not the prices of primary energy (e.g., oil). Therefore, the price path from primary energy to the final product needs to be included in the research. The significant influence of the petrol price rather than the oil price has been demonstrated in more recent studies [53–56].

The oil crises of the 1970s became the main cause of increased interest in the subject of the relationship between the energy commodity market and economic development and inflation. Oil prices were pointed out as those responsible for economic recessions [57], although modeling the relationship between oil prices and economic activity provided many problems, especially those related to the constancy of this relationship and linearity [58], which is related to an improvement in the efficiency of energy use.

From a theoretical perspective, oil price volatility affects major macroeconomic processes through supply and inflationary transmission channels [59].

Through the supply channel, changes in oil prices have a direct impact on production, where changes in marginal production costs are the cause. Decreases and corresponding increases in production costs are caused by lower and adequately higher raw material prices [60]. For the economy, uncertainty related to fluctuations in raw material prices is particularly dangerous, as it limits the amount of investment [61]. The inflation channel, on the other hand, indicates the effect of oil price changes on core inflation or inflation related expectations [62]. There is a fairly simple relationship between supply and inflation channels; changes in the production costs of a whole range of energy-intensive goods result in changes in their prices, which affects the prices of consumer goods, thus having a direct impact on inflation [63].

The economy is particularly stimulated by falling oil prices, as household budgets are relieved by lower energy bills, and overall consumption then rises [64]. On one hand, rising consumption triggers a demand inflation, while on the other, falling oil prices mitigate its effects [65]. Hence, further difficulties arise in modeling the impact of energy prices on economic activity and inflation.

The results of extensive research by Fuinhas et al. [66] prove that energy consumption drives economic growth, but only in the short-run. The ratio of oil production to oil consumption has exerted a positive impact on growth in both the short- and long-run. Oil prices only exert a positive effect on growth in the short-run. Oil rents depress growth, suggesting that oil is more of a curse than a blessing for economies.

The impact of oil prices on inflation occurs through several channels. On one hand, petroleum products constitute a component of consumption baskets, so changes in their prices directly affect inflation rates; on the other hand, these products are used in production and transport, so their price increase generates higher production costs and, consequently, higher prices of consumption goods.

Fluctuations in oil prices in world markets have particularly negative consequences for the functioning of the economies of those countries that import significant quantities of this raw material. However, in general, whether a country is an oil exporter or importer, economic activity depends on oil prices [67,68] and, even more importantly, a significant impact was found on exchange rates, interest rates, inflation, and unemployment [69–71].

In many countries including Poland, the years 2021 and 2022 brought a sharp rise in inflation. The causes of this phenomenon are seen in many social, political, and economic aspects. The most commonly cited are overly expansive fiscal and monetary policies, broken supply chains as a result of the pandemic, and the society's unwinding after the lockdown period; however, a lot of attention is paid to energy markets. In 2021, the prices of all primary energy sources: coal, oil, and gas rose sharply. Policy makers very often use the impact of energy prices on the economy to explain the general rise in inflation. The problem adopted in the study concerns the determination of the impact of energy prices and, more specifically, oil prices, on the overall price increase. Therefore, the aim of the study was to determine the direction, strength, and statistical significance of the relationship between oil prices and inflation in Poland.

Hypotheses have been put forward that:

Hypothesis 1 (H1). *Changes in oil prices in the world markets are an important pro-inflationary factor in Poland.*

Hypothesis 2 (H2). *The price impulses from oil world market indirectly passes through the prices of diesel and gasoline.*

In a practical assessment of the significance of the impact of oil prices on inflation, it is not only oil prices that may be important, but due to the fact that there are several processing stages between the primary energy source and the final product, there is an additional problem of determining the significance of the product flow chain.

The research is important because the possible confirmation of the hypotheses calls into question the effectiveness of classical methods of monetary policy in terms of price normalization. Rather, it will move toward fiscal policy. The model of the central bank's independence may be undermined. Since the causes of inflation are of a cost nature, it is easier to regulate prices with the tax system than with interest rates.

In this respect, the situation of Poland is a valuable research object because after the period of stable prices, recent years have brought increased inflation. On one hand, the Polish government has supported enterprises with anti-COVID shields, and on the other hand, energy prices have risen worldwide. Today's effect is inflation that has been unheard of for many years.

2. Materials and Methods

The research used monthly Brent crude oil prices, monthly USD-PLN exchange rate quotations, monthly wholesale prices of diesel oil offered by PKN Orlen, and the CPI inflation index. The data covered the years 2004–2021. The monthly frequency of data is dictated by the frequency of the calculations of the CPI inflation index reported by the Central Statistical Office. The data used makes it possible to trace price impulses directly from the Brent crude oil market on inflation in Poland, but also to trace price impulses in intermediate links and, hence, from Brent quotations through the exchange rate and wholesale diesel oil prices to the inflation index, according to Scheme 1.

Brent Crude Oil (in USD/bbl) → USD/PLN → Brent Crude Oil (converted in PLN/bbl) → diesel fuel (in PLN/tone) → CPI

Scheme 1. Tested price impulses.

What is very important in the context of the whole study is the presentation of world oil prices in the national currency. This is a procedure that is recommended by numerous authors [72–75].

The research was conducted in several stages:

1. Shaping the values of the variables under evaluation. The graphs illustrate the trends of the variables under evaluation in their original version. No transformation was made at this point. The relevant pairs shown in the graphs refer to the successive stages of diesel production and they end with the inflation rate.
2. Correlational study. The study allowed for an assessment of the long-term relationship between the time series examined. The data for the correlation study was logarithmized, additionally further modeling of the relationship was carried out on the basis of the data logarithmized. Due to the possible occurrence of apparent correlations, this study was not interpreted in a causal convention but only through the prism of trend consistency.
3. Study of variability. Simple statistics concerning the mean and standard deviation of the logarithmized values of the time series. The behavior of the standard deviation is crucial here, which shows the magnitude of the variability transmission. Although this is not a classic fiscal policy task, it can be used to manage the market and inflation. This is currently happening in Poland.
4. Tests of the stationarity of the time series. The study used the ADF test [76]; this allowed for an assessment of the fulfilment of the assumptions of the applicability and reliability of modeling the relationship between the time series evaluated.
5. Causality study. The Granger test for a two-variable VAR model with k lags of the form [77] and:

$$\begin{aligned} x_t &= a_1 + a_{1.1}x_{t-1} + \ldots + a_{1.k}x_{t-k} + b_{1.1}y_{t-1} + \ldots + b_{1.k}y_{t-k}, \\ y_t &= a_2 + a_{2.1}x_{t-1} + \ldots + a_{2.k}x_{t-k} + b_{2.1}y_{t-1} + \ldots + b_{2.k}y_{t-k}. \end{aligned} \tag{2}$$

The significance of the $a_{i.k}$ and $b_{i.k}$ parameters was tested with the F statistic.

6. Cointegration testing. Cointegration was tested on the basis of the following equations:

$$\ln(\mathrm{Y}) = a_1 \cdot \ln(\mathrm{X}) + a_0, \tag{3}$$

where the relationships between the X and Y variables were consistent with the course marked in Scheme 1. The residuals of these equations were subjected to the ADF stationarity test. The aforementioned equations determined the long-run equilibrium path (equation) around which the values of the economic processes analyzed were run. The differences between the value of the time series and the path determined of the long-run equilibrium were presented in the graphs and interpreted as short-run deviations.

7. Application of the Engel–Granger theorem [78]. According to the Engel–Granger theorem, if X and Y variables are integrated to the degree of (1.1), that is, the processes are non-stationary but their first differences are stationary, and it is possible to determine a long-run equilibrium path whose residuals will be stationary, then it is possible to represent, in a single equation, the short-run relationship between these variables and the process of reaching long-run equilibrium:

$$\Delta y_t = \alpha ECT^{+}_{t-1} + \beta ECT^{-}_{t-1} + \sum_{i=1}^{k-1} \theta_i \Delta y_{t-i} + \sum_{i=0}^{k-1} \gamma_i \Delta x_{t-i} + \varepsilon_t \quad (4)$$

where:

ECT_{t-1}—series of positive (+) and negative ($-$) residuals from the cointegrating equation;
α, β—the rate at which Y variable adjusts to the long-run equilibrium level with X variable after positive (α) or negative (β) precipitation; in order for the rebalancing mechanism to work properly, the value of this parameter needs to be negative;
θ_i—the impact of lagged values of the increment of Y variable on the current increment of this variable; and
γ_i—the effect of current and lagged values of the increment of X variables on the current increment of Y variable.

8. Graphical representation of the importance of oil price lags in shaping inflation.

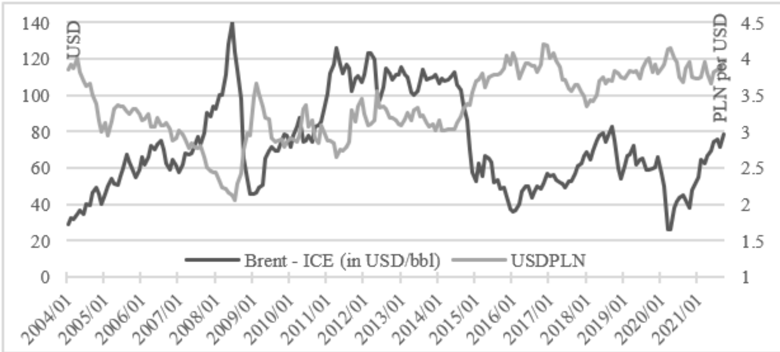
The use of the Engel–Granger model allows for the simultaneous testing of short-term and long-term effects. This is an unquestionable advantage of this model, as its results may be an important implication for macroeconomic policy. Short-term and long-term reactions as well as time shifts in the transmission of price impulses are important for its effectiveness.

3. Results

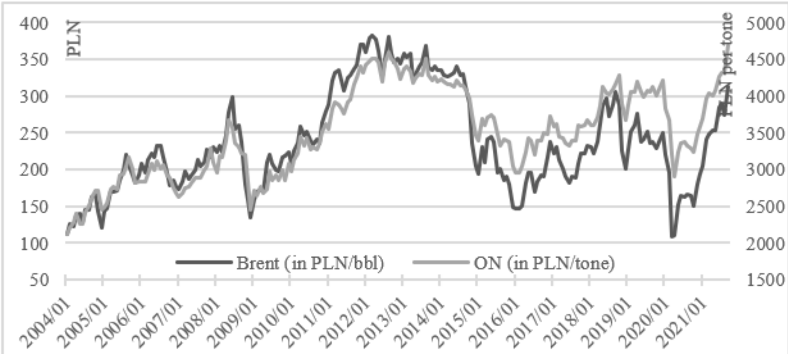
The research results are summarized under three headings: (1) an evolution of the variables evaluated and the correlations between the variables; (2) a causality analysis; and (3) modeling of dependencies.

3.1. Evolution the Values of Variables Evaluated

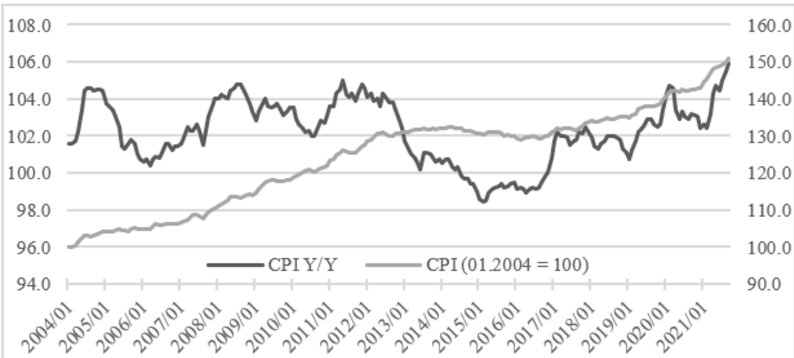
The time series analyzed in their original form are presented in Figure 1. The order of the presentation is consistent with the importance of the volumes for the economy, starting from the most global ones and descending to domestic volumes. Therefore, the first graph presents Brent crude quotations (USD/bbl) and the USD/PLN exchange rate; the second graph converts Brent crude quotations into PLN and shows the wholesale prices of diesel oil (PLN/ton), while the third graph presents the CPI Y/Y inflation indices (month-to-month inflation in the corresponding month of the previous year) and consumer price levels in subsequent months relative to January 2004 prices (CPI 01.2004 = 100).



(**a**)



(**b**)



(**c**)

Figure 1. The values of the variables evaluated. (**a**) Stock exchange oil prices and exchange rate; (**b**) Oil and diesel oil prices in Poland; (**c**) Inflation indicators in Poland.

The logarithm values of the variables analyzed underwent a correlation study (Table 1). This study can be interpreted in the context of a long-term relationship.

Table 1. Correlation connections of the logarithmic variable levels.

Correlations	LN_BRENT_USD	LN_USDPLN	LN_BRENT_PLN	LN_ON (Orlen)
LN_BRENT_USD	1	−0.6360	0.9187	0.6395
LN_USDPLN	−0.6360	1	−0.2795	0.1164 *
LN_BRENT_PLN	0.9187	−0.2795	1	0.8552
LN_ON (Orlen)	0.6395	0.1164 *	0.8552	1
CPI Y/Y	0.1922	−0.3358	0.0672 *	−0.0372 *
CPI (01.2004 = 100)	0.0994 *	0.5139	0.3867	0.7661

* Statistically insignificant at $p = 0.05$.

Over the period of 2004–2021, the variables under study followed different trends. The period was long enough to include both significant sharp increases in quotations and spectacular decreases. Oil prices recorded historic highs in 2008, when oil cost around 140 USD/bbl, and a historic low during the uncertainty surrounding the coronavirus pandemic in March 2020, when prices fell below 30 USD/bbl. Local maxima also occurred in 2011 and 2018, and the years 2009 and 2016 saw the minima. At the end of the period under review, the oil price approached 80 USD/bbl, which was slightly above the period's average of 72 USD/bbl.

What happened in the world oil market had a very strong impact on the domestic oil and diesel market. The turning points of development trends fell in the same periods, and correlation links were very strong. The correlation between Brent oil quotations in USD/bbl and Brent oil quotations expressed in PLN (in PLN/bbl) was estimated at 0.9187. This result was possible to achieve despite the negative relationship between the Brent oil quotations and the exchange rate (−0.6360). Additionally, the wholesale diesel prices of PKN Orlen were strongly correlated with oil quotations (0.6395 and 0.8552, expressed in USD and PLN, respectively). The exchange rate was very weakly related to oil and diesel prices in the domestic market but, as indicated above, it proved to be quite strongly and inversely dependent on world oil quotations.

From the perspective of the objective of this study, however, it is important which of the oil market related parameters affects inflation in Poland. It becomes evident that the current price changes expressed by CPI Y/Y are weakly influenced by world oil prices, while the general price level is influenced by diesel prices. Here, the relationship of the CPI (01.2004 = 100) with wholesale oil prices was as high as 0.7661.

In assessing the evolution of oil prices, the issue of volatility looks interesting (Table 2).

Table 2. Volatility of crude oil and diesel oil prices.

Time Series	Statistics	
	Mean	**St. Dev.**
LN_BRENT_USD	4.23	0.36
LN_USDPLN	1.20	0.15
LN_BRENT_PLN	5.43	0.29
LN_ON (Orlen)	8.14	0.18

Due to the logarithmic transformation, it becomes possible to assess the scale of the variability of the time series under study. From the perspective of domestic economy stability, it is quite important to note that the scale of wholesale diesel price variability is twice lower than the variability scale of the basic raw material (i.e., Brent crude oil: 0.18 and 0.36, respectively). This is largely influenced by the exchange rate, as after converting Brent crude prices from USD to PLN, the price volatility decreased from 0.36 to 0.29. Another issue is the stability of other production costs; it is natural that the volatility of the price of the primary raw material is higher than that of the final product, but here the scale of the difference proved to be significant and in favor of the domestic market

3.2. Causality Testing

The time series studied were classical time series in which the levels are non-stationary, and the first differences are stationary (Table 3).

Table 3. Stationarity tests.

Time Series	I(0)		I(1)	
	t-Stat	Prob.	*t*-Stat	Prob.
LN_BRENT_USD	0.2196	0.7491	−11.4215	0.0000
LN_USDPLN	−0.1760	0.6217	−13.4881	0.0000
LN_BRENT_PLN	0.4209	0.8034	−12.5273	0.0000
LN_ON (Orlen)	1.2114	0.9422	−13.6231	0.0000
CPI_Y/Y	0.5256	0.8286	−10.1048	0.0000
CPI_01.2004 = 100	4.5079	1.0000	−7.6490	0.0000

The reason for the non-stationarity here is the trend, which is also a classical situation. This situation forces the modeling of the relationship using the first differences. The trend may be responsible for the occurrence of apparent dependencies. Although the nature of the study excludes apparent dependencies, the final model was nevertheless performed for the first differences.

Very important information in the context of the problem covered by the study is contained in Table 4.

Table 4. Causality tests.

Cause (X)	Effect (Y)	Lags: 1		Lags: 2		Lags: 3		Lags: 4	
		F-Stat	Prob.	F-Stat	Prob.	F-Stat	Prob.	F-Stat	Prob.
LN_BRENT_USD	LN_USDPLN	0.1285	0.7204	2.4685	0.0872	1.7158	0.1649	1.6451	0.1644
	LN_BRENT_PLN	0.5575	0.4561	2.0265	0.1344	1.8527	0.1388	2.1488	0.0762
	LN_ON (Orlen)	0.4356	0.5100	20.1150	0.0000	14.0981	0.0000	11.3545	0.0000
	CPI_Y/Y	0.1629	0.6869	12.4984	0.0000	8.8983	0.0000	6.6557	0.0001
	CPI_01.2004 = 100	0.1945	0.6597	6.2317	0.0024	5.4606	0.0013	5.1746	0.0005
LN_USDPLN	LN_BRENT_USD	1.4272	0.2336	1.0621	0.3476	1.2001	0.3108	0.9763	0.4216
	LN_BRENT_PLN	0.5575	0.4561	2.0265	0.1344	1.8527	0.1388	2.1488	0.0762
	LN_ON (Orlen)	0.0041	0.9490	5.1204	0.0068	3.4408	0.0178	2.8493	0.0250
	CPI_Y/Y	2.8843	0.0909	1.2572	0.2866	0.8265	0.4806	1.6642	0.1598
	CPI_01.2004 = 100	0.0001	0.9912	1.8474	0.1603	1.2306	0.2997	1.3027	0.2703
LN_BRENT_PLN	LN_BRENT_USD	1.4272	0.2336	1.0621	0.3476	1.2001	0.3108	0.9763	0.4216
	LN_USDPLN	0.1285	0.7204	2.4685	0.0872	1.7158	0.1649	1.6451	0.1644
	LN_ON (Orlen)	1.3376	0.2488	15.6520	0.0000	11.4826	0.0000	8.8874	0.0000
	CPI_Y/Y	0.0982	0.7543	18.5652	0.0000	13.8072	0.0000	10.7103	0.0000
	CPI_01.2004 = 100	0.3446	0.5578	11.4435	0.0000	9.8737	0.0000	8.8370	0.0000
LN_ON (Orlen)	LN_BRENT_USD	1.9707	0.1619	0.3966	0.6731	0.3607	0.7814	0.3559	0.8397
	LN_USDPLN	2.1439	0.1446	3.9852	0.0200	3.2669	0.0223	2.9233	0.0222
	LN_BRENT_PLN	0.0294	0.8641	0.1699	0.8439	0.0980	0.9610	0.2806	0.8903
	CPI_Y/Y	0.0011	0.9733	14.3009	0.0000	9.8345	0.0000	7.1069	0.0000
	CPI_01.2004 = 100	0.0763	0.7827	12.5271	0.0000	9.1428	0.0000	6.6758	0.0001
CPI_Y/Y	LN_BRENT_USD	0.3681	0.5447	2.6104	0.0759	2.1172	0.0992	1.7283	0.1451
	LN_USDPLN	0.6363	0.4260	0.3357	0.7152	0.2802	0.8396	0.7201	0.5791
	LN_BRENT_PLN	0.0432	0.8355	1.8151	0.1654	1.7809	0.1520	1.0640	0.3755
	LN_ON (Orlen)	0.2192	0.6401	0.5863	0.5573	0.9526	0.4162	1.0066	0.4052
	CPI_01.2004 = 100	17.3214	0.0001	2.0450	0.1320	1.5107	0.2129	2.0330	0.0912
CPI_01.2004 = 100	LN_BRENT_USD	0.6119	0.4350	0.3243	0.7234	0.2975	0.8272	1.0389	0.3882
	LN_USDPLN	6.4005	0.0121	3.9869	0.0200	3.0559	0.0294	3.9583	0.0041
	LN_BRENT_PLN	0.2607	0.6102	0.6853	0.5051	0.2843	0.8367	0.3934	0.8132
	LN_ON (Orlen)	3.8648	0.0506	2.3814	0.0950	2.1150	0.0995	1.2897	0.2753
	CPI_Y/Y	0.0286	0.8659	0.4815	0.6186	0.4969	0.6849	0.4000	0.8085

This study shows the results of the causality test. The direction of the impulse flows and the response latency can be read here. The most important findings include the following:

- Brent crude oil quotations are the cause of wholesale diesel prices in Poland and the CPI_Y/Y inflation index with a minimum lag of two months and the CPI_01.2004 = 100 index with a minimum lag of four months;
- the USD/PLN exchange rate is the cause of wholesale diesel prices in Poland with a minimum lag of two months;
- Brent crude quotations expressed in PLN (and thus the combined effect of Brent crude quotations and the exchange rate) are the cause of wholesale diesel prices in Poland, the CPI_Y/Y inflation index, and the CPI_01.2004 = 100 index with a minimum lag of two months;
- wholesale diesel prices in Poland are the cause of the CPI_Y/Y and CPI_01.2004 = 100 inflation indices with a minimum lag of two months, but also of the exchange rate with a minimum lag of two months;
- CPI_Y/Y inflation index is not a cause of any variables; and
- CPI_01.2004 = 100 is the cause of the exchange rate with a minimum lag of two months.

In general, as expected, all the causal relationships listed in Scheme 1 proved to be statistically significant. In addition, the relationship between the exchange rate and wholesale diesel prices appeared to be two-way but the direction indicated in Scheme 1 was stronger than the reverse direction. The effect of inflation on the exchange rate can also be revealed, but this is a side effect to the flow of impulses in Scheme 1.

3.3. Modeling of Dependencies

Modeling of the relationship began with the implementation of cointegrating models. The long-term relationship, however, one that is on the verge of statistical significance, concerns the impact of Brent oil quotations expressed in USD and after taking the USD/PLN exchange rate into account as well as the impact of wholesale diesel prices on the CPI_Y/Y inflation rate (Table 5). The impact of wholesale diesel prices was the strongest here.

Table 5. Cointegrations models and tests (A).

Independent Variable (X)	Dependent Variable (Y)							
	CPI_Y/Y				CPI_01.2004 = 100			
	Cointegration Model		Cointegration Test		Cointegration Model		Cointegration Test	
	Coeff.	Prob.	*t*-Stat	Prob.	Coeff.	Prob.	*t*-Stat	Prob.
LN_BRENT_USD C	0.9194 98.3251	0.0049 0.0000	−1.8018	0.0681	3.6084 109.1536	0.1482 0.0000	0.2070	0.7455
LN_BRENT_PLN C	0.4002 100.0396	0.3289 0.0000	−1.8393	0.0628	17.4616 29.6693	0.0000 0.0582	−0.5074	0.4957
LN_ON (Orlen) C	−0.3567 105.1156	0.5888 0.0000	−1.8853	0.0568	55.6659 −328.8170	0.0000 0.0000	−1.9773	0.0462

On the other hand, it was only the wholesale prices of diesel oil that had a significant impact on the CPI_01.2004 = 100 inflation index. No significant impact of Brent crude oil quotations was revealed here. This result was due to lagged responses, which were not examined here.

Within the time series of crude oil and diesel, a significant influence of Brent on wholesale crude oil prices was revealed, but without cointegration (Table 6). This is partly a result of economic and political decisions related to the fuel price formation in Poland. On the other hand, Brant crude prices expressed in PLN were strongly cointegrated with original Brent crude prices.

Table 6. Cointegrations models and tests (B).

Independent Variable (X)	Dependent Variable (Y)							
	LN_ON (Orlen)				LN_BRENT_PLN			
	Cointegration Model		Cointegration Test		Cointegration Model		Cointegration Test	
	Coeff.	**Prob.**	***t*-Stat**	**Prob.**	**Coeff.**	**Prob.**	***t*-Stat**	**Prob.**
LN_BRENT_USD C	0.3195 6.7918	0.0000 0.0000	−1.0918	0.2487	0.7384 2.3048	0.0000 0.0000	−2.1243	0.0326
LN_BRENT_PLN C	0.5315 5.2581	0.0000 0.0000	−1.4495	0.1372	- -	- -	-	-

Problems with cointegration are visible in the graphs of residuals (Figures 2 and 3). Generally, stationary graphs are expected, while the trend in question is visible. This may mean that the relationships examined are not long-term in reality, but are short-term only.

Figure 2. Residuals from cointegrating models: (**a**) CPI_Y/Y; (**b**) CPI_01.2004 = 100.

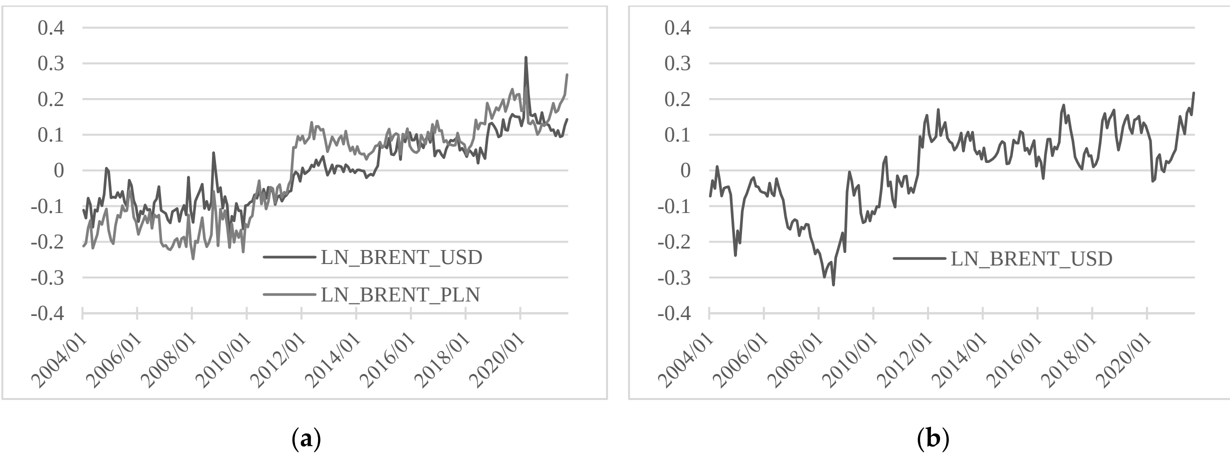


Figure 3. Residuals from cointegrating models: (**a**) LN_ON (Orlen); (**b**) LN_BRENT_PLN.

Thus, inflation could be explained by changes in fuel prices only in the short-term, recognizing that in the long-term, these variables are independent. However, a more reasonable explanation of this phenomenon is to recognize the surging influence of fuel quotations on inflation. Thus, any upward jump in fuel prices will potentially increase inflation on a permanent basis, while temporary decreases in fuel prices will not be of any special significance. This effect can be attributed to entrepreneurs' reluctance to reduce the prices of their products, even if production costs are falling. It is natural that in such circumstances, they will opt for a higher margin. This phenomenon, if true, should be observed in the error correction model with asymmetry (Table 7). This explains the procedure followed in the study.

Table 7. ECT models with asymmetry.

Variable	Dependent Variable: d(LN_BRENT_PLN)		Variable	Dependent Variable: d(LN_ON (Orlen))	
	Coeff.	Prob.		Coeff.	Prob.
d(LN_BRENT_USD)	0.8432	0.0000	d(LN_BRENT_PLN)	0.3317	0.0000
d(LN_BRENT_USD_(-1))	−0.0177	0.7907	d(LN_BRENT_PLN_(-1))	0.2053	0.0000
d(LN_BRENT_USD_(-2))	0.0263	0.6883	d(LN_BRENT_PLN_(-2))	0.1170	0.0003
d(LN_BRENT_PLN_(-1))	−0.0053	0.9408	d(LN_ON (Orlen)_(-1))	−0.4055	0.0000
d(LN_BRENT_PLN_(-2))	−0.0533	0.4556	d(LN_ON (Orlen)_(-2))	−0.1747	0.0078
ect_plus_(-1)	−0.0455	0.4365	ect_plus_(-1)	0.0197	0.6235
ect_minus_(-1)	−0.0311	0.4433	ect_minus_(-1)	−0.0896	0.0458
C	0.0017	0.7252	C	−0.0017	0.6225
Variable	**Dependent Variable: d(CPI_Y/Y)**		**Variable**	**Dependent Variable: d(CPI_01.2004 = 100)**	
	Coeff.	**Prob.**		**Coeff.**	**Prob.**
d(LN_ON (Orlen))	0.6266	0.2605	d(LN_ON (Orlen))	1.1183	0.0697
d(LN_ON (Orlen)_(-1))	2.9098	0.0000	d(LN_ON (Orlen)_(-1))	3.0643	0.0000
d(LN_ON (Orlen)_(-2))	0.4816	0.4185	d(LN_ON (Orlen)_(-2))	0.9523	0.1479
d(CPI_Y/Y_(-1))	0.3206	0.0000	d(CPI_01.2004 = 100_(-1))	0.3384	0.0000
d(CPI_Y/Y_(-2))	0.0523	0.4387	d(CPI_01.2004 = 100_(-2))	0.0407	0.5417
ect_plus_(-1)	−0.0520	0.1112	ect_plus_(-1)	0.0062	0.2913
ect_minus_(-1)	−0.0196	0.4712	ect_minus_(-1)	−0.0032	0.6744
C	0.0225	0.6085	C	0.1011	0.0456

Four error correction models were determined. These models apply to successive price transmissions concerning Scheme 1.

The first model concerns the Brent_USD→Brent_PLN transition, hence, this is between the world oil price expressed in USD and the price expressed in PLN; in essence, it is an exchange rate effect. There were no time shifts in this relationship, the current changes in Brent_PLN depend directly on the current changes in Brant_USD, and the strength of this translation was estimated to be 0.8432. In this model, the ect parameters were insignificant, which is in line with the expectations, because in fact, the study concerns the same quantity, only expressed in a different currency. Thus, it is not possible to talk about any long-run equilibrium here, since it is the same variable. However, from a practical point of view, what is most important is a combination of the information that past oil price volatility does not affect the present one and that oil price volatility expressed in PLN is smaller than that expressed in USD (Table 2). This results in a greater stability of the oil price in the domestic market.

The next phase of the transition from oil prices to inflation is between world oil quotations and domestic wholesale prices. Here, this is after taking into account the exchange rate (i.e., the Brent_PLN→ON(Orlen) model). In this model, the outcome variable was increments in wholesale diesel prices, and these were dependent on the current increments in world prices, plus their first and second lags. It is thus a reaction up to three months back, which is a positive reaction. Thus, a rise in world prices significantly increases the domestic prices, but a fall in world prices also lowers domestic prices. There was also an opposite reaction to lagged price changes. This reaction is methodologically justified because it means that the series of increments does not have a trend. The results of the ect parameter are interesting. The ect(plus) parameter was insignificant but the ect(minus) parameter was significant. This means that if the price in the domestic market deviates downward from the equilibrium price with the world price for some reason, a process is quickly triggered to restore this equilibrium, but if the price deviates upward, there is no significance of such a process. The most important finding of this model was the significant positive response of changes in domestic prices to changes in world prices and the impossibility of a permanent reduction in domestic prices relative to the world price.

What is of key importance is what is contained in models 3 and 4. These models concern the impact of wholesale diesel prices on inflation. What is also important is that the conclusions only partly depend on the CPI_Y/Y or CPI_01.2004 = 100 inflation indices adopted; mostly, they were common. First, inflation was strongly and statistically significantly influenced by changes in the price of diesel fuel, and this was a reaction with a lag of one month. Furthermore, inflation was significantly fixed as it reacted positively to its lag. In contrast, there was no long-run relationship with oil prices. However, such a rapid short-term reaction to changes in wholesale diesel prices gives ground to consider the fuel market as a key pro-inflationary factor. All the more so since these changes are unidirectional from fuel prices to inflation.

Figure 4 provides a simplified visualization of relationships that occur in the models discussed. Thus, starting from Figure 4a, current changes in world oil prices expressed in PLN are directly dependent on original prices expressed in USD. In Figure 4b, current changes in wholesale diesel prices depend on current changes in world oil prices but, also on their lags. In Figure 4c,d, inflation appears to lag one month in relation to changes in wholesale diesel prices.

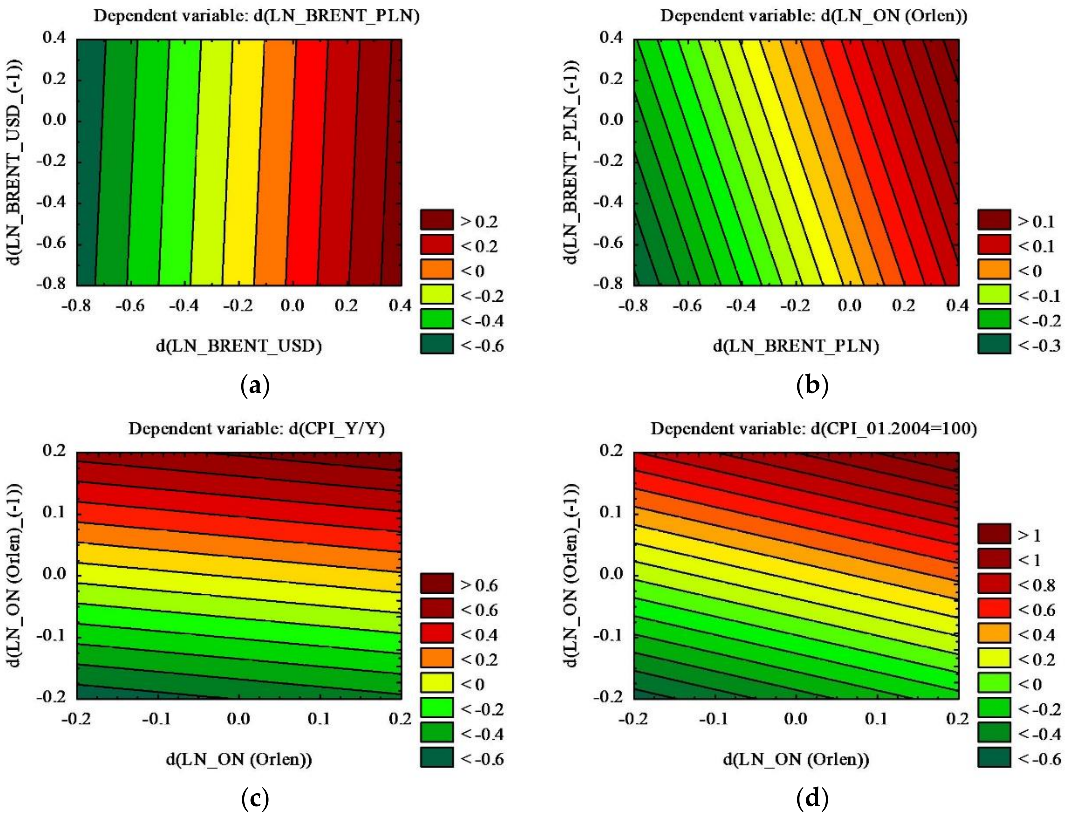


Figure 4. Dependencies taking into account time shifts. (**a**) Crude oil price response (in PLN) to changes in crude oil prices in the world markets; (**b**) Diesel oil prices response to changes in crude oil prices (in PLN); (**c**) Inflation (CPI_Y/Y) response to changes in diesel oil prices; (**d**) Inflation (CPI_01.2004 = 100) response to changes in diesel oil prices.

4. Discussion

The present study deals with a problem that is important from the economic perspective (i.e., the response of household inflation expectations (the CPI index) to fuel price shocks). This problem is still relevant, and it has especially gained in importance in the periods of increased inflation [79–81]. The issue of the transmission of price shocks from the fuel market to inflation is shown as an important cause of price increases [82–84].

The fact that the fuel market influences inflation is important not only from the perspective of the country's economy, fiscal, or monetary policy, or simply from the perspective of households. The fact that the most important CPI risk factor is the fuel market is also recognized in financial markets, where a popular strategy is to combine positions in the derivatives market for CPI swaps and RBOB futures. This strategy works in the same manner as an elimination of food price volatility risks by constructing an equivalent basket of agricultural futures [85].

One of the most serious problems of the impact of the fuel market on inflation is the controversy surrounding the short-term and long-term approach. Empirical studies are unable to unequivocally question or confirm whether the fuel market is responsible for inflation in the short- or long-term. The study finds evidence that the relationship between inflation and the fuel market is of a short-term nature, and that there is no statistically significant relationship in the long run. This conclusion is consistent with a number of empirical studies [86–88]. Generally, based on the research carried out, it can be concluded that inflation reacts quickly (up to three months) to increases in fuel prices. However, it does not react to decreases in fuel prices. This means that changes in fuel prices permanently increase inflation. Some authors have explained that during periods of falling fuel prices, inflation does not rise, and this is shown as a positive effect. The economy is particularly stimulated by falling oil prices as a result of the burden on the household budget being relieved by a reduction in energy bills; overall consumption then rises [89].

The research conducted has highlighted a unidirectional flow of price impulses: from the fuel market to inflation. Sometimes, the other direction (i.e., from inflation to the raw materials market) is discussed in the literature. It is frequently, however, that such studies treat the raw materials market as a whole and explain the increase in the prices of raw materials by running away from inflation. The oil market appears to be a good investment market against the loss of the value of money [90], which, however, does not seem to be true in light of most studies and the one carried out in this work. This is especially true if one takes into account the considerable volatility of the oil market. Recently, however, this approach has been recommended [91], but it may be the result of an excessive quantity of cash in the market and the need to look for any investment rather than a real and rational approach.

5. Conclusions and Policy Implications

The global oil market has proved to be a key pro-inflationary factor. This is not a direct influence, but an indirect one through the domestic fuel market. There are time lags in this relationship, generally up to three months. However, inflation does not take over all the volatility of the oil market. This is natural, however, as there are many more inflationary factors. Research in the context of the importance of the fuel market has important implications for economic policy, as all types of fiscal and monetary measures aimed at influencing inflation should take into account the current and projected situation in the fuel market.

The research shows important implications for macroeconomic policy. Several conclusions and suggestions can be drawn:

1. The current inflation is largely a cost-type inflation.
2. Taking into account the previous actions of the Polish government consisting of supporting enterprises during the COVID pandemic, cost-type inflation is overlapped by demand-type inflation, but additionally by more money in the market, with weak economic growth means throwing the economy out of balance. Inflation is also an effect of rebalancing, and this process has become a negative driving force for the current price increase.
3. The crude oil market, as sensitive to political conflicts, is a difficult one to control. However, the pro-inflationary effect may be mitigated by the pathway from primary energy to final product, as it turns out that at each subsequent stage of oil processing, price volatility decreases.
4. The government should reflect on full freedom to trade in energy. On one hand, economic considerations and market freedom speak for it, but on the other hand, it comes at the cost of price uncertainty.
5. Energy of the crude oil type has high marginal costs, and therefore, it is in the interest of the economy as a whole to use energy with low marginal costs. Such energy sources should no longer be pro-inflationary.

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