IJEEP
INTERNATIONAL JOURNAL OF ENERGY ECONOMICS AND POLICY
EJ EconJournals
ISSN: 2146-4553

International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2023, 13(4), 9-15.

EconJournals

The Relationship of Energy Generation from Fossil Fuels, Low Carbon Resources, and Renewable Resources and Inflation within the Framework of Taylor's Rule: The Case of Kazakhstan

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Received: 09 March 2023 **Accepted:** 01 June 2023 **DOI:** https://doi.org/10.32479/ijeep.14308

ABSTRACT

This study analyzes the relationship between energy production from fossil fuels, low-carbon sources, and renewable sources and inflation in Kazakhstan from 2000 to 2021, using the VAR method within the framework of the Taylor rule. Energy production is categorized under two headings, namely from fossil fuels and from other sources. While examining the relationship between energy production from fossil fuels and inflation, the interest rate and GDP growth rate, which affect inflation, were also included in the model as control variables following Taylor's rule. Thus, the relationship between energy production from fossil fuels and inflation can be analyzed more realistically. Energy production data are obtained from Our World in Data, GDP data from the World Bank site, and interest and inflation data from the ADB Data Library. The study showed that the interest rate affects inflation following the Taylor rule. We found a significant relationship between energy production and inflation in Kazakhstan. The relationship is that energy production from fossil sources increases inflation, while energy production from other (renewable and low-carbon) sources reduces inflation. This result once again proved the importance of energy production from renewable and low-carbon sources for Kazakhstan. Furthermore, the relationship between inflation and energy production proved not to be a causal one.

Keywords: Kazakhstan, Taylor Rule, Energy Production, Inflation, Interest, GDP, VAR Analysis.
JEL Classifications: C13, C20, C22

1. INTRODUCTION

Kazakhstan, which gained its independence in 1991, immediately started a major restructuring process in many sectors, especially in the economy. This restructuring process, which aims to integrate Kazakhstan with the world markets, is also called the transition period or the transition economy. Kazakhstan's natural resources had a major impact on Kazakhstan's success relative to other post-Soviet states (Xiong et al., 2015; Myrzabekkyzy et al., 2022; Bolganbayev et al., 2022; Taibek et al., 2023). Due to its rapid integration into world markets and especially its natural riches, the literature is full of studies examining the economy of Kazakhstan and the impact of its natural resources on the country's economy at both macro and micro levels (Oskenbayev et al., 2011; Ceyhan et al., 2016; Syzdykova, 2018; Shults and Kyssykov, 2019; Sabenova et al., 2023).

The Taylor rule, inspired by the high inflation caused by the oil crisis in the world market in the 1970s, was developed by the American economist Taylor (1993). This rule defined the Federal

Reserve's (FED) monetary policy rules that guide interest rate decisions of the Federal Open Market Committee. The rule requires central banks to adjust the short-term interest rate in response to changes in the inflation rate and the output gap (the interest rate response function) (Kodaz and Mangır, 2021). However, the Taylor rule is not effective on the long-term real interest rates. The rule states that when the general price level and output rate are above the target level, the interest rate should be increased, and when it is below the target level, it should be decreased (Yapraklı, 2011). Taylor's rule, which is called the response of the inflation gap and the production gap to the interest rate, is a monetary policy rule that shows how this change should affect the interest rates when there is a change in the targeted inflation rate (Toker and Gürel, 2020). The adequacy of the Taylor Rule was first proven in the US and later applied in other developed countries. A monetary policy following the Taylor rule works well when a floating exchange rate policy is adopted (Kodaz and Mangır, 2021).

Kazakhstan is a rich country in terms of fossil fuels as well as renewable energy resources such as hydroelectric, wind energy, solar energy, geothermal energy, and biofuels. Kazakhstan has about 3.2% of the world's total oil reserves, about 1.5% of natural gas reserves, and about 3.3% of coal reserves (Xiong, et al., 2015; Ongarova, 2018). This wealth of energy resources enabled Kazakhstan to quickly recover its economy in the post-Soviet period and became an important player in the world energy market.

Therefore, Kazakhstan is highly dependent on fossil fuels rather than renewable energy sources for energy production. Coal-fired thermal power plants account for 75% of the country's total energy production. This puts Kazakhstan at the forefront of the world rankings in terms of the ratio of greenhouse gas emissions to GDP (Syzdykova, 2020). Kazakhstan needs to turn its direction towards renewable energy sources in energy production, both in terms of diversifying its energy sources and reducing the national greenhouse gas emission rate.

Inflation, which directly affects people in daily life, can be briefly defined as the continuous increase in the prices of goods and services. Although there are many reasons for inflation, if the purchasing level of the people does not increase in parallel with the inflation rate, this causes impoverishment. In the post-Soviet period, Kazakhstan switched to a free market economy to integrate with world markets and experienced great price fluctuations (Ceyhan, et al., 2016). Thanks to its natural energy resources and the successful decisions of statesmen, Kazakhstan completed this painful process and quickly became one of the developing economies.

This study analyzes the relationship between energy production from fossil fuels, low-carbon sources, and renewable sources and inflation in Kazakhstan from 2000 to 2021, using the VAR method within the framework of the Taylor rule. GDP and interest rates were used as control variables. The energy production data used in the research are available from the Our World in Data site (https://ourworldindata.org/energy/country/kazakhstan), GDP data from the World Bank site (https://data.worldbank.org/indicator/NY.GDP.PCAP).CD?locations=KZ) and interest and inflation data from the ADB Data Library (https://data.adb.org/dataset/kazakhstan-key-indicators).

2. LITERATURE REVIEW

After the introduction of this model, many studies have appeared in the literature examining the inflation and interest policies of central banks. There are also a significant number of publications in the literature on the economy of Kazakhstan, energy resources, and energy policies of Kazakhstan. Here we will provide information on some of the relevant ones.

Syzdykova (2020) evaluated the renewable energy resources potential of Kazakhstan. After addressing factors such as low electricity tariffs, transmission losses, outdated and inefficient technologies, weak regulatory and legal frameworks, as well as a high-risk business environment that hinder the development of renewable energy sources in Kazakhstan, he provided important recommendations to overcome these problems.

Ongarova (2018), on the other hand, dealt with Kazakhstan's multi-faceted energy policy in terms of the geopolitics of the Caspian Sea. He evaluated Kazakhstan's hydrocarbon reserves and its production and exports, as well as its impact on Kazakhstan's foreign policy.

Ceyhan et al. (2016), using annual data from 1994 to 2013, analyzed the effects of openness and inflation rates on Kazakhstan's economic growth and tried to determine the effects of inflation and openness on Kazakhstan's economic growth and the direction of the effects. ARDL (autoregressive distributed lag) method was chosen as the research model. The research revealed that while the openness rate affects economic growth positively, inflation affects it negatively. Based on these results, it has been suggested that Kazakhstan should reduce inflation and increase the openness ratio to increase its economic growth to the desired level in the long term and achieve stable growth.

Kabzhalyalova (2021), in his Master's thesis, attempted to define the optimal monetary policy for Kazakhstan. In line with Taylor's rule and two versions of the model, he determined that the Central Bank of Kazakhstan reacts to the movements in the exchange rate to a limited extent and that an increase in the volatility in the nominal exchange rate will lead to deterioration of basic macroeconomic variables and a decrease in welfare.

In the study of Kodaz and Mangır (2021), the validity of the extended Taylor Rule, which includes the exchange rate as well as the inflation rate and interest rate for the 2001-2020 period in selected countries that implement the inflation targeting strategy, was estimated using panel data methods. Econometric analyses supported the Taylor rule, which states that an interest rate is an important tool in controlling inflation. However, they found that the selected countries considered the inflation gap and output gap while determining the interest rate, but did not consider the exchange rate gap.

Shults and Kyssykov (2019) discussed the monetary policy optimization of the Kazakhstan economy based on the DSGE model.

They found that the Central Bank of Kazakhstan pays attention not only to inflation but also to business activities and the exchange rate. They remarked that the inclusion of the exchange rate in the Taylor equation can increase public welfare, the sensitivity coefficients of the current interest rate policy can be revised upwards to reduce the social losses, and it would be more appropriate to focus on domestic inflation indicators rather than CPI.

Aizenman et al. (2011) discussed the inflation-targeting strategy for 16 developing countries. They analyzed Taylor's rule, which was extended to include exchange rates in countries implementing inflation-targeting regimes, using the Hausman-Taylor estimator for quarterly data for the period 1989-2006. They concluded that central banks in developing countries consider the production gap, real exchange rate, and inflation while determining the interest rate.

Based on monthly data between 1992 and 2010, Martin and Milas (2013) analyzed the British economy using the GMM method within the framework of the original Taylor rule and the extended Taylor rule. They claimed that after the 2007 crisis, Taylor's rule lost its validity, the inflation gap coefficient became meaningless and the production gap coefficient had a negative value.

Heimonen et al. (2017) analyzed the validity of the extended forward-looking Taylor rule with the OLS method, using monthly data from 14 OECD countries between 1999 and 2016. They found that the Taylor rule is still valid in those countries.

3. METHODS

In the Taylor model, the interest rate is defined as a function of inflation and the amount of production, and it is explained how the changes in these variables affect interest rates (Taylor, 1993).

$i_t = f\left(\pi gap, ygap\right)$ (*πgap*: inflation gap; *ygap*: output gap). (1)

Taylor defined two basic functions between variables:

$$i_t^* = a + \pi_t + \beta\left(\pi_t - \pi_t^*\right) + \lambda\left(y_t - y_t^*\right) \qquad \beta > 0, \lambda > 0 \quad (2)$$

$$i_t^* = r + \pi_t + 0.5\left(\pi_t - \pi_t^*\right) + 0.5\left(y_t - y_t^*\right) \quad (3)$$

(r: Federal Funds Rate; i_t: Nominal Interest Rate in the period (t); π_t: Inflation Rate in the period (t); $\neq_t^*$: Target Inflation Rate in the period (t); $\left(\pi_t - \pi_t^*\right)$: Inflation Gap; y_t: Production Quantity in the period (t); y_t^*: Potential Production Amount in the period (t); $\left(y_t - y_t^*\right)$: Production Gap; *β*: Inflation Deficit Response Coefficient; *λ*: Production Deficit Response Coefficient).

The Taylor rule is advantageous in that it has a simple formula and can be easily understood and analyzed by economic units (Plantier and Scrimgeour, 2002). The disadvantages of the Taylor rule are that giving the same level of importance to inflation and output level is not suitable for the economy, only paying attention to inflation and the output gap, not giving place to the thoughts of central banks, acting only according to Taylor rule makes it difficult for monetary policy to produce new ideas (Toker, 2020).

Bernanke and Gertler (2000) and Svensson (2002) argue that the traditional Taylor rule (1993) cannot be applied in underdeveloped and dependent countries. For this reason, they argued that the exchange rate variable should be added to the model in these countries.

The Extended Taylor rule function is given in (4):

$i_t = f\left(\pi gap, ygap, er\right)$ (*er*: exchange rate). (4)

In the traditional Taylor rule, the response of the short-term interest rate to the deviations in the output gap and output gap is positive. As a similar reaction is expected from the extended Taylor rule, a similar positive response is expected from the short-term interest rate to the deviations in the exchange rate in the expanded rule (Toker, 2020).

Taylor (2001) added the exchange rate (*er*) to the traditional Taylor rule model in his later studies and updated his model as in (5).

$$i_t^* = f\pi_t + gy_t + h_0 er_t + h_1 er_{t-1} \quad (5)$$

(i_t^*: Short Term Nominal Interest Rate; π_t: Inflation Rate; *f*: Inflation Deficit Coefficient; y_t: Deviation of Production Level from Potential Production Level; *g*: Production Deficit Coefficient; h_0: Exchange Rate Coefficient; h_1: One Period Delayed Exchange Rate Coefficient; er_t: Real Exchange Rate).

This new model shows the effects of fluctuations in inflation, output, and nominal exchange rate deficit on the formation of the interest rate.

Traditionally, in time series analysis, the stationarity of the series is examined first. In this study, the ADF (Augmented Dickey-Fuller) test, which is one of the commonly used methods in the literature, is used. The ADF test is provided by the following equality:

$$\Delta Y_t = \beta_0 + \beta_1 t + \delta Y_{t-1} + \alpha_i \sum_{i=1}^{m} \Delta Y_{t-i} + \varepsilon_t \quad (6)$$

In the ADF test, the null hypothesis is that the series contains a unit root, that is, it is not stationary, and if the null hypothesis is rejected for K= 0, 1, 3... values, the series is deemed stationary (Sevüktekin and Nargeleçekenler, 2007).

Relationships between economic time series have a complex structure. The complex nature of the series is interpreted and analyzed through systems of simultaneous equations. However, simultaneous equation systems require applying structural constraints (Tari and Bozkurt, 2006; Uysal et al., 2008). Vector autoregressive models (VAR) (Keating, 1990) are a preferred method in the analysis of the relationship between financial and economic time series since there is no restriction on the model. The bivariate VAR model is expressed as:

$$y_t = a_1 + \sum_{i=1}^{p} b_{1i} y_{t-i} + \sum_{i=1}^{p} b_{2i} x_{t-i} + \varepsilon_{1t} \quad (7)$$

$$x_t = c_1 + \sum_{i=1}^{p} d_{1i} y_{t-i} + \sum_{i=1}^{p} d_{2i} x_{t-i} + \varepsilon_{2t} \quad (8)$$

Here, p is the lag length and ε is the error term with constant variance and zero covariance with lag values. The fact that the covariance between the error terms is zero is removed from being a constraint by increasing the lag length in the model. As a result of the lean structure of the model, parameter estimation can be made using the least squares method (Özgen and Güloğlu, 2004).

In the VAR model, the first step of the analysis is to decide on the lag length. At this stage, Likelihood Ratio (LR), Final Prediction Error (FPE), Akaike Information Criterion (AIC), Schwarz Information Criterion (SC), and Hannan-Quinn Information Criterion (HQ) values are used. The second step of the analysis is to examine the goodness of fit of the model. In this step, it is checked that the inverse roots of the AR characteristic equation are within the unit circle, that there is no serial correlation in the residuals, and that there is no problem of varying variance. The existence of serial correlation is examined with the Lagrangian multiplier (LM) test, and the presence of varying variance is examined with the White variance test.

If a relationship is detected between the variables, the next step is to investigate whether this relationship is causal. For this, VAR Granger causality analysis, by Granger (1969), is used.

4. ANALYSIS AND FINDINGS

This study examines the relationship between energy production and inflation within the framework of the Taylor rule form that examines the interaction between inflation, interest, and GDP. Energy production is categorized under two headings, namely from fossil fuels and from other sources. Since the research variables are expressed as the share of resources in total energy production, it will be sufficient to create a research model for energy production from fossil sources only. Since the sums of the two variables are constant (100%), one is a negative linear function of the other. While examining the relationship between energy production from fossil fuels and inflation, the interest rate and GDP growth rate, which affect inflation, were also included in the model as control variables following Taylor's rule. While examining the relationship between energy production from fossil fuels and inflation, the interest rate and GDP growth rate, which affect inflation, were also included in the model as control variables following Taylor's rule. Thus, the relationship between energy production from fossil fuels and inflation can be analyzed more realistically.

Table 1 shows the variables used in the research and the codes used for these variables. Energy production from fossil fuels is expressed as X1, inflation X2, interest X3, and GDP growth X4.

Explanatory statistics regarding the research variables are given in Table 2. According to the Jarque-Bera test, all four variables show normal distribution.

The stationarity of the research data is examined with the ADF unit root test and the findings are given in Table 3. Only the X2 is stationary at the level and all variables are stationary at the first difference level.

The findings of the LAG criterion used to decide the appropriate number of delays for the research model are given in Table 4. According to LR, FPE, and SC criteria, 2 delays, and according to AIC and HQ criteria, the fourth delay is the appropriate delay number. In this study, considering the LR, FPE, and SC criteria, the lag number was chosen as two and the VAR(2) model was used.

The prediction values of the VAR(2) model created according to the findings of the LAG criterion are given in Table 5. The one-period lagged value of X2 has a negative effect on itself, whereas the two-period delayed value of X1 had a positive effect, and X3 had a significant positive effect on it. Only the two-period lagged value of X1 has a negative effect on X1. Accordingly, it was concluded that energy production from fossil fuels had a positive effect on inflation. As stated above, since energy production from fossil sources and energy production from other sources (renewable energy sources and low-carbon energy sources) have a negative relationship, this result also proves the existence of a negative relationship between energy production from other energy sources and inflation. It is revealed that energy production from low-carbon and renewable sources

Table 1: Research variables

Variable code	Explanation
X1	Energy Production from Fossil Resources
X2	Inflation
X3	Interest
X4	Gross Domestic Product

Table 2: Descriptive statistics of research variables

Statistics	X1	X2	X3	X4
Mean	88.85420	8.172727	9.316067	6.013636
Median	89.24705	7.200000	9.663870	5.400000
Maximum	91.65317	17.00000	11.57008	13.50000
Minimum	84.75913	5.100000	6.425930	-2.5
Standard deviation	2.091883	3.078525	1.542342	3.924805
Skewness	-0.43876	1.654978	-0.27839	-0.17528
Kurtosis	2.143689	4.849685	1.865240	2.437792
Jarque-Bera	1.647493	1.361518	1.464538	0.175498
Probability	0.438785	0.506233	0.480817	0.915991

Table 3: Augmented Dickey-Fuller test findings regarding stationarity of research variables

Variable code	Level		First Diference	
	t-Statistics	P-value	t-Statistics	P-value
X1	−1.77954	0.3795	−3.44567	0.0214
X2	−3.93668	0.0072	−5.84135	0.0001
X3	−2.91063	0.0618	−3.26661	0.0307
X4	−2.16111	0.2249	−4.6904	0.0017
Test critical values				
1% level	−3.78803		−3.80855	
5% level	−3.01236		−3.02069	
10% level	−2.64612		−2.65041	

Table 4: LAG criterion findings for the research model

Lag	LogL	LR: sequential modified LR test statistic (each test at 5% level)	FPE: Final Prediction Error	AIC: Akaike Information Criterion	SC: Schwarz Information Criterion	HQ: Hannan-Quinn Information Criterion
0	−67.2572	NA	19.10994	8.618495	8.912570	8.647727
1	−60.1512	10.03198	13.64171	8.253085	8.743211	8.301805
2	−49.4853	12.54812*	6.665772*	7.468861	8.155037*	7.537069
3	−45.8048	3.464019	7.927645	7.506447	8.388673	7.594142
4	−38.824	4.927596	7.189848	7.155769*	8.234045	7.262952*

*indicates lag order selected by the criterion (each test at 5% level)

Table 5: Research model VAR findings

	X2	X1
DX2(-1)	−0.54591	0.097089
DX2(-2)	−0.16962	−0.07615
DX1(-1)	−0.55819	0.478104
DX1(-2)	1.059987	−0.49864
DX3	2.130427	−0.18889
DX4	−0.19566	0.106480
C	−0.10084	0.200545
R-square	0.747606	0.428960
F statistics	5.924124	1.502382
Log likelihood	−39.2379	−24.3629
Akaike information criteria	4.867147	3.301359
Schwarz information criteria	5.215098	3.649310

*: denotes a significant effect for $P<0.05$.

has a decreasing effect on inflation in Kazakhstan, while energy production from fossil sources has an increasing effect on inflation in Kazakhstan.

One of the fit criteria for the VAR model is that the geometric location of the inverse roots of the AR characteristic polynomial stays within the unit circle. The graph of the characteristic polynomial inverse roots of the model for the analysis of the relationship between energy production from fossil fuels and inflation with VAR(2) is given in Graph 1. As can be seen in the graph, the inverse roots of the characteristic polynomial of the survey model satisfy the criterion.

The relationship between energy production from fossil fuels and inflation in the VAR(2) model was examined by the LM test whether there is an autocorrelation between the residuals. According to the findings given in Table 6, there is no autocorrelation in the 3-period delayed residual analysis in the research VAR model.

The problem of varying variance in the residuals of the research VAR(2) model was examined with the White test. The findings summarized in Table 7 show no variable variance problem in the model.

According to the VAR(2) model, the causality relationship between the two variables was examined with the VAR-Granger causality analysis, and the findings are given in Table 8. Both causal relationships between energy production from fossil fuels and inflation are not statistically significant. This result is interpreted as that energy production from fossil fuels is not the cause of inflation, and inflation is not the cause of energy production from fossil fuels.

Table 6: LM test findings for the residuals of the VAR model

Lag	LRE* stat	df	Prob,
1	2.209594	4	0.6973
2	3.158932	4	0.5316
3	1.235317	4	0.8723

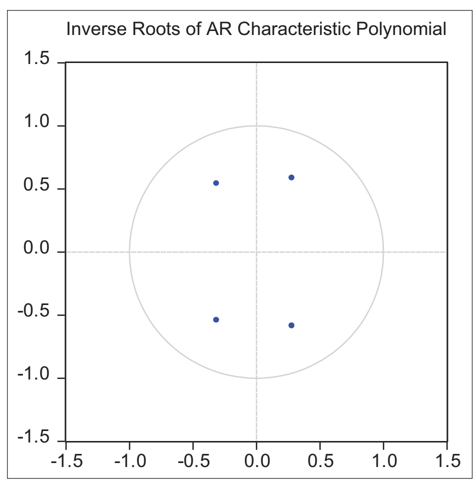
Table 7: Variance test findings in residuals according to VAR model

Chi-square	df	Prob,
35.96546	36	0.4703

Table 8: Findings of VAR Granger causality analysis for inflation variables for fossil fuel power generation

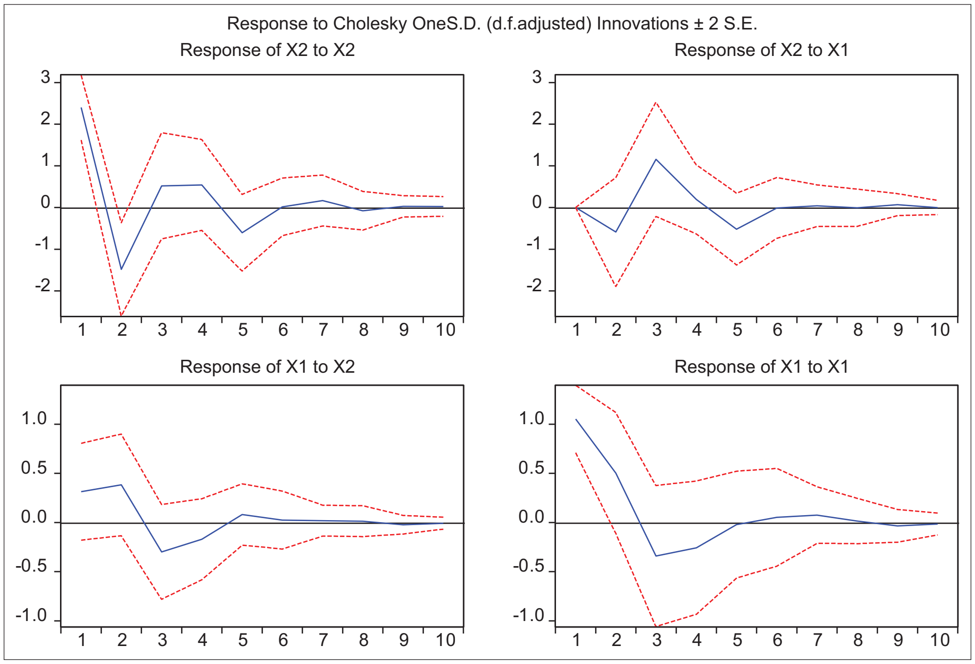
Independent variable	Dependent variable	Chi-square	df	Prob,
X1	X2	3.538149	2	0.1705
X2	X1	3.384470	2	0.1841

Graph 1: Graphic representation of Inverse Roots of AR Characteristic Polynomial of VAR model



The effects of the shocks in the variables of inflation and energy production from fossil sources over time are given in Graph 2. Accordingly, a shock in inflation has an increasing (positive) effect after one period, and a decreasing (negative) effect after two periods. The direction of the effect changes in the following periods and disappears from the eighth period. A shock in energy production from fossil resources has an increasing (positive) effect on inflation in the first two periods and a decreasing (negative)

Graph 2: Effects of shocks in the variable of energy production from fossil fuels and inflation over time



effect in the third period. The effect disappears after the fourth period.

5. CONCLUSION AND RECOMMENDATIONS

This study evaluated the relationship between energy production and inflation in Kazakhstan within the framework of Taylor's rule. Following Taylor's rule, it is concluded that the interest rate affects inflation. It has been determined that there is a significant relationship between energy production and inflation in Kazakhstan, energy production from fossil sources has an inflation-increasing effect, and energy production from other (renewable and low-carbon) sources has a reducing effect on inflation. This result once again proved the importance of energy production from renewable and low-carbon sources for Kazakhstan. Furthermore, the relationship between inflation and energy production proved not to be a causal one.

Taylor's model was taken into consideration in the study. As is known, Taylor's extended model also includes the exchange rate. The inclusion of the exchange rate as a control variable in the study should enrich its results.

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