



Анализ динамики платежного баланса Азербайджана с использованием модели коррекции ошибок

Цель исследования. Анализ изменений динамики и структуры платежного баланса для разработки превентивных антикризисных мер является одной из важных и сложнейших задач регулирования экономики на государственном уровне. Растущее число научных работ, посвященных моделированию динамики, изучению взаимосвязи платежного баланса с различными эндогенными и экзогенными факторами, свидетельствует о важности и растущем интересе к этой теме.

Материалы и методы. Исходные временные ряды являются нестационарными. При переходе к временным рядам с разностями в этих рядах сохраняется информация, соответствующая только краткосрочным изменениям. А вся остальная информация, охватывающая долгосрочные изменения динамики, теряется при переходе к разностям. Возникшая ситуация требует правильного подхода к процессу моделирования рассматриваемых временных рядов. Период наблюдения исследования охватывает годовые данные с 1995 по 2023 год. Для решения поставленной задачи и характерного описания динамики развития платежного баланса в работе впервые проведен экономический анализ динамики платежного баланса по отдельным его статьям, с 2012 по 2021 год, в частности за 2020-2021 годы. Последующие шаги по расширенному эконометрическому анализу временных рядов были посвящены определению стационарности, переходу к разностям и построению векторных

моделей коррекции ошибок. При выполнении коинтеграционного теста было выявлено его сочетание с тестом на стационарность. Были выполнены и проанализированы все необходимые тесты. Получены и проанализированы критические значения для этих статистик.

Результаты. В данной статье разрабатывается векторная модель коррекции ошибок, которая позволяет проводить анализ и моделирование более двух временных статистических рядов в указанном временном периоде. Векторная модель коррекции ошибок ограничивает динамику эндогенных факторов и направляет их на коинтеграционную связь. В статье рассматривается взаимосвязь между текущим счетом платежного баланса Азербайджана и мировыми ценами на нефть марок West Texas Intermediate и Brent.

Заключение. С помощью построенной векторной модели коррекции ошибок можно измерить отклонения от равновесия и скорость его восстановления. Очень медленное восстановление после срыва от шоковых реакций изменения мировых цен на нефть позволяет сделать вывод о наличии устойчивой, долгосрочной, равновесной взаимосвязи между изучаемыми временными рядами.

Ключевые слова: эконометрическое моделирование; платежный баланс; цены на нефть; стационарность; коинтеграция; модель коррекции ошибок.

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Analysis of the Dynamics of Azerbaijan's Balance of Payments Using Error Correction Model

Purpose of the study. Analysis of changes in the dynamics and structure of the balance of payments to develop preventive anti-crisis measures is one of the important and most difficult tasks of regulating the economy at the state level. The growing number of scientific papers devoted to modeling dynamics, studying the relationship of the balance of payments with various endogenous and exogenous factors indicates the importance and growing interest in this topic.

Materials and methods. The original time series are non-stationary. When moving to time series with differences, information corresponding only to short-term changes is stored in these series. And all other information covering long-term changes in dynamics is lost when moving to differences. The situation that has arisen requires a correct approach to the process of modeling the time series under consideration. The observation period of the study covers annual data from 1995 to 2023. To solve the problem and to provide a characteristic description of the dynamics of the development of the balance of payments, the paper first carried out an economic analysis of the dynamics of the balance of payments for its individual articles, from 2012 to 2021, in particular for 2020-2021. Subsequent steps for advanced econometric analysis of time series were devoted to

the determination of stationarity, the transition to differences, and the construction of vector error correction models. When performing the cointegration test, its combination with the stationarity test was revealed. All necessary tests were performed and analyzed. Critical values for these statistics were obtained and analyzed.

Results. This article develops a vector error correction model that allows the analysis and modeling of more than two - time statistical series in a specified time period. VECM limits the dynamics of endogenous factors and directs them to a cointegration relationship. The paper examines the relationship between the current account of the balance of payments of Azerbaijan and world prices for West Texas Intermediate and Brent oil.

Conclusion. Using the constructed VECM, it is possible to measure deviations from equilibrium and the rate of its restoration. The very slow recovery after the disruption from the shock reactions of changes in world oil prices allows us to conclude that there is a stable, long-term, equilibrium relationship between the time series under study.

Keywords: econometric modeling; payment balance; oil prices; stationarity; cointegration; error correction model.

Introduction. Statistical analysis of the dynamics of the current account and the factors influencing them is explained by the position Azerbaijan occupies as an exporter and importer of energy carriers and the impact of this phenomenon on the economy and, accordingly, on the welfare of the country.

Under the influence of instability in international financial relations, the Central Bank of Azerbaijan decided to devalue the Azerbaijani manat, which was devalued twice in February and December 2015, and this impact on the key macroeconomic indicators of the country required a revision of the principles of the infrastructure, the economic strategy of the state, systemic risk management skills and management principles of the relevant competent authorities.

The fall in energy prices can lead not only to a violation of the macroeconomic stability achieved in the country but also to a complex increase and aggravation of problems in Azerbaijan's relations with other countries, which can slow down and even stop the country's economic growth.

Review of literature. In foreign and domestic scientific literature, researchers have presented a sufficient number of works that are devoted to problems related to balance of payments. In these works, researchers analyze problems in identifying the instability of balances of payments, problems in achieving stability and constant dynamics of development of balances of payments with a positive balance [1–7]. The balance of payments is a dynamic economic system that is sensitive to all socio-economic processes, both within the country and outside [8–10]. Many problems still remain unresolved and require an ongoing, well-founded scientific approach.

In the post-Soviet countries, balance of payments problems can be explained by the variability of the regime of devaluation

expectations. These expectations, having their own specificity, make work in this area important, as well as research of an economic and statistical nature. The processes of transformation of the national economies of the post-Soviet space, their regional characteristics, integration processes between countries, between macro indicators within the country, as well as between the main macroeconomic indicators and endogenous factors, such as world energy prices, are specific characteristics of research in this direction [11–15].

The article [16] analyzes the relationships between Russia's balance of payments. The author uses data covering an 11-year period and identifies the main factors influencing the balance of payments using econometric "tools". The authors of the article [17] consider and identify the impact of extreme oil shocks and changes in the dynamics of oil price uncertainty. This is an important point when modeling processes that are affected by oil prices. Output growth has been found to respond symmetrically or asymmetrically to positive and negative shocks during periods when oil price uncertainty is lower or higher and more or less stable before or after mid-1985. The findings highlight the importance of accounting for emissions and volatility in oil prices and production growth, and the need to better understand the response of economic activity to oil shocks in the face of oil price uncertainty. A group of researchers in [18] present the results of econometric modeling of the Belarusian economy and describe the method of constructing a macromodel used for analysis and short-term forecasting of significant economic indicators. The resulting ability of the model to reflect the impact of rising prices for imports of natural energy resources on macroeconomic indicators was tested and scenario forecasts were proposed. In this paper [19], the most suitable model of the ex-

change rate dynamics was established. The approximation and standard deviation indices with the Fourier series approach were used. Dynamic forecasting of exchange rates was made based on harmonic oscillatory models with linear trends. The study [20] identifies economic indicators that influence the state of important factors of economic relations, such as accounts receivable and accounts payable. These factors are taken into account when forecasting the calculations of budget mechanisms. A methodology for budgeting the occurrence and repayment of receivables and payables based on an approximated linear relationship is proposed. The main task in the work [21] is the formation of a unified system for forecasting the balance of payments of Kazakhstan. The expected results will provide an assessment of the sustainability of the external economic processes of the economy. The authors presented an analysis of international capital flows, as well as capital flows in Kazakhstan, reviewed the experience of forecasting the financial account on a global scale, and revealed a system for forecasting the financial account of the balance of payments. An analysis [22] of the main trends in the development of international oil trade has been carried out, the main determinants of the world oil market at the present stage of development have been identified, the economic situation in the oil industry in Russia has been analyzed, a comparative analysis of financial and economic indicators has been carried out, ways to increase gross income and gross profitability. The authors concluded that the Russian oil industry depends on economic and political factors, which requires periodic analysis of the activities of subjects in this industry.

Analysis of the state of the current account of the balance of payments of azerbaijan and world oil prices. Analyzing the data proposed by the Central Bank of

Azerbaijan, one can determine the positive dynamics in the balance of payments, particularly in the current account of operations. In the first half of 2021, Azerbaijan's balance of payments showed a positive balance of \$1.3 billion. However, for the same period in 2020, there was a deficit of \$956.4 million. In the period under review, the growth and influence of prices can explain this on world commodity markets and the expansion of non-commodity exports [23].

The current account surplus amounted to \$1.9 billion, the deficit in capital and financial flows was \$0.6 billion, and reserve assets increased by \$1.3 billion. During this period, the average price of crude oil was \$58 per barrel, and non-oil exports increased by 20%. There is also a positive trend in the foreign trade balance, in the balance of services (the deficit has decreased) and secondary income. The deficit increased in the balance of primary income (see Figure 1).

In the period under review, there is a surplus in the current account of the balance of payments. The current account surplus for the first half of 2021 amounted to \$1.9 billion, or 8% of GDP (\$598.2 million for the first half of 2020). The current account surplus in the oil and gas sector increased by 40.7% year-on-year to \$4.6 billion, while the current account deficit in the non-oil sector increased by 1.8% to \$2.7 billion.

And compared to the same period, within current operations, 68% of the country's total revenue, or \$14.6 billion, was received from the oil and gas sector, and 32%, or \$6.8 billion, from the non-oil sector. During the first half of 2018, 71.1% of the country's revenue was formed from the export of goods, 18.8% from the export of services, and only 10.1% from the primary and secondary income. At the same time, 48.2% of payments to non-residents were related to the import of goods and 32.2% to ser-

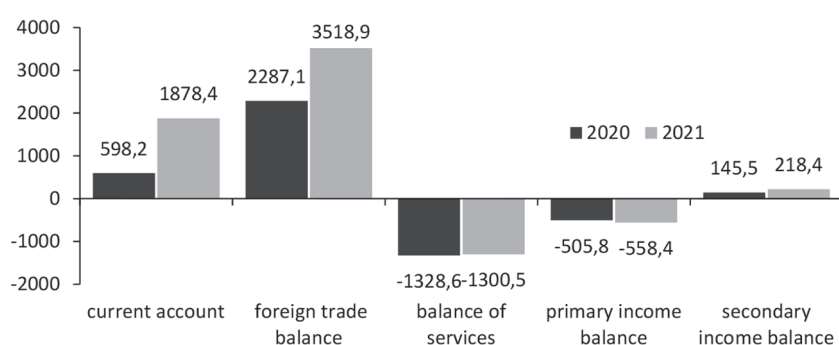


Рис. 1. Состояние текущего счета платежного баланса за 6 месяцев 2020 и 2021 годов (профицит, дефицит) (Источники данных: Маржа – агентство деловых и финансовых новостей, 2022 г.) [23].

Источник: Подготовлено автором в программе Excel.

Fig. 1. State of the current account of the balance of payments for 6 months of 2020 and 2021 (surplus, deficit) (Data sources: Marja is a business and financial news agency, 2022) [23].

Source: Prepared by the author in the Excel program.

vices. The remaining 19.6% were related to transfers to non-residents on primary and secondary income [24].

According to the foreign trade balance, the turnover for the first half of 2021 amounted to 13.2 billion US dollars, a positive balance of 6.4 billion US dollars in the oil and gas sector, closing the deficit of 2.9 billion US dollars in the non-oil sector, resulting in a positive balance of 3.5 billion US dollars was formed in the foreign trade balance. During the period under review, Azerbaijan had trade relations with 172 countries. 13.6% of foreign trade falls on the

Commonwealth of Independent States countries and 86.4% on other far-abroad countries.

The total volume of services for the economic relations of Azerbaijan with foreign countries for six months of 2021 amounted to 4.4 billion dollars. Of these, 2.9 billion dollars are services provided by non-residents to residents of Azerbaijan, and 1.5 billion dollars are services provided by residents of Azerbaijan to residents of foreign countries. The deficit in the balance of services decreased by 2.1% to \$1.3 billion. The balance of services in the oil and gas sector (mainly construction and

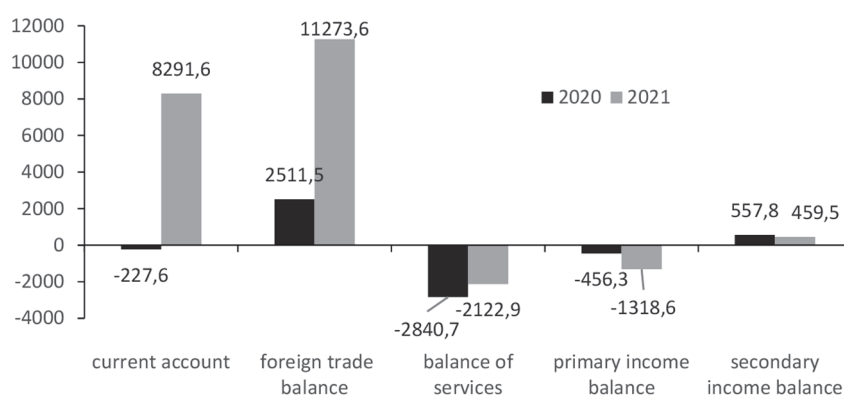
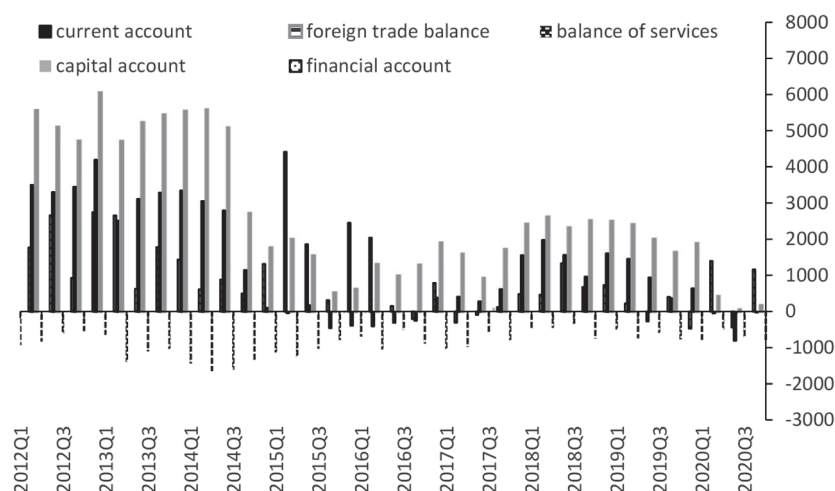


Рис. 2. Состояние текущего счета платежного баланса на конец года 2020 и 2021 (профицит, дефицит) (Источник данных: Центральный банк Азербайджана, 2022 г.) [25].

Источник: Подготовлено автором в программе Excel.

Fig. 2. State of the current account of the balance of payments at the end of the year 2020 and 2021 (surplus, deficit) (Data source: Central Bank of Azerbaijan, 2022) [25].

Source: Prepared by the author in the Excel program.

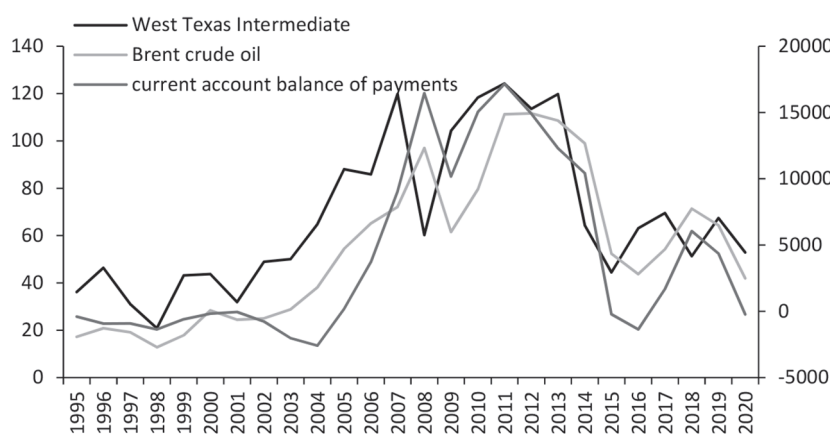


**Рис. 3. Динамика основных показателей платежного баланса
Азербайджана в 2012–2020 гг. (по кварталам) (млн. долларов США)
(Источники данных: Центральный банк Азербайджана, 2022 г.) [25].**

Источник: Подготовлено автором в программе Excel.

**Fig. 3. Dynamics of the main indicators of Azerbaijan's balance of payments
in 2012–2020 (by quarters) (million US dollars) (Data sources: Central
Bank of Azerbaijan, 2022) [25].**

Source: Prepared by the author in the Excel program.



**Рис. 4. Динамика временных рядов текущего платежного баланса
Азербайджана, цен на нефть марок Brent и West Texas Intermediate в
1995–2023 гг. (млн. долларов США) [25 - 27]**

Источник: Подготовлено автором в программе Excel.

**Fig. 4. Time series dynamics of Azerbaijan's current account balance of
payments, Brent and West Texas Intermediate oil prices in 1995–2023
(Million US Dollars) [25–27]**

Source: Prepared by the author in the Excel program.

other business services) amounted to 976.9 million US dollars (a decrease of 20.1%). The balance of services in the non-oil sector amounted to 323.6 million dollars (an increase of 3.1 times).

By the end of 2021, compared to the same period in 2020, the positive dynamics of the current account of the balance of payments continued. As noted above, the balance of revenues in 2021

was mainly affected by the price recovery on world commodity markets and a significant increase in non-commodity exports. The current account surplus amounted to \$8.3 billion, capital and financial flows made a deficit of \$5.1 billion, and reserve assets increased by \$3.1 billion. The average price of crude oil during this period was \$67 per barrel, while non-oil exports increased by 44% to \$2.6 billion.

The current account of the balance of payments consists of 4 elements: foreign trade, services, the proportion of primary income, and secondary income. In the histogram in Figure 2, one can consider the dynamics of the current account of the balance of payments, the foreign trade balance, the balance of services, and the balances of primary and secondary income [25]. As can be seen from Figure 2, the overall dynamics of the development of the central element of the balance of payments for six months of 2020 and 2021 did not change at the end of the year 2020 and 2021; that is, the trend continues. The data in Figure 3 cover a more extended period from 2012 to 2020, with quarterly values of the leading indicators of Azerbaijan's balance of payments and provide a «clear picture» of the state of the current account of Azerbaijan's proportion of revenues for the period under review.

The oil prices shown in 4 have been adjusted for inflation using the general CPI. Prices were applied in average annual format. The combined graph serves to implement a comparative analysis and visualization of patterns in time series. The graph includes polygons that describe the dynamics of the current account of the balance of payments of Azerbaijan and characterize changes in prices for West and Brent oil brands for the period 1995–2023. Analyzing the graphics in Figure 4 we can conclude that there is a close, similar relationship in dynamics between the current account of the balance of payments of Azerbaijan and the prices for West and Brent oil.

Empirical tests and results.

The study of time series of the current account of the balance of payments – BPCA, prices of oil brands Brent – BR and West – WT began with descriptive statistics. Observations covered the period from 1995 to 2023, with annual data. According to the test

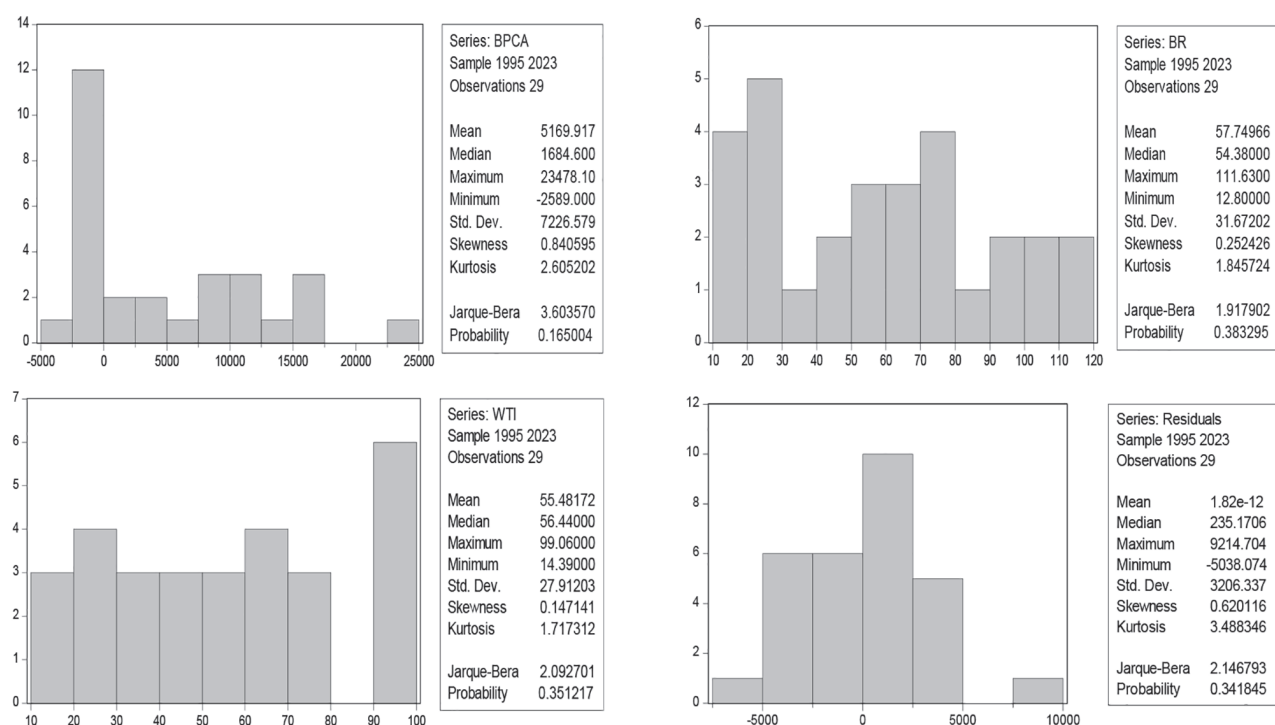


Рис. 5. Гистограмма стандартного распределения остатков для временных рядов текущего счета платежного баланса (BPCA), марок Brent, WTI и MRES.

Источник: График создан автором в программе EViews.

Fig. 5. Histogram of the standard distribution of residuals for the BPCA, BR, WTI and MRES time series.

Source: The graph was created by the author in the EViews software

results, a normal distribution was revealed in the row levels. The Jarque – Bera criterion obtained a value for the current account of the balance of payments equal to 3.6, with a probability of 0.17, for Brent oil prices of 1.92, with a probability of 0.38, and for West oil prices of 2.09, with a probability of 0.35, for resids 2.15, with 0.34. In all cases, the probabilities exceed the significance level of 0.05, which confirms the normality of the distribution. Note that the resids reflect the values of the model residuals. Studying the residuals along with the main factors of the model is important in econometric analysis.

The test for the normal distribution of levels of the BPCA, BR and WTI series gave the following results: $JB_{BPCA} = 3.60357$, with prob. = $0.165004 > 0.05$, $JB_{BR} = 1.917902$, with prob. = $0.383295 > 0.05$ and $JB_{WTI} = 2.092701$, with prob. = $0.351217 > 0.05$ and $JB_{residuals} = 2.146793$, with prob. = $0.341845 > 0.05$, which confirms

the normality of the distribution in the series (see Fig. 5). Although, the constructed histograms of standard distributions of residuals for the BPCA, BR, WTI and MRES time series do not visually confirm this. Deviations from the trend are observed in several areas of the BPCA, BR, WTI and MRES series.

In a comprehensive econometric analysis, multiple regression models often resort to methods that reveal the direction and closeness of relationships between the resulting and explanatory factors and between independent factors. Close relationships between independent factors give rise to multicollinearity, the consequences of which are undesirable for a multiple regression model. In the presence of multicollinearity, the regression coefficients change significantly in the process of adding or removing new factors to the model to improve the quality of the model, which serves for

a prospective assessment of the object under study, or the F-stat. shows the significance of the determination coefficient. Still, the regression coefficients do not have a statistical sense. Also, with an increase or decrease in the sample size, the values of the coefficients change significantly, the standard errors increase, the variances of the parameter estimates increase, the t-statistics of the coefficients decrease, etc. As a result, the parameter values and the model become unreliable for analysis or forecasting. A value close to zero of the matrix determinant ($X^T X$) may indicate the presence of multicollinearity. If the determinant of the inter-factorial correlation matrix is close to unity, then there is no multicollinearity.

The values of the paired coefficients in the correlation matrix also provide information in this direction. Consider paired correlation coefficients between factors in the correlation matrix for the analyzed model (see Table1).

Корреляционная матрица по модели множественной регрессии
Correlation matrix according to the multiple regression model

	BPCA	BR	WTI	MRES
BPCA	1	0.8914444725059371	0.8958660295249612	0.4436866754316293
BR	0.8914444725059371	1	0.9916365179847354	-8.956025622713171e-17
WTI	0.8958660295249612	0.9916365179847354	1	-3.382653182947344e-15
MRES	0.4436866754316293	-8.956025622713171e-17	-3.382653182947344e-15	1

As can be seen from the results in Table 1, most paired correlation coefficients between the factors of the model have high values. The values fall within the interval (0.7; 0.9). And this indicates a close relationship between them. The correlation coefficient between BR and WTI is very high, which characterizes a close relationship between them. This is also noticeable in the dynamics of these series in Figure 4. Multicollinearity between the explanatory factors distorts the results.

If there is a correlation between the levels of series in an autoregressive model, that is, in the presence of autocorrelation, the series may be subject to periodic fluctuations. This characterizes the insignificance and ineffectiveness of forecasts based on the autoregressive model. Cyclical fluctuations may not be random. Figure 6 shows the autocorrelation and partial autocorrelation functions of the

time series under consideration.

Analyzing the results presented in Figure 6, we come to the conclusion that AC for the series BPCA under consideration decreases, and PAC has the highest value of the first-order autocorrelation coefficient. For other orders there are no significant autocorrelation coefficients. A similar picture was revealed for the remaining time series. This means that the original time series are not stationary and represent a first-order autoregressive model – AR(1). Model can be represented in the following generalized form:

$$y_t = c + y_{t-1} + \varepsilon_t, \quad (1)$$

So, analysis of the dynamics of the series under consideration confirms their nonstationarity. There is an increasing linear trend.

The results of multiple regression analysis can also be considered not entirely satisfactory: R-squared 1; Adjusted R-squared 1; F-stat. = 6.50E+28

(prob 0.0000); Durbin-Watson stat. 0.931926; t-stat. for BR = 1.05E+13 (prob. 0.0000), for WTI=4.06E+13 (prob.0.0000), MRES= 1.96E+14 (prob.0.0000). The Durbin-Watson stat value demonstrates the presence of positive autocorrelation.

The results obtained cannot be read as completely satisfactory. The original time series are nonstationary, and positive autocorrelation is observed. And positive regression results are false.

The following equation is a formal regression equation and is insignificant according to some criteria, that is, it does not satisfy the adequacy conditions:

$$\begin{aligned} BPCA = & 42.06684 * BR + \\ & + 184.6102 * WTI + MRES - \\ & - 7501.923 \end{aligned} \quad (2)$$

Consideration of the results of the above tests requires revision and replacement of the original data with differences of the first or second order. In the work [28], which was devoted to the study of the relationship between the current account of the balance of payments of Azerbaijan and the prices of Brent and West Texas Intermediate oil, the stationarity of the series by both the first and second differences was revealed. In such cases, it is not necessary to conduct a study of the series by the second differences. It is more appropriate to use the series by the first differences, demonstrating stationarity.

Augmented Dickey–Fuller (ADF) test is an extended form of the Dickey-Fuller test, based on which the method of differences is applied to series data. If there is autocorrelation in time series, this method can eliminate it and

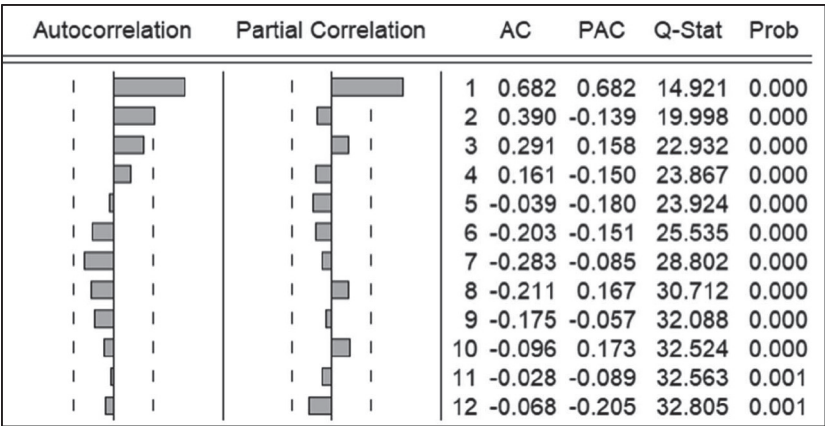


Рис. 6. Автокорреляция и частичная автокорреляция текущего счета платёжного баланса временных рядов

Источник: График создан автором в программе EViews

Fig. 6. AC and PAC of BPCA of time series

Source: The graph was created by the author in the EViews software

check the series for stationarity. The unit root ADF test calculates the value for the t test, suggesting critical values for the t test with 1%, 5% and 10% probabilities. Hypothesis H_0 defines a unit root, and its alternative hypothesis defines stationarity [29–31]. The Augmented Dickey – Fuller test can be represented based on the following equation:

$$y_t = \lambda y_{t-1} + u_t \quad (3)$$

where y_t is the time series under study at moment t ; λ – coefficient determining the unit root; u_t is white noise, which is a random process, a special case of stationary series.

If the condition $\lambda = 1$ for the coefficient is satisfied, then the time series has a unit root, is not stationary and is an integrated time series of the first order I(1). If $\lambda < 1$, then the time series is stationary and I(0).

The ADF test carried out for the original series and for series with first differences with input parameters constant, maximum

Результаты теста Дики-Фуллера
Results of the Dickey-Fuller test

Variables	BPCA	BR	WTI	MRES
According to original rows				
1%	-3,69	-3,69	-3,69	-3,69
5%	-2,97	-2,97	-2,97	-2,97
10%	-2,63	-2,63	-2,63	-2,63
t – stat.	-2,23	-1,74	-1,83	-2,97
Prob.	0,201	0,402	0,3588	0,0498
By rows with first differences				
1%	-3,70	-3,70	-3,70	-3,70
5%	-2,98	-2,98	-2,98	-2,98
10%	-2,63	-2,63	-2,63	-2,63
t – stat.	-4,94	-4,8	-5,34	-5,008
Prob.	0,0005	0,0007	0,0002	0,0004

lag = 5, lag length = 0 gave the following results (see table 2).

The t-test values at the 1%, 5% and 10% critical values produced unsatisfactory results, with significance levels exceeding 0.05 for the original series. this confirms the nonstationarity of all time series with the original data. The same cannot be said about series with first differences. Quite high t-tests with high

probabilities. So, the results of the ADF test showed that all time series with first-order difference operators are stationary.

Now let's build a correlogram for time series based on first differences. The results are presented in Figure 7.

Figure 7 demonstrates the absence of autocorrelation at all levels according to the AC and the PAC. This is justified by the

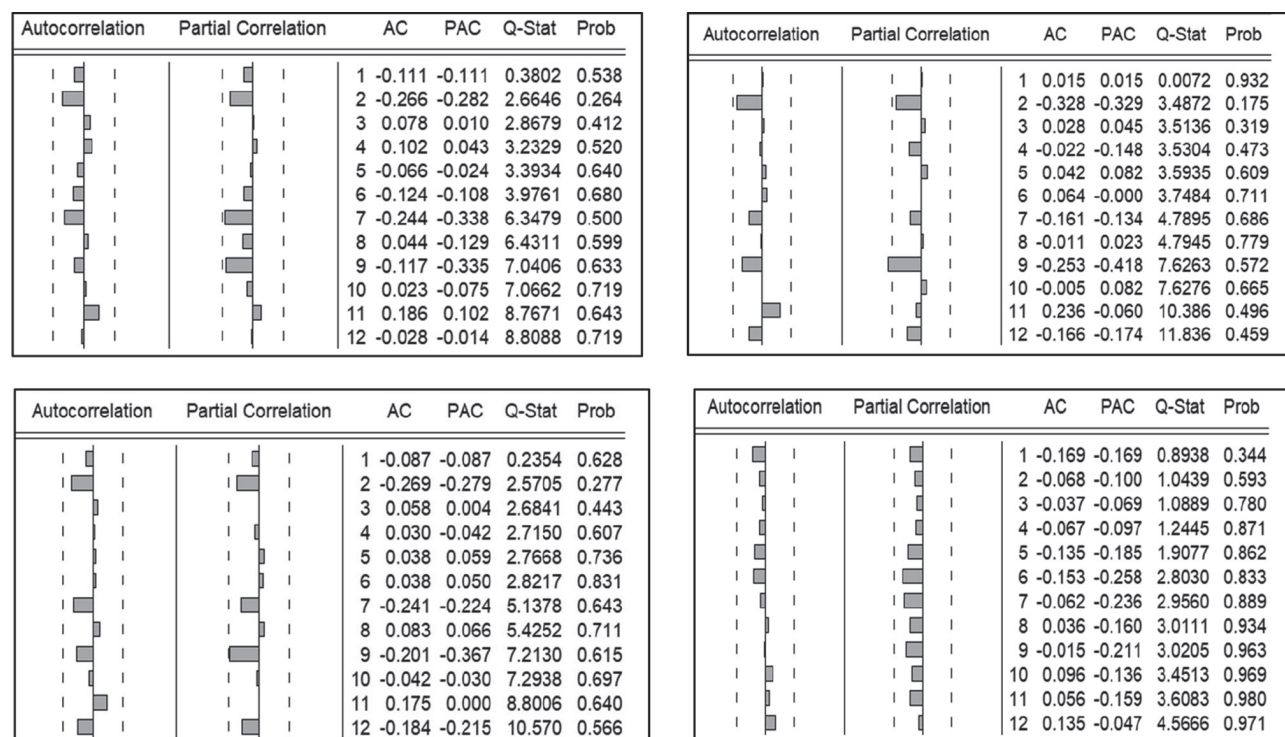


Рис. 7. Автокорреляция и частичная автокорреляция первых разностей временных рядов текущего счета платёжного баланса марок BR, WTI, MRES.

Источник: График создан автором в программе EViews

Fig. 7. AC and PAC of the first differences of time series BPCA, BR, WTI, MRES.

Source: The graph was created by the author in the EViews software

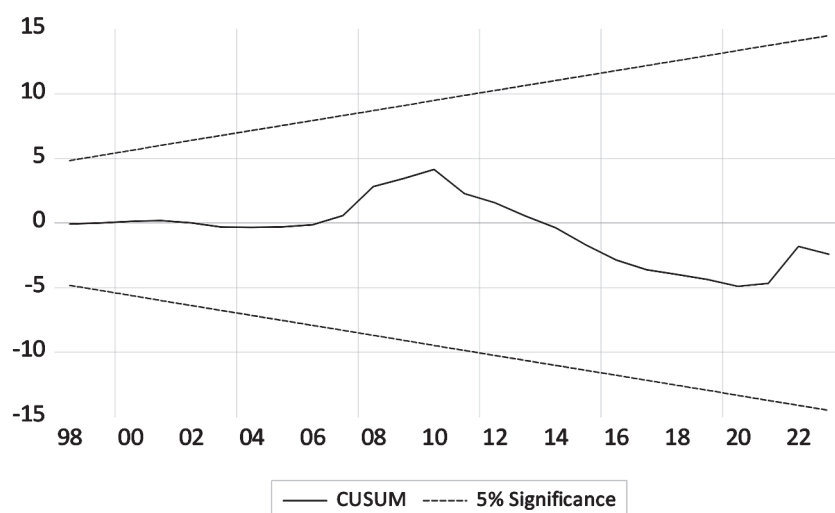


Рисунок 8. Тест контрольной карты кумулятивных сумм для проверки стабильности параметров модели.

Источник: График создан автором в программе EViews

Figure 8. CUSUM test to check the stability of model parameters.

Source: The graph was created by the author in the EViews software

probability shares for all series that received values greater than $\text{prob.} = 0.05$. The results allow us to accept the hypothesis of stationarity in the residuals of autoregressive first difference models for the time series.

Based on the results of the CUSUM test, which serves to test the stability of the model parameters, the null hypothesis about the stability of the parameters is accepted and the alternative hypothesis about the instability of the model parameters is rejected. At the 0.05 significance level, the residuals of the recursive estimates are within the confidence interval for both the CUSUM procedures (see Fig. 8). This confirms the high quality and stability of the parameters in the developed model for analyzing the dynamics and forecasting the balance of payments.

To test the cause-and-effect relationship between variables, the Granger Test is performed. When the test is applied, the values are respected with a delay. Increasing the indicators slows down the size of the series limitation, and their maximum volume depends on the length of the time series. To implement the test, quarterly data was used that covered the period from 2000 to 2021, the number of stud-

ies was 88, the values lagged from 2 to 11. From the test results, values were selected that confirmed two-way cause-and-effect relationships. $F_{\text{stat.}} = 2.24732(\text{prob.} = 0.0246)$; $F_{\text{stat.}} = 2.21965(\text{prob.} = 0.0265)$ is the result confirming the presence of a two-way causal relationship between BPCA and BR, with $\text{laqs} = 9$. $F_{\text{stat.}} = 2.24375(\text{prob.} = 0.0249)$; $F_{\text{stat.}} = 2.03296(\text{prob.} = 0.0427)$ is the result confirming the presence of a two-way causal relationship between BPCA and WT, with $\text{laqs} = 11$.

The following technique makes it possible to determine the presence of cointegration in a multiple model with several time series. If there are many series, then there will be a number of cointegration equations. A criterion is proposed for selecting and evaluating the best cointegration equation. Within the framework of the Johansen test, the H_0 hypothesis is tested, confirming the maximum r of cointegration vectors and alternative hypotheses that there are more than 1 and more than 2, etc. If the value of the calculated tests turns out to be significant, then H_0 is rejected. The found maximum value for r is the cointegration rank.

For single equations, the essence of the test for integration

can be explained by the definition of equality. This equality indicates the presence of unit roots in the autoregression [32, 33]. So, cointegration testing is mathematically expressed as a vector autoregressive model:

$$y_t = \sum_{i=1}^n C_i y_{t-i} + Dx_t + \varepsilon_t;$$

$$\varepsilon_t = \sum_{i=1}^m c_i y_{it}, \quad (4)$$

C_i this is a matrix of cointegration vectors.

As a vector model, it looks like this:

$$\Delta y_t = Zy_{t-1} + \sum_{j=1}^p P_j \Delta y_{t-j} + Dx_t + \varepsilon_t, \quad (5)$$

In the vector error correction model, hypothesis testing starts from rank 0 to rank $(n - 1)$. If the hypothesis is accepted for rank 0, then such rank is considered zero and all variables have integration $I(1)$, that is, no cointegration. And thus, the testing of hypotheses continues until $r = n$. If the conditions are met, an alternative hypothesis is accepted about the stationarity of the original series, where the variables have an order of integration $I(0)$.

The results of the Engle-Granger and Johansen test for cointegration of time series with a lag interval from 1 to 2 showed that the best values according to the Akaike and Schwartz information criteria were determined to be 34.29106 and 35.84984* (see Table 3). Trace and Maximum Eigenvalue tests were carried out with first differences of time series variables and lag intervals from 1 to 2, where the null and alternative hypotheses were tested. Tests were tested at a significance level of 0.05. According to these tests, when testing hypotheses in cases where the calculated values of statistics exceeded critical values, alternative hypotheses about the presence of one linear and two quadratic cointegration equations with a trend were accepted (see Table 4). The test results indicate the long-term relationship and the authenticity of the correlation between the time series of variables.

Результаты теста Энга-Грейнджера и Йохансена на коинтеграцию временных рядов
Results of the Engle-Granger and Johansen test for time series cointegration

Information Criteria					
Trend	There are no deterministic trends in the data	There are no deterministic trends in the data	Presence of a deterministic linear trend in the data	Presence of a deterministic linear trend in the data	Presence of a deterministic quadratic trend in the data
Test	No Intercept No trend	Intercept No trend	Intercept No trend	Intercept Trend	Intercept Trend
	1 1	0 0	1 0	0 1	1 1
	Log Likelihood by Rank (rows) and Model (columns)				
0	-411.7211	-411.7211	-411.2010	-411.2010	-409.8651
1	-401.2079	-401.2039	-400.9455	-396.2383	-396.0555
2	-398.2806	-397.8337	-397.6131	-392.8128	-392.6389
3	-398.2692	-395.6398	-395.6398	-390.3537	-390.3537
Akaike criteria by rank and model					
0	33.05547	33.05547	33.24623	33.24623	33.37424
1	32.70830	32.78492	32.91888	32.63372*	32.77350
2	32.94466	33.06413	33.12408	32.90868	32.97223
3	33.40532	33.43383	33.43383	33.25797	33.25797
Schwartz criteria by rank and model					
0	33.92646	33.92646	34.26238	34.26238	34.53556
1	33.86962*	33.99462	34.22537	33.98859	34.22515
2	34.39631	34.61256	34.72090	34.60227	34.71421
3	35.14730	35.32098	35.32098	35.29028	35.29028

Since the calculated values exceed the critical values, the null hypothesis $H_0:r = 0$ about the absence of cointegrating vectors is rejected and the alternative hypothesis $H_A:r > 0$ about the presence of one vector according to the Trace criterion is accepted ($26.90372 > 24.27596$; prob. = 0.0228) and by the maximum eigenvalue test ($21.02627 > 17.79730$; prob. = 0.0158) for the case of no trend and no intersection. The null hypothesis about the existence of one vector is accepted, since in this case the calculated values are less than critical for the Trace test ($5.877456 < 12.32090$; prob. = 0.4511) and for the Maximum Eigenvalue test ($5.854674 < 11.22480$; prob. = 0.3665). When testing hypotheses, significance levels below 0.05 are taken into account, which allows decisions to be made (see Table 4).

For a quadratic trend the situation is similar. The null hypothesis about the absence of cointegration vectors is rejected, the alternative one is accepted about the presence of quadrat-

ic trend vectors according to the Trace and Maximum Eigenvalue tests ($39.02284 > 35.01090$; prob. = 0.0176; $27.61917 > 24.25202$; prob. = 0.0173). It is accepted that $H_0:r = 1$ indicates the presence of one quadratic trend vector according to the Trace and Maximum Eigenvalue tests ($11.40367 < 18.39771$; prob. = 0.3554; $6.833133 < 17.14769$; prob. = 0.7310). The alternative hypothesis $H_A:r > 1$, which confirms the presence of more than one cointegration vectors, is rejected.

The results of the Granger test for two-way causal relationships between variables allow us to construct a cointegration equation and vector error correction model for the studied series BPCA, BR, WTI. Using the results of the Engle-Granger, Johansen, Trace Maximum and Eigenvalue tests, we could choose two options for constructing models: with and without a deterministic trend in the data (Table 3 and Table 4). A deterministic quadratic trend in the data was chosen.

Таблица 4 / Table 4

Результаты теста на максимум следа и собственных значений (интервал задержки от 1 до 2, первые разности)
Trace Maximum and Eigenvalue test results (lag interval from 1 to 2, first differences)

Hypothesis	Alternative hypothesis	Trace	Crit.5%	Prob.	Maximum Eigenvalue	Crit. 5%	Prob.
no trend no intersept							
$H_0:r = 0^*$	$H_A:r > 0$	26.90372	24.27596	0.0228	21.02627	17.79730	0.0158
$H_0:r = 1$	$H_A:r > 1$	5.877456	12.32090	0.4511	5.854674	11.22480	0.3665
$H_0:r = 2$	$H_A:r > 2$	0.022782	4.129906	0.9017	0.022782	4.129906	0.9017
quadratic deterministic trend							
$H_0:r = 0^*$	$H_A:r > 0$	39.02284	35.01090	0.0176	27.61917	24.25202	0.0173
$H_0:r = 1^*$	$H_A:r > 1$	11.40367	18.39771	0.3554	6.833133	17.14769	0.7310
$H_0:r = 2$	$H_A:r > 2$	4.570536	3.841466	0.0325	4.570536	3.841466	0.0325

Thus, the VECM was constructed with the following specifications of the deterministic trend: quadratic trend in the data with first-order differences, Intercept and Trend; linear trend in VAR, the number of lags is 1–2. The cointegration relationship (6) and the VEC model (7), (8), (9) are presented below.

$$\begin{aligned} \text{BPCA}(-1) = & -1438.686\text{BR}(-1) + \\ & + 1332.13\text{WTI}(-1) + \\ & + 344.3805\text{TREND}(1) - \\ & - 1215.014 \end{aligned} \quad (6)$$

$$\begin{aligned} \Delta(\text{BPCA}) = & 0.429569(\text{BPCA}(-1) - \\ & - 1438.686\text{BR}(-1) + \\ & + 1332.130\text{WTI}(-1) + \\ & + 344.3885\text{TREND}(1) - \\ & - 1215.014) - \\ & - 0.52498\Delta(\text{BPCA}(-1)) - \\ & - 1.095624\Delta(\text{BPCA}(-2)) + \\ & + 550.0173\Delta(\text{BR}(-1)) + \\ & + 239.3219\Delta(\text{BR}(-2)) - \\ & - 509.1630\Delta(\text{WTI}(-1)) + \\ & + 159.3341\Delta(\text{WTI}(-2)) + \\ & + 248.3869 + \\ & + 3267125\text{TREND}(1) \end{aligned} \quad (7)$$

$$\begin{aligned} \Delta(\text{BR}) = & 0.002306(\text{BPCA}(-1) - \\ & - 1438.686\Delta\text{BR}(-1) + \\ & + 1332.130\text{WTI}(-1) + \\ & + 344.3885\text{TREND}(1) - \\ & - 1215.014) - \\ & - 0.00097\Delta(\text{BPCA}(-1)) - \\ & - 0.005452\Delta(\text{BPCA}(-2)) + \\ & + 3.2445\Delta(\text{BR}(-1)) + \\ & + 2.201300\Delta(\text{BR}(-2)) - \\ & - 3.423312\Delta(\text{WTI}(-1)) - \\ & - 1.726768\Delta(\text{WTI}(-2)) + \\ & + 3.076096 + \\ & + 0.027652\text{TREND}(1) \end{aligned} \quad (8)$$

$$\begin{aligned} \Delta(\text{WTI}) = & 0.001595(\text{BPCA}(-1) - \\ & - 1438.686\Delta\text{BR}(-1) + \\ & + 1332.130\text{WTI}(-1) + \\ & + 344.3885\text{TREND}(1) - \\ & - 1215.014) - \\ & - 0.000293\Delta(\text{BPCA}(-1)) - \\ & - 0.00468\Delta(\text{BPCA}(-2)) + \\ & + 2.483572\Delta(\text{BR}(-1)) + \\ & + 1.975283\Delta(\text{BR}(-2)) - \\ & - 2.800675\Delta(\text{WTI}(-1)) - \\ & - 1.505538\Delta(\text{WTI}(-2)) + \\ & + 3.400712 - \\ & - 0.025050\text{TREND}(1) \end{aligned} \quad (9)$$

The VEC model (7), (8), (9) with a quadratic trend in the first-order differenced data, with Intercept and Trend, with a linear

trend in VAR and with lags of 1-2 cannot be considered reliable. Since the coefficient in the error correction model for BPCA is positive. This creates problems for the long-run equilibrium relationship between the variables.

Considering the current situation, the study was continued to obtain an effective VECM. Lags with a number of lags of 2-2 were used in the formation of the model. An effective result was obtained for three tests. The option with a quadratic trend in the data with first-order differences, with Intercept and Trend, with a linear trend in VAR, with a number of lags of 2-2 was selected. The

cointegration relationship (10) and the VEC model (11), (12), (13) were constructed.

$$\begin{aligned} \text{BPCA}(-1) = & -368.6261\text{BR}(-1) + \\ & + 257.4524\text{WTI}(-1) - \\ & - 68.80278\text{TREND}(1) + \\ & + 2843.146 \end{aligned} \quad (10)$$

$$\begin{aligned} \Delta(\text{BPCA}) = & -0.494192(\text{BPCA}(-1) - \\ & - 368.6261\text{BR}(-1) + \\ & + 257.4524\text{WTI}(-1) - \\ & - 68.80278\text{TREND}(1) + \\ & + 2843.146) + \\ & + 0.493162\Delta(\text{BPCA}(-2)) - \\ & - 56.81141\Delta(\text{BR}(-2)) - \\ & - 160.9999\Delta(\text{WTI}(-2)) + \\ & + 1736.942 - \\ & - 72.33535\text{TREND}(1) \end{aligned} \quad (11)$$

Таблица 5 / Table 5

**Значения отклика функций импульсного отклика переменных
Ответы текущего счета платёжного баланса**

Response values of impulse response functions of variables Responses BPCA

Periods	BPCA	BR	WT
1	6353.949	0.000000	0.000000
2	5679.541	-48.37274	117.9162
3	1987.681	241.3305	843.4566
4	4642.943	-521.4458	1405.738
5	7776.777	-616.8837	1216.715
6	6297.330	-158.0370	819.3697
7	3578.800	161.4309	656.7991
8	4159.383	-24.77987	714.4713
9	5619.335	-209.4476	764.9523
10	5287.876	-153.0836	843.2350
Responses BR			
Periods	BPCA	BR	WT
1	15.19348	9.309039	0.000000
2	17.21756	5.371575	-0.656346
3	-0.487407	9.252754	2.508565
4	13.66947	3.671204	6.936185
5	27.13823	3.112381	7.481646
6	26.29380	4.272357	6.390863
7	14.70347	6.176081	4.785495
8	13.52981	6.327378	4.214790
9	17.63514	5.660524	4.089323
10	17.22386	5.678370	4.604947
Responses WTI			
Periods	BPCA	BR	WT
1	15.29735	9.268103	1.869359
2	16.10241	4.761774	0.605674
3	0.099894	9.766527	2.646872
4	12.46727	4.441343	5.845548
5	21.12688	4.673826	6.250250
6	21.35343	5.026913	5.879994
7	13.04420	6.402203	4.811609
8	12.91919	6.487100	4.415177
9	15.55136	6.099825	4.137926
10	14.64100	6.261503	4.416202

$$\begin{aligned}\Delta(BR) = & -0.000509(BPCA(-1) - \\ & - 368.6261BR(-1) + \\ & + 257.4524WTI(-1) - \\ & - 68.80278@TREND(1) + \\ & + 2843.146) + \\ & + 0.001435\Delta(BPCA(-2)) + \\ & + 0.443833\Delta(BR(-2)) - \\ & - 1.222149\Delta(WTI(-2)) + \\ & + 8.063234 - \\ & - 0.302212@TREND(1) \quad (12)\end{aligned}$$

$$\begin{aligned}\Delta(WTI) = & -0.000944(BPCA(-1) - \\ & - 368.6261BR(-1) + \\ & + 257.4524WTI(-1) - \\ & - 68.80278@TREND(1) + \\ & + 2843.146) + \\ & + 0.001228\Delta(BPCA(-2)) + \\ & + 0.611658\Delta(BR(-2)) - \\ & - 1.181820\Delta(WTI(-2)) + \\ & + 3.400712 - \\ & - 0.025050@TREND(1) \quad (13)\end{aligned}$$

The VEC models (11), (12), (13) express the long-run relationship between the time series of the variables under study in equilibrium form. These models can also measure deviations from equilibrium and the rate at which it is very slowly restored, providing a long-run relationship.

The impulse response function makes it possible to trace the influence of surprises, some external shocks on the prospective value of variables over a certain period of time. Using this function, we characterize the process of returning an endogenous variable to equilibrium after a single shock to an exogenous variable. After constructing and evaluating the VECM, tabulated values of the impulse response function were obtained. Table values are obtained for a 10 year time period. The values in the Table 5 demonstrate the responses of the impulse functions of the variables to structural shocks that cover 2 years of the 10 year period. Then there is a gradual, slow transition to a stable period.

The forecast error variance decomposition method provides information about the relative importance of random deviations in endogenous variables [34]. It separates fluctuations in the endogenous variable into its

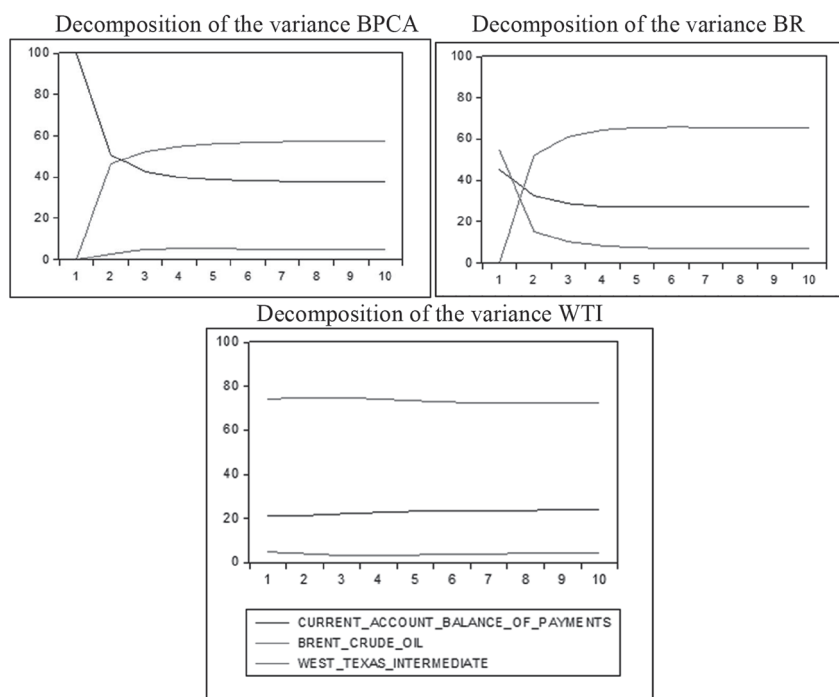


Рисунок 9. Декомпозиция отклонений

Источник: График создан автором в программе EViews

Figure 9. Decompositions of variances

Source: The graph was created by the author in the EViews software

effect components in the model. The results of the forecast error variance decomposition method are presented in Figure 9.

To check the quality of the VECM, tests were also carried out that analyze the residuals of these models. The number of observations for next tests is 26, lags are selected from 1 to 2. First

of all, VAR Residual Normality Tests were carried out on the normal distribution of residuals, the results of which are presented in Table 6. As can be seen from the results, the asymmetry in the distribution of residuals is close to zero, minimal, that is, insignificant. The kurtosis does not reach a value of 3. Only

Таблица 6 / Table 6

Тесты на нормальность остатков в моделях векторной авторегрессии
VAR Residual Normality Tests

Component	Asymmetry	Chi-square	d.f.	Probability
1	0.365470	0.578797	1	0.4468
2	-0.082824	0.029726	1	0.8631
3	-0.319045	0.441088	1	0.5066
Joint		1.049611	3	0.7892
Component	Excess	Chi-square	d.f.	Probability
1	3.404978	0.177674	1	0.6734
2	2.245362	0.616934	1	0.4322
3	2.627796	0.150081	1	0.6985
Joint		0.944689	3	0.8146
Component	Jarque-Bera	d.f.	Probability	
1	0.756471	2	0.6851	
2	0.646660	2	0.7237	
3	0.591169	2	0.7441	
Joint	1.994301	6	0.9202	

for the first component there is a slight excess of value 3. That is, there is no peak distribution. For both characteristics, the distribution can be considered normal. The Jarque-Bera test for the alternative hypothesis also confirms the normality of the distribution over the three components. In all cases, the probability values exceed the 0.05 significance level and the hypothesis about the normal distribution of model residuals is confirmed.

VAR Residual Serial Correlation LM tests analyzes relationships in residuals.

LM test results on VAR residual serial correlation, the null hypothesis of which is no serial correlation with lag delay. When testing for all lags, the probability is greater than 0.05, therefore, the H_0 hypothesis is accepted and there is no serial correlation when lags 1, 2, 3 are delayed.

Using VAR Residual Heteroskedasticity Tests to test for heteroscedasticity in the residuals, the probability of no heteroscedasticity is 7%. This justifies the decision to accept the H_0 and the absence of heteroscedasticity in the

residuals. The following results were obtained from the test: Chi-square 116.6772; d.f. = 96; prob. = 0.0743; for all dependent variables prob. > 0.05. So, according to the Gauss–Markov conditions, the variance in the residuals is constant, and the mathematical expectation is «0», which confirms the normal distribution.

The obtained test results confirm the adequacy of the constructed VECM (11), (12), (13).

Conclusions. The study presents a vector error correction model that allows the analysis and modeling of three statistical series. Error correction models (11), (12) and (13) can be considered adequate and statistically significant. This conclusion is drawn from the results of the tests carried out and analyzed in the work. Econometric tests were carried out to check the normality of distribution, correlation relationships, the presence of autocorrelation, and regression analysis. After taking the first differences from the levels of the original time series, which were initially non-stationary, positive results were obtained, allowing

the acceptance of the hypothesis about the stationarity of the studied time series BPCA, BR and WTI. Also, additional tests were carried out on cause-and-effect relationships in the series, on the presence of cointegration relationships, on the stability of parameters, on the presence of heteroskedasticity of residuals, estimates of impulse response functions were obtained, and the decomposition method was applied, which made it possible to construct and justify the adequacy of VECM.

The constructed VEC model can be useful in assessing the quantitative characteristics of the variables under study and the relationships between them, in forecasting the current account of the balance of payments of Azerbaijan in the short and long term. VECM limits the dynamics of endogenous variables in the identified 2-year time period and returns them to cointegration relationships very slowly.

The result of the study shows that the factors under consideration are significant determinants of the current account of the balance of payments of Azerbaijan in the long term.

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