CORRELATION-REGRESSION RELATIONSHIPS IN ANALYSIS OF THE ECONOMY OF THE REPUBLIC OF SOUTH AFRICA

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Abstract. In this study, a correlation-regression analysis was conducted based on the main macroeconomic indicators of the national economy of the Republic of South Africa (ZAR). In the study, the factors affecting GDP were evaluated in statistical correlation based on World Bank data. Using the correlation matrix, the level of linear correlation was determined, and a model was developed to explain the dynamics of GDP through multivariate regression. The results show that the services sector and exports are the main drivers of South Africa's GDP, while industry and agriculture are stable structural factors.

Keywords: South Africa, ZAF, GDP, exports, imports, services sector, agriculture, regression, correlation, economic growth.

Annotatsiya. Mazkur tadqiqotda Janubiy Afrika Respublikasi (JAR) milliy iqtisodiyotining asosiy makroko'rsatkichlari asosida korrelyatsion–regression tahlil amalga oshirildi. Tadqiqotda YaIMga ta'sir etuvchi omillar sifatida eksport, import, xizmatlar sohasi, sanoat, qishloq xo'jaligi va aholi soni World Bank ma'lumotlari asosida statistik o'zaro bog'liqlikda baholandi. Korrelyatsion matritsa yordamida chiziqli bog'liqlik darajasi aniqlanib, ko'p omilli regressiya orqali YaIM dinamikasini izohlashga qaratilgan model shakllantirildi. Natijalar shuni ko'rsatadiki, xizmatlar sohasi va eksport JAR YaIMining asosiy drayveri, sanoat va qishloq xo'jaligi esa barqaror tarkibiy omil sifatida namoyon bo'ladi.

Kalit so'zlar: South Africa, ZAF, YaIM, eksport, import, xizmatlar sektori, qishloq xo'jaligi, regressiya, korrelyatsiya, iqtisodiy o'sish.

Introduction

The Republic of South Africa (South Africa, ZAF) is one of the most industrialized and diversified economies on the African continent, with a GDP of approximately $405 billion as of 2024[1]. According to the World Bank classification, South Africa is an upper-middle-income economy, with a GDP per capita of over $6,500 in 2024[2].

The country has an area of 1.22 million km² and a population of approximately 61 million in 2024; with a human development index of 0.713, it is classified as a middle-income country (UNDP Human Development Report, 2024). South Africa's economic model is based primarily on the services sector (62–64% of GDP), industry (28–30%), and resource-based exports[3].

Foreign trade is the main driver of economic growth, with gold, platinum, iron ore, coal, and automotive products dominating the export segment; key partners are China, the United

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[1] IMF, World Economic Outlook, 2024
[2] World Bank WDI, 2024 https://data.worldbank.org/country/south-africa
[3] World Bank, Services & Industry Value Added, 2024

States, and Germany[4]. At the same time, the country faces structural problems such as high unemployment (over 30%), energy shortages, and inflationary pressures[5].

Therefore, assessing the main indicators of South Africa's economic development through a correlation-regression approach, linking them with exports, imports, services, industry, agriculture and demographic changes, allows us to identify the determinants of national growth. This study aims to determine the statistical relationship of GDP with factors based on World Bank data for 2015–2024. In October 2025, Uzbekistan exported goods to the Republic of South Africa worth ZAR 166 million and imported goods worth ZAR 55.4 million. As a result, the trade balance was positive by ZAR 110 million. From October 2024 to October 2025, Uzbekistan's exports to the Republic of South Africa increased from ZAR 34.5 million to ZAR 166 million, an increase of ZAR 131 million or 380%. At the same time, imports increased by ZAR 27.5 million or 98.6%, from ZAR 27.9 million to ZAR 55.4 million[6].

Research methodology

This study used a classical econometric approach of correlation-regression analysis to assess the factors affecting the growth of South Africa's GDP. The World Bank World Development Indicators (WDI) 2015–2024 statistical series was taken as the data base for the analysis, since this period covered the pandemic, recovery and foreign trade fluctuations in the South African economy (World Bank WDI, 2024).

GDP (current US$) was selected as the outcome indicator, and the population, exports, imports, industrial value added, services value added and agricultural value added were included as independent factors affecting it. Initially, pairwise correlation coefficients between the factors were calculated, and the possibility of cross-linearity and multicollinearity was assessed.

In the next stage, a multivariate linear regression model was constructed, and the statistical significance of the regression parameters was checked using the Student t-test, and the overall reliability of the model was checked using the Fisher test. The coefficient of determination (R^2) of the model showed how much of the GDP variance is explained by the selected factors.

Analysis and results

According to the analysis, the growth of exports and imports has a positive impact on the sustainable growth of GDP in the Republic of South Africa. The expansion of imports, especially through increased demand for technological equipment, energy and intermediate goods, supports industrial production, as the South African economy is dependent on high-tech equipment. Exports, in turn, confirm the country's export-oriented economic model, as export revenues from gold, platinum, coal, automobiles and metal products directly contribute to GDP growth.

The services sector is the main foundation of domestic growth in South Africa, with the banking and finance, transport and logistics, insurance and retail segments accounting for more than half of the GDP structure. This sector plays an important role in stimulating domestic demand and maintaining economic stability.

Although the industrial sector has slowed down in some years due to energy shortages and investment instability, it remains a major component of national production. Power outages, inflation, and capital flows explain the fluctuations in industrial growth.

The agricultural sector is a strategic factor for South Africa, supporting GDP as an important source of export earnings through fruits and vegetables, citrus products, and livestock, although its share in GDP is low.

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[4] World Bank WITS Trade Indicators, 2024

[5] Statistics South Africa Labour Market Review, 2024

[6] Observatory of Economic Complexity (OEC) - https://oec.world/en/profile/bilateral-country/uzb/partner/zaf

Population growth expands the domestic consumer market, increasing activity in the services, trade, and transport sectors. However, demographic growth does not always contribute to high GDP growth rates - high unemployment, inflation, and fiscal pressures can limit this process.

The essence of the correlation-regression approach is that statistical analysis identifies the relationship between two or more factors. If the correlation coefficient (r) is close to 1, there is a positive relationship, if it is close to –1, there is a negative relationship, and if $r \approx 0$, there is no relationship. Regression is used to determine the strength of the effect, modeling a single outcome indicator (y) through several independent factors (x).

There are two forms of regression: simple linear regression and multivariate regression, and it is through multivariate regression that the impact of each factor on GDP can be measured. This statistical set allows us to identify the main factors affecting the GDP of the Republic of South Africa, assess their influence, and indicate their economic limits.

The main goal of the econometric modeling used in the study is to determine which factors contribute to the increase in GDP through the practical formulation of correlation-regression analysis, and to shed light on how economically important these factors are.

The model hypothesis is expressed as follows:

$H_0 \approx$ none of the six factors affects the random variable (Y-gross domestic product).

$H_1 \approx$ at least one of the six factors affects the random variable (Y).

To test the above null hypothesis, we construct the following theoretical model:

$$Y = a + \beta X_1 + \beta X_2 + \beta X_3 + \beta X_4 + \beta X_5 + \beta X_6 + u$$

Here:

Y- GDP (millions of US dollars);

X_1 – Population, total (million people);

X_2 – Exports of goods and services (millions of US dollars);

X_3 – Industry (including construction), value added (millions of US dollars);

X_4 – Services, value added (millions of US dollars);

X_5 – Imports of goods and services (millions of US dollars);

X_6 – Agriculture, forestry and fisheries, value added (millions of US dollars);

a — free will;

β — coefficient;

u — error.

Table 1

Resultant and influencing factors selected for correlation-regression statistical analysis[7]

Years	Y	X1	X2	X3
2015	346709790459	56723537	96085897668	8228223525
2016	323585509674	57259551	91109021409	7695684452
2017	381448814653	57635162	104288394993	9006218788
2018	405260723893	58613001	111434691806	9538646314
2019	389330032224	59587885	105906059179	9196759971
2020	33974655408	60562381	93199600859	7888138653
2021	41986284375	61502603	131000485997	10457911200

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[7] https://data.worldbank.org/country/south-africa

2022	407596043068	62378410	136705431597	1018257608
2023	381440724491	63212384	126843584296	9369696801
2024	401144998374	64007187	127531645077	9752047873

The peculiarity of a multifactor correlation relationship is that its regression equation involves several important and significant factors. Of these factors, it is of great importance to correctly select the most significant and include them in the regression equation.

The selection of factors is based on qualitative and theoretical analysis and is carried out in three stages. In the first stage (initial analysis), factors are selected without any conditions. In the second stage, they are analyzed using pairwise correlation coefficients. For this, a matrix of pairwise correlation coefficients between the signs u1, x1,x2,...,xn is constructed. In the third stage of factor analysis, the regression equation is determined and the significance or otherwise of its parameters is assessed using special criteria.

Correlation analysis methods can be used to determine the influence of these factors on the resulting sign. In this case, the pairwise correlation coefficient is determined as follows:

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(2)

$$ r_{ij} = \frac{\left(\sum x_i x_j - \frac{\sum x_i \sum x_j}{n} \right)}{\sqrt{\left(\sum x_i^2 - \frac{\left(\sum x_i\right)^2}{n} \right)\left(\sum x_j^2 - \frac{\left(\sum x_j\right)^2}{n} \right)}} $$

To determine which factors should be included in the regression equation, we construct a matrix of pairwise correlation coefficients between the factors (*Table 2*).

Table 2
Matrix of pairwise correlation coefficients of influencing factors [8]

	Y	X1	X2	X3	X4	X5	X6	
Y	1							
X1	0,5438204	1						
X2	0,8477101	0,804854	1					
X3	0,9783086	0,624450	0,928265	1				
X4	0,9892459	0,460313	0,763602	0,938317	1			
X5	0,7127835	0,619192	0,86243	0,76881	0,63998	1		
X6	0,6925963	0,774629	0,84282	0,75265	0,62199	0,63758	1	

From the data in Table 2, it can be said that the pairwise correlation coefficients indicate a strong and stable positive relationship between GDP (Y) and the selected factors. The highest

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[8] Manba: 1-jadval malumotlari asosida muallif excel dasturi orqali hisob-kitoblari asosida hisoblangan.

correlations are observed in the pairs Y–X4 (0.989) and Y–X3 (0.978). This confirms that the services sector and industry are the leading determinants of South Africa's economic growth. While the services sector (banking and finance, logistics, trade) forms the main part of GDP, industry supports the production base and export potential.

The correlation of GDP with exports is also high (Y–X2 = 0.848), which indicates the orientation of the South African economic model to the external market. In this case, gold, platinum, coal and automobile exports are the main drivers, and foreign trade revenues directly affect the growth of national income.

The correlation of the import indicator with GDP is estimated at 0.713, which indicates the reliance of the economy on imports of technological equipment, machinery and raw materials. The growth of imports serves as an additional resource for domestic production processes.

The correlation with the agricultural indicator is 0.693, which indicates that this sector has a subsidiary but strategic role in GDP. It contributes to economic activity mainly through fruit and vegetables and agricultural exports, but is not as dominant as industry and services.

The impact of population on GDP is relatively lower (0.543), indicating that demographic growth does not fully correspond to economic performance. This indicates that employment, unemployment and labor market problems remain for South Africa.

At the same time, there are very high correlations between factors:

- X2–X3 = 0,928,
- X3–X4 = 0,938,
- X2–X6 = 0,842.

This result indicates a high probability of multicollinearity in the model; that is, industry, services and exports act as economic drivers that replicate each other. Care must be taken when selecting these factors in regression analysis.

The coefficient of determination shows the proportion of the variance of the resulting variable that is explained by the specified model, that is, the influence of the factors under consideration. This indicator takes values between "0" and "1". The closer its value is to the value "1", the more the factors included in the regression equation explain the behavior of the resulting indicator.

The analysis of the significance of the specified model is carried out by testing the "null hypothesis". "Null hypothesis" $H_0 : \beta_1' = \beta_2' = ... = \beta_k' = 0$ is expressed as a function of the overall significance of the regression coefficient. If the results of the analysis do not reject the null hypothesis, then: " $x_1, x_2, ..., x_k$ the effect of the factors on the resulting indicator "Y" is insignificant, the overall quality of the regression equation is low", it is concluded. The "null hypothesis" is tested using the analysis of variance, and the "null hypothesis" is expressed as $N_0:D_{fact}=D_{qold}$ and the alternative hypothesis is $N_1:D_{fakt}>D_{qold}$. The F-Fisher test is used to test these hypotheses. In this case, the true value of the test is determined by the following formula:

$$F = \frac{\sum_{i=1}^{n} (\hat{y}_i - \bar{y})^2 / k}{\sum_{i=1}^{n} (y_i - \hat{y}_i)^2 / (n-k-1)} = \frac{R^2}{1-R^2} * \frac{(n-k-1)}{k}$$

Here:

$\sum_{i=1}^{n} (\hat{y}_i - \bar{y})^2 / k$ – one-factor variance corresponding to one degree of freedom (number of degrees of freedom γ1=k);

$$\sum_{i=1}^{n} (y_i - \hat{x}_i)^2 / (n-k-1)$$ – residual variance corresponding to one degree of freedom

(number of degrees of freedom γ1=n-k-1);

n – number of observations;

k - number of factors (parameters) in a multivariate regression equation.

Real value of F- Fisher criterion (F_{real}) compared with critical value of the criterion *($F_{jadv}(α; k; n-k-1)$)*. If $F_{real} > F_{table}$, then the identified model is considered significant.

The actual value of the F-Fisher criterion in the model developed through the analysis of factors affecting GDP growth F_{real}= 11620,00467 (table 3).

Table 3

Regression statistics table[9]

Регрессионная статистика					
Множественный R	0,999978486				
R-квадрат	0,999956973				
Нормированный R-квадрат	0,999870918				
Стандартная ошибка	370884957,5				
Наблюдения	10				
Дисперсионный анализ					
	df	SS	MS	F	Значимость F
Регрессия	6	9,59038E+21	1,5984E+21	11620,00467	1,23473E-06
Остаток	3	4,12667E+17	1,37556E+17		
Итого	9	9,5908E+21			

Therefore, the factors included in the regression equation are considered highly significant, relatively significant, and insignificant. Based on the results of the analysis, we have separately distinguished the highly significant and insignificant factors included in our model (Table 4).

Table 4

Significant factors included in the linear regression model[10]

Variable	Coefficient(β)	t-stat	P-	Нижние

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[9] The author calculated based on Excel calculations.

[10] Muallif excel dasturi hisob-kitoblari asosida hisoblangan.

			Value	*95%*
Permanent limit (Intercept)	–5844315702	–0,57	0,606	- 38242116972
X1 – Population	104,04	0,53	0,633	- 520,9927039
X2 – Export	–0,0048	–0,03	0,976	- 0,493799954
X3 – Industrial value added	1,2401	3,96	0,0286	0,244360239
X4 – Value added services	1,0675	14,29	0,0007	0,829866856
X5 – Import	0,0538	1,55	0,217	- 0,056167927
X6 – Agriculture	0,3298	1,35	0,270	- 0,448245365

Table 4 shows the regression results clearly showing the direction, statistical significance and level of confidence of each coefficient in assessing the factors affecting the GDP of South Africa. According to the data in the table, the value of the constant term is negative and its P-value is very high (0.606), which means that the intercept is not statistically significant and the independent formation of GDP cannot be explained without factors. Although the coefficient on population is positive (104.04), the low t-statistic and the P-value remaining at 0.63 do not confirm the significant impact of this factor on GDP. This result shows that demographic growth in South Africa does not automatically accelerate economic growth, and the economic impact of the population factor is weak due to employment and unemployment problems.

The coefficient on the export indicator is very small and negative (–0.0048) and the P-value is very high (0.976), indicating that this factor is not statistically significant in the regression model. This result indicates that South Africa's exports are mainly based on raw materials and mineral resources, and the instability of prices and external demand cannot sustainably support economic growth. Although the coefficient on imports is positive and economically positive (0.0538), it is not statistically significant (P≈0.217), which indicates that imports act as an auxiliary resource factor rather than a main driver. Also, although the coefficient on agriculture is also positive (0.3298), its effect is not confirmed because the P-value is at the level of 0.27. Despite the strategic importance of this sector for South Africa, it does not have as strong a determining effect as services and industry in the economic model.

In the model, only two factors – industry (X_3) and services (X_4) – stand out as statistically significant factors. The coefficient of industry is 1.24, the t-statistic is 3.96 and the P-value is 0.028, confirming the significant positive impact of this factor on GDP. This result indicates that the main source of domestic growth in the South African economy is the extraction, energy and industrial processing potential. The strongest result is observed for the services sector: the coefficient is 1.067, the t-statistic is 14.29 and the P-value is 0.0007. This very low probability value confirms that the services sector is the main determinant of GDP, while finance, insurance, trade, logistics and public services remain the decisive pillars of national income formation.

Overall, the regression table shows that the service sector and industry are the main domestic economic drivers in the South African economy, while exports, imports, the agricultural sector, and demographic indicators are supporting but statistically weak factors.

These results provide scientific evidence that the country's economic structure is shaped by the service economy and that these sectors determine the structural basis of GDP growth.
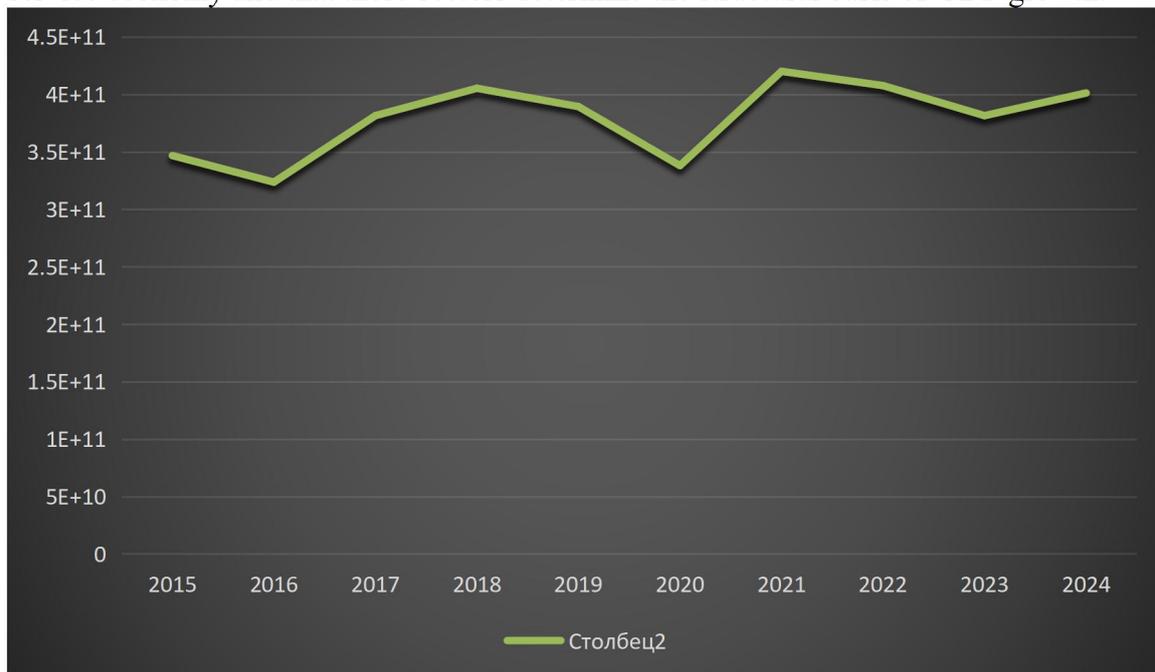

***Figure 1*. South Africa's Gross Domestic Product (GDP) from 2015 to 2024[11]**

Gross domestic product (GDP) figures for the period 2015–2024 show that the South African economy has a volatile dynamic rather than a steady growth. In 2015, GDP was ≈\$346.7 billion, and in 2016 it decreased to ≈\$323.6 billion, indicating a contraction. This decrease is due to changes in global commodity prices, domestic political and economic uncertainty, and the depreciation of the rand.

GDP will increase significantly in 2017–2018, reaching ≈\$405.3 billion in 2018, which is explained by the improvement in external market demand and the recovery of the services and industrial sectors. In subsequent years, a slight decrease is observed in 2019, and a sharp decline in 2020 to \$337.97 billion is observed - this is mainly due to the consequences of the COVID-19 pandemic and the decline in global demand.

In 2021, the economy will recover to ≈\$419.99 billion, which is explained by the post-pandemic recovery effect, fiscal stimulus and a slight improvement in the export segment. In 2022–2023, GDP will show a downward trend again, which is associated with disruptions in the energy sector, declining investment confidence and weak external economic conditions. In 2024, GDP will increase again to ≈\$400 billion, reflecting the restabilization of economic activity (World Bank 2024 nominal GDP ≈\$400.26 billion).

In general, the GDP of the South African economy in 2015–2024 is characterized by growth-decline fluctuations, in which macro factors such as the global pandemic, exchange rate, energy and external demand play a consistent role. The industry and services sector serve as a stable foundation in this dynamics, but external market shocks and domestic infrastructure problems limit the growth rate.

Conclusion

The analysis shows that South Africa's economic growth over the period 2015–2024 has been cyclical and volatile rather than a steady trend. While GDP values have risen from US\$346.7 billion in 2015 to around US\$401 billion in 2024, this growth has not been continuous, but rather has been highly correlated with global economic conditions, pandemic shocks,

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[11] https://data.worldbank.org/country/south-africa

exchange rate depreciation, and instability in domestic energy infrastructure. In particular, the decline to US$337.9 billion in 2020 is a result of the COVID-19 lockdown, the disruption in the services sector, reduced external demand, and a deterioration in employment. However, the recovery to US$419.9 billion in 2021 is explained by fiscal stimulus, a revival in the services sector, and rising global commodity prices.

Econometric results revealed that the main internal drivers of economic growth are the services sector ($P \approx 0.0007$) and industrial value added ($P \approx 0.028$). The services sector increases GDP almost linearly, confirming the priority role of finance, trade and transport in the formation of national income. The industrial sector, on the other hand, appears as a strategic base supporting national growth through mining, energy and processing potential. Although other factors - exports, imports, population growth and the agricultural segment - play a supporting role in economic activity, their impact is not among the leading factors in explaining economic results due to their low statistical power. Based on this, the South African economic model is characterized by a system based on services, dependent on resource exports, sensitive to currency fluctuations and limited by energy infrastructure.

Based on the above analysis, the following proposals are made:

1. Modernize and digitize the service sector. Expanding banking, finance, insurance, logistics, transport, trade, and government services through digital platforms, and introducing fintech solutions will strengthen the main momentum of growth.

2. Diversify industry and strengthen energy independence. Reducing dependence on mining, increasing the share of the processing industry, eliminating energy shortages, and expanding renewable energy will ensure production stability.

3. Redirect foreign trade to high-value-added products. Expanding exports of automotive parts, chemicals, metal processing, and services instead of raw material exports will increase macro-stability and protect against global price shocks.

4. Improve the investment climate and stabilize capital flows. Legal guarantees, political stability, and attracting private capital to infrastructure projects will increase foreign investment confidence.

5. Strengthen labor market efficiency. To strengthen the link between population growth and economic outcomes, mechanisms for increasing vocational training, workforce skills, and employment should be improved.

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