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Principal Component Analysis (PCA): A Multivariate Approach to Macroeconomic Indicators from Vizcarra to Sagasti During the Covid-19 Pandemic in Peru

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Abstract

This study analyzes the impact of the political crisis in Peru during the transition of the governments of Martín Vizcarra and Francisco Sagasti in the context of the COVID-19 pandemic, focusing on key macroeconomic indicators. Using Principal Component Analysis (PCA), twelve relevant macroeconomic variables, such as Gross Domestic Product (GDP), exchange rate, and capital flows, were examined to identify the main underlying dimensions that affected the Peruvian economy between March 2020 and July 2021. The results reveal four main components that explain 90.60% of the total variance, highlighting the interrelationship between economic activity, foreign trade and capital flows in a context of political instability. The study emphasizes the resilience of economic institutions and their role in mitigating the effects of the crisis. The findings offer implications for public policymaking in multidimensional crisis situations, highlighting the importance of preserving institutional autonomy in adverse environments.

Keywords: *Principal Component Analysis, Political Crisis, Macroeconomic Indicators, COVID-19, Peru, Economic Resilience, Government Transition, Capital Flows, Fiscal Policy, Economic Institutions.*

Introduction

The COVID-19 pandemic marked a before and after in contemporary history, affecting practically all aspects of social, political and economic life at a global level. In the case of Peru, the impact of this health crisis was compounded by unprecedented political instability that tested the resilience of its institutions and its government's ability to respond effectively to a multidimensional crisis. Between 2020 and 2021, the country went through a critical stage that included the impeachment of President Martín Vizcarra, a brief period of interim government under Manuel Merino, and the transition to the administration of Francisco Sagasti as interim president. This succession of events not only generated evident social polarization but also posed significant challenges for governance in the midst of the health emergency (Dargent & Rousseau, 2021; Paredes & Encinas, 2020).

In economic terms, the impact of COVID-19 was profound, affecting Peru's macroeconomic stability and exposing structural vulnerabilities in key sectors. Restrictions imposed to contain the pandemic, such as prolonged lockdowns and trade constraints, had a negative impact on gross domestic product (GDP), capital flows, the exchange rate, and other key macroeconomic indicators. These dynamics developed in a political environment that was not only volatile, but also uncertain, which made it difficult to implement coherent and timely economic policies

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(Muñoz & Guibert, 2020). In this context, the transition of power in Peru took on a particularly critical dimension, as the economic decisions taken by the Executive Branch during this period significantly affected the national response to the health and economic crisis.

This study aims to analyze the interaction between political instability and economic performance in Peru during this crucial period, using Principal Component Analysis (PCA) as a methodological tool. This approach makes it possible to reduce the complexity of macroeconomic data and reveal the underlying relationships between selected indicators. PCA has been widely used in studies of economic and political crises due to its ability to identify key patterns in multivariate datasets (Jolliffe & Cadima, 2016; Favero et al., 2005). In this analysis, twelve macroeconomic indicators are considered, including inflation, public spending, capital flow, exports, and the exchange rate, among others. These data were obtained from the Central Reserve Bank of Peru (BCRP) and the National Institute of Statistics and Informatics (INEI), covering the period from March 2020 to July 2021.

The choice of this period is not accidental, since it coincides with a moment of political and economic transition that offers a unique context for analysis. During this time, Francisco Sagasti's government faced the challenge of guiding the country through a multifaceted crisis, which included managing the pandemic, economic recovery, and restoring trust in democratic institutions. Despite the magnitude of these challenges, there are important questions about the effectiveness of the economic decisions made, as well as about the impact of political instability on the implementation of those decisions.

The main objective of this study is to identify the underlying dimensions that defined Peru's economic dynamics during this period, as well as to assess the degree to which economic decisions were influenced by the political context. The findings not only seek to contribute to the academic understanding of the relationship between politics and economics in crisis contexts but also offer practical implications for the design of public policies in similar situations. In a world where multidimensional crises are becoming more frequent, it is critical to understand how nations can meet these challenges effectively and resiliently.

Likewise, this paper highlights the importance of economic institutions in crisis contexts, underlining the role of the Central Reserve Bank of Peru and the Ministry of Economy and Finance in the preservation of macroeconomic stability. Despite the limitations inherent in the period of analysis, such as the difficulty in separating the effects of the political crisis from those of the pandemic, this study provides a solid basis for future research that explores the interaction between economic governance and political stability in highly complex scenarios.

In this sense, the analysis presented not only seeks to offer an empirical interpretation of the macroeconomic data during the period of political transition in Peru, but also to provide valuable lessons for the development of resilient strategies in similar crisis contexts, both in Peru and in other countries with comparable socioeconomic and political characteristics.

In this sense, the objective of the study is to analyze how the political crisis and the COVID-19 pandemic impacted Peru's macroeconomic indicators during the transition of the Vizcarra and Sagasti governments, using Principal Component Analysis (PCA).

Methodology

The study uses a quantitative approach based on Principal Component Analysis (PCA), a multivariate statistical technique that allows the dimensionality of a dataset to be reduced while

preserving as much information as possible. The PCA was applied to identify underlying patterns and relationships in the macroeconomic indicators selected during the period of analysis.

Data

Data Sources and Study Period

This study uses monthly macroeconomic data for Peru obtained from the Central Reserve Bank of Peru – BCRP and the National Institute of Statistics and Informatics – INEI. The period of analysis covers from March 2020 to July 2021, coinciding with the governmental transition from Martín Vizcarra to Francisco Sagasti and the effects of the COVID-19 pandemic.

Selection of Macroeconomic Indicators

Twelve key macroeconomic indicators were selected: inflation via consumer price index in Metropolitan Lima (var % monthly), non-financial public expenditure, multilateral real exchange rate index, BCRP interest rate, capital inflows ("Liabilities" of the Financial Account) of the Public and Private Sector, capital outflows "Assets" of the Financial Account) of the Public and Private Sectors, exports with FOB values, total imports with FOB values, annual GDP and GDP per capita. These indicators were chosen for their ability to reflect economic performance during periods of political instability and health crisis (Favero et al., 2005).

Principal Component Analysis – PCA

The PCA Method

The Principal Component Analysis (PCA) method is one of the multivariate techniques that aims to reduce the dimensionality of a dataset, through the process of determining the directions of the greatest variance in the space of the original number of variables (Pernice, 2020). In the PCA, the original variables are lost; They become a new set of variables that are called principal components, which are linear combinations of the original variables.

Mathematically, given a set of n observations with p variables, the PCA seeks to find a new set of k variables ($k \leq p$) that are linear combinations of the originals:

$$Y_j = a_j1X_1 + a_j2X_2 + ... + a_jpX_p$$

Where Y_j is the j-th principal component and a_ji are the coefficients that maximize the variance of Y_j subject to orthogonality constraint with the above components (Johnson & Wichern, 2007).

Data Procedure

The analysis will be performed using Python 3.7, specifically the Pandas, NumPy, scikit-learn, matplotlib and seaborn libraries for data processing and PCA application. After preparing the data, an artifact will be built that contemplates this procedure:

1) Standardization of variables to ensure that they are all on the same scale:

$$Z_i = (X_i - \mu_i) / \sigma_i$$

Where Z_i is the standardized variable, X_i the original variable, μ_i the mean and σ_i the standard deviation.

2) Calculation of the matrix of R correlations of the standardized variables.

3) Obtaining the eigenvalues (λ_i) and eigenvectors (e_i) of R, which satisfy:

$Re_i = \lambda_i e_i$

4) Selection of the number of principal components using the Kaiser criterion, retaining those with eigenvalues greater than 1. It will be complemented with the analysis of the sedimentation graph to visually confirm the inflection point in the explained variance curve (Pernice, 2020).

5) Calculating Principal Component Scores:

$PC_i = e_{i1}Z_1 + e_{i2}Z_2 + ... + e_{ip}Z_p$

Where PC_i is the i-th principal component and e_ij are the elements of the i-th eigenvector.

6) Interpretation of the principal components by analyzing the factor loads, considering significant those above 0.5 in absolute value (Adongo et al., 2018).

This approach will allow the identification of the main underlying dimensions in the macroeconomic indicators during the study period, facilitating the understanding of the factors that influenced the Peruvian economy during the political transition and the health crisis.

Reproducibility and Access to Data

To ensure that research is reproducible and transparent, all source code created while working on data analysis, Python scripts, original datasets, and generated results can be found in the GitHub repository: https://github.com/LinoCruz/article-pca. This open-access repository allows other researchers to repeat the analyses, verify the results, and even try to continue the study from different perspectives and time frames.

Like the rest of the texts in the manuscript, this page adheres to the standards of responsible scientific conduct and research, which allows for the promotion of replications, which has gained relevance within the scientific community.

Results

Analysis of correlations between macroeconomic variables

As a first step of the multivariate analysis, the correlations between the twelve macroeconomic variables selected during the period of the transition from President Martin Vizcarra to President Francisco Sagasti were examined. The correlation matrix allows the identification of the most relevant association patterns between the variables and provides a first approximation to the underlying structure of the data.

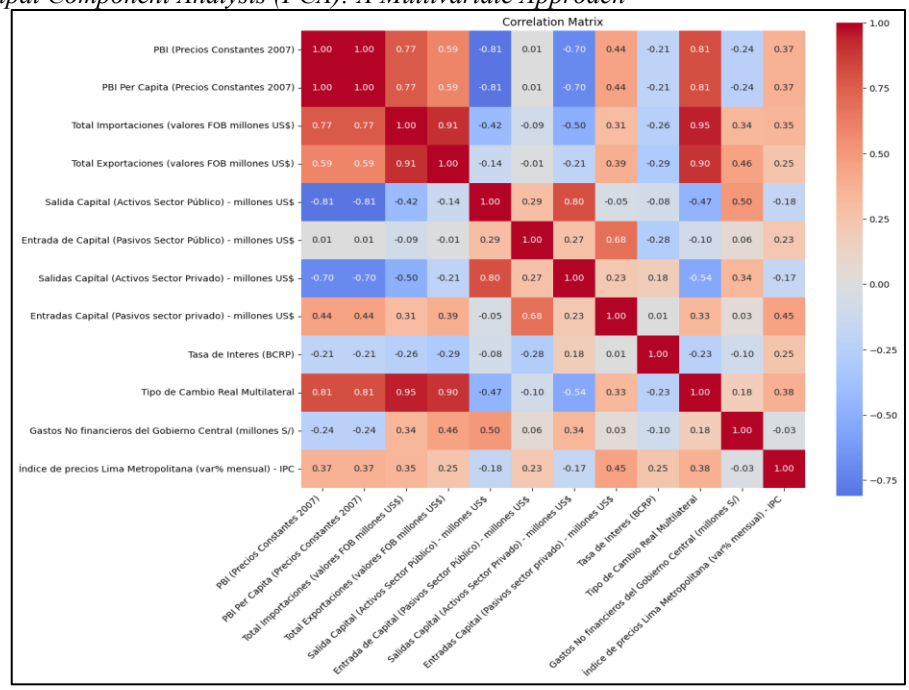

Figure 1. Correlation Matrix

Source: Prepared by the authors based on data from the National Institute of Statistics and Informatics and the Central Reserve Bank of Peru

The correlation matrix analyzes the relationship between the twelve macroeconomic variables considered in the study. These correlations allow us to identify significant patterns of association that reflect how different aspects of the Peruvian economy interact in the period of political and health crisis.

Featured Patterns:

Strong positive correlations:

- **GDP and imports/exports:**

There is a high positive correlation between the Gross Domestic Product (GDP) and imports (r = 0.772), as well as between GDP and exports (r = 0.896). This indicates that greater economic activity is directly related to an increase in international trade flows, which highlights the dependence of the Peruvian economy on foreign trade.

- **Multilateral real exchange rate and international trade:**

The multilateral real exchange rate shows significant correlations with imports (r = 0.949) and exports (r = 0.896). This suggests that exchange rate competitiveness plays a key role in the dynamics of foreign trade.

Strong Negative Correlations:

- **GDP and capital outflows:**

Capital outflows from the public (r = -0.810) and private sector (r = -0.705) are negatively

correlated with GDP. This indicates that an increase in capital outflows is associated with a decrease in economic activity, reflecting the uncertainty generated by the political crisis.

Variables With Weak or Independent Correlations:

Variables such as the BCRP interest rate and non-financial public expenditure show weaker correlations with other variables ($|r| < 0.7$). This suggests a certain independence in their behavior, possibly influenced by monetary and fiscal policy decisions specific to the period studied.

Implications of the Results:

- **Dependence on the external sector:**

The high correlation between GDP and foreign trade indicators underscores the importance of the external sector in the Peruvian economy. This implies that any disturbance in international trade or exchange rate competitiveness could have a significant impact on the country's economic performance.

- **Impact of political uncertainty:**

Negative correlations between GDP and capital outflows reflect the flight of financial resources during periods of political uncertainty, which negatively affected economic activity. This pattern reinforces the need for policies that stabilize the political environment to reduce economic vulnerability.

- **Independence of monetary and fiscal policy:**

The relative independence of variables such as the BCRP interest rate and public spending suggests that these tools were used to mitigate the effects of the crisis, although their direct impact on other indicators was limited.

3.2 Determining the Number of Principal Components

To determine the underlying dimensional structure of the macroeconomic variables, a principal component analysis was performed. The selection of the optimal number of components was based on the analysis of the scree plot and the Kaiser criterion, which retains components with eigenvalues greater than 1.

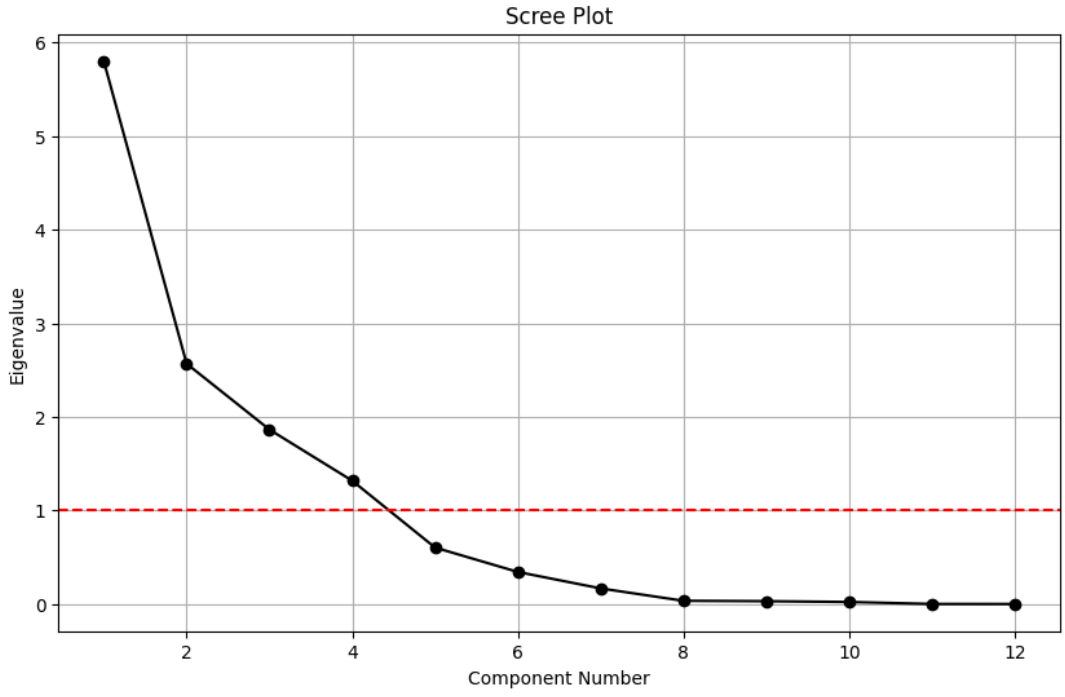

Figure 2. Scree Plot

Source: Prepared by the authors based on data from the National Institute of Statistics and Informatics and the Central Reserve Bank of Peru

The Scree Plot is a fundamental tool in principal component analysis (PCA) to determine the optimal number of components to retain. In this study, the graph represents the eigenvalues of the principal components in descending order, reflecting their ability to explain the total variance of the data.

The graph shows a pronounced initial drop in eigenvalues, indicating that the first components explain a significant proportion of the total variance. In particular, the first component stands out by explaining 45.50% of the variance, suggesting that a major dimension dominates the relationships in the data, mainly associated with economic activity and foreign trade. As you move towards the subsequent components, the eigenvalues gradually decrease.

A key point on the chart is the "elbow" or tipping point, which occurs after the fourth component. This change in slope indicates that the additional components explain minute amounts of variance and are therefore less relevant to the model. According to Kaiser's criteria, those components with eigenvalues greater than 1 should be retained. In this case, the first four components meet this criterion, collectively explaining 90.60% of the total variance.

The interpretation of this result has important methodological and practical implications. First, dimensional reduction simplifies the analysis by condensing the original 12 macroeconomic variables into four main components. Not only does this make interpretation easier, but it also preserves most of the relevant information contained in the data. Second, the first component stands out for its ability to capture most of the variability, reflecting a strong correlation between variables related to economic activity and the external sector. The other three components

capture more specific aspects, such as capital flows, fiscal policy, and monetary variables.

On the other hand, the components after the fourth have very low eigenvalues and explain less than 10% of the variance individually, which justifies their exclusion from the model. Including these components would generate noise and would not add additional value to the analysis, compromising the efficiency of the model.

In conclusion, the Scree Plot validates the decision to retain only four major components, ensuring efficient and focused analysis. This allows for a clear and understandable representation of the underlying dimensions in macroeconomic indicators, aligned with the objectives of the study. These results not only simplify the interpretation but also reinforce the importance of identifying the main economic dynamics during the critical period of political transition and health crisis in Peru.

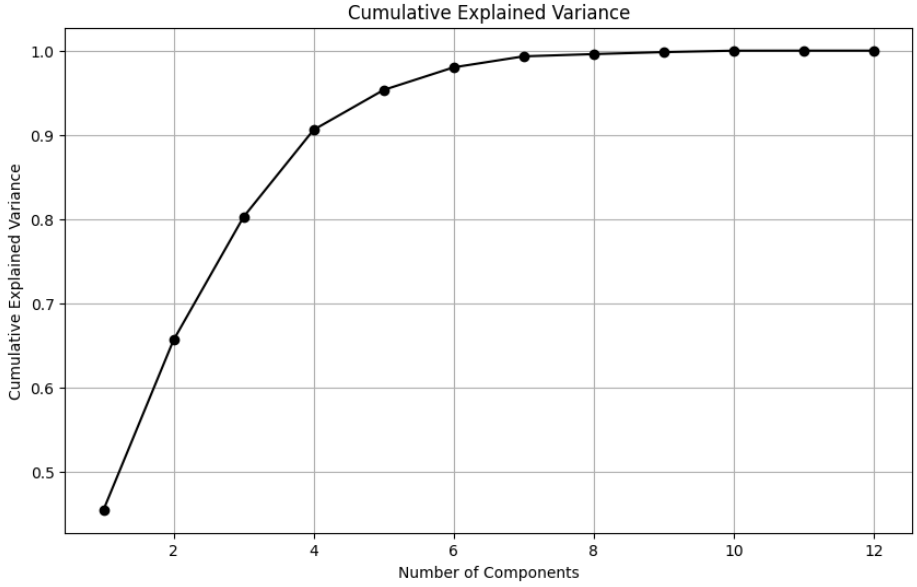

Figure 3. Cumulative Explained Variance Graph

Source: Prepared by the authors based on data from the National Institute of Statistics and Informatics and the Central Reserve Bank of Peru

The **Cumulative Explained Variance Graph** shows how the principal components progressively explain the total variance of the data, allowing the optimal number of components needed to represent the underlying structure to be determined. In this study, the first four main components explain 90.60% of the total variance, meaning that almost all of the relevant information contained in the original 12 macroeconomic variables can be captured by these four factors. The first component explains 45.50% of the variance, standing out for capturing the most significant relationships between the variables, particularly those linked to economic activity and the external sector. The second component contributes 20.15%, reflecting dynamics related to capital flows and fiscal policy, while the third and fourth explain 14.62% and 10.33%, respectively, covering aspects such as capital inflows, public expenditure and monetary variables. Beyond the fourth component, the contributions to variance are minimal, with eigenvalues below 1, which justifies its exclusion. This graph validates the decision to retain

only four components, ensuring an efficient dimensional reduction that preserves most of the critical information, facilitating the interpretation of macroeconomic dynamics during the period of political and health crisis in Peru. The cumulative representation confirms that these four components offer a clear and precise view of the behavior of the macroeconomic indicators analyzed, making the model a robust and effective tool to understand the complexity of this context.

Composition of the Main Components

Once the maximum number of components has been decided, the factor structure is examined by looking at factor loads, which are the correlations between the original variables and the components. It was assumed that the factor loads for absolute values greater than 0.5 were significant, which allowed the identification of the most relevant variables for each of the components.

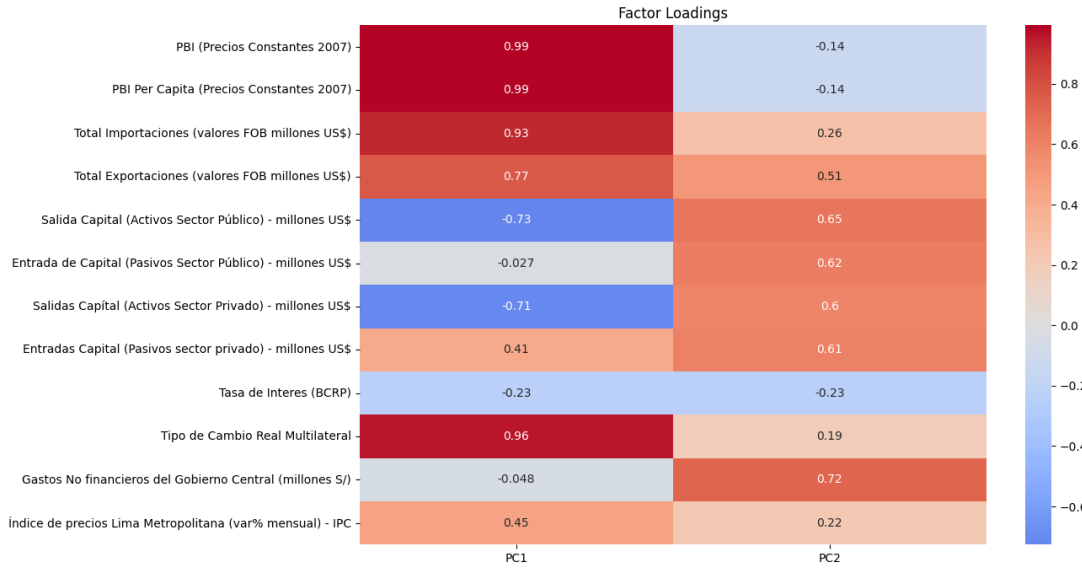

Figure 4. Factor Loadings

Source: Prepared by the authors based on data from the National Institute of Statistics and Informatics and the Central Reserve Bank of Peru

The analysis of factor loads reveals the following structure of the principal components:

- Component 1: Economic Activity and External Sector (45.50% of the variance)

The first component shows a concentration that is related to international trade and economic activity of a certain dimension. Production, in terms of GDP and GDP Per Capita, has the highest value (0.994 for both), the Multilateral Real Exchange Rate occupies second place (0.956) and third place is covered by international trade variables, with the Imports figures carrying a weight of 0.926 and the Exports figures of 0.771 considerably positive. Therefore, this component maintains a significant negative correlation with Capital Outflows, from the Public Sector (-0.727) and the Private Sector (-0.711). Each country-specific factor supports the strong link between international trade and economic performance during the period analyzed.

- Component 2: Capital Flows and Fiscal Policy (20.15% of the variance)

The second component is characterized by grouping variables related to capital flows and fiscal policy. The Non-Financial Expenditure of the Central Government shows the highest burden (0.725), followed by a set of variables related to capital flows that present moderate positive charges: Public Sector Capital Outflow (0.652), Public Sector Capital Inflow (0.618), Private Sector Capital Inflow (0.610), and Private Sector Capital Outflow (0.598). Exports also contribute to this component with a moderate burden (0.510). This structure suggests a dimension that captures the joint dynamics of fiscal policy and capital movements.

- Component 3: Capital Inflows and Public Expenditure (14.62% of the variance)

The third component focuses specifically on capital inflows and their relationship to public spending. Capital Inflows from the Private Sector (0.652) and the Public Sector (0.633) show similar positive charges, while Non-Financial Expenditure from the Central Government has a significant negative burden (-0.574). This configuration suggests a dimension that captures the dynamics between capital inflows and their inverse relationship with government spending.

- Component 4: Monetary Variables and Prices (10.33% of the variance)

The fourth component groups the monetary and price variables, with the Interest Rate showing the highest burden (0.879), followed by the Metropolitan Lima Price Index with a moderate burden (0.501). This component identifies an independent dimension related to the monetary aspects of the economy, suggesting that during the period analyzed, monetary and price variables showed a distinctive behavior with respect to the other macroeconomic variables.

The structure identified in these four components reveals a clear hierarchy in the variability of macroeconomic indicators during the study period, where the dimension of real economic activity and external sector predominates, followed by the dimensions of capital flows, fiscal policy and monetary variables.

The findings of the multivariate analysis of macroeconomic indicators for the Vizcarra-Sagasti transition period present a well-structured pattern. The correlation analysis revealed that there were positive correlations greater than 0.7 with respect to the external sector and economic activity variables, with the important correlation of GDP, foreign trade and the exchange rate, while there was an inverse correlation with investments abroad. Using Principal Component Analysis and following Kaiser's criteria, twelve original variables were collapsed into four components that explain 90.60% of the total variance. The structure of these components indicates a clear order in the variation of macroeconomic variables: the first component is related to real productive activity and the external sector, capturing 45.50% of the variance; the second 20.15% corresponded to capital and fiscal policy; the third component explained 14.62% of the total variance - capital flows and their relationship with government spending; and the fourth component captured 10.33% of the variance with respect to monetary and price variables. This dimensional structure offers a plausible representation of the dominant forces that explained the trend of the Peruvian economy at that time.

Discussion

The results obtained through principal component analysis (PCA) provide a deeper understanding of the economic dynamics that characterized the period of political transition and health crisis in Peru. The identification of four main components that explain 90.60% of the total variance of the data evidences the relevance of certain key macroeconomic factors in shaping the economic outlook during the COVID-19 pandemic and political instability.

Dimension of economic activity and the external sector:

The first component, which explains 45.50% of the variance, highlights the interrelationship between GDP, foreign trade (imports and exports) and the multilateral real exchange rate. This finding shows that Peruvian economic activity during this period was significantly influenced by the performance of the external sector. Despite the political instability, this dimension suggests a certain structural coherence in the country's macroeconomic fundamentals. However, the negative correlations observed between GDP and capital outflows reflect an adverse impact of political uncertainty, which coincides with previous literature that points out how political volatility tends to generate distrust in markets and capital flight (Paredes & Encinas, 2020; Jaramillo & López, 2021). This pattern is indicative of economic vulnerability to external shocks and the need to strengthen political stability to mitigate these effects.

Influence of capital flows and fiscal policy:

The second component, which explains 20.15% of the variance, captures the dynamics between capital flows and government spending. This result underscores the importance of tax decisions and their interaction with capital movements during the period under review. The fiscal policies implemented, such as "Reactiva Perú", were key to mitigating the effects of the pandemic and stimulating the economy in a context of severe economic contraction (Camargo, 2020). However, the results suggest that these policies faced inherent limitations in the political environment, which may have restricted their effectiveness in a context of growing social pressure and economic demands.

Relationship between capital inflows and public expenditure:

The third component (14.62% of the variance) reveals a remarkable interaction between public and private sector capital inflows and non-financial government spending. Factor loads indicate a significant inverse relationship between capital inflows and public expenditure, which could be interpreted as a trade-off between the attraction of external financial resources and the capacity for direct public investment. This result highlights the importance of efficient management of public and private resources during periods of crisis.

Monetary variables and prices:

The fourth component, which explains 10.33% of the variance, groups monetary variables such as the BCRP interest rate and the consumer price index in Metropolitan Lima. This component suggests that, despite political instability, economic institutions, particularly the Central Reserve Bank of Peru, managed to maintain a certain degree of autonomy in the implementation of monetary policies. This finding coincides with studies that highlight institutional resilience in contexts of multidimensional crises, where central bank independence can play a crucial role in preserving macroeconomic stability (García Marín, 2023).

Methodological challenges and limitations:

Despite the richness of the findings, it is important to recognize certain limitations inherent in the study. The period analyzed (March 2020 - July 2021) corresponds to the most critical moment of the pandemic, which makes it difficult to separate the effects of the health crisis from the impacts of political instability. In addition, the PCA is a descriptive tool that, although effective in identifying underlying patterns, does not allow direct causal relationships to be established. Future studies could extend the period of analysis and consider additional variables, such as social and governance factors, to gain a more holistic understanding of economic

dynamics.

Implications for public policy

The results of the analysis have significant implications for policymaking in crisis contexts. The Peruvian economy's heavy dependence on the external sector and capital flows highlights the need for policies that reduce vulnerability to external shocks and improve political stability. Likewise, the autonomy observed in monetary variables suggests that preserving and strengthening the independence of economic institutions is essential to guarantee effective responses in times of crisis.

Conclusions

This study, based on principal component analysis (PCA), has identified the underlying dynamics of Peru's macroeconomic indicators during a critical period of political transition and health crisis. The results show that, despite the adversities imposed by the COVID-19 pandemic and political instability, economic institutions managed to maintain some capacity to manage the complexity of economic challenges, highlighting several key findings.

First, real economic activity and the external sector emerge as the predominant dimension in the analysis, represented by the first component, which explains 45.50% of the total variance. This finding underscores the interdependence between foreign trade, the multilateral real exchange rate, and GDP as fundamental pillars of the Peruvian economy during the period analyzed. The high positive correlation between these variables highlights the importance of an economic policy that promotes competitiveness and stability in international trade. However, the negative correlations between GDP and capital outflows reflect the adverse impact of political uncertainty on the economy, highlighting the urgency of addressing institutional governance as a key factor for economic stability.

Second, capital flows and fiscal policy, captured by the second and third components, explain a significant portion of the variability in the data (34.77% of the total combined variance). This result reveals that government decisions, such as the implementation of economic stimulus programs (e.g., "Reactiva Perú"), played an essential role in mitigating the impacts of the pandemic. However, the effectiveness of these policies was limited by political and social tensions, highlighting the importance of a stable policy environment for the efficient implementation of fiscal measures.

The fourth component, related to monetary and price variables, highlights the autonomy and effectiveness of the Central Reserve Bank of Peru in the implementation of monetary policies. The ability of this institution to operate independently despite the political crisis is evidence of the resilience of Peruvian economic institutions, a crucial aspect to guarantee macroeconomic stability in times of crisis.

Despite these findings, the study faces certain limitations. The time frame analysed coincides with the most critical period of the pandemic, making it difficult to accurately distinguish the effects of the health crisis from those caused by political instability. In addition, PCA, while useful for reducing the dimensionality of data and revealing underlying patterns, is a descriptive technique that does not allow for direct causal relationships. Therefore, future research should consider a longer period of analysis, include additional variables related to the social and political context, and complement the approach with methodologies that allow for the exploration of causalities.

The results of this study offer important implications for public policymaking. The strong dependence on the external sector and the vulnerability to capital flows highlight the need for strategies that reduce the economy's exposure to external shocks. The findings also reinforce the relevance of preserving the autonomy of economic institutions, such as the Central Bank, and strengthening the government's capacity to implement effective fiscal policies even in contexts of high uncertainty.

In conclusion, this study contributes to the academic understanding of economic dynamics in multifaceted crisis scenarios, such as the combination of pandemic and political transition. It also offers practical lessons to strengthen economic and institutional resilience in the face of future challenges. The Peruvian experience during this period underscores the importance of an integrated approach that combines sound economic policies, institutional autonomy, and political stability to successfully manage multidimensional crises.

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Data Availability: The data supporting the findings of this study are available from the corresponding author, upon reasonable request.

Generative AI Statement

The author declares that no Gen AI was used in the creation of this manuscript.

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