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Exploring the asymmetric relationship between macroeconomic factors and corporate profitability in the MSCI Colombia index

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Abstract

Purpose – This study aims to explore the asymmetric effects of macroeconomic factors on the profitability of large-cap companies in an emerging country like Colombia, using the Morgan Stanley Capital International (MSCI) Colombia index as the basis.

Design/methodology/approach – We employ a combination of singular spectrum analysis (SSA) and principal component analysis (PCA) to identify and estimate four key macroeconomic factors that account for approximately 47.8% of Colombia's macroeconomy. These factors encompass indicators related to inflation and cost of living, foreign trade and exchange rate, employment and labor force and trade and production in Colombia. We utilize the distributed lag nonlinear model (DLNM) to analyze the asymmetric relationships between these factors and corporate profitability, considering different scenarios and lags.

Findings – Our analysis reveals that there are indeed asymmetric relationships between the identified macroeconomic factors and corporate profitability. These relationships exhibit variability over time and lags, indicating the nuanced nature of their impact on corporate performance.

Originality/value – This study contributes to the existing literature by applying a novel methodology that combines SSA and PCA to identify macroeconomic factors within the Colombian context. Additionally, our focus on asymmetric relationships and their dynamic nature in relation to corporate profitability, using DLNM, adds original insights to the research on this subject.

Keywords Asymmetry, DLNM, Factor analysis, MSCI index, Profitability

Paper type Research paper

1. Introduction

The Morgan Stanley Capital International (MSCI) index is a stock market index used to measure the performance of companies' stocks worldwide and is followed by many investors and analysts as an indicator of the overall health of the global stock market (Chakrabarti *et al.*, 2005). A company's profitability refers to its ability to generate profits and is a crucial

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indicator of business success. Thus, when a company is profitable, it is usually a positive signal for investors and the market as a whole; therefore, understanding the determinants of financial profitability in times of widespread uncertainty due to various external or internal factors is of utmost importance for policymakers and market players seeking to maximize their profits in the stock market.

The relationship between a company's profitability and the MSCI index can be complex and may vary according to several factors (Sermpinis *et al.*, 2021), such as the industry in which the company operates, its size and market position or specifically external factors including the country's monetary policy, economic growth and inflation, among others. In practice, financial profitability clearly responds to both internal and external determinants. Still, the critical point for different analysts, investors and policymakers is to identify the different scenarios of uncertainty that are clearly greater in the external scope compared to the internal one. This study approaches the relationship between external determinants measured through macroeconomic conditions and corporate profitability from the behavior of the MSCI index.

Studying the relationship between macroeconomic conditions and corporate profitability is a topic of great importance since it allows us to understand how changes in a country's economy affect the companies that are operating within its territory. We start from the hypothesis that an asymmetric relationship exists between the MSCI Colombia index and macroeconomic variables. That is, changes in macroeconomic variables do not affect all firms uniformly (Konchitchki *et al.*, 2016), but some firms are more sensitive to these changes than others instead. Therefore, understanding this asymmetric relationship is crucial to identify the companies that benefit or are adversely affected by changes in the country's macroeconomy and thus being able to make more accurate investment decisions. In addition, it helps identifying how the stock market behaves under different macroeconomic scenarios. In this sense, exploring the asymmetric relationship between these factors in the MSCI Colombia index becomes a fundamental task to understand the behavior of the economy and companies in the country.

For this purpose, motivated by McCracken and Ng (2021), we promoted the creation of a sizeable macroeconomic database for Colombia by collecting information from different institutional and private sources. From this database (153 variables), we use the singular spectrum analysis (SSA) to remove the different trends and autocorrelations in the time series, and we apply principal component analysis (PCA) to estimate the different components that we will identify as macroeconomic factors. We use a novel technique in the financial field, the distributed lag nonlinear model (DLNM), which has been applied mainly in the environmental field. DLNM allows us to identify the existing asymmetries in the effect of macroeconomic factors on the MSCI Colombia index through the spectrum of factor values and the different time lags.

Our results show that about four factors are needed to explain 47.8% of the macroeconomic variability in Colombia. These macroeconomic factors are identified as inflation and cost of living, foreign trade and exchange rate, employment and labor force and trade and production in Colombia. We find that there are asymmetric relationships for different scenarios in each macroeconomic factor, and we highlight the importance of considering the different lags of the macroeconomic factors when analyzing their impact on the stock market. In line with Kruel and Ceretta (2022), we conclude that a Latin American market, such as Colombia, presents asymmetric behaviors. Furthermore, our results have implications for investors, who may have more information, in this case, through external macroeconomic information, to manage their portfolios and investments in search of higher profitability.

The rest of the article is divided as follows: Section 2 contains the literature review, Section 3 presents the methodology, Section 4 shows the results, Section 5 includes the discussion and finally, we conclude in Section 6.

2. Literature review

Financial markets allow for an efficient allocation of resources over time. In the case of Colombia, the BVC (Bolsa de Valores de Colombia) is the leading operator of the financial market and the entity in charge of this task. There are four markets of operation in this exchange: the foreign exchange market, derivatives market, fixed income market and equity market. In the latter, there are different capitalization indexes; among them are the MSCI Colombia and the MSCI COLCAP, both managed by MSCI Inc. Each one of these indexes has its own calculation methodology and its own characteristics, and investors can use them to evaluate different aspects of the Colombian stock market. The MSCI COLCAP is a more specific stock market index that only includes the 25 largest and most liquid companies listed on the Colombian Stock Exchange. At the same time, the MSCI Colombia is a broader stock market index that includes all Colombian companies listed on the stock exchange, including not only the 25 most significant and liquid companies in the country but also smaller and less liquid companies. This index is useful for evaluating the overall performance of the Colombian stock market and, thus, approximating companies' financial performance. Cardona *et al.* (2017) studied the MSCI Colombia index, comparing different markets, where they tested the volatility transmission between the United States and the six largest stock markets in Latin America (Argentina, Brazil, Chile, Colombia, Mexico and Peru). In the case of Latin America, Kyaw *et al.* (2006) analyze the persistent characteristics of Latin American financial markets (Argentina, Brazil, Chile, Colombia, Mexico and Venezuela).

Stock market capitalization indexes represent the average profitability of the stocks that comprise them as well as financial institutions, and the different changes in profitability which may have been influenced by internal or external factors (Joaqui-Barandica *et al.*, 2022). Internal factors include the economic situation of the company and all aspects that may affect it, such as internal decisions, public controversies, changes in senior management, development or elimination of products or services and crisis management, among others. These factors can affect companies' direction and profitability and alter the stocks that make up the market capitalization index. In addition, external factors, such as macroeconomic variables like exchange rates, fixed-term deposit rates, oil prices, unemployment rates, interest rates and national and international events, can also have an impact on the market indexes and the stock market as a whole (Vlamis, 2007).

In the literature, studies mainly refer to macroeconomic variables and their impact on market performance in general. Chen *et al.* (1986) argue that economic variables impact income market returns. They also highlight the robustness of the arbitrage pricing theory model, where a strong relationship is generated between stock returns, interest rate, both short and long-term, inflation rate and industrial production growth. This relationship can be observed in different stock markets, as in the case of the Japanese market, where Hamao (1988) found consistency with Chen *et al.* (1986) in the same variables except for industrial production, which seems insignificant. Rapach *et al.* (2005) studied the behavior of inflation, aggregate expenditure and money supply variables on securities prices in the United States through a vector autoregressive (VAR) model, finding that inflation is negatively correlated with security yields. Likewise, a study that explains the development of the United States stock market from 1992 to 2012. Sirucek (2012) asserts that inflation has a negative relationship with stock prices and that another significant macroeconomic variable to be considered is the money supply.

In the Latin American case, Abugri (2008) also studied stock performance and macroeconomic variables in markets such as Argentina, Brazil, Chile and Mexico, using variables including exchange rate, interest rate and the profitability of the United States Treasury bonds. In this case, unlike the previous references, an exogenous variable relationship is presented: the yield of the United States Treasury bonds versus the yield of the four Latin American countries studied between the years 2003 and 2010. Agudelo and Gutierrez (2011) conclude that the stock markets of Chile and Colombia are affected by the interest rate, while the Mexico stock market is affected by inflation, and all these three

markets are affected by unemployment. Acevedo Prins *et al.* (2017) present an analysis of possible macroeconomic variables that may affect the income market in Colombia. They used the Colombian GDP, the Colombian inflation rate, the Colombian unemployment rate, the United States GDP, the United States inflation rate and the United States unemployment rate as variables. The authors state that a significant relationship was found between the Colombian income market and the United States GDP. In addition, they conclude that, under the COLCAP stock index, the most significant local variable is the real production of the country, since it has a directly proportional relationship. The intervention rate of the Central Bank of the Republic of Colombia has an impact, but a negative one, as do the rates set by the Federal Reserve of the United States and the exchange rate.

It can be observed that, in the above literature, macroeconomic effects on the stock market are studied individually (at the variable level). However, from the statistical and econometric point of view, the possible omission of different effects associated with macroeconomic variables not considered in the different models in the literature, such as the correlation between them, is raised, which shows a possible increase in estimation error and can generate biased estimates of macroeconomic movements on the Colombian stock market yields. For this reason, the individual evaluation of macroeconomic variables does not capture the overall effect of the so-called macroeconomic factors.

Poon and Taylor (1991) argue that the results of Chen *et al.* (1986) may be an example of a spurious regression, where two variables generate a high correlation between them. Yet, that relationship is due to an unconsidered variable. Bernanke *et al.* (2005) proposed a methodology that solves the problem found by Poon and Taylor (1991). The methodology of Bernanke *et al.* (2005) is the factor augmented VAR (FAVAR) method, which combines autoregressive vectors with dynamic factor models. The advantage of FAVAR is the use of a large number of macroeconomic variables and the reduction of omitted variable bias. Oviedo Gómez and Sierra Suárez (2019) implement a FAVAR model on a large database, consisting of 129 variables. This impulse-response functions analysis of the macroeconomic series of interest, such as production, investment, consumption, trade balance, real exchange rate and inflation in Colombia, where it is observed that a positive relationship produces a boom in economic activity. Joaqui-Barandica *et al.* (2022) identify macroeconomic factors based on bank profitability for a sample of banks in the United States. A similar case is observed in McCracken and Ng (2021), where a large database is created, which allows the creation of large macroeconomic factors useful for studying the economic cycle. Given the clear relationship between external macroeconomic variables and the financial market, we follow the approach proposed by Bai and Ng (2021), Bernanke *et al.* (2005) and Stock and Watson (2002, 2016) to identify the macroeconomic factors underlying the financial market and their effects on it.

3. Method

3.1 Research design/model

In this section, we present the comprehensive research design and model underlying our investigation. Our methodology draws from a diverse range of methods in the literature for determining the number of factors required to explain macroeconomic behavior. Bai and Ng (2002) advocate minimizing information criteria, while Onatski (2010) relies on eigenvalue distribution. Dynamic factor tests developed by Hallin and Liška (2007) and Amengual and Watson (2007) contribute to this landscape. Notably, for Colombia, Oviedo Gómez and Sierra Suárez (2019) propose a model based on penalty functions by Bai and Ng (2002) and identify seven factors driving the Colombian economy's behavior.

To establish a robust analytical foundation, we employ SSA. This technique, although originating in the natural sciences, has gained traction in recent years within economics and finance disciplines (Bógalo *et al.*, 2021; Coussin, 2022; de Carvalho *et al.*, 2012; de Carvalho and

Rua, 2017; Hassani *et al.*, 2019; Hassani and Thomakos, 2010; Rodrigues *et al.*, 2020). SSA offers a powerful framework to delve into time series data and extract underlying patterns.

Our approach begins by decomposing macroeconomic series into distinctive components: trend, cycle and noise. Each series can be envisioned as the amalgamation of a signal composed of trends and oscillations, complemented by a noise component. The aim of SSA is to unveil the full structure of the signal, including the identification of trends, seasonal components and other periodicities. Simultaneously, the noise must be isolated and differentiated from the signal. The decomposition is guided by considerations such as component interpretability and the absence of signal parts within the noise residue. As we progress, the stochastic residual components derived from this decomposition enable us to discern subtle patterns and formulate uncorrelated principal components over time (Zamprogno *et al.*, 2020) in such a way that we manage to define a matrix of macroeconomic series free from autocorrelation. Finally, we estimate the asymmetric effects that arise from the relationship between macroeconomic factors and the MSCI Colombia index by means of a DLNM.

3.2 Data and variables

The database stems from the need to evaluate the large number of existing macroeconomic variables. This construction is based on McCracken and Ng (2021), who – inspired by Stock and Watson (1996) – created a large database from 134 macroeconomic series representing monthly indicators of the United States. However, for Colombia, Oviedo Gómez and Sierra Suárez (2019) made the first attempt to construct a database that explains and quantifies the shocks in terms of the exchange of macroeconomic variables, for which 136 series were used. To construct the macroeconomic database, the Refinitiv Eikon data repository and institutional sources in Colombia were used. We obtained 153 unbalanced series of monthly macroeconomic variables from the year 2001 to 2020. An imputation process for some periods with the (regularized) iterative PCA algorithm was performed (Josse and Husson, 2012).

The MSCI Colombia index is measured over the same period and includes information from the following companies: Bancolombia, Banco de Bogotá, Bolsa de Valores de Colombia, Celsia, Cementos Argos, Canacol Energy, Corporación Financiera Colombiana, Ecopetrol, Empresa de Telecomunicaciones de Bogotá, Grupo Energía Bogotá, Grupo Bolívar, Grupo Argos, Grupo Inversiones Suramericana, Interconexión Eléctrica, Mineros, Grupo Nutresa, Grupo Aval, Bancolombia Acciones Preferentes, Cementos Argos, Corporación Financiera, Colombiana Acciones Preferentes, Banco Davivienda, Grupo Argos Acciones Preferentes, Grupo Inversiones Suramericana, Promigas and Organización Terpel.

3.3 Analytical procedures

3.3.1 Singular spectrum analysis (SSA). To obtain the macroeconomic factors from the macroeconomic variables of Colombia, we use SSA, a technique that has been explored in recent years to analyze time series; although its origin was in the natural sciences, it has been implemented in economics and finance (Bógalo *et al.*, 2021; Coussin, 2022; de Carvalho *et al.*, 2012; de Carvalho and Rua, 2017; Hassani *et al.*, 2019; Hassani and Thomakos, 2010; Rodrigues *et al.*, 2020).

The SSA method aims to extract the structure of a time series. Within this framework, any macroeconomic series considered can be represented as the sum of a signal, composed of a trend and oscillations, along with accompanying noise. Consequently, the primary goal of SSA is to capture the complete structure of the signal. This entails extracting any discernible trends, identifying seasonal components, uncovering periodic patterns and so forth. Concurrently, the residual noise component must be isolated and characterized.

The process of decomposing the signal into its constituent components hinges on various factors, including the interpretability of these components. Concerning the residual series, it is imperative to ascertain its independence from the signal. If the noise is assumed to be stochastic, several statistical methods can be applied to assess the randomness of the residuals. The stochastic white noise model is commonly used due to its simplicity. From a practical perspective, it is typically satisfactory to ensure that the residual series lacks overt structural characteristics (de Carvalho *et al.*, 2012). In this manner, each macroeconomic series can be disassembled, as illustrated in Equation (1).

$$Y_t = T_t + C_t + R_t \tag{1}$$

where T_t is a trend term, C_t is a cycle term and R_t is a noise term. By decomposing each macroeconomic series, we can use the stochastic residual components to capture more subtle patterns and construct uncorrelated principal components over time (Zamprogno *et al.*, 2020).

Appendix Figure A1 summarizes the decomposition process of a time series using the SSA methodology. The upper panel of the graph shows the original time series, which represents the evolution of the macroeconomic variable over time.

In the three lower panels, the different components of the time series decomposed by SSA are presented. The first lower panel shows the component that is interpreted as a trend, which captures the evolution or general direction of the long-term series, representing the systematic variations that may be present. The second lower panel presents the second decomposition of the original series, which represents the recurring or periodic fluctuations of the series, such as seasonal or cyclical fluctuations. This component helps identify repetitive patterns within the time series. The third lower panel shows the third component that represents the non-systematic or random fluctuations present in the series once the trends and cycles have been extracted. The decomposition of the time series into these components allows for a deeper understanding of its underlying structure.

3.3.2 Principal component analysis (PCA). The principal component analysis is considered one of the most widely used tools in multivariate analysis to represent data optimally under mathematical and geometrical criteria. For the construction of our macroeconomic factors, let $M_{\{t \times p\}}$ M be a matrix with t number of periods and p number of macroeconomic variables.

Let $R = [R_{t1}, \ldots, R_{tp}]$ be a matrix of noise terms generated from SSA, where the rows represent the periods and the columns the p stochastic white noise terms. The φ_q principal components are uncorrelated composite variables such that a few explain most of the variability of R, where, following Lebart *et al.* (1995), our macroeconomic factors are defined by Equation (2).

$$\begin{aligned} \varphi_1 &= u_{11}R_{t1} + u_{12}R_{t2} + \ldots + u_{1p}R_{tp} \\ \varphi_2 &= u_{21}R_{t1} + u_{22}R_{t2} + \ldots + u_{2p}R_{tp} \\ \varphi_q &= u_{q1}R_{t1} + u_{q2}R_{t2} + \ldots + u_{qp}R_{tp} \end{aligned} \tag{2}$$

3.3.3 Distributed lag nonlinear model (DLNM). To measure the performance of the MSCI Colombia index, the DLNM will be used. A representation of this model can be seen in Gasparrini (2011), where the authors represent the algebraic notation of DLNM under the cross-form definition. This model has been mainly implemented in environmental or meteorological studies (Gronlund *et al.*, 2014; Guo *et al.*, 2011, 2014; Islam *et al.*, 2021). On the other hand, the application of this methodology in the field of finance and economics turns out to be novel in its entirety, which opens the way to exploring new methodological approaches to find possible asymmetries in the effect of macroeconomic factors on the equity market.

This family of models relaxes the assumptions about relationships by allowing effects to vary across the range of predictor variables and over different lags. The DLNM model for measuring the effect on the MSCI Colombia index over time can be expressed as a weighted sum of cumulative macroeconomic factors from Colombia's macroeconomic variables $R_{t-l_0}\ldots R_{t-L}$, where $l = 1, \ldots, L$ is defined as the lags with l_0 and L minimum and maximum, respectively.

Thus, the model is summarized in two initial functions defined as exposure-response $f(\varphi)$ and lag-response $w(l)$. In our case, these functions are called Factors-MSCI and Lags-MSCI, respectively. The combination of these functions on a plane results in an Exposure-Lag-Response function (Exposure-Lag-MSCI), which is presented as a smoothing function on a multidimensional plane in which the effects along the predictor and its lag dimension can be observed.

Gasparrini (2011) defines the model in general terms; in our case, Equation (1) describes the response variable $MSCI_t$ with $t = 1\ldots T$ as a function of the estimated macroeconomic factors φ.

$$g(\mu_t) = \alpha + \sum_{j=1}^{J} s_j(\varphi_{tj};\, \beta_j) + \sum_{k=1}^{K} \gamma_k u_{tk} \tag{3}$$

where $\mu \equiv E(MSCI)$ is a monotonic link function. The function s_j represents the smoothed relationship between the macroeconomic factors estimated by principal components from the spectral decomposition and the MSCI index, defined by the parameter vectors β_j. The u_k variables include other predictors with linear effects specified by the related α_k coefficients. In our case, we do not consider other predictors within the model. Since the Gasparrini (2011) model proposal allows us to evaluate the relationship in space or the spectrum of values that the predictor may have over time, we generalize the function s_j, defined by Equation (4).

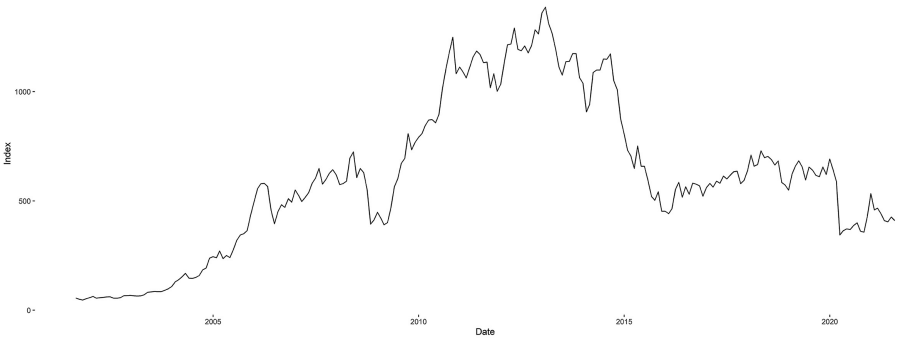
$$\mathrm{s}(\varphi_t;\, \eta) = \int_{l_0}^{L} f(\varphi_{t-\ell}).\, w(\ell) d\ell = \sum_{\mathrm{j}=1}^{v_\varphi} \sum_{\mathrm{k}=1}^{v_\mathrm{l}} \mathbf{r}_{\mathrm{tj.}}^{\mathrm{T}} \mathbf{c}_{.\mathrm{k}} \eta_{\mathrm{jk}} = \mathbf{w}_{\varphi,t}^{\mathrm{T}} \eta \tag{4}$$

where, $w_{t.}$ is obtained by applying cross-basis functions $v_\varphi \bullet v_l$ to φ_t. A cross-basis is a two-dimensional space of functions that describes the relationship between φ and its effects at different time periods. The vector $r_{tj.}$ represents the lagged impacts at time t that are converted by the basis function j. Matrix C consists of vector constituents $c_{.k}$ and is a $(L+1) \times v_l$ matrix of basis variables obtained by applying specific basis functions to the lag vector l. Finally, the vector η represents the parameters that must be estimated.

4. Results

4.1 MSCI Colombia

In an exploratory way, we describe the MSCI Colombia index. Figure 1 shows the performance behavior of the index for Colombia over the analyzed period. A drop in the index is observed around the years 2009–2010 due to exogenous factors, such as the 2008 economic crisis known as the subprime crisis. The year 2010 marks the end of the economic cycle caused by this crisis, followed by an increase in the index. However, two new crises emerged from 2014 onwards, resulting in a decrease in the index: an economic and diplomatic crisis in 2014 with structural effects on foreign trade between Colombia and Venezuela, and the COVID-19 crisis in 2020.



Note(s): The MSCI Colombia index during the period 2001 to 2020. The main highlights are the subprime crisis around 2008, the economic and diplomatic crisis with Venezuela in 2014, and the COVID-19 crisis in 2020
Source(s): Authors' own work

Figure 1.
MSCI Colombia

4.2 Macroeconomic factors

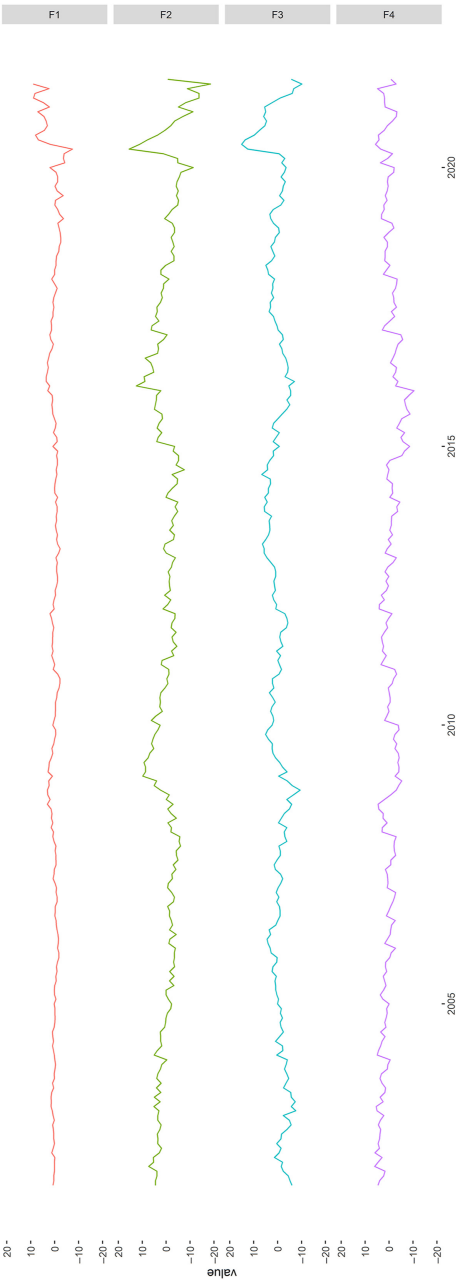
By applying the PCA to the R_t series of the decomposition of the spectral analysis based on monthly macroeconomic variables, the first four principal components that explain 47.8% of the variability in Colombia's macroeconomy can be estimated (Figure 2). Table 1 presents the identification of each component as a macroeconomic factor based on the contribution of each variable to the estimated component.

For factor 1, since the contributing variables are related to construction costs, consumer and producer prices and monitoring of the economy in Colombia, it is possible that the first component has a focus on inflation or the cost of living in the country. Therefore, we could call this first component "Inflation and Cost of Living Indicators," which explain 19.5% of the macroeconomic variability of the country.

In factor 2, based on the nature of the variables presented, we could name this component "Foreign Trade and Exchange Rate Indicators" with 13.3% of explained variability. This component includes variables that measure the exports and imports of goods, nominal and real broad effective exchange rate indices as well as the M3 monetary supply and consumer confidence and expectations indices. Therefore, it is reasonable to assume that this component is related to the measurement and analysis of the trade position and exchange rate stability in Colombia.

In factor 3, it is possible that this component is related to the analysis of the labor market. Therefore, we can name it "Employment and Labor Force Indicators" with 8.9% of explained variability. This component includes variables that measure the unemployment rate, the level of unemployment, retail sales, producer and consumer prices and underlying inflation. These variables are likely to be related to each other in terms of their impact on the economy and the general welfare of the population.

Finally, factor 4 is identified as "Trade and Production Indicators" with an explained variability of 6.1%. This component includes variables that measure the exports and imports of goods, industrial production, capacity utilization, employment and money supply. These variables are likely to be related to each other in terms of their impact on the economy and overall economic growth. Under the principle of parsimony, the first four components are chosen, which are sufficient to explain approximately 50% of the country's macroeconomic variability.



Note(s): The first four principal components explain 47.8% of the variability in Colombia's macroeconomy. We identify the components as follows, F1: Colombian inflation and cost of living indicators, F2: Colombian foreign trade and exchange rate indicators, F3: Colombian employment and labor force indicators, F4: Colombian trade and production indicators
Source(s): Authors' own work

Figure 2.
Macroeconomic factors

Factor	Indicator	Interpretation
Factor 1 (19.5%)	Colombia Construction Costs, Housing, Total, Index, 1999M12 = 100	Inflation indicators and cost of living
	Colombia Consumer Prices, Total, Total, Index, 2008M12 = 100	
	Colombia Consumer Prices, Core CPI, Core inflation, Index, 2008M12 = 100	
	Colombia Consumer Prices, By Commodity, Housing, Total, Index, 2008M12 = 100	
	Colombia Consumer Prices, By Commodity, Transport, Transport, Index, 2008M12 = 100	
	Colombia Producer Prices, PPI, Standardized, SA, Index, 2010 = 100	
	Colombia Producer Prices, PPI, Standardized, Not SA, Index, 2010 = 100	
	Colombia Indicator monitoring the economy, SA, Index, 2005 = 100	
	Colombia Indicator monitoring the economy, Trend, Index, 2005 = 100	
	Colombia Producer Prices, ISICRev4 B, Total, Index, 2014M12 = 100	
Factor 2 (13.3%)	Colombia Exports of Goods, Balance of Payments Basis, % year on year, Standardized, Chg Y/Y	Foreign trade and exchange rate indicators
	Colombia Imports of Goods, Balance of Payments Basis, % year on year, Standardized, Chg Y/Y	
	Colombia Merchandise Imports, % year on year, Standardized, SA, Chg Y/Y	
	Colombia BIS, Nominal Broad Effective Exchange Rate Index, 2010 = 100	
	Colombia BIS, Real Broad Effective Exchange Rate Index, 2010 = 100	
	Colombia Nominal Effective Exchange Rate (NEER) based on consumer price index, 2010 = 100, Not SA	
	Colombia Real Effective Exchange Rate (REER) based on consumer price index, 2010 = 100, Not SA	
	Colombia Money Supply M3, Standardized, SA, Chg Y/Y	
	Colombia Consumer Surveys, Consumer Confidence Index	
	Colombia Consumer Surveys, Consumer Expectations Index	
Factor 3 (8.9%)	Colombia Retail Sales, Without vehicles, Constant Prices, Chg Y/Y	Indicators of employment and labor force
	Colombia Unemployment Rate, Standardized, SA	
	Colombia Unemployment Level, % month on month, Standardized, Chg P/P	
	Colombia Unemployment Level, % year on year, Standardized, Chg Y/Y	
	Colombia Unemployment Rate, year on year, Standardized, SA	
	Colombia Unemployment, Overall, Rate in 13 largest cities	
	Colombia Core CPI, Standardized, SA, Chg P/P	
	Colombia Producer Prices, PPI, % year on year, Standardized, SA, Chg Y/Y	
	Colombia Producer Prices, PPI, % year on year, Standardized, Not SA, Chg Y/Y	
	Colombia Producer Prices, ISICRev4 B, Total, Chg Y/Y	

Table 1.
Identification of macroeconomic factors

(*continued*)

Factor	Indicator	Interpretation
Factor 4 (6.1%)	Colombia Exports of Goods, Balance of Payments Basis, % year on year, Standardized, Chg Y/Y Colombia Imports of Goods, Balance of Payments Basis, % year on year, Standardized, Chg Y/Y Colombia Merchandise Exports, % year on year, Standardized, SA, Chg Y/Y Colombia Merchandise Imports, % year on year, Standardized, SA, Chg Y/Y Colombia Industrial Production Index, % year on year, Standardized, SA, Chg Y/Y, 2010 = 100 Colombia Capacity Utilization, Total Industry (ANDI) Colombia Employment, Overall, 3MMA, Rate in 13 largest cities Colombia Money Supply M0, Standardized, SA, Chg Y/Y Colombia Producer Prices, PPI, % month on month, Standardized, Not SA, Chg P/P Colombia Producer Prices, ISICRev4 B, Total, Chg P/P	Trade and production indicators

Note(s): The first four principal components explain 47.8% of the variability in Colombia's macroeconomy. We identify the components as follows, F1: Colombian inflation and cost of living indicators, F2: Colombian foreign trade and exchange rate indicators, F3: Colombian employment and labor force indicators and F4: Colombian trade and production indicators
Source(s): Authors' own work

Table 1.

4.3 Asymmetric relationship between macroeconomic factors and MSCI Colombia

To measure the impact of macroeconomic shocks on the Colombian economy on the MSCI Colombia index. The DLNM model will be used due to the asymmetric and non-linear characteristics of these macroeconomic variables. This model relaxes the assumptions about the form of the relationship that can describe effects that vary simultaneously, both along the spectrum of the values taken by the predictor (in this case the macroeconomic factors) and in the lag dimension.

The selection of the appropriate model in the DLNM method continues to be a subject of research (Gasparrini, 2011). Therefore, different smoothing iterations are performed to choose the model with the best fit. The use of natural cubic B-splines *ns* and quadratic B-splines *bs* ($df = 2$) with equally spaced cuts or nodes in the spline functions ($k = 1$; $k = 2$) for the exposure functions $f(\varphi)$ and lag $w(l)$ is applied; simulation studies indicate that methods based on the Akaike information criterion (AIC) perform well in defining the smoother and dimensions (Gasparrini and Armstrong, 2013). Table 2 shows the chosen models for fitting. By means of simulation, it was observed that, as the value of the nodes (k) in the lag function

Model	Exposure	Lag	AIC
1	ns; k = 1	bs; k = 2	−549,00
2	bs; k = 1	bs; k = 2	−540,65
3	ns; k = 4	bs; k = 3	−539,27
4	bs; k = 4	bs; k = 3	−525,19

Note(s): The use of natural cubic B-splines *ns* and quadratic B-splines *bs* ($df = 2$) with equally spaced cuts or nodes in the spline functions ($k = 1$; $k = 2$) for the exposure functions $f(\varphi)$ and lag $w(l)$. AIC: Akaike information criterion
Source(s): Authors' own work

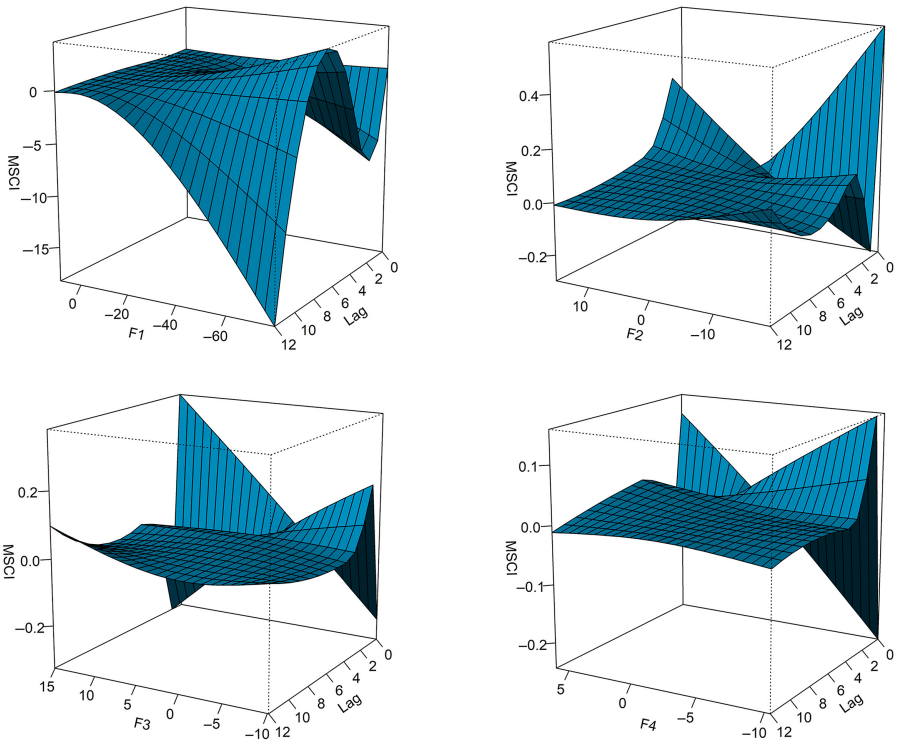
Table 2.
Choice of parameters in the DLNM model

$w(l)$ or in the exposure function $f(\varphi)$ increases, the AIC also increases. By defining this behavior, we were able to smooth the function for different values of k. By means of the AIC criterion, it was determined that $k = 3$ is the best node for the model.

As stated in the methodology, the DLNM model is complemented by means of graphical methods such as three-dimensional surface plots of exposure-lag-response, which summarize the effect of macroeconomic factors on the MSCI Colombia index.

Figure 3 presents the surface plots; it is observed that the macroeconomic factors manage to capture the existing asymmetries of the effect of macroeconomic factors on market returns. This is reflected in the different undulations of the graphs, which can be expressed as a greater effect on the returns of the MSCI index. To evaluate the behavior of each of the macroeconomic factors in relation to the MSCI Colombia index in more detail, contour plots are produced in Figure 4 to help better compare the asymmetry of the response in returns to changes in macroeconomic factors.

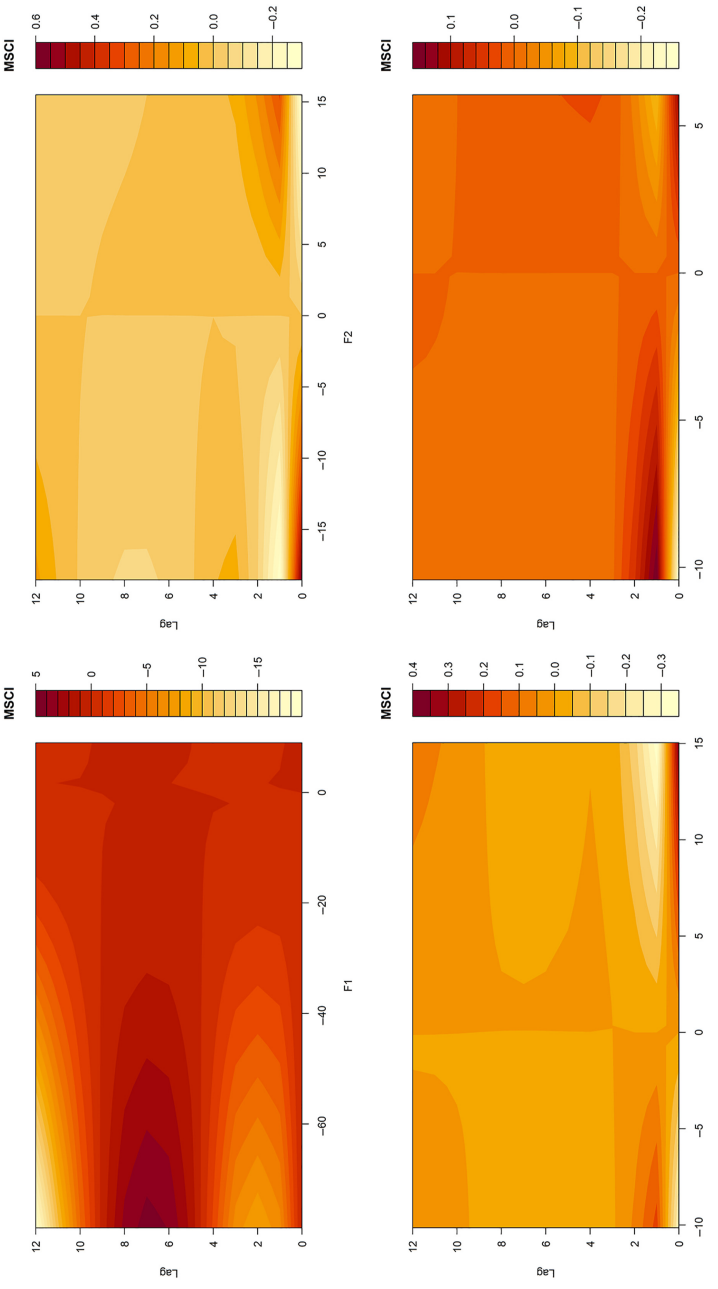
For factor 1, "Inflation and Cost of Living Indicators," Figure 4 shows that if there is an increase in inflation or cost of living in Colombia, the MSCI index tends to increase and



Note(s): These plots show on the surface the estimated effect of macroeconomic factors on the MSCI Colombia index. The 3D relationship is given by the lag function and the macroeconomic factor function. F1: Colombian inflation and cost of living indicators, F2: Colombian foreign trade and exchange rate indicators, F3: Colombian employment and labor force indicators, F4: Colombian trade and production indicators

Source(s): Authors' own work

Figure 3.
Surface plots of the DLNM model



Note(s): These graphs show the estimated effect of macroeconomic factors on the MSCI Colombia index. F1: Colombian inflation and cost of living indicators, F2: Colombian foreign trade and exchange rate indicators, F3: Colombian employment and labor force indicators, F4: Colombian trade and production indicators

Source(s): Authors' own work

Figure 4.
Contour plots of the DLNM model

remains constant across all lags. In contrast, when there is a decreasing inflation and cost of living factor shock, the effect changes across lags. First, contemporaneously (lag = 0) the effect is inverse, i.e. if inflation decreases, the MSCI index increases, which makes sense since, if consumers have more purchasing power due to lower prices, they are likely to buy more goods and services, which can boost corporate profits and, therefore, boost the performance of the MSCI Colombia index. Our estimation shows that with a lag of two months after the macroeconomic shock on inflation, market profitability conditions change. If inflation decreases, a decrease in market returns is perceived; although counter-intuitive, it can be explained in some sectors; for example, companies that produce goods and services with fixed prices may be affected by low inflation, as their revenues and profit margins may decrease. Only after six months of a shock in the decrease in inflation and cost of living, the stock market reacts positively in a very strong way, as there is clearly more market confidence in terms of economic stability, which can attract different foreign investors and boost the performance of the MSCI Colombia index. There is a clear asymmetry regarding the effect observed when there is an increase or decrease in the cost of living, where the market has a greater effect on returns if inflation decreases.

Factor 2, which is related to "Indicators of Foreign Trade and Exchange Rate," shows its relationship with the MSCI Colombia index in Figure 4. Observing the contemporaneous effect (lag = 0) on the shock, it is perceived that the MSCI Colombia index increases when there is a decrease in foreign trade or exchange rate. This can be explained by the fact that Colombian companies can be considered more competitive internationally, which could have a positive effect on the stock market performance contemporaneously. In contrast, as intuitively expected, as months go by (lag 1, 2, . . .), the performance of the MSCI Colombia index decreases. It is important to keep in mind that the MSCI Colombia index is composed of several companies, and each of them may be affected differently by changes in foreign trade indicators and the exchange rate. However, in general, a decrease in foreign trade indicators, such as exports or imports, can be interpreted as a signal of a possible economic slowdown, which can negatively impact stock market performance.

Factor 3, which is identified as "Employment and Labor Force Indicators," shows its relationship with the MSCI Colombia index in Figure 4. Contemporaneously (lag = 0), when labor force indicators increase, the MSCI Colombia index increases. Likewise, when they decrease, the MSCI index tends to decrease. Generally speaking, an increase in employment and labor force indicators in Colombia is usually an indicator of a growing economy and increased business activity, which can lead to an increase in investment and thus an increase in the value of companies listed on the Colombian Stock Exchange. In this sense, it can be said that there is a direct relationship between employment and labor force indicators and the MSCI Colombia index.

One month after the shock on the labor force, an indirect effect is observed. One of the factors of this phenomenon could be explained by the government's monetary and fiscal policy, which can have a significant effect on the economy and, therefore, on the stock markets. For example, if the government takes measures to stimulate investment and economic growth, this could lead to a decrease in the unemployment rate and, in turn, to an increase in the MSCI Colombia index. However, if fiscal and monetary policy does not have the desired effect or if unexpected external factors arise, such as a financial crisis or a pandemic, the MSCI Colombia index could decrease even though labor force indicators have improved. Another factor to consider is investor behavior and market trends. In some cases, investors may decide to focus on other factors that are not directly related to labor force indicators, which could lead to a decrease in the MSCI Colombia index, even if labor force indicators are improving.

Factor 4, identified as "Trade and Production Indicators," is directly related contemporaneously to the MSCI Colombia index. When trade and production indicators

increase, the index also increases, and likewise when they decrease. An increase in production and trade can indicate a growing economy and increased business activity, which in turn can lead to an increase in investment and the value of companies listed on the Colombian Stock Exchange. It is striking that one month after the shock on the factor, the relationship becomes indirect. In the short term, the MSCI Colombia index may increase despite a decrease in trade and production indicators because investors have a positive outlook on the future of the Colombian economy, based on other factors such as GDP growth, foreign investment, political stability and other macroeconomic indicators.

5. Discussion

5.1 Theoretical implications

The insights gleaned from our research contribute substantively to theoretical foundations, offering a nuanced understanding of the interplay between macroeconomic factors and market performance. Notably, our PCA reveals four dominant macroeconomic factors that explain nearly 50% of Colombia's macroeconomic variability.

Although traditionally we seek to explain the greatest possible amount of variability with the first principal components, it is important to recognize that there are cases where an explanation of less than 50% can be valid and significant. In our study, the choice to include the first four principal components is based on several factors. First, these components capture fundamental aspects of the Colombian economy, such as inflation, foreign trade, the labor market and production, indicating a significant understanding of the underlying structure of the data. Furthermore, the interpretation of these components in terms of the variables that contribute to their formation reveals coherent and important relationships for the country's economic context.

It is important to note that the selection of a 50% threshold as a criterion for the inclusion of principal components is arbitrary and may vary depending on the specific objective of the analysis and the characteristics of the data. In our case, we consider that the first four principal components provide a sufficient and parsimonious explanation of the variability observed in the macroeconomic variables of interest. Furthermore, the complex and multifaceted nature of the economy may mean that a significant portion of its variability cannot be fully captured by a few principal components. Therefore, the inclusion of components that explain less than 50% of the total variability can be justified if these components offer relevant and useful information for the economic analysis.

Factor 1, centered on "Inflation and Cost of Living Indicators," aligns with established economic theories linking inflation to consumer behavior and market performance. The inverse relationship observed between decreased inflation and increased MSCI index underscores the complex interplay of consumer sentiment, corporate profits and market dynamics. Factor 2, denoting "Foreign Trade and Exchange Rate Indicators," adds depth to the understanding of how international trade influences the stock market. The counterintuitive relationship between decreased foreign trade indicators and increased MSCI index suggests intricate interactions between global market conditions, domestic economic health and investor sentiment. These insights enrich existing theories of market globalization and contagion effects.

Factor 3, identified as "Employment and Labor Force Indicators," corroborates theories relating economic growth to employment. Our findings resonate with established frameworks linking increased labor force indicators to positive market sentiment. However, the lagged effects underscore the multifaceted nature of market responses to economic signals, with the intricate interplay of government policies, unexpected external factors and investor behavior potentially shaping market dynamics. Lastly, Factor 4, characterized as "Trade and Production Indicators," reinforces theories highlighting the

significance of production and trade in market performance. The dynamic relationship, particularly the short-term inversion, underscores the importance of investor perceptions, economic outlook and macroeconomic indicators in shaping market responses. The implication for theory lies in acknowledging the intertwined nature of economic variables and investor behavior, a phenomenon that adds layers of complexity to existing market models.

5.2 Managerial and policy implications

The practical implications of our research are evident for decision-making and policy development. The asymmetrical effects uncovered by our DLNM model illuminate intricate decision landscapes for investors, policymakers and businesses. Market reactions to macroeconomic shocks hinge on timing and context, aiding stakeholders in navigating financial uncertainties adeptly.

Regarding management decisions, our study underscores aligning strategies with wider economic trends. The dynamic interplay between macroeconomic factors and market performance underscores the need for adaptable strategies. Firms can tailor operations, pricing and resource allocation based on our insights to harness favorable conditions and manage risks during downturns. From a policy perspective, our work underscores the complexities of economic stimuli and their market impact. While employment-focused government initiatives can bolster market sentiment, lagged effects demand comprehensive, forward-looking policy frameworks to anticipate market responses. Understanding foreign trade, exchange rates, and market dynamics can guide balanced international trade policies that promote economic growth and market stability. Ultimately, our research equips companies to adjust strategies and policymakers to craft effective approaches, enhancing decision-making across the business and policy domains.

5.3 Limitations and future research agenda

While our study advances understanding in multiple dimensions, certain limitations warrant acknowledgment and pave the way for future research avenues. Firstly, our analysis relies on historical data up to 2020, and it is imperative to assess the applicability of our findings in the context of evolving market conditions and unforeseen events. Secondly, the DLNM model, while offering insights into asymmetric effects, is still a subject of ongoing research. Future studies can delve deeper into refining the model and exploring other non-linear methodologies that capture the intricate interplay of macroeconomic factors and market dynamics. Furthermore, our analysis focuses on the MSCI Colombia index; extending this research to encompass a broader spectrum of market indices could provide a comprehensive understanding of how different sectors and market segments respond to macroeconomic shocks. Additionally, exploring cross-country comparisons could uncover nuanced variations in the relationships between macroeconomic factors and market performance across different economies and financial systems.

6. Conclusion

In conclusion, our study has revealed profound insights into the intricate interplay between macroeconomic factors and the MSCI Colombia index. These factors collectively explain 47.8% of Colombia's macroeconomic variability and significantly impact the performance of this index. Notably, our findings highlight the asymmetric effect of inflation and cost of living, reflecting the complex relationship between economic stability and investor sentiment. Factor 2 underscores the interrelation between foreign trade, exchange rates and the index, suggesting enhanced competitiveness during reduced foreign trade but subsequent

performance declines. Factor 3 establishes a direct link between employment indicators and the index, though lag effects warrant further investigation due to multifaceted influences. Factor 4 reveals complexities between trade, production indicators and the index, driven by investor sentiment and external events.

While these insights are specific to Colombia, they offer a roadmap for understanding macroeconomic effects in diverse markets. Understanding time lags is crucial for analysis. Overall, our study equips investors and analysts with a nuanced perspective, enhancing informed decision-making within the Colombian stock market.

References

Abugri, B.A. (2008), "Empirical relationship between macroeconomic volatility and stock returns: evidence from Latin American markets", *International Review of Financial Analysis*, Vol. 17 No. 2, pp. 396-410, doi: 10.1016/j.irfa.2006.09.002.

Acevedo Prins, N.M., Jiménez Gómez, L.M. and Castaño, N.E. (2017), "Relación de causalidad de variables macroeconómicas locales y globales sobre el índice COLCAP", *Espacios*, Vol. 38 No. 21, pp. 1-10.

Agudelo, D.A. and Gutierrez, A. (2011), "Anuncios macroeconómicos y mercados accionarios: el caso latinoamericano", *Academia. Revista Latinoamericana de Administración*, Vol. 48, pp. 1-20.

Amengual, D. and Watson, M.W. (2007), "Consistent estimation of the number of dynamic factors in a large N and T panel", *Journal of Business and Economic Statistics*, Vol. 25 No. 1, pp. 91-108, doi: 10.1198/073500106000000585.

Bai, J. and Ng, S. (2002), "Determining the number of factors in approximate factor models", *Econometrica*, Vol. 70 No. 1, pp. 191-221, doi: 10.1111/1468-0262.00273.

Bai, J. and Ng, S. (2021), "Matrix completion, counterfactuals, and factor analysis of missing data", *Journal of the American Statistical Association*, Vol. 116 No. 536, pp. 1841-1855, doi: 10.1080/01621459.2021.1967163.

Bernanke, B.S., Boivin, J. and Eliasz, P. (2005), "Measuring the effects of monetary policy: a factor-augmented vector autoregressive (FAVAR) approach", *Quarterly Journal of Economics*, Vol. 120 No. 1, pp. 387-422, doi: 10.1162/0033553053327452.

Bógalo, J., Poncela, P. and Senra, E. (2021), "Circulant singular spectrum analysis to monitor the state of the economy in real time", *Mathematics*, Vol. 9 No. 11, 1169, doi: 10.3390/math9111169.

Cardona, L., Gutiérrez, M. and Agudelo, D.A. (2017), "Volatility transmission between US and Latin American stock markets: testing the decoupling hypothesis", *Research in International Business and Finance*, Vol. 39, pp. 115-127, doi: 10.1016/j.ribaf.2016.07.008.

Chakrabarti, R., Huang, W., Jayaraman, N. and Lee, J. (2005), "Price and volume effects of changes in MSCI indices - nature and causes", *Journal of Banking and Finance*, Vol. 29 No. 5, pp. 1237-1264, doi: 10.1016/j.jbankfin.2004.04.002.

Chen, N.-F., Roll, R. and Ross, S.A. (1986), "Economic forces and the stock market", *The Journal of Business*, Vol. 59 No. 3, pp. 383-403, doi: 10.1086/296344.

Coussin, M. (2022), "Singular spectrum analysis for real-time financial cycles measurement", *Journal of International Money and Finance*, Vol. 120, 102532, doi: 10.1016/j.jimonfin.2021.102532.

de Carvalho, M. and Rua, A. (2017), "Real-time nowcasting the US output gap: singular spectrum analysis at work", *International Journal of Forecasting*, Vol. 33 No. 1, pp. 185-198, doi: 10.1016/j.ijforecast.2015.09.004.

de Carvalho, M., Rodrigues, P.C. and Rua, A. (2012), "Tracking the US business cycle with a singular spectrum analysis", *Economics Letters*, Vol. 114 No. 1, pp. 32-35, doi: 10.1016/j.econlet.2011.09.007.

Gasparrini, A. (2011), "Distributed lag linear and non-linear models in R: the package dlnm", *Journal of Statistical Software*, Vol. 43 No. 8, pp. 1-20, doi: 10.18637/jss.v043.i08.

Gasparrini, A. and Armstrong, B. (2013), "Reducing and meta-analysing estimates from distributed lag non-linear models", *BMC Medical Research Methodology*, Vol. 13 No. 1, p. 1, doi: 10.1186/1471-2288-13-1.

Gronlund, C.J., Zanobetti, A., Schwartz, J.D., Wellenius, G.A. and O'Neill, M.S. (2014), "Heat, heat waves, and hospital admissions among the elderly in the United States, 1992-2006", *Environmental Health Perspectives*, Vol. 122 No. 11, pp. 1187-1192, doi: 10.1289/ehp.1206132.

Guo, Y., Barnett, A.G., Pan, X., Yu, W. and Tong, S. (2011), "The impact of temperature on mortality in Tianjin, China: a case-crossover design with a distributed lag nonlinear model", *Environmental Health Perspectives*, Vol. 119 No. 12, pp. 1719-1725, doi: 10.1289/ehp.1103598.

Guo, Y., Gasparrini, A., Armstrong, B., Li, S., Tawatsupa, B., Tobias, A., Lavigne, E., De Sousa Zanotti Stagliorio Coelho, M., Leone, M., Pan, X., Tong, S., Tian, L., Kim, H., Hashizume, M., Honda, Y., Guo, Y.L.L., Wu, C.F., Punnasiri, K., Yi, S.M., Williams, G. and Saldiva, P.H.N. (2014), "Global variation in the effects of ambient temperature on mortality: a systematic evaluation", *Epidemiology*, Vol. 25 No. 6, pp. 781-789, doi: 10.1097/EDE.0000000000000165.

Hallin, M. and Liška, R. (2007), "Determining the number of factors in the general dynamic factor model", *Journal of the American Statistical Association*, Vol. 102 No. 478, pp. 603-617, doi: 10.1198/016214506000001275.

Hamao, Y. (1988), "An empirical examination of the Arbitrage Pricing Theory. Using Japanese data", *Japan and the World Economy*, Vol. 1 No. 1, pp. 45-61, doi: 10.1016/0922-1425(88)90005-9.

Hassani, H. and Thomakos, D. (2010), "A review on singular spectrum analysis for economic and financial time series", *Statistics and Its Interface*, Vol. 3 No. 3, pp. 377-397, doi: 10.4310/sii.2010.v3.n3.a11.

Hassani, H., Rua, A., Silva, E.S. and Thomakos, D. (2019), "Monthly forecasting of GDP with mixed-frequency multivariate singular spectrum analysis", *International Journal of Forecasting*, Vol. 35 No. 4, pp. 1361-1372, doi: 10.1016/j.ijforecast.2019.03.021.

Islam, A.R.M.T., Hasanuzzaman, M., Azad, M.A.K., Salam, R., Toshi, F.Z., Khan, M.S.I., Alam, G.M.M. and Ibrahim, S.M. (2021), "Effect of meteorological factors on COVID-19 cases in Bangladesh", *Environment, Development and Sustainability*, Vol. 23 No. 6, pp. 8159-8178, doi: 10.1007/s10668-020-01016-1.

Joaqui-Barandica, O., Manotas-Duque, D.F. and Uribe, J.M. (2022), "Commonality, macroeconomic factors and banking profitability", *The North American Journal of Economics and Finance*, Vol. 62, 101714, doi: 10.1016/j.najef.2022.101714.

Josse, J. and Husson, F. (2012), "Handling missing values in exploratory multivariate data analysis methods", *Journal de la Société Française de Statistique*, Vol. 153 No. 2, pp. 79-99.

Konchitchki, Y., Luo, Y., Ma, M.L.Z. and Wu, F. (2016), "Accounting-based downside risk, cost of capital, and the macroeconomy", *Review of Accounting Studies*, Vol. 21 No. 1, pp. 349-392, doi: 10.1007/s11142-015-9338-7.

Kruel, M. and Ceretta, P.S. (2022), "Asymmetric influences on Latin American stock markets: a quantile approach", *The Journal of Economic Asymmetries*, Vol. 26, e00262, doi: 10.1016/j.jeca.2022.e00262.

Kyaw, N.N.A., Los, C.A. and Zong, S. (2006), "Persistence characteristics of Latin American financial markets", *Journal of Multinational Financial Management*, Vol. 16 No. 3, pp. 207-218, doi: 10.1016/j.mulfin.2005.08.001.

Lebart, L., Morineau, A. and Piron, M. (1995), *Statistique Exploratoire Multidimensionnelle*, 3rd ed., Dunod, Paris.

McCracken, M.W. and Ng, S. (2021), "FRED-QD: a quarterly database for macroeconomic research", *Federal Reserve Bank of St. Louis Review*, Vol. 103 No. 1, pp. 1-44, doi: 10.20955/r.103.1-44.

Onatski, A. (2010), "Determining the number of factors from empirical distribution of eigenvalues", *The Review of Economics and Statistics*, Vol. 92 No. 4, pp. 1004-1016, doi: 10.1162/REST_a_00043.

Oviedo Gómez, A.F. and Sierra Suárez, L.P. (2019), "Importancia de los términos de intercambio en la economía colombiana", *Revista de la CEPAL*, Vol. 2019 No. 128, pp. 49-64, doi: 10.18356/73298cb5-es.

Poon, S. and Taylor, S.J. (1991), "Macroeconomic factors and the UK stock market", *Journal of Business Finance and Accounting*, Vol. 18 No. 5, pp. 619-636, doi: 10.1111/j.1468-5957.1991.tb00229.x.

Rapach, D.E., Wohar, M.E. and Rangvid, J. (2005), "Macro variables and international stock return predictability", *International Journal of Forecasting*, Vol. 21 No. 1, pp. 137-166, doi: 10.1016/j.ijforecast.2004.05.004.

Rodrigues, P.C., Pimentel, J., Messala, P. and Kazemi, M. (2020), "The decomposition and forecasting of mutual investment funds using singular spectrum analysis", *Entropy*, Vol. 22 No. 1, p. 83, doi: 10.3390/e22010083.

Sermpinis, G., Hassanniakalager, A., Stasinakis, C. and Psaradellis, I. (2021), "Technical analysis profitability and Persistence: a discrete false discovery approach on MSCI indices", *Journal of International Financial Markets, Institutions and Money*, Vol. 73, 101353, doi: 10.1016/j.intfin.2021.101353.

Sirucek, M. (2012), "Macroeconomic variables and stock market: US review", *IJCSMS International Journal of Computer Science and Management Studies*, Vol. 12 No. 2, pp. 22-31.

Stock, J.H. and Watson, M.W. (1996), "Evidence on structural instability in macroeconomic time series relations", *Journal of Business and Economic Statistics*, Vol. 14 No. 1, pp. 11-30, doi: 10.1080/07350015.1996.10524626.

Stock, J.H. and Watson, M.W. (2002), "Forecasting using principal components from a large number of predictors", *Journal of the American Statistical Association*, Vol. 97 No. 460, pp. 1167-1179, doi: 10.1198/016214502388618960.

Stock, J.H. and Watson, M.W. (2016), "Dynamic factor models, factor-augmented vector autoregressions, and structural vector autoregressions in macroeconomics", in *Handbook of Macroeconomics*, Elsevier, Amsterdam, pp. 415-525, doi: 10.1016/bs.hesmac.2016.04.002.

Vlamis, P. (2007), "Default risk of the UK real estate companies: is there a macro-economy effect?", *The Journal of Economic Asymmetries*, Vol. 4 No. 2, pp. 75-88, doi: 10.1016/j.jeca.2007.02.007.

Zamprogno, B., Reisen, V.A., Bondon, P., Aranda Cotta, H.H. and Reis, N.C. (2020), "Principal component analysis with autocorrelated data", *Journal of Statistical Computation and Simulation*, Vol. 90 No. 12, pp. 2161-2181, doi: 10.1080/00949655.2020.1764556.

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Appendix

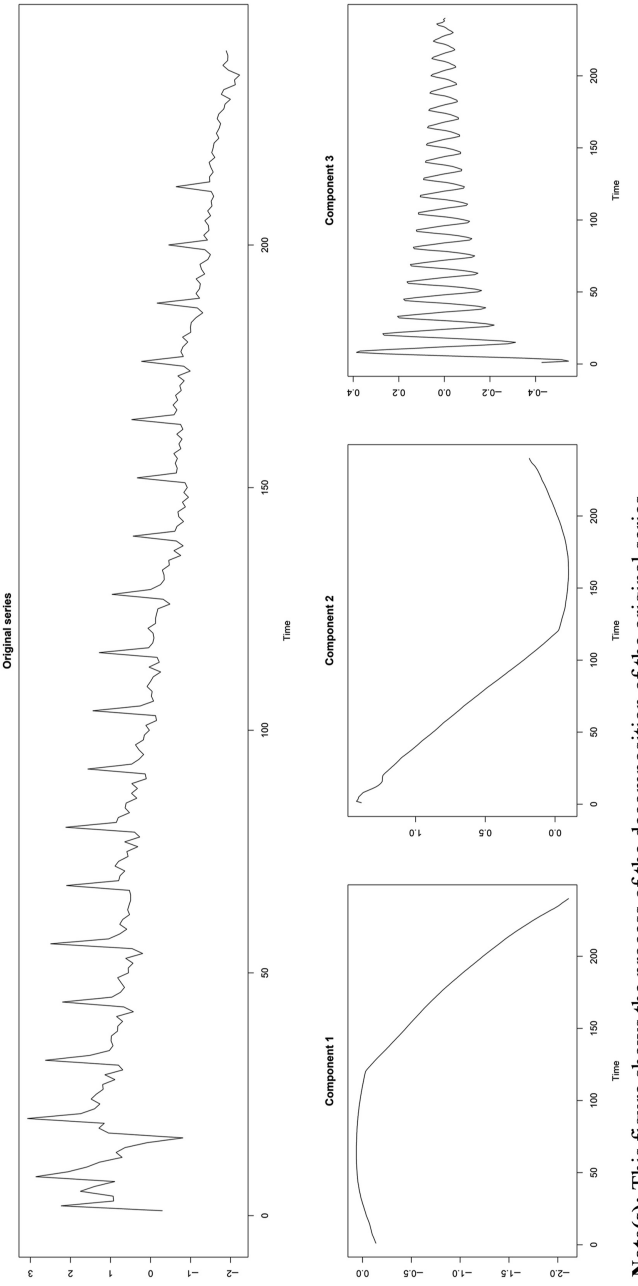

Figure A1.
Process of SSA

Note(s): This figure shows the process of the decomposition of the original series
Source(s): Authors' own work