Cointegration Analysis of Stock Indices and Money Supply M2 in Selected Countries

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Abstract

This paper focuses on the examination of the long-run relationship between money supply and selected national and global stock indices. Detailed knowledge of this relationship can be used by analysts, investors and monetary policy makers. Analysis of the relationship was performed using a 2-stage Engle-Granger cointegration. First, the stationarity of the time series was tested, then both the long-term OLS model and the short-term EC model were estimated. Time series were always tested on the longest period for which data were available. The long-term dependence of stock indices on the respective M2 was confirmed for the BOVESPA, FTSE100, S&P/BMV IPC, S&P BSE500, TSX and The 5000 Wilshire Small Cap Price Return indices. In contrast, the dependence between world money supply indicator GlobalM2, the stock index FTSEALL World, and the S&P500 index was not demonstrated. Additionally, no dependence was identified between the respective M2 and the DAX, PX, Nikkei225, KOSPI, SMI, SPCITIC300, Eurostoxx50, Willshire5000PR and ATX indices. Backward dependence of M2 on the stock index was found only for the Chinese SPCITIC300 index.[3]

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Money supply, stock index, interest rate, Engle-Granger test, EC model	*https://doi.org/10.54694/stat.2024.7*	*G12, G17*

INTRODUCTION

Movement of stock price is determined by numerous global, macroeconomic and microeconomic factors, whose influence on stock prices is examined in detail by fundamental stock analysis. Among the factors affecting stock prices belongs money supply. In financial theory, the prevailing opinion is that there is

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a positive causal relationship between money supply and stock prices. This view is supported across a number of studies by the likes of Rogalski and Vinso (1977), Bernanke and Kuttner (2005), or Maskay (2007). Assuming the existence of the aforementioned relationship between money supply and stock prices, changes in the money supply can be reflected in the development of stock markets, since changes in the money supply can affect the wealth of investors and, consequently, their investments and consumption.

The positive causal relationship between money supply and stock prices is supported by the negative causality between the money supply and interest rates, as well as the negative causality between interest rates and stock prices (Keran, 1971). It therefore means that there is not necessarily a causal relationship between money supply and stock prices.

The considered negative relationship between money supply and interest rates, which assumes that an increase in the money supply will lead to a decrease in nominal interest rates, can be explained using the liquidity effect. With the growth of money supply excess monetary liquidity is released into circulation and the money supply increases, which, assuming an unchanged price level, can lead to a decrease in nominal interest rates, i.e. a decrease in the price of money, since the demand for money is a decreasing function of nominal interest rates. However, if, as a result of the increase in money supply, there was an increase in price level or real output, the effect of a decrease in interest rates would not occur. Rather, on the contrary, there could be an increase or no change in interest rates. The demand for money would shift to the right in this case. When considering these two scenarios, it is important to keep in mind that an increase in money supply may or may not necessarily be followed by a decrease in nominal interest rates.

Several interrelated explanations can be used to account for the negative relationship between the movement of interest rates and stock prices. The correct price of a stock, i.e. its intrinsic value, is calculated as the present value of future cash flows from the stock. The discount interest rate for discounting future cash flows when determining the intrinsic value of a stock is derived from the level of interest rates. As interest rates fall, analysts, with other factors being constant, set higher intrinsic values for stocks, which investors in the stock market react to. A decrease in interest rates will reduce the borrowing costs of companies, which can, under certain conditions, contribute to higher profits, to which stock prices respond by rising. However, despite a decrease in the borrowing costs of firms, profits may not increase if the demand for the firms' products and their sales decline. In this case, stock prices would rather react to a decline in company sales and profits by falling. The positive effect of the decrease in borrowing costs can also be eliminated by the increase in the price of production inputs, as a result of which the total company outlay may not decrease at all. Given that, in addition to the stock market, the bond market also functions as a competitive market where the most important determinant of the movement of bond prices is the interest rate. When interest rates move, it is also necessary to consider the possible reactions of investors to changes in interest rates and the movement of investors between the two markets with regard to the movement of stock and bond prices, along with rates of return from both instruments, as the value of different types of debt and equity instruments is not equally sensitive to interest rate movements.

From the above, it is clear that the expected positive relationship between money supply and stock prices may not necessarily be fulfilled under the influence of various factors and circumstances, just as the considered negative relationships between money supply and interest rates and interest rates and stock prices may not be maintained. However, the movement of macroeconomic variables is a significant determinant of the movement of stock prices. Therefore, for the successful implementation of an investment strategy, and for taking a suitable investment position, the nature of the impact of macroeconomic quantities on stock prices must be investigated.

The aim of this paper is to determine whether there is a long-run relationship between the development of money supply and stock prices represented by national and global stock indices. The purpose of this investigation is to assess the nature and intensity of the relationship between the money supply and stock prices, with the resulting understanding of this relationship being a potential aid in forecasting the development of stock prices by fundamental analysts or as information to be taken into account when assessing the effects of monetary policy on stock markets.

1 LITERATURE REVIEW

The relationship between money supply and stock prices has been a subject of interest to many economists for more than 60 years. Some studies, such as Rogalski and Vinso (1977), confirm the existence of a positive relationship between money stock and stock price, while others, i.e. Kraft and Kraft (1977), do not. Some studies – Pearce and Roley (1985), for example – even point to a negative relationship between money stock and stock prices.

B. Sprinkel had already stated in her 1964 study that money supply precedes the onset of a bear stock market by fifteen months and at the same time precedes the bull stock market by two months. This author examined the turning points of money supply and stock indices for the period 1918–1960 in data from the USA.

Homa and Jaffe (1971) concluded that the average level of stock price is positively related to money supply. These authors state that stock prices are affected by the dividend growth rate, the risk-free rate of return and the risk premium, with the risk-free rate being a function of the money supply. The authors point out that the relationships between these variables can serve as a forecasting tool when implementing investment strategies.

Based on his analysis using the US market data from 1956–1970, Keran (1971) expressed the view that changes in the nominal money supply have only a weak positive direct impact on stock prices. According to Keran, stock prices are strongly influenced by inflation, interest rates and expected corporate profits. Keran also points to the strong effect of changes in the money supply on interest rates, as well as the strong effect of changes in interest rates on stock prices.

According to a study by Gupta (1974), turning points in the money supply can be used to forecast the stock price movements. The aforementioned author states that 59% of stock price peaks can be accurately predicted using the turning point in the money supply. In this study, monthly data over a period of 23 years was used.

The long-run positive relationship between M2 monetary aggregate and stock prices represented by general and sectoral indices in Pakistan was confirmed by Husain and Mahmood (1999) using the cointegration analysis for the time period June 1991–June 1999. This long run relationship between the variables analysed in the model used, indicates unidirectional causality running from M2 to stock prices. However, the model used also provided evidence of short-term effects of M2 on stock prices.

Kulhánek and Matuszek (2006) investigated the existence of a long-run relationship between money supply and stock prices in the Czech Republic, Slovak Republic, Poland, the USA, UK, Switzerland and EMU using a parametric Johansen cointegration test for different time periods. The research has shown the existence of a long-run equilibrium link between money supply and stock market in all countries studied.

In contrast, Alatiqi and Fazel (2008), using the Engle-Granger cointegration test, Granger causality test and monthly US market data from 1965–2005, did not identify a significant long-run relationship between the money supply represented by the M1 aggregate and stock prices represented by the S&P500 index. The two authors explain the result of their research by the absence of a stable negative causal relationship between money supply and interest rates and, also, by the absence of a relationship between interest rates and stock prices.

Ariff, Chung and Mohamad (2013) examined the relationship between money supply, liquidity and stock prices in Canada, the US and the UK over the period 1968–2012. The results of the study supported the existence of the Friedman effect of liquidity. In all three monitored countries, the money supply had a significant positive effect on stock prices through its creation of liquidity. The study confirmed the endogenity of the money supply and the existence of bidirectional causality from money to the interest rate in accordance with the post-Keynesian endogenous money theory.

The positive effect of changes in money supply on stock prices is also pointed out by Pícha (2017), who used the Johansen's cointegration methodology and data from the US market for a relatively long time period spanning 1952–2015. The results of his study show that money supply significantly affects the S&P 500 index in both the short and long run. At the same time, according to the results of this research, the money supply acts as a leading indicator, when compared to the stock index, by 6 months.

Qing and Kusairi (2019) made a study about performance of stock market in Malaysia. The study employed monthly data, from January 1997 to August 2018. Method analysis is the autoregressive distributed lag (ARDL) and GARCH model. The findings stated that the money supply, real effective exchange rate and interest rate spread, had a long-run effect on the performance of the stock market. Money supply and the real effective exchange rate had a positive effect on the stock market performance in the short run.

John and Ezeabasili (2020) investigated the effect of money supply on stock market performance in Nigeria, South Africa and Ghana using data from 1986 to 2018. Apart from the preliminary tests, Johansen cointegration test, error correction model and Granger causality test were applied in the study. The findings of the study revealed that money supply had a long-run relationship with stock market performance in Nigeria, South Africa and Ghana. Also, causal relationships were established in the three economies; running from stock market indexes of the three economies to money supply of the economies respectively. It meant that stock prices were not influenced by the money supply but the opposite was true.

Sahu and Pandey (2020) dealt with the relationship between the money supply and stock prices in India in the period 1996–2016 using time-varying parameter models with vector autoregressive specification. Using the Johansen cointegration test, the authors identified a significantly positive long-term co-movement between the money supply and stock prices, however, using the vector error correction model they failed to demonstrate a significant relationship in the short-term. Furthermore, the aforementioned authors point out the unidirectional causality of the money supply to stock prices.

Conrad (2021) focused on the impact of expansionary monetary policy and changes in interest rates on the behaviour of investors in the stock market. The research was carried out in the winter semester 2019/20 at the University of Applied Science HTW at Saarbrücken in Germany, and 56 + 43 participants took part in it. The result of this research was the finding that an increase in the money supply and a decrease in interest rates directly positively affects stock prices. The author points out that an extremely expansionary monetary policy with low, zero or even negative interest rates supports the emergence of financial bubbles on the stock market, and therefore central banks should change interest rates very slowly.

McMillan (2022) turned his attention to the relationship between stock returns and three variables in the form of the rate of return on long-term government bonds, inflation and money supply for the period 1959–2020. The method used was correlation analysis, which was applied to data from the US market. The study found negative relationships between government bond returns and stock returns, as well as between inflation and stock returns before the Dotcom bubble and the financial crisis in 2008. After the mentioned events, both relationships turned positive. Regarding the relationship between money supply and stock returns before 2000 it was measured as positive and after 2000 mostly as negative. The authors point out that change in correlation occurred in the period of 2008 financial crisis.

Tsai, Chang and Tzang (2022) focused on the relationship between money supply and stock returns before and after the quantitative easing (QE) policy of the United States. The authors examined data from the US and Taiwanese markets for the period 1998–2019 using a vector autoregressive model. The positive relationship between money supply and stock returns was insignificant in Taiwan before QE, but became significant after QE. The relationship between money supply and stock returns in the USA was insignificant before and after QE. In the USA, a study identified a causal relationship between stock returns and money supply before and after QE. In Taiwan, a causal connection between stock returns and money supply was discovered before QE, but not after QE. A causal relationship between Taiwanese stock returns and US stock returns has been demonstrated before and after QE.

2 DATA AND METHODOLOGY

In an attempt to test the analysed time series for cointegration over the longest possible period, the longest time series available will always be selected and used in the following analysis.

2.1 Exogenous variables

M2 monetary aggregates from selected countries were chosen as the exogenous variable. M2 for the US is defined as the aggregate that includes M1 (currency and coins held by the non-bank public, cheque deposits and travellers' cheques) plus savings deposits (including money market deposit accounts), small term deposits of up to $100 000 and shares in retail money market mutual funds. The methodology for other countries may vary slightly and even for the US there have been changes in the calculation methodology (FRED, 2023).

Monthly data were available. The observation period then, was set as the longest possible given the data at hand and Trading Economics was used as the main data source. In addition, Bloomberg's GlobalMoneySupply USD aggregate (hereafter referred to as GlobalM2) was also used, being composed of the total M2 money supply from the US, China, Eurozone, Japan, South Korea, Australia, Canada, Brazil, Switzerland, Russia, Taiwan and Mexico.

2.2 Endogenous variables

The following stock indices from major global financial markets were considered as dependent variables. Both investing.com and finance.yahoo.com were used as data sources. Countries were chosen according to countries with largest stock markets worldwide ranked by share of total world equity market value. Our objective was to analyse world markets in aggregate with the majority of worldwide market capitalization – in our case it was more than 85% (Statista, 2024). If a market capitalization-weighted index was available for a given market, it was preferred over a price-weighted index which is more prone to distortion of its value. The major indices with the largest total capitalization, and best representing the performance of a given market, were preferred. As the most important stock market, for the US several indices were chosen, namely the S&P500, which covers approximately 80% of US market capitalization, and the Wilshire5000PR index, having a very broad base containing all publicly traded companies in the US market. The Wilshire Small Cap index was also used, which represents the market performance of small market capitalisation companies, along with the NASDAQ Composite, whose base contains a significant portion of the IT sector and growth companies.

In addition, the global index The FTSE All World containing stock titles from global stock exchanges was selected for the GlobalM2 time series analysis.

Following indices were analysed:

- the Wilshire 5000 Price Return Index: similar to The Wilshire Total Market Index, except that this index does not include dividend reinvestment and is an index weighted by the market capitalization of all U.S.-traded stocks. As of September 30, 2021, it contained 3 641 companies (Wilshire Advisors, 2021);
- the Wilshire US Small Cap Price Return Index: an index of smaller companies traded in the US market with the average market capitalization of these firms amounting to $6.457 billion. This index is weighted by market capitalization and as of 1/31/2023 its base contained 1 272 companies (Wilshire Advisors, 2022);

- the S&P 500: includes the top 500 publicly traded companies in the U.S. which represents approximately 80% of the market capitalization of the U.S. stock market (S&P Global, S&P 500, 2023);
- the NASDAQ Composite: a market capitalization-weighted stock index that includes nearly all stocks listed on the NASDAQ exchange. Together with the price-weighted Dow Jones Industrial Average and the market-cap-weighted S&P 500, it is one of the three most followed stock indices in the US. The composition of the NASDAQ Composite is heavily focused on companies in the information technology sector (NASDAQ, 2020);
- the DAX (Deutscher Aktien Index): a German market capitalization-weighted stock index composed of 40 selected German blue chip stocks traded on the Frankfurt Stock Exchange. This is an index that takes into account both the share price and the dividend paid (Qontigo, 2023);
- the ATX (Austrian Traded Index): a market capitalisation-weighted index composed of the most liquid stocks listed on the Vienna Stock Exchange and consisting of 20 titles (Wiener Boerse, 2023);
- the BOVESPA: a market capitalisation weighted index, this is the main stock index of the B3 stock exchange in Sao Paulo, Brazil (B3, 2023);
- the PX index: the main index of the Prague Stock Exchange, this is a market capitalization-weighted index based on the most liquid stocks traded on the Prague Stock Exchange (Prague Stock Exchange, 2023);
- the FTSE100: the main market capitalisation-weighted index of the London Stock Exchange and based on the 100 largest companies traded on the Exchange (London Stock Exchange, 2023);
- the Nikkei 225: a price-weighted stock index calculated from 225 stocks traded on the main market of the Tokyo Stock Exchange (Nikkei 225 Official Site, 2023);
- the S&P/BMV IPC: the main index of the Bolsa Mexicana de Valores weighted by modified market capitalization. Its base includes the 35 largest and most liquid stocks listed on the Bolsa Mexicana de Valores (S&P Dow Jones Indices, 2023);
- the KOSPI (Korean Composite Stock Price Index): the main index of the South Korean Stock Exchange. The KOSPI index consists of the 200 largest companies and their most liquid stocks on the Korean Exchange. The KOSPI index is market capitalization weighted (Morningstar Office, 2023);
- the S&P BSE500: a broad proxy of the Indian market, its base contains 500 stocks of the largest companies. The S&P BSE AllCap covers all major industries of the Indian economy and is weighted by market capitalization (S&P Dow Jones Indices, 2023);
- the SMI (Swiss Market Index) index: the most important stock index of the SIX Swiss Exchange, its base comprises the 20 stocks of the largest companies, equivalent to approximately 80% of the total capitalization of the Swiss stock market. The weights of the individual stocks in the index are limited so that no stock exceeds a weight of 20% (Six, 2023);
- the S&P China A 300 index: contains more than 2 500 Chinese A-shares traded on the Shenzhen or Shanghai stock exchanges. The index includes the 300 largest and most liquid stocks of companies from 24 Global Industry Classification Standard (GICS®) industry groups, selected to represent all sectors of the broad market (S&P Dow Jones Indices, 2023);
- the TSX S&P/TSX Composite: the main index of the Canadian stock market and weighted by market capitalization. As of January 31, 2023, the index contained 236 stock titles (S&P Dow Jones Indices, 2023);
- the TA-125 Index: the most important index of the Tel-Aviv Stock Exchange (TASE) and considered the benchmark index of the Israeli market. The index base includes 125 stocks with the highest market capitalization included in the TA-35 and TA-90 indices. The TA-125 Index was launched as the TA-100 Index and, as of February 9, 2017, was expanded to TA-125 (Tradingeconomics, 2024);
- the EuroStoxx50: a global stock index for the Eurozone with its base including the 50 stocks of the largest companies in terms of market capitalization from the 20 super sectors in the Euro area.

The index is part of the STOXX blue-chip index family and captures approximately 60% of the tradable market capitalisation of the EURO STOXX Total Market Index (TMI) (Stoxx, 2023);

– the FTSE All World: a market capitalization-weighted index comprising large, mid-size and small cap stocks traded worldwide. The index base covers developed and emerging markets (FTSE Russell, 2023).

Table 1 Analysed variables

Variable	Period	T	End of period [Index beginning = 1]	Growth p.a. [%]	Variable	Period	T	End of period [Index beginning = 1]	Growth p.a. [%]
USA M2	1959:01–2023:06	774	72.89	6.88	SP500	1959:01–2023:08	776	82.76	7.07
					NASDAQ	1971:03–2023:06	629	135.38	9.81
					WILL5000PR	1971:01–2023:06	631	53.18	7.85
					WILLSMLCAPPR	1992:02–2023:06	379	12.62	8.36
Canada M2	1979:07–2023:06	528	94.51	8.55	TSX	1979:07–2023:06	530	13.24	6.02
Brazil M2	1998:01–2023:06	420	38 546 765	64.72	BOVESPA	1993:05–2023:06	365	3 494.07	30.77
Czechia M2	2002:01–2023:06	258	4.66	7.42	PX50	2002:01–2023:06	359	3.01	3.75
EURO M2	1992:12–2023:06	354	14.12	6.28	ATX	1992:12–2023:06	369	4.34	4.89
					7.42	2001:02–2023:06	428	17.57	8.37
					EuroStoxx50	2003:09–2023:06	240	1.87	3.17
China M2	2000:02–2023:06	281	49.19	13.16	SPCITIC300	2000:02–2023:06	283	2.8	4.46
Israel M2	1992:11–2023:06	368	102 895.95	31.48	TA125	1992:11–2023:06	370	10.24	7.84
India M2	2003:03–2023:06	244	51.72	13.2	SPBSE500	2003:03–2023:06	246	25.26	17.06
Japan M2	1984:03–2023:06	472	1.83	0.1	Nikkei225	1984:03–2023:06	474	3.04	2.85
Mexico M2	1987:02–2023:06	437	828.65	19.58	SPBMVIPC	1987:02–2023:06	439	686.78	19.55
South Korea M2	1970:01–2023:06	644	6 382.64	17.73	KOSPI	1981:05–2023:06	508	20.84	7.44
Switzerland M2	1988:02–2023:06	425	4.74	4.11	SMI	1988:02–2023:06	427	7.81	5.94
United Kingdom M2	2001:02–2023:06	269	18.2	8.25	FTSE100	2001:02–2023:06	271	1.27	1.07
Global M2	2003:05–2023:06	234	4.19	7.33	FTSEAllWorld	2005:11–2023:08	214	2.39	5.00

Source: Own computation, bloomberg.com, investing.com, finance.yahoo.com

World M2 growth, as measured by the GlobalM2 variable, has reached 7.33% p.a. over the last 20 years. Comparing M2 growth (Table 1) for developed market countries, we can generally observe growth around this value up to about 10% p.a. The exception is the South Korea, which is, however, influenced by the high M2 growth of the 1970s and 80s.

Conversely, for emerging countries, long-term growth above 10% p.a. is evident (India, Mexico, China), something often associated with higher growth in the respective stock index. It is important to note that this growth is nominal and those countries that have shown such M2 growth in the past have also often suffered from higher inflation than developed countries. As a result, the real growth of their markets has been lower. Table 1 contains variables with different lengths of T (number of observations) by time series as were available. Such a comparison may, therefore, produce inaccuracies.

2.3 Time series cointegration

As the time series used are non-stationary, classical regression cannot be used. Since the dependence of non-stationary time series cannot be tested by an ordinary OLS model, their cointegration was tested, which examines long-run dependence and equilibrium (Verbeek, 2008). Engle-Granger cointegration of time series was used, where the cointegration relationship was always tested for two time series.

The variables were exponential according to Figures 1 and 2 in the Appendix. Furthermore, according to Tables 11 and 12, the variables also had skewness and were therefore logarithmized. This also linearized them and reduced their skewness (see Tables 13 and 14).

Heteroskedasticity was often present in both the short- and long-run relationship equations. Logarithmization is also one possible way to remove or at least mitigate it (Brooks, 2002). We denote new variables with a 'l' before their name to make it clear that they are logarithmic variables.

2.4 Stationarity

To test for cointegration, it is necessary that the time series be integrated in the same order. The next step, therefore, was to check the stationarity of the variables. According to Enders (2014), if the time series of the variables are not stationary, the classical regression according to Formula (2) cannot be used except when cointegration is present.

A stationary time series is one in which the mean, variance and covariance of the residuals do not change with time (Verbeek, 2008).

The stationary process AR(1) has the following properties:

1) $E(Yt) = 0$, i.e., the unconditional mean is zero,
2) $D(Yt) = \sigma 1^2/(1 - \rho^2)$, i.e. the unconditional variance is constant,
3) $\rho k = \rho^k$, $k \geq 0$, i.e., the autocorrelation function does not depend on time t and its values decrease with increasing displacement k; the process has temporary memory,
4) the expected time to cross zero is finite (Arlt, 1997).

All log-transformed variables were tested with the ADF test, suitable for long time series with more than 250 observations (Arltová and Fedorová, 2016).

Three variants of the ADF were tested: without constant, with constant, and with constant and trend. In the case of a time series that exhibits stable exponential growth (each observation period by the same rate) and converted to a logarithmic time series, the model with a constant would be the best fit. Or, alternatively, if growth varies over time, then the model with a constant and trend would be the best fit.

The maximum lag was according to Akaike's information criterion and also not exceeding the maximum lag $p_{max} = 12(T/100)^{1/4}$ according to Schwert (1989). With a small lag, if p is too low, the test will be affected by autocorrelation. On the other hand, if p is too large, the power of the test will be lower.

In order to perform a test for cointegration, it is necessary to always have a reading from both time series for a given number of observations T during the same time period. The shorter time series always represents the limit. Some time series have been tested more than once, for example the SP500 against the US money supply, but also against the world money supply (Global M2). Global M2 is only available from 2003, whereas US M2 has been available since 1959, so the stationarity of the SP500 has been tested for both the period 2003–2023 and the period 1959–2023.

If one only applied the test to the longest available period of the time series and then made a statement about its (non-)stationarity, then used the time series in a variant with fewer observations T, it might exhibit a different characteristic.

2.5 Engle-Granger test

Time series that were integrated by the same order, in our case I(1), were used for the Engle-Granger cointegration test. The stock index was chosen as the dependent variable and one of the money supply time series M2 as the independent variable. US stock index-US l_M2, Brazilian stock index-Brazilian l_M2 were used, and for the German DAX and Austrian ATX series the EURO l_M2 series, with 1 January 1999 as the start of testing when both countries adopted the Euro.

The lag order was chosen according to the result of the Akaike information criterion with a maximum lag of 12, the model being tested with no constant, with constant and with constant and trend.

Asset prices sometimes play a role in setting monetary policy (Czech National Bank, 2010), so the rejection of reverse causality – the situation where stock indices would affect the money supply – was also tested, i.e. the exchange of endogenous and exogenous variables in the Engle-Granger test.

2.6 EC model

In cases where cointegration was found, i.e. a long-run relationship between M2 and the respective stock index, the EC Model (Error Correction Model) was further used to express the short-run relationship between the variables. The ECM model is able to report whether a stock index tends to return to its equilibrium position after a deviation from equilibrium and with what speed. Moreover, this is another confirmation of cointegration because if this short-run relationship were missing – and thus the tendency of the index to return to equilibrium after its deviation was missing – then the long-run relationship (cointegration) according to Engle and Granger (1987) would not be possible. The ECM model can be written by Formula (1). The error correction term was constructed from the residuals from Formula (2) lagged by one period.

$$\Delta yt = \alpha + \beta_1 \Delta x_t + p_1 \hat{u}_{t-1} + \varepsilon_t, \tag{1}$$

where y_t is the first difference of the endogenous variable, β_1 is parameter of variable and Δx_t is the first difference of exogenous variable, ρ_1 is parameter of error correction term, $\hat{u}_{t-1}$ is error correction term estimated from residuals of Formula (2) delayed by one period and εt is error term.

2.7 OLS model

The OLS model was used to estimate the long-run relationship between time series of the form in Formula (2) when the p-value of the Engle-Granger test rejected the null hypothesis.

$$INDt = \alpha + \beta_1 M2_t + \varepsilon t, \tag{2}$$

where α is constant, β_1 parameter of variable, INDt is one of the chosen stock indices, $M2_t$ is money supply M2 in the chosen country and ε_t error term.

3 RESULTS AND DISCUSSION

All logarithmized variables were tested for the Augmented ADF test at the 5% significance level. Only where both or only one of the time series were not integrated by order I(1) are they reported in the notes in Table 8.

To test for cointegration, it is necessary that the time series be integrated by the same order. In our case, the integration shall be by order 1 marked as a I(1), which means that the time series was non-stationary. However, only after first differencing did it become stationary.

Except for the Czech and European (Euro) money supply, the result of the stationarity test of exogenous variables showed that the time series was integrated by order 1, thus being able to be tested for cointegration.

Euro M2 over the period September 2003–June 2023 was neither stationary nor integrated by order 1. Had the logarithmic transformation not been used, however, the I(1) series would have been stationary and integrated. Nevertheless, as the series is exponential in nature, this would not have been a suitable solution from a methodological point of view, so the series was not tested further against Eurostoxx50. Similarly, this was the case for the Japanese M2.

Neither was the time series of the Czech aggregate M2 stationary, but neither was it I(1). In order to be declared I(1) it would have to be tested only at the 10% significance level, which was rejected.

Table 2 Stationarity test of endogenous variables (bold time series I(1))

Variable	Period	T	Model	Variable (level)		Variable 1(d)		Integration
				test statistic	p-value	test statistic	p-value	I(d)
l_Global M2	2003:05–2023:06	234	w/o constant	4.2446	1	−2.89268	0.003719***	I(1)
			with constant	−1.90545	0.3301	−6.18682	4.201e-08***	I(1)
			with constant and trend	−1.60281	0.7923	−6.42626	9.615e-08***	I(1)
l_USA M2	1959:01–2023:06	774	w/o constant	4.04941	1	−2.47238	0.013**	I(1)
			with constant	−1.4277	0.5703	−5.39939	2.898e-06***	I(1)
			with constant and trend	−1.77276	0.7182	−5.51349	1.56e-05***	I(1)
l_USA M2	1971:03–2023:06	626	w/o constant	3.58744	0.9999	−2.50381	0.0119**	I(1)
			with constant	−1.48635	0.5408	−5.24881	6.15e-06***	I(1)
			with constant and trend	−2.6943	0.2389	−5.38281	2.995e-05***	I(1)
l_USA M2	1971:01–2023:06	630	w/o constant	3.5593	0.9999	−2.43017	0.0146**	I(1)
			with constant	−1.60301	0.481	−5.20568	7.601e-06***	I(1)
			with constant and trend	−2.83423	0.1848	−5.36186	3.319e-05***	I(1)
l_USA M2	1992:02–2023:06	377	w/o constant	4.26572	1	−2.10681	0.03377**	I(1)
			with constant	0.733428	0.9929	−5.5029	1.709e-06***	I(1)
			with constant and trend	−3.23171	0.07821*	−5.59157	1.046e-05***	I(1)
l_Canada M2	1979:07–2023:06	528	w/o constant	2.83682	0.999	−2.1728	0.02869**	I(1)
			with constant	−1.08294	0.7248	−3.67717	0.00447***	I(1)
			with constant and trend	−2.9084	0.1597	−3.74624	0.0194**	I(1)
l_Brazil M2	1993:05–2023:06	362	w/o constant	0.289901	0.7698	−3.5973	0.0003179***	I(1)
			with constant	−3.25401	0.0171**	−3.61621	0.005487***	
			with constant and trend	−8.41467	7.64e-14***	−3.48649	0.04077**	
l_Czechia M2	2002:01–2023:06	258	w/o constant	2.11256	0.9922	−0.92927	0.3142	
			with constant	−0.693795	0.8466	−2.62371	0.08811*	
			with constant and trend	−3.1322	0.09873*	−2.64614	0.2596	

Table 2 (continuation)

Variable	Period	T	Model	Variable (level)		Variable 1(d)		Integration
				test statistic	p-value	test statistic	p-value	I(d)
l_EURO M2	2003:09–2023:06	238	w/o constant	1.83656	0.9846	−1.59564	0.1043	
			with constant	−1.52506	0.5211	−2.42148	0.1357	
			with constant and trend	−2.32099	0.4219	−2.61667	0.2727	
l_EURO M2	2001:02–2023:04	234	w/o constant	2.59692	0.998	−1.39767	0.1512	
			with constant	−2.21377	0.2014	−3.12415	0.02485**	I(1)
			with constant and trend	−2.32849	0.4178	−3.50938	0.03831**	I(1)
l_EURO M2	1992:12–2023:06	354	w/o constant	2.85154	0.9991	−1.75208	0.07576*	
			with constant	−1.00492	0.7538	−3.40709	0.01075**	I(1)
			with constant and trend	−1.72204	0.7417	−3.43457	0.04685**	I(1)
l_China M2	2000:02–2023:06	281	w/o constant	3.30726	0.9998	−1.15061	0.2284	
			with constant	−2.81652	0.05592*	−4.18136	0.0007048***	I(1)
			with constant and trend	−0.215768	0.9928	−5.08183	0.0001***	I(1)
l_Israel M2	1992:11–2023:06	368	w/o constant	1.23985	0.9457	−2.00507	0.04309**	I(1)
			with constant	−2.92736	0.04225**	−2.58403	0.09626	
			with constant and trend	−3.72878	0.02044**	−3.35741	0.05726*	
l_India M2	2003:03–2023:06	244	w/o constant	6.42312	1	−2.25725	0.02315**	I(1)
			with constant	−1.73051	0.4158	−8.1016	2.512e-13***	I(1)
			with constant and trend	−2.1096	0.5399	−8.26498	2.504e-13***	I(1)
l_Japan M2	1984:03–2023:06	472	w/o constant	1.15675	0.9368	−1.58851	0.1057	
			with constant	−1.34627	0.6101	−2.26868	0.1823	
			with constant and trend	−4.05418	0.007277	−2.34516	0.4088	
l_Mexico M2	1987:02–2023:06	437	w/o constant	1.61214	0.9744	−3.25719	0.001101***	I(1)
			with constant	−2.68045	0.07741*	−3.59277	0.00593***	I(1)
			with constant and trend	−3.9892	0.00903***	−3.69463	0.02261**	
l_South Korea M2	1981:05–2023:06	506	w/o constant	1.58247	0.9727	−2.43531	0.0144**	I(1)
			with constant	−3.44263	0.009621***	−2.92266	0.04277**	
			with constant and trend	−1.76081	0.7238	−4.10885	0.006046***	I(1)
l_Switzerland M2	1988:02–2023:06	425	w/o constant	1.06048	0.925	−3.51819	0.0004282***	I(1)
			with constant	−1.00314	0.7544	−3.81913	0.00273***	I(1)
			with constant and trend	−4.17284	0.004847***	−3.8199	0.01549**	
l_United Kingdom M2	2001:02–2023:06	269	w/o constant	5.23314	1	−2.43236	0.01452**	I(1)
			with constant	−2.48329	0.1195	−14.3729	2.883e-33***	I(1)
			with constant and trend	−1.11428	0.9253	−14.6553	2.941e-41***	I(1)

Source: Own elaboration

The time series of monetary aggregates was therefore broadly in line with the assumption I(1). The series that was not consistent with the assumption could have been used in a non-logarithmic variant, but this was rejected both to maintain a uniform methodology and also because these variables showed exponential growth over time, which would have impaired their statistical properties when tested.

Table 3 Stationarity test of endogenous variables (bold indices I(1))

Variable	Period	T	Model	Variable (level)		Variable 1(d)		Integration
				test statistic	p-value	test statistic	p-value	I(d)
l_SP500	1959:01–2023:06	774	w/o constant	3.62142	0.999	−10.5819	4.996e-21***	I(1)
			with constant	0.225641	0.9743	−11.1501	6.214e-23***	I(1)
			with constant and trend	−2.39446	0.3824	−11.1732	1.016e-24***	I(1)
l_SP500	2003:05–2023:06	242	w/o constant	3.27259	0.9998	−10.5656	5.534e-21***	I(1)
			with constant	0.262191	0.9764	−11.1344	6.991e-23***	I(1)
			with constant and trend	−2.3867	0.3865	−11.1576	1.189e-24***	I(1)
l_NASDAQ	1971:03–2023:06	628	w/o constant	2.75544	0.9988	−22.3366	1.086e-41***	I(1)
			with constant	−0.0492124	0.9529	−22.6399	5.171e-5***	I(1)
			with constant and trend	−2.89594	0.1637	−22.6336	3.466e-83***	I(1)
l_DAX	2001:02–2023:06	269	w/o constant	0.849735	0.8938	−15.491	3.115e-33***	I(1)
			with constant	−0.479647	0.8928	−15.5038	1.211e-36***	I(1)
			with constant and trend	−3.84158	0.01448**	−15.5404	8.701e-46***	
l_ATX	1992:12–2023:06	367	w/o constant	0.885991	0.8997	−16.4148	4.338e-35***	I(1)
			with constant	−1.98444	0.2939	−16.4465	2.739e-39***	I(1)
			with constant and trend	−2.48391	0.3362	−16.4445	1.691e-50***	I(1)
l_BOVESPA	1993:05–2023:06	362	w/o constant	1.7809	0.9824	−13.1222	1.002e-27***	I(1)
			with constant	−6.57202	4.474e-09***	−13.4579	2.079e-30***	
			with constant and trend	−8.41734	7.479e-14***	−13.8747	2.368e-37***	
l_PX50	2002:01–2023:06	258	w/o constant	0.697543	0.8661	−6.26784	1.088e-09***	I(1)
			with constant	−3.07533	0.02846	−6.31794	1.983e-08***	I(1)
			with constant and trend	−2.90801	0.1598	−6.39103	1.19e-07***	I(1)
l_FTSE100	2001:02–2023:06	269	w/o constant	0.338969	0.7831	−16.3671	5.352e-35***	I(1)
			with constant	−1.49794	0.5349	−16.3483	5.071e-39***	I(1)
			with constant and trend	−3.2677	0.07167*	−16.3328	6.517e-50***	I(1)
l_Nikkel 225	1984:03–2023:06	472	w/o constant	0.821607	0.889	−20.6039	8.322e-41***	I(1)
			with constant	−1.4048	0.5816	−20.6139	1.966e-48***	I(1)
			with constant and trend	−1.38789	0.8648	−20.5975	1.454e-72***	I(1)
l_SPBMVIPC	1987:02–2023:06	437	w/o constant	2.87439	0.9991	−12.8714	4.311e-27***	I(1)
			with constant	−3.73123	0.003715***	−17.4628	6.218e-42***	
			with constant and trend	−3.05071	0.1184	−17.68	4.962e-57***	I(1)
l_KOSPI	1981:05–2023:06	506	w/o constant	1.58048	0.9726	−21.0888	3.804e-41***	I(1)
			with constant	−1.81155	0.3753	−21.1843	2.7e-49***	I(1)
			with constant and trend	−2.21286	0.4818	−21.1835	1.184e-75***	I(1)
l_SPBSE500	2003:03–2023:06	244	w/o constant	2.78637	0.9989	−13.5071	1.107e-28***	I(1)
			with constant	−2.51403	0.112	−13.9294	6.813e-32***	I(1)
			with constant and trend	−4.2238	0.004052***	−13.9997	5.694e-38***	

Table 3 (continuation)

Variable	Period	T	Model	Variable (level)		Variable 1(d)		Integration
				test statistic	p-value	test statistic	p-value	I(d)
l_SP CITIC300	2000:02–2023:06	281	w/o constant	0.298594	0.7722	−6.11998	2.431e-09***	I(1)
			with constant	−1.81666	0.3728	−6.12499	5.959e-08***	I(1)
			with constant and trend	−3.65325	0.02553**	−6.11436	6.064e-07***	
l_TSX	1979:07–2023:06	528	w/o constant	2.06047	0.9911	−20.8524	5.459e-41***	I(1)
			with constant	−1.22792	0.6647	−21.0382	4.388e-49***	I(1)
			with constant and trend	−3.56163	0.03315**	−21.0271	7.862e-75***	
l_WILL5000PR	1971:01–2023:06	630	w/o constant	3.37624	0.9999	−23.5818	9.417e-42***	I(1)
			with constant	−0.114937	0.9461	−23.9818	5.88e-52***	I(1)
			with constant and trend	−2.52253	0.3171	−23.9682	6.346e-90***	I(1)
l_ WILLSMLCAPPR	1992:02–2023:06	377	w/o constant	2.16972	0.9933	−18.0598	6.746e-38***	I(1)
			with constant	−1.05329	0.7361	−18.2794	7.038e-44***	I(1)
			with constant and trend	−3.76468	0.01835**	−18.2616	3.969e-60***	
l_EuroStoxx50	2003:09–2023:06	238	w/o constant	0.747042	0.8756	−8.45359	2.965e-15***	I(1)
			with constant	−2.28176	0.178	−11.5542	2.976e-24***	I(1)
			with constant and trend	−2.52943	0.3137	−11.5326	2.642e-26***	I(1)
l_TA125	1992:11–2023:06	368	w/o constant	1.71618	0.9796	−9.38762	8.948e-18***	I(1)
			with constant	−1.17904	0.6859	−9.60189	6.181e-18***	I(1)
			with constant and trend	−2.55202	0.3028	−9.60296	3.172e-18***	I(1)
l_MSCIWorld	2003:05–2023:06	234	w/o constant	3.02442	0.9995	−4.27859	2.004e-05***	I(1)
			with constant	−0.0530925	0.9526	−15.2388	7.181e-36***	I(1)
			with constant and trend	−1.67715	0.7616	−15.2215	3.821e-44***	I(1)
l_SMI	1988:02–2023:06	425	w/o constant	1.63375	0.9756	−7.89162	9.106e-14***	I(1)
			with constant	−1.81663	0.3728	−8.1067	2.427e-13***	I(1)
			with constant and trend	−2.03203	0.5831	−8.15821	5.766e-13***	I(1)

Source: Own elaboration

Testing for stationarity of the endogenous variables showed that all time series was integrated of order 1 as expected, i.e., it was non-stationary, but was stationary after first differencing.

Only the BOVESPA index turned out to be I(1) only when using a model without a constant. The time series of money stocks was also overwhelmingly integrated of order 1, providing the opportunity to test for long-run dependence by cointegration, with the exception of the Eurostoxx50 index, the Czech PX and the Japanese Nikkei225, none of which had their money aggregates I(1). The solution would be to use them in a non-logarithmic version or to use another methodology, such as the ADL model, allowing the testing of the dependence of stationary and non-stationary variables simultaneously.

Next, we performed the Engle-Granger test for cointegration, which showed the dependence between the respective money stock and stock index at 5% significance level for the indices l_WILLSMLCAPPR, l_BOVESPA, l_FTSE100, l_S&P/BMV IPC, l_S&P BSE500, l_CITIC300 and l_TSX.

If we were less stringent and chose a 10% significance level, we would be able to prove the dependence of the l_ATX and l_TA125 on the respective money supply as well as l_FTSEAllWorld, l_SP500 and the l_Willshire5000PR index on l_GlobalM2.

Table 4 P-value Engle-Granger cointegration test with stock index and corresponding M2 money supply (bold models significant at 5% significance level)

	Period	Test w/o constant	Test with constant	Test with constant and trend	T
l_SP500	1959:01–2023:06	0.8196	0.6722	0.3677	774
l_Willshire 5000PR	1971:01–2023:06	0.5353	0.2333	0.5286	630
l_WillshireSMLCAPPR	1992:02–2023:06	0.03465**	0.0236**	0.05078	377
l_NASDAQ	1971:03–2023:06	0.8229	0.1304	0.3198	628
l_DAX	1988:01–2023:07	0.1982	0.2211	0.2308	427
l_ATX	1992:12–2023:07	0.08125*	0.216	0.134	368
l_BOVESPA	1993:05–2023:07	0.0004056***	0.1235	0.4171	363
l_PX50	2002:01–2023:06	0.1112	0.1318	0.2535	258
l_FTSE100	2001:02–2023:07	0.01541**	0.09607*	0.1654	270
l_NIKKEI 225	1984:03–2023:07	0.5102	0.7953	0.9524	473
l_S&P/BMV IPC	1987:02–2023:07	0.03142**	0.2653	0.5645	438
l_KOSPI	1981:05–2023:08	0.1189	0.3303	0.5772	508
l_S&P BSE500	2003:03–2023:08	5.13e-05***	0.000874***	0.003709***	246
l_SMI	1988:02–2023:07	0.1264	0.3419	0.7789	426
l_CITIC 300	2000:02–2023:07	0.005709***	0.0114**	0.06679*	282
l_TSX	1979:07–2023:06	0.1559	0.2054	0.02325**	528
l_TA125	1992:11–2023:06	0.2987	0.05093*	0.1971	363
l_FTSEAllWorld	2005:11–2023:07	0.7248	0.4846	0.06348*	213
l_EURO STOXX 50	2003:09–2023:07	0.1019	0.2618	0.4984	239
l_SP500 x l_Global M2	2003:05–2023:07	0.9222	0.7328	0.06025*	243
l_Willshire 5000PR x l_Global M2	2003:05–2023:07	0.8926	0.6934	0.05778*	243

Source: Own elaboration

Where the Engle-Granger test rejected the null hypothesis, the application of the EC model followed to confirm the long-term dependence on the short-term dependence.

In order for the ECM model outputs to be significant, the error correction term must be statistically significant and ρ1 must be negative, as only then does it revert back to its equilibrium value when deviating from that value. Conversely, if ρ1 were positive, the deviation would increase and the long-run dependence would not be satisfied. Since the models exhibited heteroskedasticity, the HAC model was used.

In general, the outputs of all models were characterized by low R^2 and coefficient of ρ1, implying that the cycles of overvaluation and undervaluation in stock markets are multi-year. This is confirmed by the residuals from the models constructed according to Formula (2) in Figure 3 in the Appendix, which show cycles where the stock index is undervalued or overvalued relative to M2 and takes several years to return to equilibrium. In our case, using monthly data, the low coefficient ρ1 on the error correction term (converted to a 2–8% correction from the deviation from equilibrium over one observation period) makes sense.

If we require a 5% significance level, the short-run relationship and thus confirmation of the long-run relationship (cointegration) can be confirmed for the Wilshire5000CAPR, ATX, BOVESPA, FTSE100, S&P/BMV IPC, S&P BSE500, TSX and the respective money supply.

Table 5 P-value of EC models and parameter of error correction term of stock indices with respective money supply (models significant at 5% significance level, ECT with minus sign and without seral correlation)

Variables				Tests			
Y	Konst.	X	$ρ_1$	Breusch-Pagan	F-test p-value	DW	R^2
d_l_Willshire SMLCAPPR	0.00676980 0.0561*	d_l_USAM2 −0.0323195 0.9582	−0.0506880 0.0062***	0.000000***	0.019779**	1.844060	0.026992
d_l_BOVESPA	5.38420e-05 0.9920	d_l_BrazilM2 0.930885 3.23e-014 ***	−0.0399976 0.0073***	0.000006***	3.59e-14***	1.866717	0.337052
d_l_FTSE100	0.000567137 0.8299	d_l_UnitedKingdomM2 0.0823271 0.6760	−0.0590829 0.0055***	0.000158***	3.37e-14	1.944561	0.337124
d_l_S&P/BMV IPC	0.0124748 0.0055 ***	d_l_MexicoM2 0.184212 0.5948	−0.0308341 0.0353**	0.000000***	0.030147**	1.621680	0.016532
d_l_S&P BSE500	0.0119333 0.0088 ***	d_l_IndiaM2 0.115233 0.4518	−0.0834395 0.0002***	0.257237	0.000830***	1.750507	0.056948
d_l_CITIC 300	0.00528225 0.4593	−0.160238 0.7275	−0.0298864 0.1670	0.000000***	0.334876	1.757747	0.015603
d_l_TSX	0.00344610 0.2611	d_l_CanadaM2 0.244341 0.5976	−0.0229328 0.0494**	0.000006***	0.102755	1.797608	0.011970

Source: Own elaboration

For time series where cointegration was confirmed, an OLS model was applied to estimate the long-run relationship. All estimates resulting from the application of OLS models were characterized by autocorrelation and high R2, and the F-test was conclusive. This may be a symptom of the so-called apparent regression, which is likely if R^2>DW (Granger and Newbold, 1974). Then, the OLS model does not provide relevant information. The only exception may be when there is cointegration between the variables. In this case, the OLS model can be used to capture long-run relationships.

Table 6 OLS model for variables satisfying cointegration (endogenous variables in bold where a long-run relationship has been proved)

Variables			Tests			
Y	**const**	**X**	**Breusch-Pagan**	**F-test p-value**	**DW**	**R^2**
l_WillshireSMLCAPPR	−2.93216 2.30e-059 ***	l_USAM2 1.26021 8.25e-229 ***	0.001035***	8.3e-229***	0.096963	0.938217
l_BOVESPA	−1.70298 6.52e-06 ***	l_BrazilM2 0.884315 3.86e-110 ***	0.006133***	2.0e-216***	0.070388	0.935553
l_FTSE100	3.43847 8.57e-08 ***	l_UnitedKingdomM2 0.364471 1.61e-015 ***	0.000525***	1.62e-47***	0.098300	0.544631
l_S&P/BMV IPC	−16.1409 2.22e-228 ***	l_MexicoM2 1.18000 5.19e-308 ***	0.575080	5.2e-308***	0.070625	0.960765
l_S&P BSE500	−0.707002 0.1015	l_IndiaM2 0.987092 3.96e-064 ***	0.000000***	0.000830***	0.140309	0.925736
l_TSX	−2.95844 9.76e-064 ***	l_CanadaM2 0.889074 6.20e-290 ***	0.305922	6.2e-290***	0.047140	0.919494

Source: Own elaboration

Table 7 provides the variables for which cointegration, i.e. the long-run dependence of the stock index on the corresponding money supply, has been confirmed.

Table 7 Variables where cointegration was confirmed between them

Cointegration confirmed	
Endogenous variable	Exogenous variable
l_WilshireSMLCAPPR	l_USA M2
l_BOVESPA	l_Brazil M2
l_FTSE100	l_UnitedKingdom M2
l_S&P/BMV IPC	l_Mexico M2
l_S&P BSE500	l_India M2
l_TSX	l_Canada M2

Source: Own elaboration

Table 8 contains pairs of time series for which, conversely, cointegration was not confirmed.

Table 8 Time series where cointegration was not confirmed between them

Cointegration not confirmed		
Endogenous variable	**Exogenous variable**	**Reason of not confirmed cointegration**
l_SP500	l_USA M2	Engle-Granger test
l_NASDAQ	l_USA M2	Engle-Granger test
l_DAX	l_EURO M2	Engle-Granger test
l_PX 50	l_Czechia M2	l_Czechia M2 není I(1)
l_Nikkei225	l_Japan M2	l_Japan M2 není (1)
l_KOSPI	l_Korea M2	Engle-Granger test
l_SMI	l_Switzerland M2	Engle-Granger test
l_SPCITIC300	l_China M2	ECM model
l_Eurostoxx50	l_Euro M2	l_Euro M2 není I(1)
l_Willshire5000PR	l_USA M2	Engle-Granger test
l_SP500	l_GlobalM2	Engle-Granger test
l_ATX	l_EURO M2	Engle-Granger test
l_TA125	l_EURO M2	Engle-Granger test
l_FTSEAllWorld	l_GlobalM2	Engle-Granger test

Source: Own elaboration

According to Keran (1971), the fact that some stock indices have not been found to be dependent on the money supply may be due to the fact that a rising money supply lowers interest rates which affect stock prices. Thus, the relationship between the change in M2 and stock price may not necessarily be causal but may only be mediated, possibly affecting the cointegration test.

Another explanation is also possible: according to Borio, Hofmann et al. (2023), a rising money supply increases (expectations of) inflation in the long run, especially if inflation is already of a higher order. Stock prices are then discounted by a higher nominal required rate of return, leading to a lower intrinsic value or stock fair value. In this case, an increase in the money supply would even affect the stock price negatively.

The fact that the dependence of some stock indices on the cash stock has not been discovered does not necessarily mean that there is no dependence between the variables mentioned. Possible reasons could be as follows:

- Incorrectly chosen monetary aggregate. For our analysis M2 was chosen, however, some authors also mention M0, M1 (Shaoping, 2008), or MZM (Money Zero Maturity) (Sirucek, 2012).
- Inappropriate choice of length or period for the time series used, where, for example, a shorter time series may contain a structural break or otherwise deviate significantly from equilibrium but already miss the period when it returns to equilibrium.
- A missing parameter, such as money velocity, GDP growth or other variables that are necessary to fully explain the relationship being analysed.
- Poorly chosen methodology. Under certain conditions it might be more appropriate to use multiple variables, for instance, together with a Johansen cointegration test.

– Where there may not be a relationship between a country's stock index and the relevant M2 aggregate, but where foreign M2 (especially US M2) may have a greater influence, especially in the case of an economy with a significant foreign investor presence in the local stock market.

According to the specific equations of the long-run relationship constructed according to the general Formula (2) with the results presented in Table 6, it is possible to infer whether stock markets are undervalued or overvalued according to M2. Specifically, the above can be inferred by the residuals from the given equations in Figure 3 in the Appendix, which show that some stock markets are overvalued relative to the dates ending in the period June 2023 (l_WilshireSMLCAPPR, l_TSX). Some stock markets, however, are overvalued only in the period July 2023 (l_BOVESPA, l_FTSE100, l_S&P/BMV IPC) while others only in the period August 2023(l_S&P BSE500). Other indices, namely l_WilshireSMLCAPPR, l_BOVESPA, l_TSX, and l_S&P BSE500, are undervalued at this date.

Equations of long run relationship between stock indices and related money supply

$$l\_WilshireSMLCAPPR = 2.93216 + 1.260211\_USAM2$$

$$l\_BOVESPA = -1.70298 + 0.8843151\_BrazilM2$$

$$l\_FTSE100 = 3.43847 + 0.3644711\_UnitedKingdomM2$$

$$l\_S\&P/BMV\ IPC = -16.1409 + 1.181\_MexicoM2$$

$$l\_Wilshil\_S\&P\ BSE500 = -0.707002 + 0.9870921\_IndiaM2$$

$$l\_TSX = -2.95844 + 0.8890741\_CanadaM2$$

Equations of short run relationship between stock indices and related money supply

$$d\_l\_WilshireSMLCAPPR = 0.0067698 - 0.0323295\,d\_l\_USAM2_t - 0.0506880\,\hat{u}_{t-1}$$

$$d\_l\_BOVESPA = 5.38420e-05 + 0.930399\,d\_l\_BrazilM2 - 0.0399976\,\hat{u}_{t-1}$$

$$d\_l\_FTSE100 = 0.000567137 + 0.0823271\,d\_l\_UnitedKingdomM2 - 0.0590829\,\hat{u}_{t-1}$$

$$d\_l\_S\&P/BMV\ IPC = 0.000567137 + 0.0823271\,d\_l\_MexicoM2 - 0.0590829\,\hat{u}_{t-1}$$

$$d\_l\_S\&P\ BSE500 = 0.0119333 + 0.115233\,d\_l\_IndiaM2 - 0.0590829\,\hat{u}_{t-1}$$

$$d\_l\_TSX = 0.00344610 + 0.244341\,d\_l\_CanadaM2 - 0.0429381\,\hat{u}_{t-1}$$

To test for reverse causality, i.e., a situation where stock indices affect the money supply, time series was again tested and integrated with the same order of magnitude as in Tables 2 and 4. This was followed by the Engle-Granger test for cointegration and then estimation of the ECM model. The two tests conducted showed reverse causality only for the SPCITIC300 index according to Tables 9 and 10, suggesting that the stock index affects the Chinese money supply.

Thus, it seems that China's SPCITIC300 index is not influenced by the country's M2 money supply, but instead the index value influences the amount of money supply. As an explanation for this relationship one can use the reasoning that, as stock prices rise, entities feel wealthier and therefore further increase their investments in the domestic market (property acquisitions, company incorporations, etc.), which then leads to an increase in bank lending activity and thus an increase in the money supply.

Observed reverse causality in China's SPCITIC300 is similar to the results of the aforementioned study of John and Ezeabasili (2020). Explanation can be that developing countries could be prone for reverse causality because capital markets in developing countries positively affect economy growth according to Nordin and Nordin (2016), who proved this link in Malaysia and was also observed in India (Mishra, et al., 2010). Economic growth and increasing output then causes money supply growth.

Table 9 Engle-Granger test for reverse causality (models at 5% significance level bold)

	Period	Test w/o constant	Test with constant	Test with constant and trend	T
l_SP500	1959:01–2023:06	0.7951	0.9764	0.7325	774
l_Willshire 5000PR	1971:01–2023:06	0.5285	0.172	0.5886	630
l_Willshire 5000CAPR	1992:02–2023:06	0.03285	0.04946	0.02271	377
l_NASDAQ	1971:03–2023:06	0.7856	0.04436	0.1637	628
l_DAX	1988:01–2023:07	0.1689	0.39	0.7303	427
l_ATX	1992:12–2023:07	0.9991	0.6756	0.6501	368
l_BOVESPA	1993:05–2023:07	0.000397	0.3338	0.04953	363
l_PX50	2002:01–2023:06	0.1092	0.9863	0.2046	258
l_FTSE100	2001:02–2023:07	0.01724	0.0957	0.9723	270
S&P/BMV IPC	1987:02–2023:07	0.01734	0.193	0.3547	438
KOSPI	1981:05–2023:08	0.1208	0.3652	0.8231	508
S&P BSE500	2003:03–2023:08	4.706e-05	0.02267	0.3636	246
SMI	1988:02–2023:07	0.1155	0.6404	0.02893	426
CITIC 300	2000:02–2023:07	0.006869	0.08005	0.9783	282
TSX	1979:07–2023:06	0.1529	0.2705	0.1834	528
TA125	1992:11–2023:06	0.2957	0.03329	0.05522	363
l_FTSEAllWorld	2005:11–2023:07	0.6736	0.3368	0.08645	213
EURO STOXX 50	2003:09–2023:07	0.1031	0.7567	0.1929	239
SP500 x l_Global M2	2003:05–2023:07	0.8991	0.496	0.115	243
Willshire5000PR x l_Global M2	2003:05–2023:07	0.8659	0.4912	0.3235	243

Source: Own elaboration

Table 10 EC for reverse causality (models at 5% significance level bold)

Variables				Tests			
Y	Konst.	X	ρ_1	Breusch-Pagan	F-test p-value	DW	R^2
d_l_USAM2	0.00483465 6.45e-020 ***	d_l_Willshire 5000CAPR −0.000934586 0.8808	0.000254898 p-value 0.9595	0.000000	0.980075	0.784047	0.000108
d_l_USAM2	0.00549950 9.24e-048 ***	d_l_NASDAQ 0.00450994 0.3085	−0.00194293 0.1058	0.000000	0.174257	0.722472	0.009239
d_l_BrazilM2	0.0163790 3.99e-06 ***	d_l_BOVESPA 0.344479 0.0060***	−0.0224829 0.0813*	0.000000	0.022796	0.813553	0.337745
d_l_UnitedKingdomM2	0.00483307 1.68e-010 ***	d_l_FTSE100 0.0120201 0.3894	−0.00289695 0.3654	0.000000	0.459242	1.741808	0.006411
d_l_MexicoM2	0.0133287 2.21e-014 ***	d_l_S&P/BMV IPC 0.0156969 0.5226	−0.0116952 0.1355	0.000000	0.294173	1.347369	0.020948
d_l_IndiaM2	0.0100947 2.89e-09 ***	d_l_S&P BSE500 0.0181095 0.4263	−0.017137 0.0782	0.029960	0.172703	1.767890	0.013706
d_l_ChinaM2	0.00996413 1.81e-054 ***	d_l_CITIC 300 −0.00270171 0.7571	−0.00414605 0.0059***	0.000005	0.019241	2.361229	0.035706
d_l_IsraelM2	0.0101613 1.24e-018 ***	d_l_TA125 0.0273992 0.0290**	−0.00925664 0.0938*	0.001712	0.068292	1.181632	0.050371
d_l_SwitzerlandM2	0.00318796 0.0011 ***	d_l_SMI 0.00503308 0.8010	0.00322105 0.2002	0.008829	0.417633	1.121118	0.005433

Source: Own elaboration

After aforementioned overall results and discussed reasons of not discovered cointegration in some cases we suggest deeper analysis focused on:

- possible higher probability of reverse causality between money supply and stock market in emerging markets,
- cointegration using another monetary aggregates including modifications of existing official ones,
- influence of foreign investors on the domestic markets using capital from abroad, thus interference into link between domestic money supply and domestic stock market.

CONCLUSION

The results of our calculations show the dependence of some of the analysed indices on the respective M2 money supply. The longest time series available were used to investigate the relationship between M2 and stock indices. Notably, the long-run dependence (cointegration) of stock indices on the respective M2 was confirmed for the BOVESPA, FTSE100, S&P/BMV IPC, S&P BSE500 and TSX indices.

In contrast, our analysis did not show a dependence between the proxy global M2 money supply as measured by the GlobalM2 index and the FTSEALLWorld stock index. Furthermore, the dependence between the GlobalM2 variable and the SP500 index was not demonstrated either. Finally, and also not confirmed, was the dependence between the respective M2 and the DAX, PX, Nikkei225, KOSPI, SMI, SPCITIC300, Eurostoxx50, Willshire5000PR and ATX indices.

An especially noteworthy outcome of the analysis performed is that the dependence of the US indices on M2 mentioned by authors such as Parhizgari and Nguyen (2011), or Chung and Ariff (2016) has also not been shown on the highly liquid SP500 and NASDAQ. However, the dependence on M2 has neither been demonstrated in relation to the Wilshire5000 index, the most representative benchmark of the entire US market.

A certain exception among the examined indices from the US market is the 5000 Wilshire Small Cap Price Return index, which showed a long-term dependence on M2, something also demonstrated by the subsequent short-term dependence according to the EC model. This relationship is a rather surprising outcome, as the index's dependence on M2 was rather assumed and expected for larger and more liquid indices whose base contains stocks of companies with larger market capitalisation. This assumption was itself based on the premise that highly liquid stocks of larger capitalization companies would allow investors, both institutional and retail, to frequently adjust positions in light of the changing (and generally steadily increasing) money supply. However, changes in M2 appear to be a significant factor affecting the stock prices of smaller market capitalization companies whose prices are more volatile, more risky and more sensitive to fundamental influences compared to the more stable stocks of large market capitalization companies.

In all cases, the short-term EC model showed a very small coefficient for the error correction term, specifically converted to 2–8% per period. These results are consistent with the fact that monthly data was used. Stock market cycles, however, are generally multi-year, as is evident from the residuals of the long-term OLS model which represent the state of under- or over-valuation of the index.

The small coefficient on the error correction term is also related to the small R^2 in the EC model, where the change in M2 over the period explains the change in the stock index in very limited terms, as stock under/overvaluation cycles take place over a longer time period.

When testing for backward dependence, i.e., the dependence of M2 on stock indices, only the Chinese SPCITIC300 demonstrated this property, meaning the Chinese stock index in turn affects Chinese M2. According to the residuals from the OLS model, it was possible to infer whether the stock market is overvalued or undervalued relative to M2.

In interpreting the results obtained, it is important to note that the existence or absence of a relationship between M2 and the stock index identified from the analysis of past data does not imply that this will be the case in the future, especially if focusing on a shorter period and if the OLS model according to Formula (2) suggests an undervalued or overvalued market. A return to its equilibrium may take a very long time, but in the meantime the movement may still continue to the extreme and pose a possible risk to the investor. The outputs of our analysis are currently applicable to global fundamental equity analysis focusing on the effects of M2 on equity markets in the markets under study, but the relationships between M2 and equity indices need to be monitored further in the future as the nature of these relationships may be subject to change.

Investors and asset allocators are encouraged to take our analysis into consideration in their long term decision making only, since model suggests multiyear cycles. Thus, not appropriate for short-term allocation and speculation. Policy makers should bear in mind, that money supply can also influence stock market and be cautious especially when increased rate of money supply growth is observed due to possible influence on stock market not supported by fundamentals.

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APPENDIX

Table 11 Exogenous variables of monetary aggregates M2 and their statistical characteristics

Variable	Mean	Median	Minimum	Maximum	Standard deviation	Coefficient of variation	Skew-ness	Kurtosis
GlobalM2	5.9636e+013	5.9847e+013	2.4002e+013	1.0380e+014	2.3012e+013	0.38588	0.27675	–0.87680
USAM2	5062.8	3327.2	286.60	21703.	5316.0	1.0500	1.4567	1.4853
BrazilM2	1.2146e+006	5.6974e+005	0.010000	5.4165e+006	1.3446e+006	1.1070	1.1998	0.57498
CanadaM2	6.2552e+005	4.3889e+005	25523.	2.4322e+006	6.1105e+005	0.97686	1.2906	0.87444
CzechiaM2	3.2106e+006	2.8929e+006	1.3268e+006	6.2432e+006	1.3668e+006	0.42572	0.51941	–0.75411
EUROM2	5.9102e+006	4.5438e+006	1.0705e+006	1.5447e+007	4.0231e+006	0.68070	0.71372	–0.60983
ChinaM2	82465.	49614.	5840.1	2.8730e+005	77440.	0.93906	0.92872	–0.32775
IsraelM2	3.3307e+005	2.3435e+005	12.400	1.3990e+006	3.6358e+005	1.0916	1.2182	0.69720
IndiaM2	15917.	9789.4	1127.5	61024.	15753.	0.98970	1.1723	0.38910
JapanM2	4.6662e+005	5.0131e+005	8404.0	1.2390e+006	3.5118e+005	0.75261	0.28741	–1.0441
MexicoM2	3.6767e+009	2.3553e+009	1.5370e+007	1.2737e+010	3.4528e+009	0.93910	0.91503	–0.21875
SouthKoreaM2	8.9359e+005	4.2077e+005	590.60	3.8027e+006	1.0538e+006	1.1793	1.1220	0.19648
SwitzerlandM2	5.5727e+005	4.5359e+005	1.9823e+005	1.0956e+006	2.9518e+005	0.52969	0.53415	–1.2060
UnitedKingdomM2	1.3861e+006	1.1266e+006	1.6734e+005	3.2181e+006	8.5348e+005	0.61575	0.36438	–1.2245

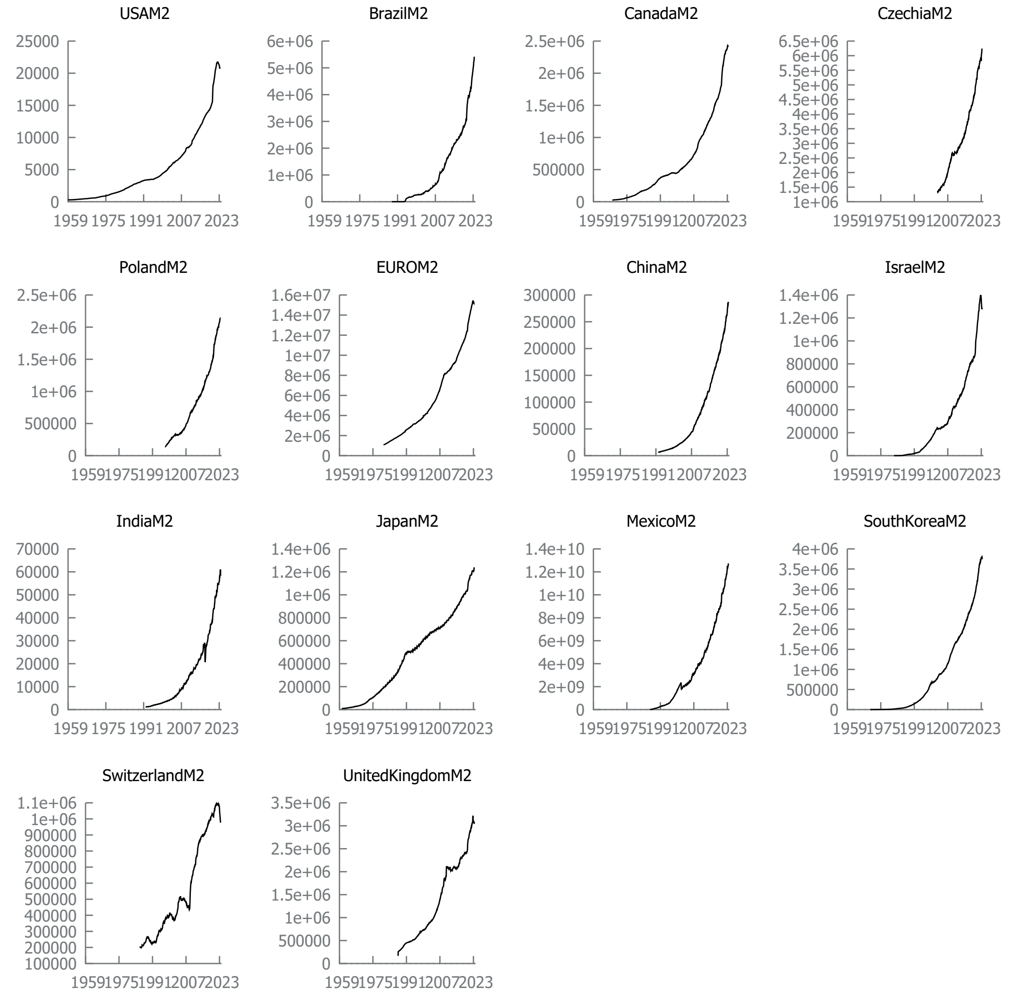
Source: Own elaboration, investing.com, finance.yahoo.com

Table 12 Endogenous variables of stock indices and their statistical characteristics

Variable	Mean	Median	Minimum	Maximum	Standard deviation	Coefficient of variation	Skewness	Kurtosis
SP500	871.33	375.22	53.390	4766.2	1050.4	1.2055	1.6852	2.4700
NASDAQ	2456.9	1314.8	55.670	15645.	3317.7	1.3504	2.0943	4.0385
DAX	6483.6	5738.9	936.00	16447.	4165.1	0.64240	0.60308	–0.70608
ATX	2249.2	2250.2	747.70	4885.4	1019.5	0.45327	0.43822	–0.68783
BOVESPA	40759.	36232.	1.0000	1.2680e+005	36248.	0.88934	0.65986	–0.70810
PX50	919.25	957.86	331.90	1908.3	364.26	0.39626	0.30273	–0.51963
FTSE100	6039.8	6076.6	3567.4	7876.3	1069.7	0.17712	–0.32602	–0.79363
Nikkei225	17886.	17336.	7568.4	38916.	6557.4	0.36662	0.62865	–0.067425
SPBMVIPC	21298.	13486.	79.820	56537.	19063.	0.89505	0.30656	-1.5783
KOSPI	1199.6	909.22	114.57	3296.7	795.14	0.66286	0.46275	–0.88674
SPBSE500	10108.	7687.7	1068.0	27069.	6480.8	0.64117	0.86644	–0.070718
SMI	6370.8	6595.1	1351.0	12876.	2938.4	0.46123	–0.16589	–0.86694
SPCITIC300	2419.3	2418.9	695.14	4750.4	1110.7	0.45910	0.14038	–1.0264
TSX	8727.7	7622.8	1366.8	21890.	5515.5	0.63195	0.44359	–0.99674
WILL5000PR	10540.	7559.4	550.04	48835.	11086.	1.0518	1.4900	1.7442
WILLSMLCAPPR	5436.0	4245.6	989.12	15299.	3807.7	0.70046	0.88546	–0.29423
EuroStoxx50	3264.6	3239.3	1976.2	4512.6	574.44	0.17596	0.20210	–0.61842
TA125	883.68	942.10	145.45	2109.2	524.22	0.59323	0.27831	–0.97020
MSCIWorld	2.4753e+005	1.9266e+005	10000.	1.0032e+006	2.3678e+005	0.95655	1.4401	1.4730
FTSEAllWorld	286.12	268.88	122.52	496.89	86.273	0.30153	0.66293	–0.32437

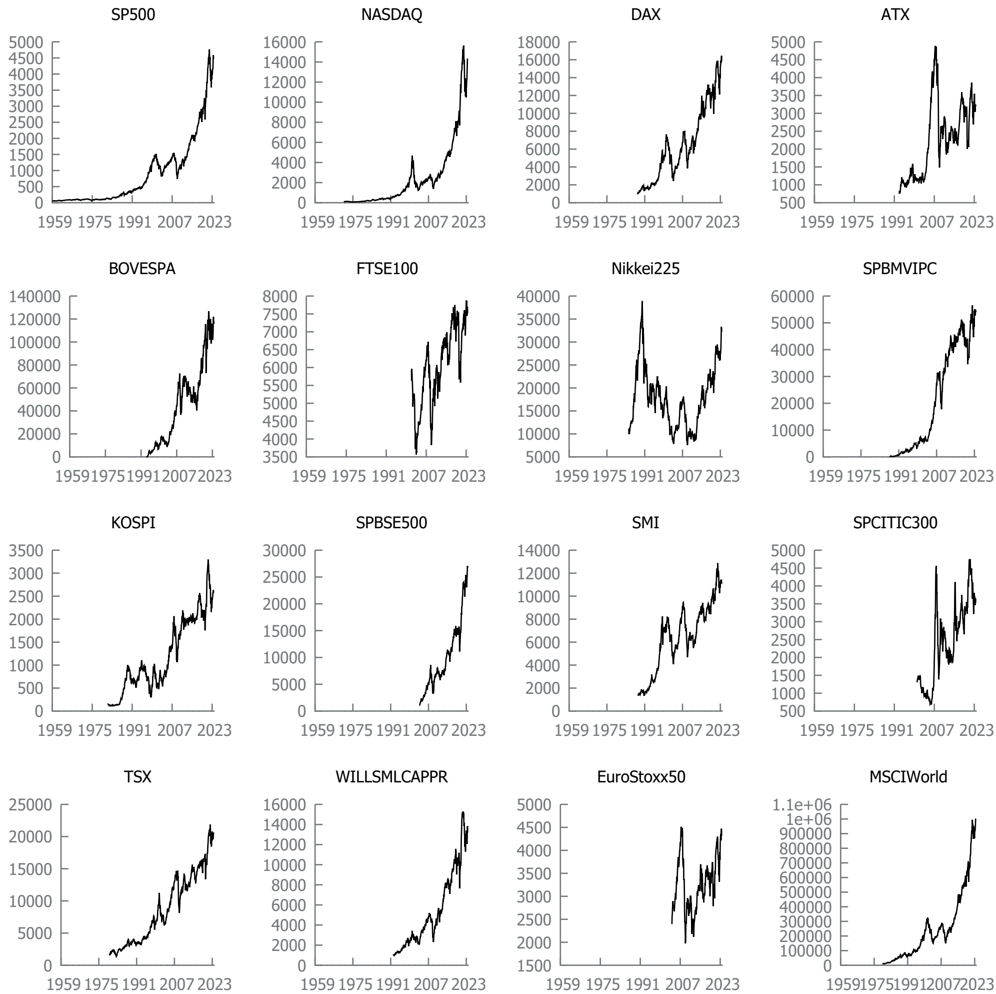
Source: Own elaboration, bloomberg.com, tradingeconomics.com

Figure 1 Exogenous variables in time



Source: Own elaboration, bloomberg.com, tradingeconomics.com

Figure 2 Endogenous variables in time



Source: Own elaboration

Table 13 Exogenous variables of logarithmized data series of M2 and their statistical characteristics

Variable	Mean	Median	Minimum	Maximum	Std. dev.	C.V.	Skewness	Ex. kurtosis
l_USAM2	7.8834	8.0972	5.6619	9.9922	1.2158	0.15423	–0.21016	–1.0596
l_BrazilM2	11.682	13.195	–4.6052	15.403	4.7878	0.40985	–2.0734	3.2326
l_CanadaM2	12.741	12.977	10.147	14.681	1.2113	0.095073	–0.46605	–0.70751
l_CzechiaM2	14.868	14.870	14.098	15.597	0.42849	0.028819	–0.12728	–0.98939
l_EUROM2	15.318	15.312	13.884	16.553	0.74087	0.048366	–0.14575	–1.1416
l_ChinaM2	10.814	10.953	8.6725	12.493	1.1348	0.10495	–0.18922	–1.3204
l_IndiaM2	9.0639	9.1537	7.0277	10.928	1.1395	0.12572	–0.10446	–1.2300
l_JapanM2	12.465	13.121	9.0365	14.008	1.3592	0.10904	–0.98680	–0.24345
l_MexicoM2	21.232	21.571	16.548	23.221	1.5749	0.074175	–1.0077	0.34136
l_RussiaM2	8.4706	9.3469	1.8718	11.250	2.2914	0.27051	–0.82464	–0.28391
l_SouthKoreaM2	12.008	12.901	6.3811	15.149	2.5826	0.21508	–0.67921	–0.84083
l_SwitzerlandM2	13.075	13.018	12.197	13.907	0.54029	0.041323	0.081798	–1.2992
l_UnitedKingdomM2	13.897	13.907	12.028	14.983	0.71010	0.051099	–0.26822	–1.2012

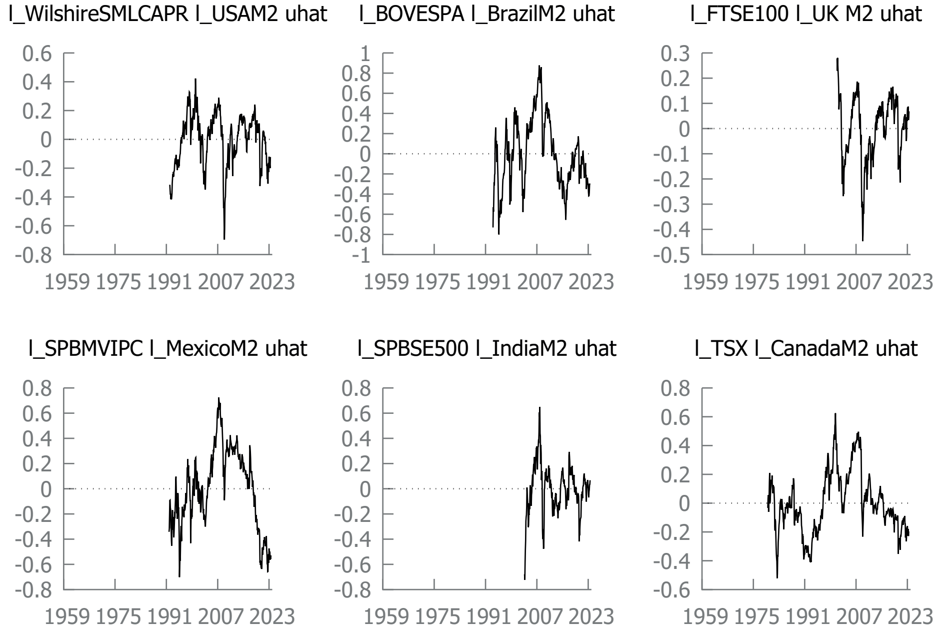
Source: Own elaboration

Table 14 Endogenous variables of logarithmized data series of stock indices

Variable	Mean	Median	Minimum	Std. dev.	C.V.	Skewness	Ex. kurtosis
l_SP500	5.9650	5.9275	3.9776	1.3494	0.22621	0.13584	–1.4348
l_NASDAQ	6.8652	7.1815	4.0194	1.5080	0.21966	–0.080962	–1.1231
l_DAX	8.5325	8.6550	6.8416	0.74599	0.087429	–0.36090	–0.97040
l_ATX	7.6082	7.7188	6.6170	0.48146	0.063282	–0.16766	–1.2406
l_BOVESPA	9.6338	10.498	0.00000	2.3127	0.24006	–2.3059	5.7190
l_PX50	6.7370	6.8647	5.8048	0.43066	0.063924	–0.36570	–0.98624
l_FTSE100	8.6893	8.7122	8.1796	0.18797	0.021633	–0.65143	–0.36310
l_Nikkei225	9.7244	9.7605	8.9317	0.37116	0.038168	–0.093370	–0.78474
l_SPBMVIPC	9.1072	9.5094	4.3798	1.6933	0.18593	–0.84639	–0.24635
l_KOSPI	6.7810	6.8126	4.7412	0.89525	0.13202	–0.83474	–0.094108
l_SPBSE500	8.9935	8.9474	6.9736	0.71999	0.080058	–0.48504	–0.19803
l_SMI	8.6075	8.7941	7.2086	0.61280	0.071194	–0.94720	–0.33844
l_SPCITIC300	7.6646	7.7911	6.5441	0.53326	0.069575	–0.51531	–0.93738
l_TSX	8.8328	8.9389	7.2202	0.73745	0.083490	–0.28362	–1.2122
l_WILL5000PR	8.6197	8.9305	6.3100	1.2409	0.14396	–0.15489	–1.2432
l_EuroStoxx50	8.0753	8.0831	7.5889	0.17813	0.022059	–0.16726	–0.52853
l_TA125	6.5535	6.8481	4.9798	0.73784	0.11259	–0.49802	–1.0721
l_MSCIWorld	11.897	12.169	9.2103	1.1429	0.096068	–0.50480	–0.41146
l_FTSEAllWorld	5.6125	5.5943	4.8083	0.29694	0.052907	0.050827	–0.43045

Source: Own elaboration

Figure 3 Residuals of OLS models where was confirmed cointegration



Source: Own elaboration