



ASSOCIAÇÃO DE POLITÉCNICOS DO NORTE (APNOR)
INSTITUTO POLITÉCNICO DE BRAGANÇA

**The financial contagion between developed and emerging countries
with US market : An analysis using NARDL models**

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Final Dissertation submitted to *Instituto Politécnico de Bragança*

To obtain the Master Degree in Management, Specialisation in Business
Management

Supervisor:

Professora Doutora Ana Paula Monte

Bragança, December, 2023.



Instituto Politécnico
de Viana do Castelo

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Abstract

The aim of this dissertation is to examine the short- and long-term asymmetric relationship between the US market and some developed and emerging countries.

Based on the literature and given that the academic research on the asymmetric long-run relationship between developed and emerging stock markets is not very developed in the old studies and to our knowledge. So, our objective here is to analyse this relationship by a Nonlinear Auto Regressive Distributed Lag (NARDL) model between the US market and some developed and emerging markets considering the subprime crisis.

The outcomes demonstrated that server variables , have short-Terme effects on the market index , SP500, with significant influences from BOVESPA, SPTSX, NIKKEI225, and FTSE on the US market index.

However, the SHANGH variable no notable impact. The SP500 is negatively influenced by other factors such as the DAX , STI , and CAC40 .

Moreover, there is a long- term cointegration relationship between all markets , and the US market index yield is driven by both positive and negative movements.

Thus, the other objective is also to test whether this asymmetric effect between those different market depends on the methodology using a particular group of stock market indices were chosen for a period from 2007 to 2022 using a NARDL model.

Keywords: Long-run, asymmetric relationship, developed and emerging countries, NARDL

Resumo

O objetivo desta dissertação é examinar a relação assimétrica de curto e longo prazo entre o mercado norte-americano e alguns países desenvolvidos e emergentes.

Com base na literatura e dado que a pesquisa acadêmica sobre a relação assimétrica de longo prazo entre mercados de ações desenvolvidos e emergentes não é muito desenvolvida nos estudos antigos e para o nosso conhecimento. Assim, nosso objetivo aqui é analisar essa relação por um modelo de Defasagem Distribuída Auto Regressiva Não Linear (NARDL) entre o mercado dos EUA e alguns mercados desenvolvidos e emergentes considerando a crise do subprime.

Os resultados demonstraram que as variáveis do servidor têm efeitos de curto prazo no índice de mercado , SP500, com influências significativas da BOVESPA, SPTSX, NIKKEI225 e FTSE no índice de mercado dos EUA.

No entanto, a variável SHANGH sem impacto notável. O SP500 é negativamente influenciado por outros fatores, como o DAX , STI e CAC40 .

Além disso, há uma relação de cointegração de longo prazo entre todos os mercados , e o rendimento do índice de mercado dos EUA é impulsionado por movimentos positivos e negativos.

Assim, o outro objetivo também é testar se esse efeito assimétrico entre esses diferentes mercados depende da metodologia que utiliza um determinado grupo de índices do mercado de ações que foram escolhidos para um período de 2007 a 2022 usando um modelo NARDL.

Palavras-chave: Longo prazo, relação assimétrica, países desenvolvidos e emergentes, NARDL

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Abbreviations and/or Acronyms

ACF: Auto-Correlation Function

ADF: Augmented Dickey-Fuller

ARCH: Autoregressive Conditional Heteroskedasticity

ARDL: AutoRegressive Distributed Lag

BOVESPA: It is the benchmark of the São Paulo Stock Exchange in Brazil.

CAC 40: This index represents the 40 largest companies listed on the Paris Stock Exchange in France.

CUSUM: Cumulative Sum

DAX: The DAX Index measures the performance of the 30 largest companies listed on the Frankfurt Stock Exchange in Germany.

FTSE 100: This is the flagship index of the London Stock Exchange in the UK, and it includes the country's top 100 companies.

K: The thresholds of significance

LM: Lagrange Multiplier test

NARDL: Nonlinear AutoRegressive Distributed Lag

NIKKEI 225: This index tracks the performance of the 225 largest companies listed on the Tokyo Stock Exchange in Japan.

OLS: Model estimation by Ordinary Least Squares

PACF: Partial Auto-Correlation Function

Prob: Probability

RTSI: This is the benchmark of the Moscow Stock Exchange in Russia.

SHANG_COMP (SHANGHAI COMPOSITE): It represents the stock market of Shanghai, China, and includes many Chinese companies.

S&P/TSX: This index represents the Canadian stock market and includes a variety of Canadian companies.

S&P 500: It is one of the most followed indices in the US, including the 500 largest publicly traded companies.

STI: The STI index is associated with the Singapore Stock Exchange and tracks the performance of Singapore companies.

Std.Dev : Standar deviation

Sum Sq.Dev : Sum of squares of variances

Std. Error: Standard Error.

Wald: Wald chi-squared test

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Introduction

Over the past two decades, the international financial scene has experienced a series of successive crises, which have affected emerging and developed markets. These crises have mainly highlighted the banking, financial and economic failures of the affected countries.

Most of these crises have occurred in emerging markets, which are more sensitive to shocks due to their underdeveloped financial markets and huge government deficits.

In financial markets, large fluctuations in the prices and returns of financial assets have been observed, which is considered an increase in risk for investors.

However, developed countries have also been affected, such as the global crisis in the United States. The feature of 2007 was the emergence of a new crisis, namely the "housing crisis" in the United States, also known as the subprime crisis. Indeed, it is considered the worst global crisis in a long time. (Claessens et al., 2010).

This crisis triggered a rapid decline in the U.S. stock market, which quickly spread to most global financial markets and advanced and emerging market economies.

We observe that this crisis is dominated by a new phenomenon linked to the outbreak of the financial crisis, and this crisis is manifested by the spread of the financial crisis. This will increase the turbulence of financial markets to other markets.

At this level, it can be said that the cause of contagion is the disappearance of national barriers and the causality of the world financial market, financial globalization. Therefore, Forbes and Rigobon (Forbes & Rigobon, 2002) define contagion as a significant increase in the relationship between financial markets due to a specific shock from a country or national community.

We note that this crisis has been led by a new appearance linked to the conjuncture of financial crises that presents itself by the phenomenon of the contagion of financial crises. This deploys the increase of turmoil from one financial market to other markets.

As a result, the literature on contagion generally points to increased linkages between financial markets during periods of crisis (Calvo & Reinhart, 1996; Forbes & Rigobon, 2002; King & Wadhvani, 1990; Lee & Kim, 1993). More specifically, in order to show the existence of contagion, the work attempts to highlight changes in the relationship between periods of calm and periods of crisis. While these links are clearly established and remain stable over time, the mechanism for transmitting shocks between exchanges is often achieved by fundamentals. On the other hand, if these links intensify during a crisis, it indicates that there is contagion.

Based on this literature and given that academic research on the long-term asymmetric relationship between stock markets in developed and emerging countries is underdeveloped in previous studies and to our knowledge, this is the first analysis to examine this relationship using a NARDL model. So, our objective here is to analyze this relationship between the US market and certain developed and emerging markets by considering the subprime crisis.

The subprime crisis, a financial issue, has been studied both in developed countries (United States, Canada, Japan, Germany, France, United Kingdom, Australia, Singapore, Sweden, and Switzerland...) and emerging countries (China, India, Brazil, Russia, South Africa, Mexico, Turkey, Indonesia, Malaysia, South Korea...). The crisis has caused shocks to spread, destabilizing economies, a phenomenon known as contagion.

Thus, the other objective is also to test whether this asymmetric effect between these different markets depends on the methodology using a particular group of stock indices were chosen for a period from 2007 to 2022 using a NARDL model.

This thesis is composed of three chapters, apart from this introduction and the conclusion, limitations and suggestions for further research.

In the first chapter, a literature review is done, the definitions of financial contagion and its different types were first identified. Then, we presented the subprime crisis and its impacts on developed and emerging countries.

Then, in the second chapter, the different approaches and works on the effect of contagion were described according to a theoretical framework.

We begin this part with a presentation of the data and the methodology followed will be presented. Finally, the analysis and discussion of the findings will be presented.

1. Theoretical framework - Contagion and financial crisis

1.1. Definitions of contagion and the different mechanisms

Financial development, which has certainly experienced its boom since the 1980s with financial liberalization therefore encouraging public decision-makers in emerging and developed countries to adopt the same policy. This was followed by the rise of a series of financial incidents, both nationally and internationally, which are illustrated, among others, by the Asian (1997), Russian (1998), Brazilian (1999), Argentine (2001) and Subprime crisis (2007) crises, which are the subject of our work. These accidents, additional in more regular and draconian, by their rapid repercussions, drag economies into depressed states. This spread of shocks from one country to another is known in the literature via the name of contagion.

Generally, contagion refers to the spread of disturbances in the financial markets of one country to the financial markets of other countries. In addition, the literature on contagion remained embryonic until the subprime crisis. Since then, many have studied both theoretically and empirically. The latter on the concept of contagion “paradoxically, ...there is no accordance on what contagion means” (Rigobon, 2001) or “... there is no consensus on exactly what constitutes contagion or how it should be defined” (Forbes & Rigobon, 2000). In this chapter we first present and discuss the different conceptions of contagion developed in the literature. Then, we study on the one hand the different types of contagion with their different transmission channels, and on the other hand we present a review of the main empirical works that have dealt with this phenomenon.

1.1.1. Definitions of contagion

Eichengreen, Rose & Wypolysz (1996) define contagion as "a systematic effect on the probability of a speculative attack from an attack on other currencies, and which is therefore an effect additional to those of domestic fundamentals."

Calvo and Reinhart (1996) analyze contagion as "the transmission of a crisis to a particular country because of its real and financial interdependence with the country or countries already in crisis.

Another definition is also often used is "contagion occurs when volatility spreads from the financial market of the country in crisis, to the other financial markets of other countries " (Dornbush et al., 2000). This definition analyzes volatility in financial markets by showing that the volatility of financial asset prices increases during the period of financial turmoil. Thus, this definition exposes the fact of increased volatility to identify the crisis. So, contagion can be measured as the pass-through of this volatility from one market to another, which leads to an extension of uncertainty in international financial markets. These last two definitions study contagion in a very general and broad context and do not define it in a precise way. Indeed, in these two definitions, in order to study contagion, the study period is subdivided into two sub-periods: the period of tranquility and the period of crises. Contagion may be due to a shock in a country or a set of countries that induces important links between markets (Dornbush et al., 2000).

The contagion reflects a situation where the effect of an external shock is greater than expected by experts and analysts. This definition implies that contagious effects must be differentiated from "normal" shock transmissions between countries, also known as interdependencies.

Pure contagion can also occur if investors change their assessment of the rules by which international finance takes place. Pericoli and Sbracia (2001) defined contagion as an excess of co-movements in their third and fifth definitions. Using a similar methodology, Masson (1999) and Claessens (2001) looked at the reasons behind the excessive co-movements in operator irrationality, herd mentality, and financial panic.

Contagion is defined by Forbes and Rigobon (2001,) "as a significant increase in the links between markets, after the realization of a shock on a country or a group of countries". They believe that periods of tranquility and crisis are intrinsically different. Therefore, the significant increase in links between financial markets causes new transmission channels during the crisis period regardless of fundamentals, which generates contagion.

According to Sander and Kleimeier (2003), contagion amplifies causality between markets following a shock. Samarakoon (2011) Identifies contagion as the impact of shocks during periods of crisis while interdependencies as their impact in normal times.

1.1.2. Mechanisms of contagion

Theoretical work on shock propagation can be classified into three categories representing three mechanisms at the origin of contagion: aggregate shocks affecting the economic fundamentals of more than one country, shocks intrinsic to a specific country and affecting other countries and, finally, shocks that are not explained by fundamentals and are known as pure contagion (Masson, 1999).

Interdependence: The first two mechanisms highlight the spread of crisis resulting from interdependence between markets. Interdependence implies that shocks, whether global or local, spread through genuine or financial ties and affect the fundamentals of countries. This is why these two mechanisms can be grouped together under the name of "fundamentals-based contagion" (Kaminsky & Reinhart, 2000). However, as these forms of common movement are linked to the interdependence that existed before the impact, it can also be considered that it is not a true contagion.

Global shocks have also affected the fundamentals of several economies. Examples include rapid declines in aggregate demand, large changes in commodity prices, or large exchange rate movements between major currencies that can slow economic growth in many countries. Then, the stock markets of all the countries affected by this shock will develop simultaneously, and, after the shock, the correlation of these markets could increase. These types of shocks are also called the "monsoon effect" because they affect all affected countries in a similar way.

A shock in one country (or group of countries) affects the fundamentals of other countries (Eichengreen, Rose & Wypolysz, 1996). This mechanism can work through many economic links, such as trade and financial links or economic policy coordination. Therefore, we are talking about the effects of "spillover" or macroeconomic interdependence. Devaluation in one country can improve the competitiveness of that country's goods and can reduce the competitiveness of other countries' commodities. This can not only affect sales of goods and accommodation in these countries, but if the loss of competitiveness is large enough, it can also increase expectations for devaluation. Economic policy coordination can also transfer shocks and affect fundamentals. For example, a country that changes its economic or financial policies after a shock may force other countries to adopt similar crisis policies, or lax monetary policy in one country may encourage other countries to increase trade barriers...

Pure contagion: The last, purely contagious shock-transmission mechanism is defined as an increase in market volatility, which cannot be explained by the two preceding processes. This means, therefore, that the spread of the financial crisis is not due to changes in macroeconomic fundamentals, but only to the behavior of investors and other financial agents. Consequently, this contagion is caused by so-called "irrational" phenomena, such as panic, loss of confidence, increased risk aversion or herd behavior (Dornbusch, Park & Claessens, 2000).

Owing to the lack of evidence that a country's economic base is always at the root of financial contagion, researchers have attempted to find alternative explanations by modeling investor psychology. They looked at different channels through which investors pass shocks on to financial markets. On the one hand, we can distinguish channels related to investor behavior, that is to say a set of behaviors that first seem to be personal rationality, but which will lead to excessive turbulence in the financial market. In the sense that they cannot be explained by fundamentals. In the first channel, we can visually distinguish two problems: the problem of the liquidity shock and the problem of asymmetry of information. On the

other hand, multiple equilibrium can also mean contagious behavior (Dornbusch, Park & Claessens, 2000).

Liquidity shock: After market turbulence, investors can automatically readjust their portfolios by selling the same type of assets. This has the effect of transmitting the initial shock to other markets. Thus, this kind of portfolio rebalancing refers to a contagion based on fundamentals. Compared to the baseline, however, if these adjustments are over-made, we will call them purely contagious. When a country's crisis causes large losses, it cuts off market participants' liquidity, this is liquidity shocks. While liquidity restrictions may affect all investors, this behavior is generally verified by leveraged investors. Because they must meet the margin call, they are more likely to experience liquidity difficulties at the onset of the crisis. Faced with these liquidity problems, investors tend to hold assets whose prices have fallen, and market liquidity has declined, and to sell other assets in their portfolios. This will lead to lower prices in other markets. As a result, the initial disease can spread through different financial instruments and markets.

Information asymmetry: The imperfection of information between market agents represents another channel for transmission of pure contagion. This is information asymmetry. A shock in country X that would have no real and financial effect in country Y if the information were publicly perceptible, can have a genuine and financial impact if the information is not publicly observable. The presence of information asymmetries increases the price movements of financial assets. This is why we find the concept of excessive co-movements characterizing pure contagion.

Faced with this problem of asymmetry, liquidity shocks can be even more contagious. Indeed, informed agents may be forced to sell assets in response to margin calls or regulatory requirements. Uninformed agents, however, cannot distinguish between a liquidity shock and a signal of deterioration in the fundamentals of countries involved in asset sales. This phenomenon of mimicry, resulting from a misinterpretation of the actions of conscious agents. Therefore, leads to an increase in capital withdrawals from the countries concerned.

Moreover, without information to the contrary, a financial crisis in one country can lead investors to believe that other countries are facing the same problems. This transmission narrow implies that investors are not fully informed about each country's actual macroeconomic conditions. As a result, they take their decisions based on known indicators, including those of other countries, which may or may not reflect the true sensitivity of those countries. They can also make decisions based on the actions of other investors (who think they have a better understanding of the situation or are acting in front of them).

When information asymmetries are present, sheep's behavior appears (herding behavior). Two groups of investors can be distinguished effectively: informed investors and less informed investors (or not at all). Given the cost of collecting and processing information, most retail investors cannot afford to collect information on specific countries. As a general rule, investors with a low level of knowledge follow the actions of informed agents at a lower cost than obtaining information.

So, agents with a low level of knowledge will make investment decisions based on the behaviors of informed agents rather than relying on their incomplete information. In times of crisis, this standardization of investors' shares leads to the sale of large amounts of financial assets. The contagion is then marked by portfolio adjustments that are not directly related to fundamentals.

We can prove the increase in herding behavior through two factors. On the one hand, the more countries where investments can be made (the process of financial liberalization), the higher the cost of collecting and processing information. On the other hand, it is increasingly difficult to earn one's reputation in an environment of increasingly diverse investors. Given this cost, it is often more meaningful for investors to adjust to the trend than to make their own decisions and risk being discredited.

Moreover, if reputational expenses are high, even if market changes are conducive to the creation of a new investment portfolio, the individual investor may not take the first step because he is afraid to do so. If his position is bad, he will suffer a loss of reputation. For security reasons, individual investors will follow the herd.

Some investors (such as fund managers) will adjust their decision-making orientation to maintain their reputation. However, this depends on the performance of their portfolios in relation to a given market portfolio, not on the absolute performance. It is therefore in their interest not to deviate too much from the trend of this market portfolio. All these situations point to investor behavior, which is individually rational but can lead to increased financial volatility.

Multiple equilibria: Pure contagion involves the anticipation of a crisis in one country triggering another, regardless of changes in economic fundamentals. This induces a shift in "self-fulfilling" in expectations can lead to a poor balance in financial markets, causing depreciation, falling asset prices, capital outflows, or defaults. The transition depends on investors' confidence in the market and expectations, and the economy may be vulnerable to a shift to the wrong equilibrium. Informed investors may ignore information, causing imbalances in the economy. Obstfeld (1986, 1995), following a suggestion by Flood and Garber (1987).

1.2. The subprime crisis and its effects on developed and emerging countries

The 2007-2008 financial crisis, which originated in the US subprime mortgage market, has spread with devastating effects on the rest of the US economy, as well as global financial markets, is considered to be the most severe recession since World War II (Kenourgios & Dimitriou, 2015). The problem in the mortgage market, which was a relatively small part of the US economy, spread to other financial sectors through covered mortgage bonds (CMOs), which are a type of secured debt obligation (CDO). Problems in the mortgage market became more pronounced with the presence of credit default swaps (CDS), which were used as insurance contracts for individual CMOs. Falling prices in mortgage markets caused

the value of CMOs to fall and, as demand from CMOs was very low, they were no longer traded, making it difficult to price them. This triggered CDS protection payments and inflicted severe losses on financial institutions. Lehman's default caused significant turmoil in global financial markets, resulting in the failure of several financial institutions and investors selling risky assets, such as stocks and derivatives, causing asset prices to fall sharply (Dooley & Hutchison, 2009).

The global financial system experienced unprecedented crises in 2007 and 2008. This crisis has spread, it has reached different markets, different actors and different countries, and has evolved into an economic crisis, i.e., a crisis affecting the real economy. In fact, the interaction between the financial sector and the real economy is often mutually supportive, including through bank capital. The collapse of Lehmann Brothers in September 2008 marked a turning point in the financial crisis that erupted in the United States in the summer of 2007 (Johnson & Mamun, 2012).

This is undoubtedly the 2007 international financial crisis, the worst since the Great Depression. This has had a catastrophic impact, and its spread has affected directly or indirectly all countries of the world. Indeed, from the US epicenter, this financial and economic disaster has spread around the world with alarming intensity and speed. This is one of the most serious crises in developed and emerging financial markets, affecting the most stable countries (Europe, Japan) and the most active BRICS country (Brazil, Russia, India, China, and South Africa).

1.2.1. The impact of the crisis on the US market

The 2007-2008 had several impacts on the US market that are explain as follows.

- The impact of the crisis on household spending

In 2005, U.S. household spending has been very strong. However, these opportunities have disappeared again. Mainly the costs of these homes are financed by the stock market mainly housing. In fact, in 2005 and 2006 more than 5% of household spending in the U.S comes from mortgage withdrawals .However, after the current decline in house prices this source of financing expenses may not be easily accessible .Furthermore, consumer enthusiasm in the U.S. will affect not only the consumer sector but also many other areas of the market .Therefore, the decline in U.S. household demand will be transferred to manufacturing and manufacturing industries market services. (Casian & Marius, 2008)

- The impact on the dollar

Since the onset of the subprime crisis, the US dollar has continued to depreciate against the euro (around 16%). Indeed, today's dollar has hit its lowest level since the 1970s, when the dollar's exchange rate against gold reversed. As the Federal Reserve continues to pursue a monetary policy of lower interest rates, concerns about the depreciation of the U.S. dollar and rising inflation risks are expected to intensify.

Another concern for the US dollar is the shift from a unipolar system based on the US dollar to a bipolar system based on the US dollar and the euro. Indeed, the financial crisis has allowed global banks' activities to continue, including the reduction of US dollar foreign-exchange reserves. These global banks find themselves in a situation where the Federal Reserve's anti-recession monetary policy is no longer suited to their economic conditions, characterized by rising inflation and rapid inflation. As a result, many countries no longer accept the US dollar as their primary reserve currency. This crisis has surpassed the American territory by contaminating the markets of other developed and emerging countries:

- **The impact of the subprime crisis on global financial systems**

The damage caused by the sub-prime mortgage crisis is no longer limited to the insolvency of US mortgage borrowers. Indeed, on the one hand, it led to the bankruptcy of US specialized lending firms or the loss of major US banks that cooperated with it, triggering a global liquidity crisis. By contrast, the mortgage crisis has led to huge losses on various stock exchanges. The impact of the subprime mortgage crisis in the United States on financial markets in those countries is enormous. Major investment banks in the US and Europe have pointed to sharp asset-value write-downs. Indeed, the British bank Northern Rock announced in September 2007 that there had been a bank run. In just three days, the bank's customers withdrew 12% of the amount that was deposited.

In France, the Secretary-General of the Banking Commission of the State Banking Supervisory Body explained at a hearing in the National Assembly on 5 February 2008 that French banks now have a good understanding of the risk of subprime and its impact is slightly high. BNP PARIBAS' investment will exceed €1 billion (but the company's reported profit will exceed €7 billion), general companies' turnover will reach €2 billion and farm credit turnover will reach €3 billion. As a result, the full magnitude of the loss cannot be known in early 2008. The IMF released its April Global Financial Stability Report on April 8. The report estimated the cost of the global financial system crisis at about \$945 billion, more than half of which came from banks (\$565 billion) (Orléan, A., 2009).

Another consequence of the banking crisis is that its impact on stock-market value spreads. Shares prices of major banks were affected in the summer of 2007, which also reduced major stock indices such as Dow Jones (-7%), CAC (-12%), Nikkei (-10%) and FTSE (-10%). For example, the share price of the Paris Stock Exchange fell by 6.83% on January 21, 2008, the lowest level since September 11, 2001. (Jawadi, F., & Arouri, M., 2008).

To be sure, the world's major stock exchanges were severely liquidated in the summer of 2007. The sub-prime crisis has thus spread worldwide, and these are mainly caused by the following transmission factors: transmission by securitization of mortgages and transmission by investment funds.

1.2.2. Transmission mechanisms

- The transmission of mortgages by securitization

Securitization is a mechanism for financial institutions to issue risky mortgages. This is a financial transaction in which banks can strip these weak or rather suspect debts of their balance sheets by converting them into MBS (Mortgage-Backed Securities) (Orléan, A., 2009, p. 55) which are traded on the financial market. As a result, the banks that issued the loans created intermediate companies in which the loans were assets, and, in turn, the bonds that were the liabilities.

Interest and repayment of the loan are used to pay interest on the bonds issued and to repay the loan. These companies are known as SPVs (Special Purpose Vehicles) or SPVs because they are not used for any corporate purpose and are created on a case-by-case basis. Through this mechanism, banks can refinance and reduce their risks.

It is a phenomenon of “mutual assistance of risks”. Everybody has a certain percentage of risks, but no large organization bears enough risks to harm it. These securitized loans were subsequently repurchased by investors. To compensate for poor debt-service quality, these securities charge much higher interest rates than market standards. Therefore, securitization appears to be an important risk allocation phenomenon. But as this spilled over the sub-prime mortgage crisis into other parts of the world, and international investors became suspicious of US residential mortgage RMBS (Residential Mortgage-Backed Securities) and of diversified loan packages known as Collateralized Debt Obligations (CDOs), the panic intensified. (Orléan, A., 2009).

- Transmission by venture investment funds

A hedge fund is used to buy securitized debt. They are characterized by high incomes because the interest rate paid by the borrower is higher than the interest rate offered by the main market. As the sub-funds' bearish performance intensified, many depositors withdrew their funds and creditors refused to roll over their loans. As a result, the finances of some international financial institutions could not support and failed. In this case, some US banks have announced a freeze on the assets of these money market funds. But a few months later, aggressive reduction measures revitalized the financial situation.

Although there are no products comparable to the US subprime mortgage market in Europe, European banks and investment institutions have been severely affected, which can be explained by the fact that these banks have large reserves of US bank subprime backed securities.

1.2.3. The impact of the crisis in emerging countries

The financial crisis is affecting emerging countries through multiple channels. From Figure 1, we can distinguish between real links related to world trade and financial links on the other hand.

This distinction is important because it shows that emerging markets have not been affected in the same way by the financial crisis. While some countries can suffer both real and financial shocks, such as Russia, other countries are still affected through trade channels (Asian countries) or financial channels (Central and Eastern European countries).

- **The financial channel**

The financial crisis mainly affected emerging countries via financial channels after the collapse of Lehman Brothers. As a result, EM currencies have depreciated against the U.S. dollar (Figure 1, left) and net capital inflows have declined significantly (Figure 1, right).

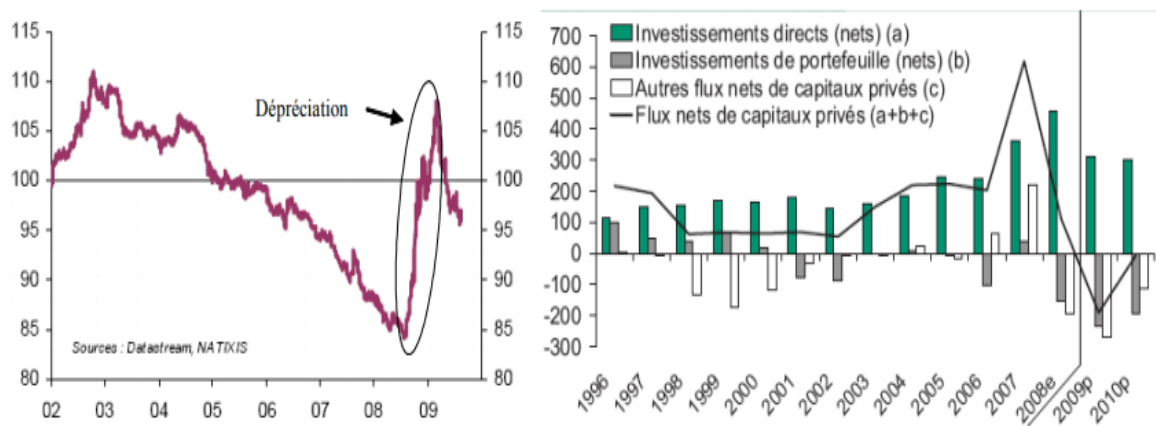


Figure 1. Indicators of financial stress in emerging markets

(Sources : Artus, 2009 ; BNP Paribas, juillet 2009).

Financial fragility is different in different emerging countries. In a study published in October 2008, Artus (2008) distinguished four groups of countries according to the degree of severity. These groups are explained as follows.

- The first group concerns the most severe cases. These countries may suffer losses of foreign exchange reserves due to capital outflows. In order to identify this type of country, it is necessary to compare the size of possible capital outflows (linked to previous cumulative inflows) with that of foreign exchange reserves. Since 2004, countries with cumulative inflows greater than or equal to foreign exchange reserves are India, Turkey, South Africa, Poland, Hungary and Romania.
- For the second category concerns economies in which the lowering of bank liquidity, credit and currency depreciation after capital outflow have a significant debilitating effect on business. In

these countries, capital inflows are linked to the monetary base, domestic credit, or exchange rates. Thus, these capital inflows offer the possibility of financing banks and borrowers in the countries concerned. for India, Russia, Turkey, South Africa, Poland, Romania, and Brazil.

- The third group consists of the countries with the least severe case. Capital inflows produce a decline in stock markets, but the impact on the economy is still small, on the one hand, if the impact of wealth is limited, on the other hand the depreciation of the domestic currency is still very small. China, South Korea, and Thailand, these are countries in which capital inflows and outflows have little correlation to credit and do not cause marked exchange rate fluctuations. Finally, the country of Mexico is mentioned in the last group, this country concerns the economy where changes in capital flows are still small.

The table 1 below explains that Central European countries are specifically vulnerable to financial channels. The example of Hungary has clearly demonstrated this. These countries have large current account deficits and high dependence on international bank financing.

Table 1. Macroeconomic imbalance indicators in 2007, as % of GDP

	Current balance	IDE	IDE/Current account balance	External debt	Short-term external debt
Pologne	-3.8	3.6	95%	40.2	8.7
Hongrie	-6.4	1.0	16%	91.0	11.2
Rep.tchèque	-2.5	4.3	73%	42.7	13.3
Slovaquie	-5.4	2.5	47%	48.9	27.5
Estonie	-18.1	4.5	25%	116.7	37.1
Lettonie	-22.8	7.1	31%	123.4	45.1
Lituanie	-14.6	4.2	29%	70.9	22.2
Roumanie	-14.0	5.7	41%	42.2	12.7
Bulgarie	-21.4	20.5	96%	76.0	32.0

(Source: Rodado, J.C. NATIXIS Special Report, 27 octobre,2008)

A situation in which international banks withdraw their capital from these countries to offset their losses in other markets cannot be ruled out. Figure 2 clearly shows that the decline in international banking activity is particularly pronounced in emerging markets considered riskier.

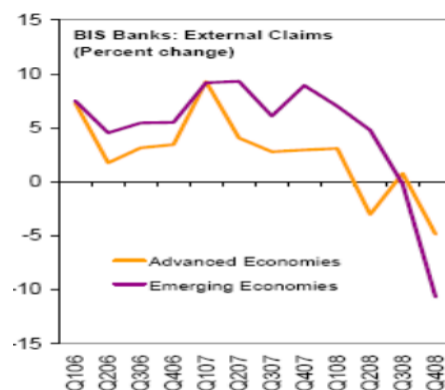


Figure 2. International bank claims on developed and emerging countries, % change

(Source: FMI, World Economic Outlook Update, juillet 09)

-In order to benefit from lower interest rates, many agents use their national currency for debt (Table 2). In this case, the depreciation of the national currency can significantly increase the cost of debt. For example, foreign currency loans accounted for 54% of total loans to households in 2007. The percentages are 77% and Estonia and Latvia accounted for 86%.

Table 2. Foreign currency loans as % of total outstanding amount in 2007

	Households	Entreprises
Bulgarie	6%	68%
Roumanie	53%	55%
Hongrie	54%	52%
Rep.tchèque	0,1%	17%
Pologne	28%	19%
Slovaquie	3%	35%
Estonie	77%	79%
Lettonie	86%	86%
Lituanie	50%	59%

(Source: Rodado (2008), NATIXIS Special Report, 27 octobre, p.133)

Some countries, particularly the Baltic countries, have experienced a housing boom and a credit boom as figure 3 shows, making them highly vulnerable to global financial stress.

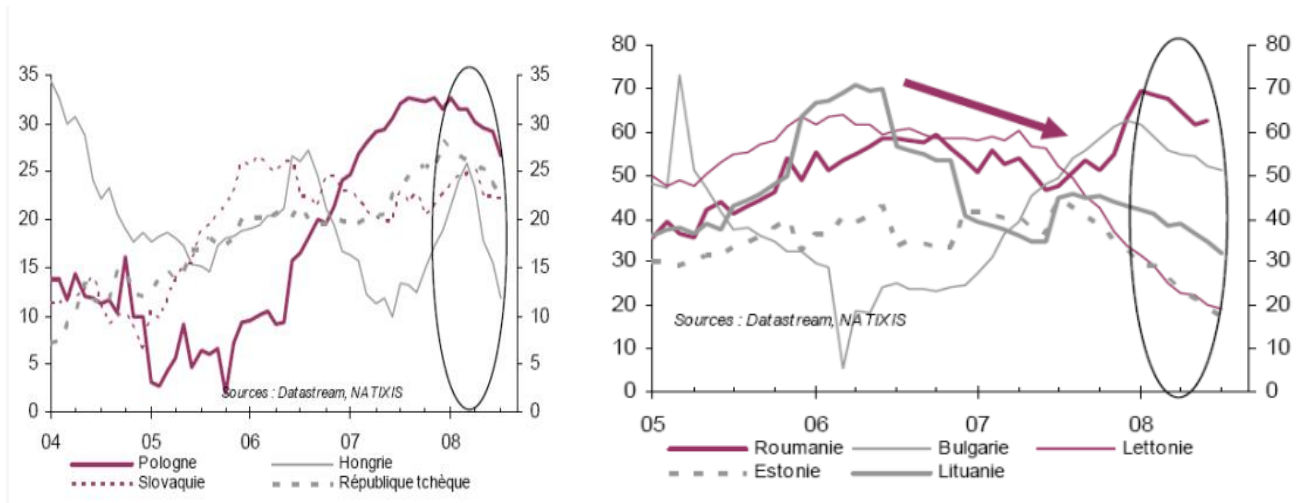


Figure 3. Private sector loans, Year-on-year, in %

(Source: Rodado (2008), NATIXIS Special Report, 27 octobre, 133)

Emerging Asia is generally less sensitive to the financial channel. They often have a banking system that is less developed, and they have accumulated significant reserve funds.

Emerging countries are generally economies open to the outside world. From this point of view, the pace of their economic activities is very sensitive to the vitality of their exports. This is called the commercial channel. Figure 4 illustrates the link between export and industrial production dynamics in this group of countries.

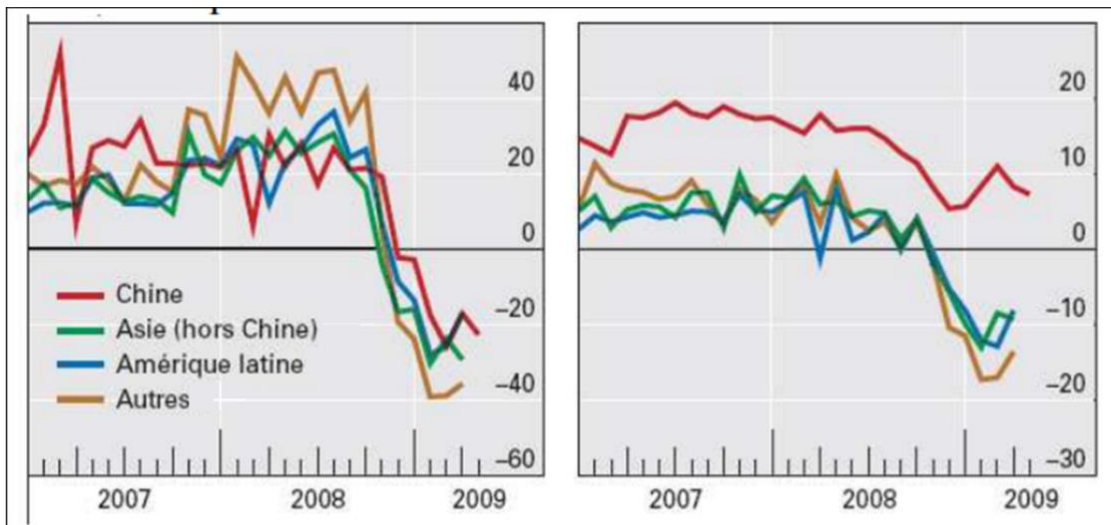


Figure 4. Exports and industrial production in emerging countries, annual % change

(Sources : Artus, (2009) ; BNP Paribas, juillet 2009)

* Asia: South Korea, Hong Kong, India, Indonesia, Malaysia, Philippines, Singapore, Taiwan and Thailand

** Latin America: Argentina, Brazil, Chile, Colombia, Mexico, Peru and Venezuela

*** Others: Czech Republic, Hungary, Poland, Russia, South Africa, and Turkey

Asian manufacturing export economies (South Korea, Singapore, Taiwan, Hong Kong, and to a lesser extent China) have been severely affected by trade channels and their exports have declined significantly (Figure 5).

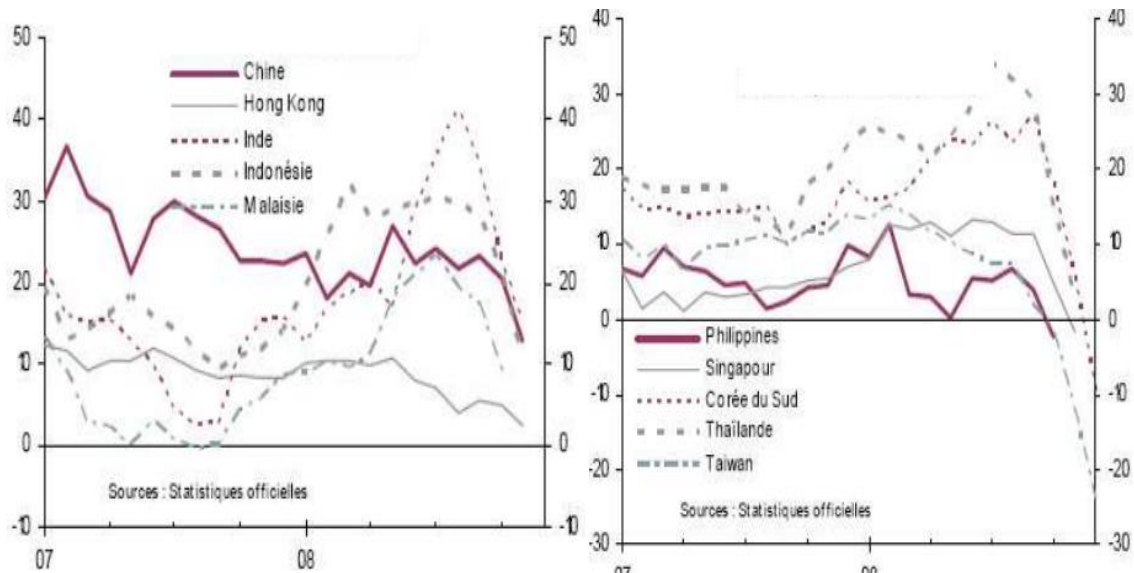


Figure 5. Emerging Asia: exports in dollars, year-on-year, 3-month moving average.

(Source : Torija-Zane (2009), Note mensuelle Asie, NATIXIS, Recherche économique)

This section also attempts to identify and theoretically describe the contagion of the financial crisis. However, it is important to note that economists are not unanimous in agreeing on a single definition of contagion and that they have not succeeded in unifying a single and clearly defined mechanism for this phenomenon. As a result, several so-called "contagion" factors have been identified.

The first is interdependence between countries. Because of the existence of commercial and financial links between the countries before the crisis. Another factor is called the "monsoon effect", which means that several economies are affected by a common shock (rising interest rates, falling oil prices, etc.).

This random shock affects a set of countries in similar ways without there being a first country affected. These three factors represent infectious diseases that respond to "fundamental contagion". If none of the above factors justify serial crises, then for Masson (1999), it is an infectious disease called "pure contagion." This contagious disease occurs in one country and forces investors to withdraw their funds

to other countries in panic campaigns not justified by economic ties, this is due to the following factors: a wake-up call, multiple equilibrium situations or changes in investor coordination. In all three cases, there is contagion, because the transmission process will change during the crisis, i.e., investors change their behavior.

The severity and scale of the crisis and the speed at which it is spreading around the world only cause people to worry about the phenomenon of contagion. An attempt has been made to analyze the impact of the 2007 financial crisis on developed and emerging countries.

The idea that emerging economies are strong enough to withstand the 2007 financial crisis and could even offset the decline in aggregate global demand has proven false. The violence of this type of global shock prevents any country from getting rid of this crisis. Its impact is negative and has been severely affected, but its impact varies in degree and intensity for various reasons.

On the one hand, for the existing interdependence between developed and emerging countries. In fact, the degree of global integration continued to increase in the years leading up to the crisis. At the root of the major contagion effect, global interdependence tends to shrink in business and finance, so that the country, especially emerging market economies, can properly define unique vulnerabilities without explaining the deterioration of its macroeconomic and macro-financial fundamentals. On the other hand, because of the impact of fundamentals. Of course, if the emerging market crisis worsens fundamentals, the growth losses will be greater, and the financial consequences will undoubtedly be worse. Therefore, for some, this flexibility can partly be explained by stronger fundamentals before the crisis.

In the end, the 2007 financial crisis affected all the countries examined, albeit to varying degrees. The nature and magnitude of the impact depends on the above factors, but positive growth is quickly restored and rebounds well.

In next chapter it will be done a literature review on the financial contagion between the U.S.A. market and selected developed and emergent economies.

1.3. Theoretical Analysis of Financial Contagion – a literature review on different approaches

Contagion is defined as the significant change in the mechanisms of propagation of shocks caused by a country or group of countries. This change is in fact synonymous with the generation of new propagation channels, which leads to the presence of contagion in the sense of Forbes and Rigobon (2001).

In this context of empirical studies, Dornbusch et al. (2000) and Forbes and Rigobon (2001, 2002) pointed out that four approaches had been used to measure how shocks were transmitted internationally: inter-market correlation coefficients, ARCH or GARCH frameworks, mechanisms direct estimation of a specific transmission and cointegration techniques.

1.3.1. Approach to inter-market correlation coefficients

We will now deal with analyses based on correlation coefficients. The purpose of this type of empirical research is to measure the correlation between two yields over a period defined as stable, and then to test whether the correlation between these same two yields has increased significantly following a shock to one of the two returns. So, we have a case of contagion if the correlation has increased significantly.

This is the method used by Lee and Kim (1993) The author measured the correlation between the stock index returns of twelve countries (United States, Canada, Japan, Hong Kong, Singapore and seven Western European countries) before and after the 1987 stock market crisis, they conclude that there is contagion in stock markets following the shock.

Many researchers have considered significant increases in correlation or co-movement of stock markets to be indicators of a contagion effect.

King and Wadhvani (1990), Lee and Kim (1993) and Cha and Oh (2000) used the correlation approach and found that international stock markets became more interdependent after the 1987 U.S. stock market crash and the 1997 Asian financial crisis, respectively. The strengthening of co-movement between international stock markets continued for a longer period after these two crashes.

Forbes and Rigobon (2002) argued that contagion tests based on inter-market correlation coefficients were problematic because of the bias introduced by the changing volatility of market returns (heteroscedasticity), under the assumption of the absence of omitted variables or endogeneity; It is possible to adjust this bias. Using this adjustment, there were virtually no high levels of market co-movement, which they called interdependence, i.e., no contagion, during the 1987 United States.

Guidi and Ugur (2013) reported that the correlation patterns between the UK, the US, and Southern and Eastern European stock markets changed over time around the subprime crisis between 2007 and 2009.

Bekaert and Harvey (2017) identify a sharp increase in correlations between emerging market stock returns, including the BRICS, and those of developed markets over the past two decades.

The GFC and ESDC provide unique structural breakpoints to study the impact of market contagion and abrupt changes in fallout. Many emerging markets decoupled from developed markets (e.g., US and European) at the beginning of GFC, but recoupled after the crisis (Aloui et al., 2011; Kenourgios et al., 2011; Alexakis et al., 2016; Burzala, 2016; Mullah et al., 2016).

These crises also identify differences in emerging market financial linkages with the United States and other developed markets (Sui & Sun, 2016).

For example, Hwang et al. (2013) find multiple models of contagion effects among emerging economies due to the subprime mortgage crisis in the United States.

Zhang et al. (2013) show that the GFC has resulted in a positive correlation between the BRICS and developed stock markets (US and European).

Mohti, Dionísio, Vieira, and Ferreira (2019) assess the effects of the US financial crisis and the euro area debt crisis on a wide range of frontier stock markets. Extended cross-correlation analysis (DCCA) and relaxed moving cross-correlation analysis (DMCA) are used to determine whether the correlations between the equity markets of the crisis origin countries (the United States and Greece) and the frontier stock markets have gone from calm in each period of crisis.

The results indicate that this was indeed the case and that frontier markets were affected by both crises.

Zorgati, Lakhali and Zaabi (2019) Study the influence of the spatial dimension on financial contagion in the subprime crisis based on adjusted and local correlation measures. The results show the existence of a spatial contagion between the United States and all countries in the American region.

1.3.2. Conditional distribution approach

Most empirical research on contagion focuses on the analysis of conditional co-movements of yields. Examples include Lee and Kim's (1993) analysis of pre- and post-crisis correlations, or Forbes and Rigobon's (2002) adjusted correlation coefficient.

On the other hand, Martin and Wang (2011) proposed comparing the conditional distribution of returns before and during turbulence to test for the existence of contagion effect. This makes it possible to detect possible contagion effects through different conditional moments, and not only via conditional co-movements of yields.

Empirically, they used a Gaussian copula on data from three stock market indices (the FTSE 100, the S&P 500 and Euro Stoxx 50) over a period from July 30, 2004, to March 3, 2009, they find that there is a significant contagion effect between all markets, but less significant with regard to the contagion between the Euro Stoxx 50 and the FTSE 100.

Hamao et al. (1990) used the GARCH model and found that there were spillovers of volatility in equity markets from New York to Tokyo, London to Tokyo, and New York to London after the collapse of the U.S. stock market in 1987.

Edwards and Susmel (2001) used univariate and bivariate switching volatility models to analyze volatility behavior over time in Latin American countries, and they showed that there were short-term episodes of high volatility, in general, lasting two to 12 weeks, and the result supported the existence of volatility co-movements across these countries.

Naoui et al. (2010) test the existence of contagion following the subprime crisis in the United States for six developed countries and ten emerging countries equity markets by applying the dynamic conditional correlation model. They conclude that contagion is strong between the United States and developed and emerging countries during the subprime crisis.

Thus Hwang et al. (2010) examine the contagion effects of the US subprime crisis on international stock markets using a DCC-GARCH model on 38 national data. In conclusion, they find evidence of contagion not only in emerging markets but also in developed markets during the subprime crisis in the United States.

Aloui et al. (2011) Identify greater financial dependence on the United States for the Brazilian and Russian markets during GFC than for the Chinese and Indian markets. Many empirical studies explore the impact of GFC and ESDC on spillover effects on BRICS equity markets using multivariate DCC-GARCH models.

Celik (2012) aims to test the existence of financial contagion between the foreign exchange markets of several emerging and developed countries during the subprime crisis in the United States. As a result of the DCC-GARCH analysis, finds evidence of contagion during the subprime crisis in the United States for most developed and emerging countries.

Bouaziz et al. (2012) test the contagion effect of US market stock on developed country stock markets during the subprime financial crisis (2007–2008) using the DCC-GARCH model. As a result of the DCC-GARCH model, they find that correlations between markets increased significantly during the subprime crisis in the US period and conclude that the crisis spread to different markets, which is clear evidence of contagion.

Hemche (2014) examines the contagion hypothesis for ten developed and emerging stock markets (France, Italy, United Kingdom, Japan, China, Argentina, Mexico, Tunisia, Morocco, and Egypt) in relation to the US market in the context of the subprime crisis. It uses a DCC – MGARCH model. It highlighted an increase in dynamic correlations following the subprime crisis for most of the markets considered regarding the US market.

Lee (2014) examines how global market sentiment spreads among markets and how interdependence by propagation changes during the US subprime crisis. It adopts a model of bivariate autoregressive generalized conditional heteroscedasticity (GARCH) and uses a sample of eight global markets: Japan, Korea, Taiwan, Belgium, Germany, the Netherlands, the United Kingdom, and the euro area in our survey.

The results indicate that a long-term equilibrium relationship existed between market sentiment in the United States and other major global markets during the subprime crisis.

Mensi et al. (2017) explore the ripple effects of volatility and perform portfolio analysis between four major developed exchanges (US, Europe, Japan, and Asia) and BRICS stock markets using the DECO-FIEGARCH multivariate model. They point out that developed/BRICS mixed equity portfolios offer both diversification benefits and downside risk reduction.

McIver and Kang (2020) examine the impact dynamics between U.S. and BRICS equity markets using the DECO-GJR-GARCH Multivariate Model and the Fallout Index Method. Market spillovers are

intensifying after the onset of the global financial crisis and the subsequent European sovereign debt crisis. Thus, after the onset of the crisis periods, they also note that the American, Brazilian, and Chinese markets are net vectors of volatility, while the Russian, Indian and South African markets are net recipients. These results shed new light on the channels of information transmission between the US and BRICS stock markets.

Alexakis and Pappas (2018) investigate the existence of financial contagion in the European Union during the Global Financial Crisis (GFC) of 2007-2009 and the European Sovereign Debt Crisis (ESDC) that began in 2009. By adopting an ADCC-GJR-GARCH model for time-varying correlations and a Markov-Switching model to identify the advance/delay relationship in crisis transition dates across countries and sectors. results support financial contagion across all business lines under GFC and ESDC.

Gkillas, Tsagkanos and Vortelinos (2019) examine the extent of contagion (i.e., integration and co-movement) of globally weighted portfolios to determine whether the amplification of transmission channels between emerging or developed financial markets may be affected by different values of a country's characteristics (variable macro-economic) across and globally. Key findings from generalized autoregressive conditional heteroscedasticity to regime change model in accordance with a regional-local capital pricing model indicate distinct changes in co-movement that are detected at the regional or global level. The robustness analysis provides more evidence of the regional contagion effect of the US crisis.

The subprime crisis in the United States provides a perfect framework for studying the mechanisms of contagion between assets in US financial markets.

Soylu and Güloğlu (2019) focusing on eight emerging markets from South Asia to South America, they analyze three risk fallouts – flight to quality, quality flight and financial contagion – between market equities and US bonds. In doing so, they use Granger point-in-time causality tests developed by Chen (2016) that distinctly examine the causality of the left tail of one distribution to the right tail of another distribution, and vice versa. Their findings suggest that the results of Chen's tests outperform others in terms of robustness and reveal that U.S. monetary policy could indeed influence investors eager to put their money in emerging markets.

Although the 2008 global financial crisis took root in advanced economies, its shocks spilled over into emerging economies, reflecting the increasingly interconnected global financial system.

1.3.3. Direct transmission estimation

Horta et al. (2008) analyze the impact of U.S. subprime mortgage crisis contagion on Canadians, Japanese, Italians, France, German and Portuguese stock markets using the copula of models.

Consequently, while Horta et al. (2008) confirm a remarkable contagion impact for Canada, Japan, Italy, France, and the United Kingdom, for Germany this impact is not significant like other countries and the most contagious impact is observed in Canada.

Dungey (2009) Examines contagion between the United States, the United Kingdom, Europe, Japanese and Australian money, and stock markets during the credit crunch. The conclusions can be summarized as follows: the volatility of global shocks is transmitted to all markets in the same way as during the non-crisis period. The contribution of contagion to volatility in non-US markets is in line with the results found for the contribution of contagion in evidence obtained for previous crises. The U.S. stock market appears to have a role in absorbing shocks from the U.S. money market and acting as a distributor of those shocks in other markets.

Hui and Chung (2011) discussed the pass-through effect of the CDS market to other euro area financial markets during the EMU sovereign debt crisis, and found that the flow of information on CDS, futures and options markets was the main cause, which led to the spread of the crisis.

Similar research conducted by Aloui et al. (2011) found that there was strong evidence of a time-varying dependence between each of the BRIC markets (Brazil, Russia, India, and China) and the US markets during the subprime crisis.

Samarakoon (2011) showed evidence of contagion between US and frontier stock markets, but not between the US and emerging markets, by constructing various shock models.

Kenourgios and Padhi (2012) demonstrated that stock market data appeared to be a more robust transmission mechanism during Russian default crises, Asian financial crises, and the subprime crisis.

Xu and Hamori (2012) show a weakening of information transmission between the BRICS and US markets during the GFC and ESDC periods.

Dimitriou et al. (2013) discussed the financial contagion between the BRICS (BRIC and South Africa) and the United States during the subprime crisis and showed that contagion emerged after the collapse of Lehman Brothers on almost all stock markets.

Kenourgios (2015) reported contagion of volatility in US and European equity markets during the subprime and eurozone sovereign debt crises, and their empirical evidence showed contagion in inter-market volatilities.

Flavin and Sheenan (2015) considered that securities backed by subprime mortgages the market is often identified as the source of the crisis that swept the US financial system from 2007, they investigate whether its role in the spread of the crisis was due to contagion or interdependence. Using a Markov switching VAR with transition probabilities, they analyze the transmission of shocks through the financial system. There is little evidence of changes in asset correlation between normal and stress regimes and those that occur are primarily associated with liquidity variables. Otherwise, relationships are stable

under all market conditions, implying that the US financial crisis was due to interdependencies rather than contagion.

Luchtenberg and Quang (2015) Showed that market linkages increased between many financial markets during the 2008 financial crisis. Some studies on the impact of crises, including political and financial crises, on Eastern and Southern European countries included compared the effects of political crises to selected stocks on US and Russian stock markets, including the NYSE, NASDAQ and MOEX indices, around the 2014 Ukraine crisis, from the point of view of a market microstructure. They indicated that the MOEX index did not have an appropriate channel or mechanism for the transmission of sophisticated investors to other markets.

Using MSCI's daily US-dollar-denominated indices of fifty-five stock markets for the period 2003-2013, Mollah, et al. (2016) found evidence of contagion in developed and emerging markets during the global and eurozone crises. They show that contagion spread from the United States to global markets during both crises. Regression results indicate that the transfer of banking risk between the United States and other countries is the main transmission channel for cross-border correlations.

Finally, using the wavelet square coherence approach and wavelet-based VAR. Mensi et al. (2017) identify that of BRIC markets, and only China offers a high level of diversification benefits when added to a developed market portfolio. They suggest that investments in Asian frontier markets (Bangladesh, Pakistan and Sri Lanka) can be seen as alternatives to investments in BRIC markets.

BenMim and BenSaïda (2019) use a regular vine copula approach to model the dynamics of dependence between US and European stock markets by distinguishing between effects in times of crisis and periods of tranquility.

The empirical results show a significant change in connectivity and shock transmissions over both periods, indicating strong evidence of financial contagion with the eurozone at its origin. In addition, the regular vine copula surpasses the multivariate t-copula. Therefore, the path of transmission of shocks is as important as the addiction itself.

Guidolin, Hansen and Pedio (2019) examine how and to what extent an initial negative shock in the low-quality asset-backed securities (ABS) market spread to higher-quality ABS markets, treasury repo markets, treasury bills, corporate bonds, and equity markets. It relies on dynamic time series models estimated with Bayesian methods to capture the (potentially) time-varying relationship between different financial markets. It provides evidence of structural changes in interactive relationships and therefore contagion.

In addition, the impulse response functions of the models, it concludes that contagion occurred mainly through the flight to liquidity, the risk premium and correlated information channels.

Ye, Jiang and Liu (2020) implement a TIR-MIDAS model to examine contagion between the United States and five major developed economies using daily levels of stock market indices, empirical analyses

reveal interesting results. First, a significant structural disruption exists for all test markets, and it takes place in 2008, except for Hong Kong where the point of change is in August 2007. Second, it is interesting to note that the inclusion of macroeconomic variables hardly affects the location of breaks. Finally, we show that there is contagion between the US as the home economy and Germany and Hong Kong as beneficiary markets.

1.3.4. Approach to cointegration techniques

Arshanapalli and Doukas (1993) reported that co-integration relationships did not exist in the U.S. Dow Jones index and stock markets in France, Germany, and the United Kingdom prior to the collapse of the U.S. stock market in 1987; However, there were co-integration relationships between them after the collapse of the US stock market.

Chen et al. (2002) used cointegration and GCED to study the dynamic interdependence between the six major Latin American stock markets, including Argentina, Brazil, Chile, Colombia, Mexico, and Venezuela from 1995 to 2000, and found price dependency effects.

Kizys and Pierdzioch (2011) found that long-term links between different stock markets also changed over time. Long-term links between the US stock market and the stock markets of the Czech Republic, Hungary and Poland increased in fundamentals and speculative bubbles during the subprime crisis.

Many academics have studied topics related to the subprime crisis, the EMU sovereign debt crisis and QE policy Gorton (2009) has been thorough in his work on subprime mortgage derivatives, e.g., mortgage-backed securities (MBS), secured debt securities (CDOs), credit default swaps (CDS), as well as their development processes, modes, and structures of issuance. For example, Longstaff (2010) studies the contagion effects of the CDO market on equity and bond markets. For example, Longstaff (2010) discussed the contagion effect of CDOs on U.S. equity markets between 2006 and 2008; The ABX index of CDOs was used to examine whether the contagion effect existed in the mortgage bond market in this study, and it was found that the contagion effect spread first from CDOs with lower credit ratings to CDOs with higher credit ratings in the CDO market, and then from the CDO market to the treasury bill and equity markets.

Kao et al. (2018) used the Enders and Siklos framework asymmetric cointegration, including the autoregressive momentum threshold (M-TAR) and soft transition logistics cointegration models (LSTC), to investigate whether contagion effects had existed in equity markets using changes in asymmetric cointegration relationships between the US S&P 500 index and a total of 23 markets in Asia, in Europe and America during the subprime crisis. The main results have shown that the subprime crisis did not reinforce the co-movement tendencies between the S&P 500 index and these stock markets, by applying the symmetric cointegration test of Engles Granger (1987).

Chen, W. Ho and Yang (2020) combine Granger conditional causation and network analysis to examine the interdependence of the European sovereign credit default (CDS) market. They determine that the network is unstable in the short term and stable in the long term. In addition, they visualize the dynamic networks and confirm the financial contagion of the 2012 European debt crisis. The sources of risk spillovers and how spillovers are transferred between countries are identified accordingly.

In addition, they conclude that interconnection can be a pricing factor in determining the performance of sovereign CDS. The results of the network analysis indicate that the European sovereign CDS market is a complex network system and can serve as a valuable reference for investors and policymakers.

As mentioned in the table 17 (appendix), several studies have examined the effect of financial contagion between different markets in different countries and the relationship between them based on different models and tests (VAR model, DCC model, Granger test, copula VEC GJR-GARCH-Skewed-t, DCCA and DMCA, BEKK).

But few of the work that looks at the long-run asymmetric relationship between financial markets hence the interest of this study is taking a NARDL approach to examining this asymmetric relationship between U.S. markets and some developed and emerging markets.

2. Research Methodology

2.1. Objective of the study and Research Hypotheses

Despite the multitude of theoretical and empirical studies that have studied the phenomenon of contagion between stock markets, little work has focused on the asymmetric contagion effect between the United States and some developed and emerging countries around the subprime crisis.

This paper seeks to examine the asymmetrical relationship between the markets of the United States, Canada, France, Germany, Japan, the UK, Brazil, China, Russia, and Singapore, with particular emphasis on the short- and long-term relationships between the variables of interest.

In practice, we try to find answers to the following questions:

- Is there evidence of long-term links between the US stock market and other developed and emerging stock markets?
- Are there asymmetric effects in long-term relationships between variables of interest?

2.2. Description of Data Collection

In order to conduct our empirical investigation, we consider daily data on daily stock index returns for the following stock markets: The Standard & Poor 500 (S&P 500) index was used in the United States, S&P/TSX (Canada), CAC40 (France), DAX (Germany), NIKKEI 225 (Japan), FTSE (United Kingdom), Bovespa (Brazil), Shang.comp (China), RTS (Russia), and STI (Singapore) from 2007 to 2022. The figure 9 (appendix) represents the data base used in this work and extracted from google finance (<https://www.google.com/finance/https://finance.yahoo.com/>).

The S&P 500 Index's commercial stocks included the 500 NYSE and AMEX companies, and the total market value of the S&P 500 Index dominated more than 80% of the total NYSE value. could reflect the

conditions of the capital markets, securities markets, and US economy more accurately than the Dow Jones Index (Nieh et al., 2011).

Bannigidadmath and Narayan (2016) reported that daily data was better than weekly or monthly data, with the former providing much more information than the latter.

2.3. Descriptive statistics

Table 3 represents the statistics of the variables in our research, which provide key information on the central trend, dispersion, asymmetry, and kurtosis of each index. You can use them to understand the past performance of these indices and assess their volatility:

- The lowest average return among developed countries was recorded in Japan and the highest in United States
- Among emerging countries, the lowest average yield was recorded in Russia (1326.633) and the highest in Brasil (72735.16).
- In addition, Russia is the least risky market, as it has the lowest standard deviation (366.4276) of all the markets in our sample.
- Among emerging markets, the standard deviation is between 366.4276 for Russia and 23848.47 for Brasil. Brasil has the highest average returns and is the most volatile emerging equity market.
- The results also show that the asymmetry coefficient is negative for the returns of the FTSE and STI index, which implies that the distribution of returns has a long tail to the left and positive for SP, SHANGH, BOVESPA, CAC40, RTS, SP\TSX, NIKKIE225 and DAX, so the distribution has an elongated tail to the right.
- The kurtosis of the SHANGH, STI, RTS, SP\TSX, and SP500 are greater than 3: therefore, the distribution of index returns is tokurtic and incompatible with the assumption of normality; large-scale returns occur more frequently than a normal distribution.
- For variables, CAC40, DAX, NIKKIE225, BOVESPA and FTSE have kurtosis less than 3, so their distribution is platykurtic.
- In addition, the Jarque-Bera test results indicate that the assumption of normality is strongly rejected for all series.

Table 3. Descriptive statistics

	BOVESPA	CAC40	DAX	FTSE100	NIKKEI_225	RTSI	S_P_TSX	SHANG_CO MP	SP500	STI
Mean	72735.16	4591.075	9655.368	6344.667	17112.85	1326.633	14442.36	2973.838	2136.589	3019.966
Median	64383.00	4488.690	9700.570	6458.020	16758.67	1300.670	14262.19	2977.700	1984.130	3109.850
Maximum	130776.3	7376.370	16271.75	7877.450	30670.10	2487.980	22087.22	6057.430	4796.560	3875.770
Minimum	29435.00	2519.290	3666.410	3512.090	7054.980	498.2000	7566.940	1671.400	676.5300	1456.950
Std. Dev.	23848.47	975.7254	3108.949	889.0659	6361.297	366.4276	2727.363	682.0210	979.5654	369.6112
Skewness	0.694871	0.369175	0.141398	-0.637278	0.268334	0.516058	0.542365	1.224036	0.884751	-1.566460
Kurtosis	2.209731	2.659372	1.950353	2.973340	1.973954	3.252370	3.525370	5.970147	3.037122	6.489310
Jarque-Bera	398.6149	103.1178	184.3009	253.4641	209.1064	176.0700	226.5531	2310.496	488.5422	3429.598
Probability	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Sum	2.72E+08	17184393	36140043	23748090	64053384	4965587.	54057748	11131075	7997253.	11303733
Sum Sq. Dev.	2.13E+12	3.56E+09	3.62E+10	2.96E+09	1.51E+11	5.02E+08	2.78E+10	1.74E+09	3.59E+09	5.11E+08
Observations	3743	3743	3743	3743	3743	3743	3743	3743	3743	3743

(Source: Compiled by us: calculations are made using Eviews software)

2.4. Analysis of simple and partial auto-correlation functions (ACF and PACF)

Single (ACF) and Partial (PACF) auto-correlation functions are statistical analysis tools used to explore the temporal structure of data, particularly in the context of time series. Definitions for each of these functions are as follows:

Simple Autocorrelation (ACF) function

The simple auto-correlation function (ACF) measures the correlation between a time series and its own values shifted at different delays. In other words, the ACF examines how each observation in the time series correlates with its past observations (Flores, Engel & Pinto, 2012, p1-8).

Partial Auto-correlation Function (PACF)

The partial auto-correlation function (PACF) measures the correlation between an observation in a time series and its past observations, eliminating the effect of intermediate observations. In other words, PACF isolates the direct correlation between an observation and its past observations without being influenced by intermediate observations (Flores, Engel & Pinto, 2012, p1-8).

2.5. Approach to nonlinear models with staggered delays

2.5.1. Phased Delay Autoregression Model (ARDL)

An ARDL model that, as part of the dynamic model family, allows to predict the dynamic ARDL model which predicts short-term dynamics and long-term effects for cointegrated or even embedded series in separate orders as seen with the terminal test method of Pesaran et al. (1996) short-term and long-term effects for cointegrated or even embedded series in separate orders as seen with the terminal test method of Pesaran et al. (1996),

Pesaran et al. (2001) and Pesaran and Shin (1995) are both examples. An ARDL model cannot be employed for integrated series with commands greater than 1. The ARDL model has quadrupled the advantages compared to traditional and conventional error correction models.

First, using the bounds test of Pesaran and Shin (1999) and Pesaran, Shin and Smith (2001), the ARDL model offers the opportunity to test the long-term co-integration between $I(0)$ and $I(1)$ time- results of the series. It thus relaxes the condition of integration of all-time series from order 1 as required in the co-integration tests of Johansen (1988, 1991) and Engle-Granger (1987).

Secondly, in a single equation, the ARDL model verifies cointegration and thus decreases the dimensionality of the cointegration system as in Johansen (1988, 1991).

Third, in the ARDL model, endogeneity is no longer a problem. since it is free of residual correlation, it is assumed that all variables are endogenous.

Fourth, the ARDL method can differentiate dependent and explanatory variables in the presence of a single long-term relationship via a single long-term relationship, according to Pesaran et al. (2001).

In this part, as long as the series are I (0) (even if they are I (1) but never I (2)) we therefore test the existence of a long-term relationship (cointegration) using tests and estimates procedure.

* Autoregressive models (AR): These are dynamic models where the shifted dependent variable is located among the explanatory variables. They are generally the following implicit form:

$$\text{Equation 1: } Y_t = f(X_t, Y_{t-p})$$

The term «autoregressive» translates the regression of a variable on itself or on its own shifted values.

* Staggered or distributed shift (DL) models: these are dynamic models with explanatory variables: X_t and its past or staggered values. In general, their form is:

$$\text{Equation 2: } Y_t = f(X_t, X_{t-q})$$

The term 'staggered delays' shows that X_t 's short-term effects on Y_t are different from those of the long-term. From one moment to another, the answer evolves according to the change of X_t on the Y_t differences.

* ARDL: These models incorporate the characteristics of two previous ones; the displaced dependent variable (Y_{t-p}) and the passed values of the independent variable (X_{t-q}) among the explanatory variables (X_t). They have the general form below:

$$\text{Equation 3: } Y_t = f(X_t, Y_{t-p}, X_{t-q})$$

The null hypothesis suggests the non-existence of the long-term relationship. In fact, the ARDL model (1,2,3,4) shows that the dependent variable has a shift order 4.

Equation 4: ARDL model equation:

$$\Delta Y_t = \beta_0 + \sum_{i=1}^n \beta_i \Delta Y_{t-1} + \sum_{i=0}^n \alpha_i \Delta X_{t-1} + \varphi \alpha_1 Y_{t-1} + \alpha_2 X_{t-1} + \mu_t$$

2.5.2. Nonlinear Autoregressive Phased Delay Model (NARDL)

Shin et al. (2014) developed a nonlinear approach to develop a versatile dynamic parametric system based on the ARDL model of Pesaran and Shin (1998) and Pesaran et al. (2001) to form relationships that reveal asymmetries both in the long and short term. It works best for determining cointegration relationships in small samples.

Positive and negative regimes, i.e., positive, and negative combinations of explanatory variables, determine non-linearity in the NARDL model. However, due to the complexity of the economic system that determines the relationship between variables, it is more likely that emerging markets will be influenced differently by the US market. It is therefore unlikely that the US market will be affected by an average variation in emerging markets.

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Due to the use of nonlinear autoregressive distributed offset (NARDL) estimates, we investigated the impact of the U.S. stock index on emerging market indices.

The NARDL method is an asymmetric elaboration to verify the degree of long-term relationships of the simple linear ARDL technique. The approach was developed by Pesaran, Shin and Smith (2001) and thus extended by Shin, Yu and Greenwood (2009), via partial sum, non-linearity decompositions. Therefore, the process model, the long-term relationship, and the dynamic relationship simultaneously in a natural aspect, are means of adaptation. In addition, the approach gives space for corrections for serial correlation and endogeneity. It also makes possible asymmetric changes in the evolution of value-added output and financial growth. We chose to use this approach because it can capture nonlinear and asymmetric cointegration between variables.

In this way the equation of NARDL model is the equation 5 (similar to equation 4):

$$\text{Equation 5: } \Delta Y_t = \beta_0 + \sum_{i=1}^n \beta_i \Delta Y_{t-1} + \sum_{i=0}^n \alpha_i \Delta X_{t-1} + \alpha_1 Y_{t-1} + \alpha X_{t-1} + \mu_t$$

Were,

Y : Dependent variable

X : Independent variables

α and β are the coefficients of the variables.

i and t are the countries and times, respectively.

μ : White Noise

$$X_t^+ = \sum_{j=1}^t \Delta X_t^+ = \sum_{j=1}^t \max(\Delta X_j, 0): \text{ a positive variation} \quad (\text{Equation 5.1})$$

$$X_t^- = \sum_{j=1}^t \Delta X_t^- = \sum_{j=1}^t \min(\Delta X_j, 0): \text{ A negative variation} \quad (\text{Equation 5.2})$$

Accordingly, we will test Hypothesis 1 (H1): presence of a long-term asymmetric relationship.

2.6. EViews software

To do the analysis and hypothesis tests it will be used the EViews® software, which is a powerful software that enables statistical and econometric analysis, generating simulations and forecasts. It offers an intuitive interface, allowing users to perform searches directly in programming mode, resulting in high-quality graphics.

The main feature are as follows:

- Data manipulation
- Handling time series
- Statistics
- Estimation methods
- Systems of equations
- Tests & Evaluations
- Forecasts & Simulations
- Graphs & Tables
- Orders & Programming
- External Interface & Add-Ins

3. Presentation and Analysis of Results

As it was explained in previous chapter the first step of the data analysis is the analysis of simple and partial auto-correlation functions (ACF and PACF). In next section it is analysed these functions for each index under analysis.

3.1. Analysis of simple and partial auto-correlation functions (ACF and PACF)

The critical probabilities of the Q-stat (Ljung-Box Test: is a test for the non-correlation of residues) are all very much lower than 0.05, we reject the hypothesis H_0 of nullity of the correlation coefficients of the S&P 500, BOVESPA, CAC40, SP1TSX, DAX, NIKKIE225, RTSI, FTSE, STI and SHANGN-COMP series respectively and therefore it is not a white noise (See Figure from 10 to 19).

3.2. Unit root test

The order of integration of variables is studied first. Stationarity tests are performed by levels to establish the presence of unit roots and the order of integration in all variables.

However, it is not appropriate for all series to be $I(0)$ and $I(1)$ if one of the series is $I(2)$, then spurious results are given by the ARDL method. Therefore, it is important to test the unit root of each variable before applying the ARDL cointegration method.

The Dickey-Fuller Augmented Unit Root Test (ADF) is used to analyze the time series properties of the data, it examines whether the coefficient of the first difference in the series is significantly different from zero.

Table 4. Unit root test to the level

Variable	T-statistic	Critical value at 1% threshold	Critical value at 5% threshold	Critical value at 10% threshold	Stationary	Prob
SP500	-0.141039	-3.431847	-2.862086	-2.567104	NO	0.9432
BOVESPA	-1.262221	-3.431912	-2.862115	-2.567120	No	0.6492
CAC40	-1.620019	-3.431824	-2.862076	-2.567099	No	0.4722
DAX	-1.020938	-3.431839	-2.862083	-2.567103	No	0.7479
FTSE	-2.276107	-3.431847	-2.862087	-2.567104	No	0.1799
NIKKIE225	-0.733053	-3.431901	-2.862110	-2.567117	No	0.8366
RTSI	-2.630216	-3.431861	-2.862093	-2.567108	No	0.0869
SP\TSX	-1.120537	-3.431861	-2.862093	-2.567108	No	0.7099
SHANG	-2.873814	-3.431907	-2.862113	-2.567119	Yes /No	0.0485
STI	-2.574543	-3.431856	-2.862091	-2.567106	No	0.0984

Source: Compiled by us: calculations are made using Eviews software

As can be observed in table 4, the t-statistic is higher than the critical values at the thresholds (significance level) of: 1%, 5% and 10% for all variables, and only at the threshold of 1% for the Shangh-Comp. The series are not stationary at the first level. They are therefore not integrated of order 0.

Hence, the T-statistics are only below the threshold of 5% and 10% for the Shangh-Comp index. The series is stationary at the first level. They are therefore integrated of order 0.

It is important to note that the stationarity of time series is crucial for many econometric and time series analyses. If a series is non-stationary, it may be necessary to differentiate it (i.e., calculate the difference between consecutive values) to make it stationary before it can be applied to forecast or analysis models.

In summary, the ADF test shows that some of our series are stationary, while others are non-stationary based on the test results.

Table 5. ADF test

Series	Prob.	Lag
D(BOVESPA)	0.0001	0
D(CAC40)	0.0001	0
D(DAX)	0.0001	0
D(NIKKEI_225)	0.0001	0
D(FTSE100)	0.0001	0
D(RTSI)	0.0001	0
D(SHANG_COMP)	0.0001	0
D(S_P_TSX)	0.0001	0
D(SP500)	0.0001	0
D(STI)	0.0001	0

Method	Statistic	Prob. **
ADF - Fisher Chi-square	184.207	0.0000
ADF - Choi Z-stat	-11.7606	0.0000

(Source: Compiled by us: calculations are made using Eviews software)

The obtained results in table 5, indicate that the null hypothesis of the presence of a unit root was rejected for each of the time series we specified. This means that the differences between each series and its own delayed value (lag) are stationary. In other words, these series are first-order stationary.

This is important in time series analysis, as many econometric analysis and time series modelling methods assume that the series are stationary. When data is not stationary, it may be necessary to differentiate (i.e., take the difference between consecutive values) to make them stationary before applying more advanced modelling techniques.

The next step is to estimate the model using, first the OLS regression model represented by equation 7.

$$\text{Equation 7: } SP500_t = C + SPTSX_t + CAC40_t + DAX_t + N225_t + BOVVESPA_t + RTS_t + STI_t + SHANGH_t + FTSE_t + \varepsilon_t$$

- $SP500_t$ is a dependent variable of the United States stock market index.
- $SPTSX_t$ is an independent variable of the Canada stock market index.
- $CAC40_t$ is an independent variable of the France stock market index.
- DAX_t is an independent variable of the Germany stock market index.
- $FTSE_t$ is an independent variable of the United Kingdom stock market index.
- STI_t is an independent variable of the Singapore stock market index.

- RTS_t is an independent variable of the Russia stock market index.
- $SHANGH_t$ is an independent variable of the China stock market index.
- $BOVESPA_t$ is an independent variable of the Brazil stock market index.
- $NIKKEI_t$ is an independent variable of the Japan stock market index.
- C are the coefficients to be estimated
- t are the countries and times, respectively.
- ε is the error term.

The table 6 (below) shows that all variables are significant except for the RTSI, whose coefficient is close to zero (0.004913), indicating a weak and statistically insignificant relationship with the S&P 500 index.

Table 6. Estimation by OLS with constant

Variable	Coefficient	Std. Error	T-Statistic	Prob.
C	-703.4465	31.59417	-22.26507	0.0000
BOVESPA	0.005229	0.000197	26.49160	0.0000
CAC40	0.095350	0.006589	14.47036	0.0000
DAX	0.133613	0.004227	31.61206	0.0000
FTSE100	-0.114763	0.009314	-12.32135	0.0000
NIKKEI_225	0.021613	0.001594	13.55890	0.0000
RTSI	0.004913	0.011607	0.423280	0.6721
S_P_TSX	0.147000	0.003272	44.92083	0.0000
SHANG_COMP	-0.125754	0.005387	-23.34567	0.0000
STI	-0.220337	0.016192	-13.60760	0.0000
R-squared			0.973527	
Adjusted R-squared			0.973463	
Log likelihood			-24292.46	
F-statistic			15253.03	
Akaike info criterion			12.98555	
Mean dependent var			2136.589	

(Source: Compiled by us: calculations are made using Eviews software)

It is also observed a coefficient of determination (R^2) of 0.973527, which is close to one, indicates that 97.35% of the variability of the S&P 500 index is explained by the independent variables included in the model (see table 6).

The model seems to fit well with a high R-squared. In fact, the variables SPTSX, CAC40, DAX, BOVESPA, and STI have a positive effect on the U.S. market index, while other variables (STI, FTSE, and SHANGH) have negative coefficients and therefore have a negative relationship with the S&P 500 index. The F-Test has a statistic of 15253.03 and an associated probability close to zero (0.0000). This indicates that the model as a whole is statistically significant. Akaike (AIC) and Schwarz (SC) information criteria are provided, which may be useful for comparing this model with other models.

$$SP500_t = \alpha + SP500_{t-1,t-3} + SPTSX_{t-1} + CAC40_{t-1} + DAX_{t-1} + N225_{t-1} + BOVESPA_{t-1} + RTSI_{t-1,t-2} + STI_{t-1} + SHANGH_{t-1} + FTSE_{t-1} + \varepsilon_t$$

- $SP500_t$ is a dependent variable of the United States stock market index.
- $SPTSX_t$ is an independent variable of the Canada stock market index.
- $CAC40_t$ is an independent variable of the France stock market index.
- DAX_t is an independent variable of the Germany stock market index.
- $FTSE_t$ is an independent variable of the United Kingdom stock market index.
- STI_t is an independent variable of the Singapore stock market index.
- RTS_t is an independent variable of the Russia stock market index.
- $SHANGH_t$ is an independent variable of the Chine stock market index.
- $BOVESPA_t$ is an independent variable of the Brazil stock market index.
- $NIKKEI_t$ is an independent variable of the Japan stock market index.
- a are the coefficients to be estimated.
- i and t are the countries and times, respectively.
- ε is the error term.

Table 7. Estimate the dynamic model.

Variable	Coefficient	Std. Error	T-Statistic	Prob.
C	-21.74481	5.608378	-3.877202	0.0001
SP500(-1)	0.851751	0.016428	51.84760	0.0000
SP500(-2)	0.171568	0.021377	8.025644	0.0000
SP500(-3)	-0.030623	0.016515	-1.854256	0.0638
BOVESPA (-1)	6.71E-05	3.59E-05	1.872212	0.0613
CAC40(-1)	-0.003938	0.001140	-3.455831	0.0006
DAX (-1)	-0.002148	0.000805	-2.667505	0.0077
FTSE100(-1)	0.004621	0.001600	2.888032	0.0039
NIKKEI_225(-1)	0.001100	0.000272	4.040731	0.0001
RTSI (-1)	-0.023524	0.016782	-1.401768	0.1611
RTSI (-2)	0.023575	0.016703	1.411423	0.1582
S_P_TSX (-1)	0.002680	0.000678	3.953729	0.0001
SHANG_COMP (-1)	-0.000529	0.000963	-0.549335	0.5828
STI (-1)	-0.004385	0.002764	-1.586226	0.1128
R-squared			0.999269	
Adjusted R-squared			0.999266	
Log likelihood			-17568.91	
F-statistic			391674.3	
Mean dependent var			2137.679	

(Source: Compiled by us: calculations are made using Eviews software)

The delayed variables RTSI (-1), BOVESPA (-1), STI (-1), and SHANGH (-1) are statistically insignificant at the 5% threshold, while SP&TSX (-1), CAC40(-1), FTSE (-1), NIKKIE225(-1) and DAX (-1) are statistically significant at the 0.05 threshold (see table 8). Statistically significant coefficients are present in the delayed indexes of S&P 500 (-1) and S&P 500 (-2), except for SP (-3), which has negative coefficients and is statistically insignificant. (Table 7)

The regression explanation for around 99% of the total variability can be attributed to the R² value determination coefficient of 0.99, which is close to one.

The S&P 500 index is negatively affected by variables like DAX (-1), CAC40(-1), STI (-1), RTSI (-1), and SHANGH (-1), which have negative coefficients, while other variables such as SP&TSX (-1), N225(-1), BOVESPA (-2), RTSI (-1), and FTSE (-1) have a positive influence on it.

3.3. The structure of the residues

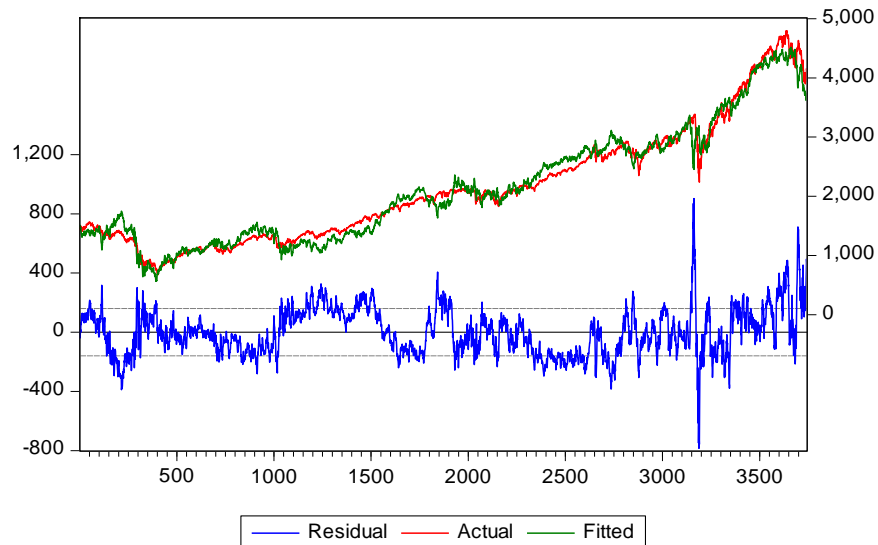


Figure 6: Graphical representation of the structure of the residuals

(Source: Compiled by us: calculations are made using Eviews software)

As the figure 6 shows, the visual evidence of serial correlation is strong due to the long periods of positive values followed by negative values in the residuals of this regression.

3.4. Estimation by the ARCH model

Analysing the table 8, the value of R-squared in the model explains 97.35% of the variation in the conditional volatility of SP500, with a lower AIC or Schwarz criterion generally preferred. In this case, the AIC is about 13.05, which is an indicator of a well-adjusted model, and a higher log-likelihood indicates a better fit. In this case, the score is about (-24417.79).

These results show that the well-adjusted ARCH model can explain the conditional volatility of SP500 with a good fit to the data. The coefficients of the ARCH and GARCH parameters have constant coefficients that are positive and significant above the 5% threshold for variance, as well as other statistics that provide useful information for analysing the time series and understanding the volatility dynamics of the SP500.

Table 8. Estimation by the ARCH model

Variable	Coefficient	Std. Error	T-Statistic	Prob.
C	-703.4465	71.02795	-9.903798	0.0000
BOVESPA	0.005229	0.000445	11.75558	0.0000
CAC40	0.095350	0.013537	7.043876	0.0000
DAX	0.133613	0.009122	14.64673	0.0000
FTSE100	-0.114763	0.020142	-5.697649	0.0000
NIKKEI_225	0.021613	0.003288	6.572302	0.0000
RTSI	0.004913	0.024928	0.197085	0.8438
S_P_TSX	0.147000	0.007104	20.69221	0.0000
SHANG_COMP	-0.125754	0.010962	-11.47188	0.0000
STI	-0.220337	0.034889	-6.315297	0.0000
Variance Equation				
C	16507.12	9292.718	1.776350	0.0757
RESID (-1) ^2	0.150000	0.069484	2.158756	0.0309
GARCH (-1)	0.600000	0.216556	2.770650	0.0056
R-squared				0.973527
Adjusted R-squared				0.973463
Log likelihood				-24417.79
Mean dependent var				2136.589
Akaike info criterion				13.05412
Schwarz criterion				13.07575

(Source: Compiled by us: calculations are made using Eviews software)

3.5. Phased Delay Autoregression Model (ARDL)

Table 9. Short-term ARDL model estimation

Variable	Coefficient	Std. Error	T-Statistic	Prob.
SP500(-1)	0.847183	0.016200	52.29681	0.0000
SP500(-2)	0.146827	0.016300	9.007581	0.0000
BOVESPA	7.09E-05	3.57E-05	1.983855	0.0473
CAC40	-0.004532	0.001133	-3.998927	0.0001
DAX	-0.002857	0.000802	-3.561004	0.0004
STI	-0.007547	0.002752	-2.742087	0.0061
SHANG_COMP	0.000280	0.000961	0.291280	0.7709
S_P_TSX	0.002786	0.000673	4.137740	0.0000
RTSI	-0.000278	0.001928	-0.144200	0.8854
NIKKEI_225	0.000958	0.000271	3.533993	0.0004
FTSE100	0.007808	0.001591	4.908233	0.0000
C	-27.01351	5.571106	-4.848860	0.0000
R-squared			0.999271	
Adjusted R-squared			0.999268	
Log likelihood			-17561.68	
Mean dependent var			2136.946	
Prob(F-statistic)			0.000000	

(Source: Compiled by us: calculations are made using Eviews software)

As the table 9 represent the short-term equation is:

$$\begin{aligned}
 \text{SP500} = & 0.847183470962 * \text{SP500}(-1) + 0.146826991681 * \text{SP500}(-2) + 7.09035877416e- \\
 & 05 * \text{BOVESPA} - 0.00453170335632 * \text{CAC40} - 0.00285699500087 * \text{DAX} + \\
 & 0.0078084322491 * \text{FTSE100} + 0.000957896520959 * \text{NIKKEI}_225 - 0.00027796521637 * \text{RTSI} + \\
 & 0.00278636137037 * \text{S_P_TSX} + 0.000279809566749 * \text{SHANG_COMP} - 0.00754732411579 * \text{STI} - \\
 & 27.0135122882
 \end{aligned}$$

The BOVESPA Stock Index, the SPTSX, the NIKKEI225 and the FTSE have positive and significant effects on the S&P 500 Index in the short term as opposed to the SHANGH variable that they have positive and non-significant effects in the short term on the US market index.

Other CAC40 and STI and DAX variables have a negative and significant effect on the S&P 500 while RTS have a negative and non-significant effect on the short-term dependent variable.

Cointegration Testing

Table 10. F-Bonds test

Test Statistic		Value	
F-statistic		11.94141	
K		0	
Signif.	I (0)	I (1)	
10%	3.8	3.8	
5%	4.6	4.6	
2.5%	5.39	5.39	
1%	6.44	6.44	

(Source: Compiled by us: calculations are made using Eviews software)

Note that the value of test F is 11.94141, which is compared to critical thresholds (see table 10). According to these results, it seems that there is a long-term cointegration relationship between the variables.

3.6. Nonlinear Autoregressive Phased Delay Model (NARDL)

NARDL Model Estimation

Initially, the general form of long-term asymmetric regression of our model is as the equation 6:

$$\begin{aligned}
 SP500_t = & \beta_0 + \alpha_1 SPTSX_t^+ + \alpha_2 SPTSX_t^- + \alpha_3 CAC40_t^+ + \alpha_4 CAC40_t^- + \alpha_5 DAX_t^+ + \alpha_6 DAX_t^- + \alpha_7 FTSE_t^- + \alpha_8 FTSE_t^+ \\
 & + \alpha_9 NIKKEI_t^+ + \alpha_{10} NIKKEI_t^- + \alpha_{11} RTS_t^+ + \alpha_{12} RTS_t^- + \alpha_{13} STI_t^+ + \alpha_{14} STI_t^- + \alpha_{15} SHANGH_t^+ \\
 & + \alpha_{16} SHANGH_t^- + \alpha_{17} BOVESPA_t^+ + \alpha_{18} BOVESPA_t^- + \mu_t
 \end{aligned}$$

- $SP500_t$ is a dependent variable of the United States stock market index
- $SPTSX_t$ is an independent variable of the Canada stock market index
- $CAC40_t$ is an independent variable of the France stock market index.
- DAX_t is an independent variable of the Germany stock market index.
- $FTSE_t$ is an independent variable of the United Kingdom stock market index
- STI_t is an independent variable of the Singapore stock market index.
- RTS_t is an independent variable of the Russia stock market index.
- $SHANGH_t$ is an independent variable of the Chine stock market index.
- $BOVESPA_t$ is an independent variable of the Brazil stock market index.
- $NIKKEI_t$ is an independent variable of the Japan stock market index
- α and β are the coefficients of the variables.
- i and t are the countries and times, respectively.
- μ : White Noise

Table 11. Short-term estimate

Variable	Coefficient	Std. Error	T-Statistic	Prob. *
SP500(-1)	0.856360	0.015960	53.65817	0.0000
SP500(-2)	0.119744	0.016116	7.430320	0.0000
BOVESPA_POS	-7.08E-05	8.52E-05	-0.830831	0.4061
BOVESPA_NEG	-0.000129	7.17E-05	-1.805347	0.0711
CAC40_POS	-0.007055	0.002950	-2.391865	0.0168
CAC40_NEG	0.001174	0.002023	0.580444	0.5616
DAX_POS	-0.002712	0.001327	-2.043912	0.0410
DAX_NEG	-0.001601	0.001066	-1.501667	0.1333
FTSE100_POS	0.024630	0.002838	8.679696	0.0000
FTSE100_NEG	0.008467	0.002184	3.877282	0.0001
NIKKEI_225_POS	-5.39E-05	0.000394	-0.136908	0.8911
NIKKEI_225_NEG	-6.74E-06	0.000379	-0.017781	0.9858
RTSI_POS	-0.014904	0.004110	-3.626330	0.0003
RTSI_NEG	-0.005070	0.002973	-1.705088	0.0883
S_P_TSX_POS	0.003218	0.000828	3.887580	0.0001
S_P_TSX_NEG	0.002025	0.000798	2.538498	0.0112
SHANG_COMP_POS	-1.34E-05	0.001190	-0.011235	0.9910
SHANG_COMP_NEG	-0.001130	0.001325	-0.852397	0.3940
STI_POS	-0.005619	0.004070	-1.380766	0.1674
STI_NEG	0.011039	0.004337	2.545179	0.0110
C	38.04282	7.154618	5.317240	0.0000

(Source: Compiled by us: calculations are made using Eviews software)

The results described in table 11 indicate that some explanatory variables have a significant effect on the dependent variable SP500, while others have no significant effects. While changes in the SPTSX and FTSE indexes have a positive impact on the S&P 500 variations increase the S&P 500 yield by 0.007831 and .001369, The increase in the negative change of CAC40 and STI in the broad sense causes the variable S&P 500 to rise by 0.001174 and 0.011039. The decrease of variables BOVESPA, DAX, NIKKEI, RTSI, and SHANGH generates the decrease of the S&P 500.

Table 12. Long term estimate

Variable	Coefficient	Std. Error	T-Statistic	Prob. *
C	38.04282	7.154618	5.317240	0.0000
SP500(-1) *	-0.023896	0.004319	-5.533166	0.0000
D(SP500(-1))	-0.119744	0.016116	-7.430320	0.0000
BOVESPA_POS	-7.08E-05	8.52E-05	-0.830831	0.4061
BOVESPA_NEG	-0.000129	7.17E-05	-1.805347	0.0711
CAC40_POS	-0.007055	0.002950	-2.391865	0.0168
CAC40_NEG	0.001174	0.002023	0.580444	0.5616
DAX_POS	-0.002712	0.001327	-2.043912	0.0410
AX_NEG	-0.001601	0.001066	-1.501667	0.1333
TSE100_POS	0.024630	0.002838	8.679696	0.0000
FTSE100_NEG	0.008467	0.002184	3.877282	0.0001
NIKKEI_225_POS	-5.39E-05	0.000394	-0.136908	0.8911
NIKKEI_225_NEG	-6.74E-06	0.000379	-0.017781	0.9858
RTSI_POS	-0.014904	0.004110	-3.626330	0.0003
RTSI_NEG	-0.005070	0.002973	-1.705088	0.0883
S_P_TSX_POS	0.003218	0.000828	3.887580	0.0001
S_P_TSX_NEG	0.002025	0.000798	2.538498	0.0112
SHANG_COMP_POS	-1.34E-05	0.001190	-0.011235	0.9910
SHANG_COMP_NEG	-0.001130	0.001325	-0.852397	0.3940
STI_POS	-0.005619	0.004070	-1.380766	0.1674
STI_NEG	0.011039	0.004337	2.545179	0.0110

(Source: Compiled by us: calculations are made using Eviews software)

Similar to the short term, following the negative variations of the STI and CAC40 index, the US market represents an increase of 0.011039 and 0.001174.(see table 12)

The increase of the CAC40, BOVESPA, DAX, NIKKEI, RTSI, SHANGH, and STI leads to a reduction of the S&P 500. Also, the negative variation of the BOVESPA, DAX, NIKKEI, RTSI, and SHANGH leads to a decrease in the S&P 500, while the growth of the SPTSX and FTSE generates a rise in the S&P 500 with 0.003218 and 0.024630, respectively, and their losses will increase the SP index by 0.002025 and 0.008467.

Table 13. F-Bonds test

Test Statistic	Value	
F-statistic	15.45835	
K	0	
Signif.	I (0)	I (1)
10%	3.8	3.8
5%	4.6	4.6
2.5%	5.39	5.39
1%	6.44	6.44

(Source: Compiled by us: calculations are made using Eviews software)

Statistical test F as represented in table 13, has a value of 15.45835, with a significance threshold of 10%. Since the value of the test is above the 10% threshold, the null hypothesis is rejected, showing the presence of a long-term relationship between the variables.

3.6.1. Wald test

Table 14. Wald test result

Test Statistic	Value	Df	Probability
F-statistic	13984.65	(12, 3867)	0.0000
Chi-square	167815.8	12	0.0000

(Source: Compiled by us: calculations are made using Eviews software)

We note that the P-value is less than 5%, so we reject the null hypothesis of the existence of significant evidence of heteroscedasticity (table 14).

3.6.2. Residue Diagnostics

Table 15. Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	56.91915	Prob. F (20,3867)	0.0000
Obs*R-squared	884.2546	Prob. Chi-Square (20)	0.0000
Scaled explained SS	6110.914	Prob. Chi-Square (20)	0.0000

(Source: Compiled by us: calculations are made using Eviews software)

The test rejects the hypothesis of no correlation in series. The LM test indicates that residues are correlated in series (Table 15).

Table 16. Breusch-Godfrey Serial Correlation LM Test

F-statistic	9.266636	Prob. F (1,3866)	0.0023
Obs*R-squared	9.297084	Prob. Chi-Square (1)	0.0023

(Source: Compiled by us: calculations are made using Eviews software)

This is the p-value associated with the F-statistic. It represents the probability of observing an F-statistic as extreme as the one computed, assuming the null hypothesis of no serial correlation. In this case, the p-value is 0.0023, which is below the conventional significance level of 0.05.(table 16)

3.6.3. Stability diagnostic

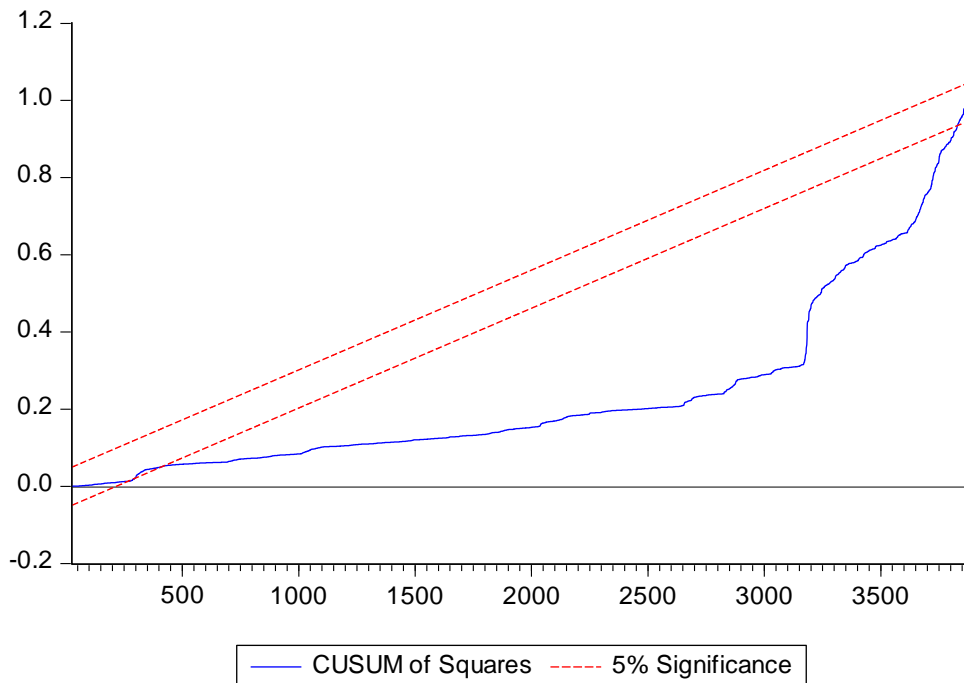


Figure 7: CUSIM graphic

(Source: Compiled by us: calculations are made using Eviews software)

In addition, the stability tests performed by plotting the CUSUM statistics against the breakpoints are checked and described in the figure on the basis of the null hypothesis that the parameters are unstable.

This is the stability test of the CUSUM statistics (Brown et al., 1975) plotted to assess the significance of the 95% confidence limit trajectory. In this belief, the figure 7 below indicates acceptance of the null hypothesis. We therefore conclude that the parameters of this regression are not stable.

This chapter has just answered our assumptions. An analysis and discussion of the results of our research was presented.

In this work, in order to answer our questions, we applied the NARDL (Auto Regressive Distributed Lags) nonlinear approach which allows to test the presence of asymmetric effects in the short and long-term relations between the markets of United States, Canada, France, Germany, Japan, United Kingdom, Brazil, China, Russia and Singapore.

The obtained results are:

- The BOVESPA Stock Index and SPTSX and NIKKEI225 and FTSE have positive and significant effects on the S&P 500 Index in the short term as opposed to the SHANGH variable that they have positive and non-significant effects in the short term on the US market index.
- Other CAC40 and STI and DAX variables have a negative and significant effect on the S&P 500 while RTS have a negative and non-significant effect on the short-term dependent variable.
- We capture a long-term co-integration relationship between all the markets in question.
- Using NARDL's short- and long-term estimates, positive and negative movements in Canadian and UK market indices are driving up the US market index yield.
- The positive and negative variation of the Canadian and United Kingdom market indexes is causing the S&P 500 index to decline.
- The increase in the negative change of CAC40 and STI in the broad sense causes the variable S&P 500
- The decrease of variables BOVESPA, DAX, NIKKEI, RTSI, and SHANGH generates the decrease of the S&P 500.
- There is a long-term asymmetric relationship between the variables in question. We also make a diagnosis of residues and conclude that there is no significant evidence of heteroscedasticity.
- There is a long-term asymmetric relationship between the variables in question.

There is also a diagnosis of residues, it is concluded that there is no significant evidence of heteroscedasticity.

Conclusions, Limitations and Future Research Lines

The unfavorable financial and economic conditions on the ground at the international level in recent decades. These disturbances highlight the violent and systematic nature of the spread of financial crises and are not limited to the country where the crisis occurred but have spread outside to overthrow other economies. These events make the financial system fragile.

We recall that our problem is to seek the long-term asymmetric relationship between the US markets and certain developed and emerging markets to the exposure of the subprime crisis, which originated in the United States in July 2007.

To do so, we proceeded in a first chapter to the exposure of the definitions of the financial contagion and its different types of contagion with their different channels of transmission and on the other hand we presented the subprime crisis, its transmission mechanisms, and their impact on developed and emerging countries.

In the second chapter we presented a literature review of the various approaches that have addressed this phenomenon. Finally, we summarised previous work on the effect of contagion.

To answer our questions, the last chapter was devoted to empirical study. First, we made tests of the unit roots, estimation by OLS and dynamic and ARCH models. Then we made an estimate on 10 stock markets related to developed and emerging countries, via the ARDL and NARDL technique and in addition we made a diagnosis of residues and stability. The study covers a period from 01/08/2007 to 30/12/2022 on the stock markets.

Similar to any research, this study is not without its limitations. Its scope is confined to the application of the NARDL approach exclusively to stock markets, focusing on a phenomenon commonly utilized to discern relationships within financial markets. Exploring this approach primarily in the context of stock markets highlights the need for further investigation into its applicability across diverse financial instruments.

To enhance the breadth of our understanding, it would be valuable to extend the research to encompass a broader spectrum of events and crises. For instance, examining the period surrounding the onset of the COVID-19 pandemic in 2020, both pre- and post-outbreak, could offer insights into how the NARDL approach responds to unprecedented market conditions. Additionally, considering geopolitical events such as the Russian and Ukrainian conflicts and conflicts in Palestine as variables could provide a more comprehensive understanding of the NARDL approach's effectiveness in capturing nuanced market dynamics during times of global instability. These contextual expansions would contribute to a more holistic evaluation of the NARDL approach, transcending its application solely to stock markets and broadening its relevance across various financial landscapes.

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Appendix

Table 17. Articles summarize

Article titles	Authors	Objectives	Data	Models	Results
Did the crash of October 1987 strengthen co-movement between national equity markets?	Lee & Kim, 1993	Examining the effect of the October 1987 crash on movements in national stock markets	12 national stock market indices. Weekly returns in local currency and U.S. dollars	Contagion test based on correlation calculation	An increase in market correlations after the US Crash for 12 major stock markets.
Capital flows to Latin America: is there evidence of contagion effects?	Calvo & Reinhart, 1996	Studying the effect of the 1994 Mexican crisis on market linkages for a range of emerging Asia and Latin America	Capital account balance as a percentage of GDP U.S. short-term real interest rates.	Contagion test based on correlation calculation	Market correlations increased for many emerging markets during the crisis.
Financial market contagion in the Asian crisis	Baig & Goldfajn, 1999	Search for evidence of contagion between the financial markets of Thailand, Malaysia, Indonesia, Korea and the Philippines	equities, currency rates, interest rates and sovereign spreads for selected emerging markets	Correlations and vector autoregressions (VAR)	The correlation between foreign exchange and equity markets remains high and significant.
Structure and performance: global interdependence of equity markets around the October 1987 crash	Bertero & Mayer, 1999	Studying the impact of the 1987 US crash on the contagion effects on equity markets in 23 industrialized and developing countries	price indices (an index of the evolution of stock prices in 23 countries).	OLS REGRESSION	Higher correlations between markets have persisted since the crash, despite volatilities returning to pre-crash levels

Stock Market Causality and Co-Integration Between the United States, Japan and the South China Growth Triangle	<i>Huang et al., 2000</i>	Examining Financial Integration Between the United States, Japan and the South China Growth Triangle	Daily stock prices at the close	Cointegration tests by Gregory and Hansen (1996)	A co-integration relationship exists only between the Shanghai and Shenzhen stock markets.
Central European Equity Market Integration Emerging Markets: An Analysis of Co-Integration with Changing Regimes.	<i>Voronkova ,2004</i>	Testing co-integration between Central and developed European stock markets	Three emerging EC markets (Hungary, Poland), Three developed European stock markets (Great Britain, France, Germany) and the United States.	Gregory and Hansen (1996) residual cointegration tests	European stock markets are becoming more integrated with their developed counterparts
Equity market integration in the NAFTA region: Evidence from unit root and cointegration tests	<i>Aggarwalet al., 2005</i>	test long-term ties between countries in the North American Free Trade Agreement (NAFTA) region before and after 1993)	Three stock market indices are: MSCI USA, MSCI Canada and MSCI Mexico. The Stanley Capital Investments (MSCI) Stock Index.	Johansen's (1988) approach (unrestricted error correction model)	Financial integration between countries was significant only after the formation of the NAFTA Area in 1993.

Market integration and contagion	Bekaert & Harvey, 2005	Examine periods of crisis and investigate whether the model can generate sudden increases in correlations between Countries.	Stock market returns in three different regions: Europe, Southeast Asia and Latin America	A two-factor model: The two factors are the performance of the U.S. stock market and a Performance of the regional equity portfolio.	there is no evidence of further contagion caused by the Mexican Crisis. However, they see increases in residual correlation, particularly in Asia, during the Asian crisis.
Asymmetric dynamics in global equity correlations And bond yields	<i>Cappiello et al., 2006</i>	Study the correlations between equity and bond returns	Bond indices and equity indices 21 countries (Europeans, Australasia and the Americas)	a GARCH model of generalized asymmetric dynamic conditional correlation (AGDCC-GARCH)	a significant break in correlations between variables at the time of the introduction of the euro in January 1999.
Testing the financial benefits in calm and turbulent times	<i>Białkowski et al., 2006</i>	Study the financial contagion between stock markets in times of calm and crisis between stock markets	United States, United Kingdom, Japan and German	Markov switching model	No evidence of strong financial contagion from the U.S. to other markets
Links to Russian stock markets before and after the 1998 crisis: evidence from stochastic cointegration and regime change tests	<i>Lucey & Voronkova, 2008</i>	Assessing the impact of the 1998 crisis on the link between Russian and international stock markets	The indices of Russia, EMU countries, the United Kingdom, the United States, Japan, Hungary, the Czech Republic and Poland. Les indices MSCI	Co-integration techniques for different purposes.	The Russian stock market is independent of long-term international stock markets before and after the 1998 crisis.

<p>A dynamic conditional correlation analysis of financial contagion: The case of the subprime credit crisis</p>	<p><i>Naoui, et al., 2010</i></p>	<p>Examine the contagion induced by the subprime crisis that began in 2007 in the US mortgage market and spread around the world.</p>	<p>daily returns of stock market indices for developed and emerging markets (S&P 500), (CAC 40), (DAX), (AEX), (FTSE 100) (MIB 30). (ESB 30), (Hang seng), (KLSE), (KS11), (Shang.comp), (STI), (Bovespa), (IPC), (MerVal) and (Tunindex).</p>	<p>Dynamic conditional correlation model.</p>	<p>an increase in dynamic conditional correlations after the onset of the subprime crisis. During the subprime crisis, contagion is strong between the United States and developed and emerging countries.</p>
<p>Integration of equity markets in emerging Balkan markets</p>	<p><i>Kenourgios & Samitas, 2011</i></p>	<p>To study the linkages between emerging stock markets in the Balkans, the United States and mature markets in Europe over the period 2000-2009</p>	<p>Stock market indices: Bulgaria, Romania, Croatia, Turkey, Serbia, S&P500 UK, Germany and Greece.</p>	<p>DCC-GARCH asymmetric model</p>	<p>correlations between Balkan stock markets and the United States and developed European markets tend to be higher during the 2008 global financial crisis. They point out that the results have important implications for the international diversification of the portfolio.</p>
<p>More contagion effect on emerging markets: evidence from the DCC-GARCH model</p>	<p><i>Celik, 2012</i></p>	<p>test the existence of financial contagion between the foreign exchange markets of several emerging and developed countries during the US subprime crisis</p>		<p>Modèle DCC-GARCH</p>	<p>It finds evidence of a contagion effect during the subprime crisis for most of the countries considered and that emerging markets are more affected by financial contagion.</p>

Efficiency of the foreign exchange market in recent crises: Asia-Pacific Focus	<i>Rubi Ahmad 2012</i>	Test the effectiveness of the foreign exchange market during the 1998 Asian global financial crises and 2008.	12 Asia-Pacific currencies and forward exchange rates Spot exchange rates	The cointegration model and conventional regressions	the Asian crisis was more worrisome than the 2008 financial crisis in the Asia-Pacific region, as stronger evidence of inefficiency is observed during the AFC than the GFC.
Integration of international stock markets: Comparison of Central and South-Eastern Europe	<i>Horvath & Petrovski, 2013</i>	Examining stock market movements between Western countries Europe.	Daily closing levels of stock indices.	BEKK-GARCH bivariate models	Much higher correlations for Central European markets and low dependence between Southeastern and Western European markets, with the exception of Croatian equities, which are correlated only with mature stock markets. The financial crash of 2007-2009 had no impact on the correlation dynamics between stocks.
Stock market developments in Central Europe: evidence of the asymmetric DCC model	<i>Gjika & Horvath, 2013</i>	To examine the short-term links between Central Europe and the euro area over the day-to-day period from 2001 to 2011		DCC-GARCH	There are also signs of asymmetry in conditional variances and correlations across stock markets.
Equity Market Co-movements Among Selected Emerging Countries from Long-	<i>Jouini et al., 2014</i>	Empirically examining long-term links between emerging market equities	Equities from five emerging countries (Brazil, China, Mexico, South Africa, Thailand)	ARDL (Autoregressive Distributed Lag de cointegration)	the integration of equities between the selected set of countries and have important implications for the international diversification of the portfolio.

and Short-Run Perspectives							
Non-linearities and financial contagion on Latin American stock markets	Rafael Meza Bonilla, Hugo Benedetti, Apostolos Serletis <i>2015</i>	Romero-Claudio	present non-linear events detected in Latin American stock markets and the intensity and persistence of non-linear episodes.	daily data for six Latin American stock indices – Brazil, Venezuela, Peru, Chile, Argentina and Mexico	Test the Portmanteau Bicorrelation		a systematic non-linear structure in stock index return series that has been associated with a temporary lack of market efficiency.
Financial contagion of the global financial crisis of U.S. to other developed countries	<i>Sirin Tangpornpaiboon Nattapong Puttanapong (2016)</i>		Examining the co-movement of exchange rates And stock market indices	Monthly equity returns (2003-2015) and real effective exchange rate change for the United States, Canada, United Kingdom, Germany, France, Italy and Spain.	Correlation and vector autoregression (VAR)		Statistically significant co-movements than during the period of global financial crisis.
On the study of contagion in the context of the subprime crisis: a dynamic approach to conditional correlation - Multivariate GARCH	Hemche, et al., <i>2016</i>		Examines the contagion hypothesis for ten developed and emerging equity markets vis-à-vis the US market in the context of the subprime crisis in order to capture further temporal variations of contagion effects and dynamic links between stock markets.	closing prices of shares expressed in USD of eleven markets (5 developed stock markets and 6 emerging markets) MIB30 (FTSE100), (Nikkei22) (Dow Jones); (Shcomp), (Marvel), Mexico (IPC), (Tunisindex), (Masi) and (ECX30)).	DCC model – MGARCH		an increase in dynamic correlations following the subprime crisis for most of the markets considered with regard to the US market.

Financial crises and dynamic links between international equities and currency markets	<i>Pami Dua, Divya Tuteja</i> 2016	study the contagion of the stock and money markets of China, the euro area, India, Japan and the United States during the global financial crisis and the euro area crisis.	weekly frequency for stock and currency markets in China, EZ, India, Japan and the United States.	Markov change models and the DCC-GARCH model	significant contagion as well as a flight to quality effects both between and within asset classes.
Global financial crisis and emerging stock market contagion: A volatility impulse response function approach	Xiaoye Jin Ximeng An 2016	discuss the magnitude of contagion effects between BRICS and US stock markets and how BRICS stock markets have been influenced in the context of CFM	daily aggregate Morgan Stanley Capital Index (MSCI) prices for U.S. and BRICS stock markets	BEKK model.	There are significant spillover effects from the US to the BRICS stock markets. the degree of stock market reaction to such heightened stock market integration shocks between the US and the BRICS is such a negative effect as if the financial crisis occurs today.
Contagion effects in selected European capital markets during the financial crisis of 2007–2009	<i>Burzala, 2016</i>	Discusses the process of contagion in selected capital markets during the 2007–2009 financial crisis	daily rates of return on four indices of certain European stock exchanges (the German Dax, the French CAC, the British FTSE100 and the Polish WIG20)	Cospectral analysis	The rates of return of the European markets studied react simultaneously to a much more extent due to interdependencies (or a response to the situation observed in third country markets) than as a result of mutual contagion.
Financial crises, exchange rate links and unhedged interest parity:	<i>Dimitrios Dimitrioua, Dimitris Kenourgiosa, Theodore Simos</i>	examines the dynamic links between major exchange rates during the global	daily bond indices of major developed G7 markets, Canada, EMU, Japan, the	Dynamic conditional correlation	Evidence of the varying vulnerability of currencies to the two crises.

Evidence from G7 markets	2017	financial crisis and the euro area sovereign debt crisis	United Kingdom and the United States		
Impact of volatility on U.S. and Asian equity markets:	<i>Donald Liena, Geul Leeb, Li Yangc, Yuyin Zhang</i>	examines the changing nature of the fallout from volatility between U.S. stock markets and eight East Asian stock markets between two financial crises: the Asian currency crisis and the U.S. subprime credit crisis	Daily prices of stock market indices :P oor's 500 Nikkei 225, (HK), (KO), (MA), (PH), (SI), (TA), and (TH)	Multiplicative error model	Japan, Hong Kong and Singapore, are the markets in which volatility is transmitted unidirectionally from several other countries during the subprime credit crisis, but not during the Asian currency crisis.
A comparison between the Asian currency crisis and the subprime credit crisis	2018				
Causality and contagion in emerging equity markets	Emna Abdennadher Slaheddine Hellara 2018	study interdependencies in terms of market volatility and assess the impact of the global financial crisis (GFC) on these interdependencies	Cours de clôture des indices (BHSEASI), DFM) EGX100) ASE) KSE) MSM) TASI) FTSE/JSE BIST National 100) (Tunindex) Morgan Stanley Capital International	Granger causality test	causality during both calm and crisis.
Time-varying volatility indices and their determinants:	Nalin Prasad, Andrew Grant, Suk-Joong Kim	studies the impact on 16 major equity markets	16 equity, European, US and Asia-Pacific market indices	VAR	the United States dominates the transmission of volatility to other markets. Emerging markets such as China, India and Brazil are still relatively isolated, although their contribution to the fallout from global
Evidence of developed and emerging stock markets	2018				

					volatility increased significantly after 2006.
Country risk ratings and stock market returns in the BRICS countries (Brazil, Russia, India and China): A dynamic non-linear approach	Adnen Ben Nasr, Juncal Cunado 2,, Riza Demirer , Rangan Gupta 2018	examine the links between the stock market returns of Brazil, Russia, India and China (BRICS), Country Risk Ratings and International Factors	the three BRICS country risk rating factors, their respective national stock market returns Commodity Index and MSCI Developed Country Index.	nonlinear autoregressive distributed delay models (NARDL)	Not all BRICS countries are the same in terms of reaction to rating changes and interaction with global market variables.
Contagion through domestic and regional exposures to foreign banks During the global financial crisis	<i>Park, C-Y & Shin, K., 2020</i>	Testing the contagion effect at the country level using bilateral data on cross-country bank claims.	Bilateral data on cross-border positions of responsibility are collected from CBS and LBS from BIS.	Direct/indirect exposures	The financial vulnerability of an emerging economy can be influenced by aggregate exposure to crisis countries, indicating regional spillovers.
Dynamic volatility and correlation between US stocks and bond and futures cash in the face of a financial crisis: a copula approach	<i>Hsiang-Hsi Liua, Teng-Kun Wangb, Weny Li 2019</i>	study the dynamic interrelationships between U.S. stocks, Bond cash and futures	Stock and bond price returns: S&P500 index Treasury bond index cash Treasury bond index futures	Copula model VECGJR-GARCH- Skewed-t	The correlations of yield and volatility between the three markets are not only the result of fundamental co-movements, but are also affected by the excessive propagation of shocks as a contagion effect of the occurrence of negative shocks resulting from financial crisis events.
Multi-asset contagion in the financial crisis:	<i>Guidolin, Hansen & Pedio, 2019</i>	examine how and to what extent an initial negative shock to the low-quality	time series of ex ante returns of several asset	dynamic time series models estimated with Bayesian methods	structural changes in inter-active relationships and therefore contagion.

A Bayesian approach to time-varying parameters		asset-backed securities (ABS) market has spread to ABS markets	classes traded on the US financial market		Contagion occurred mainly through liquidity flight, risk premiums and information channels.
Analysis of financial contagion in frontier markets: Testimonials on US subprime and the eurozone debt crisis	<i>Mohti, Dionísio, Vieira & Ferreira, 2019</i>	assess the effects of the US financial crisis and the euro area debt crisis on a wide range of frontier stock markets	Daily closing prices of the indices of the eighteen frontier markets	DCCA and DMCA correlation coefficients	Frontier stock markets have been hit harder by the US financial crisis.

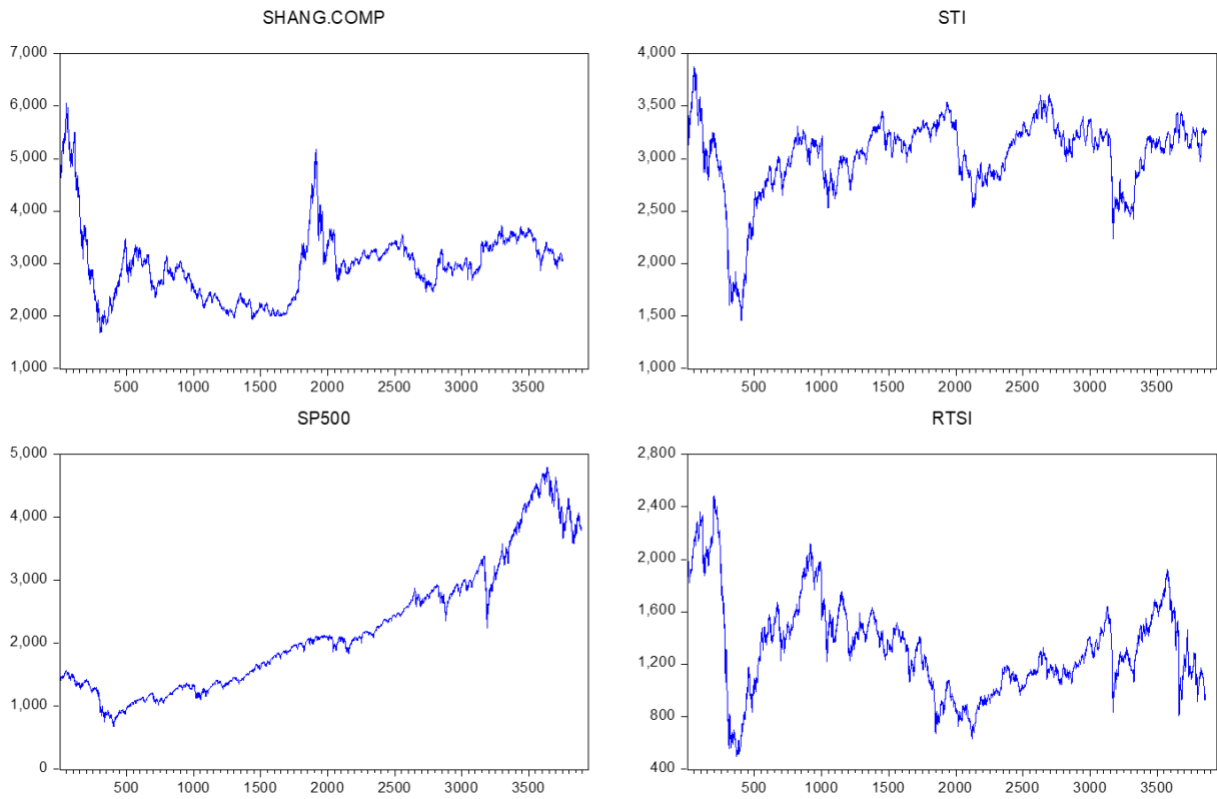


Figure 8. Stock index variation (Continue)

(Source: Compiled by us: calculations are made using Eviews software)

Continuation

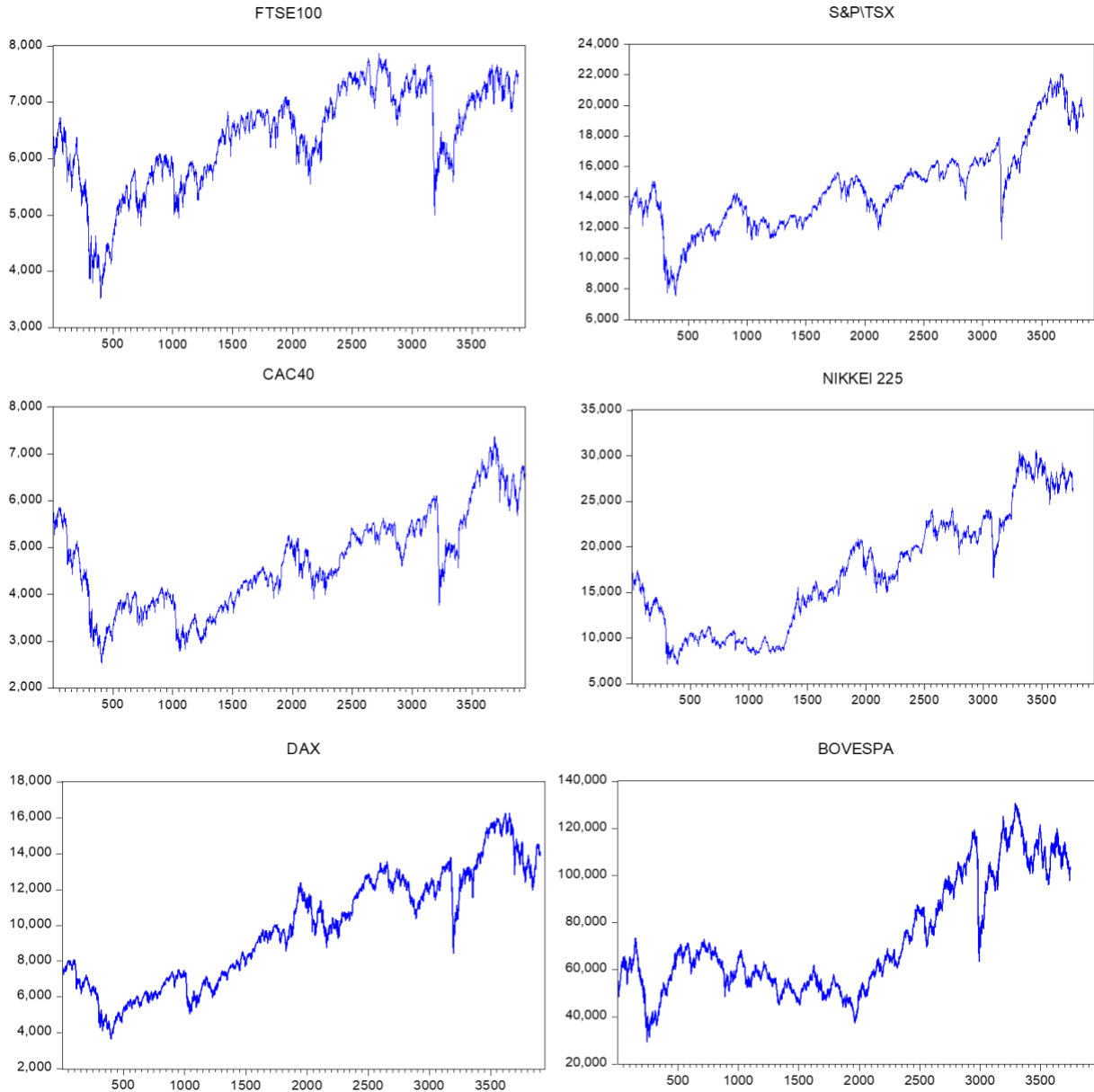


Figure 9. Stock index variation

(Source: Compiled by us: calculations are made using Eviews software)

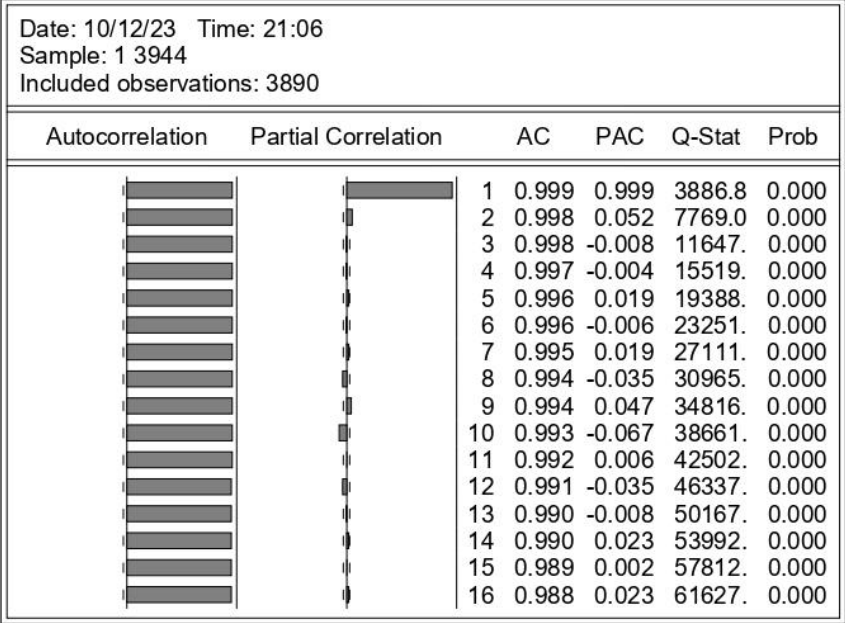


Figure 10. S&P 500 Index Correlations

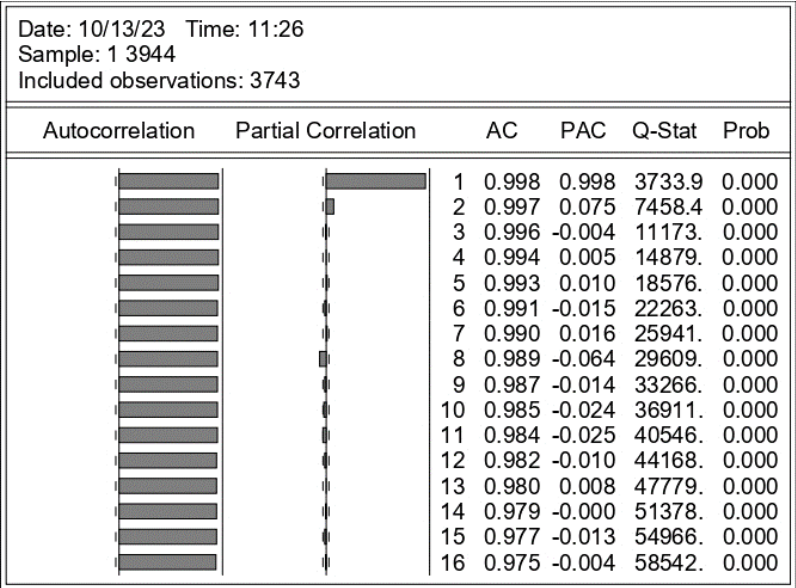


Figure 11. BOVESPA Index Correlations

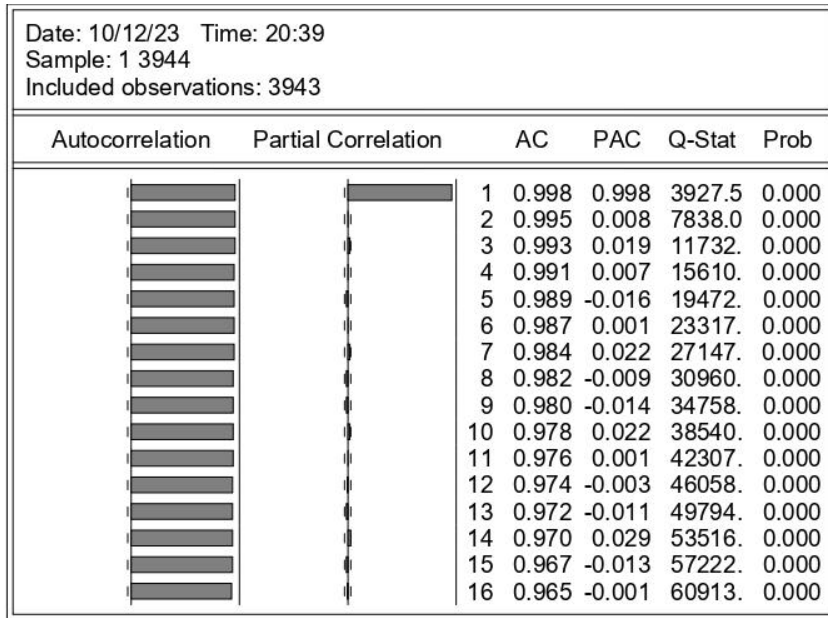


Figure 12. CAC40 Index Correlations

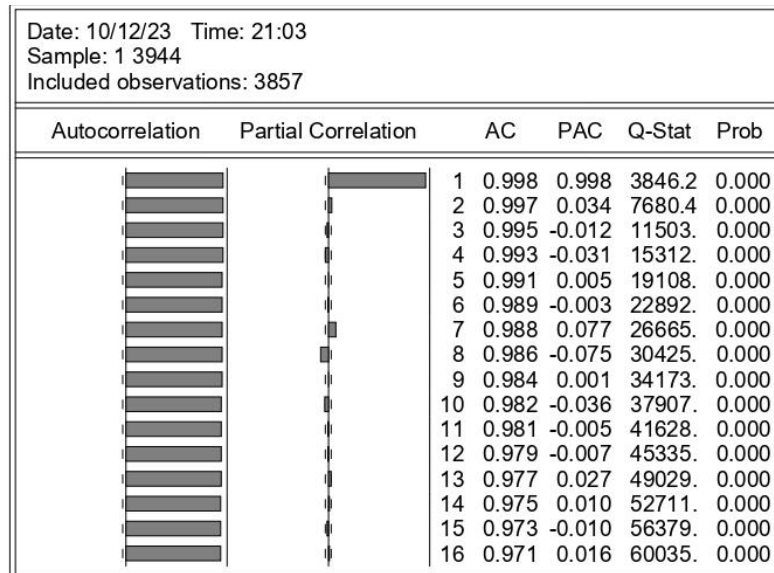


Figure 13: SP\TSX Index Correlations

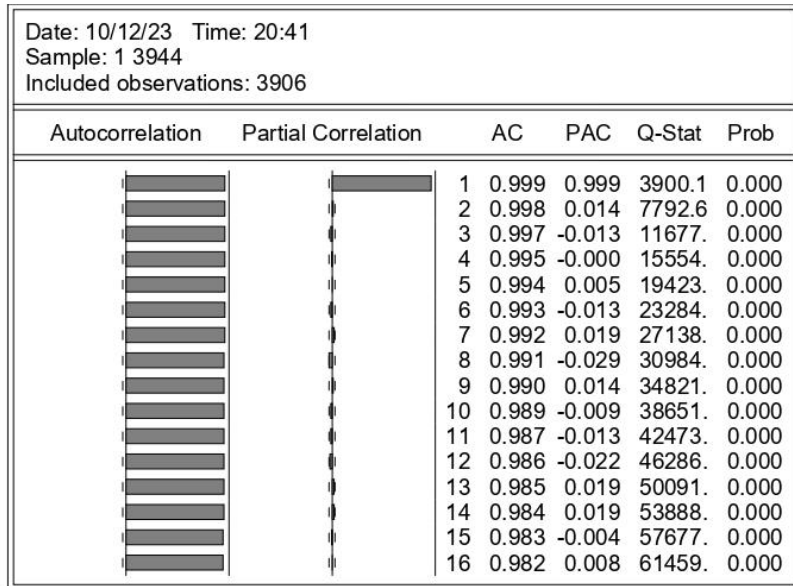


Figure 14: DAX Index Correlations

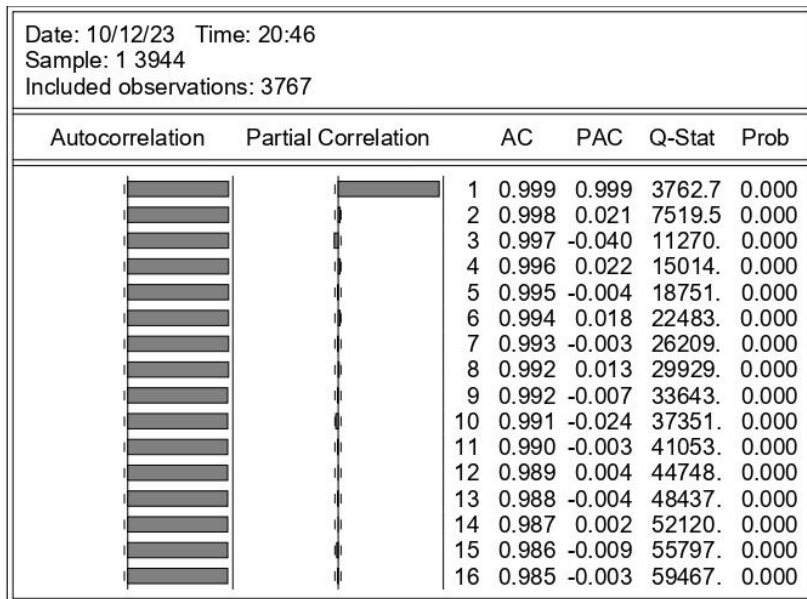


Figure 15: NIKKIE225 Index Correlations

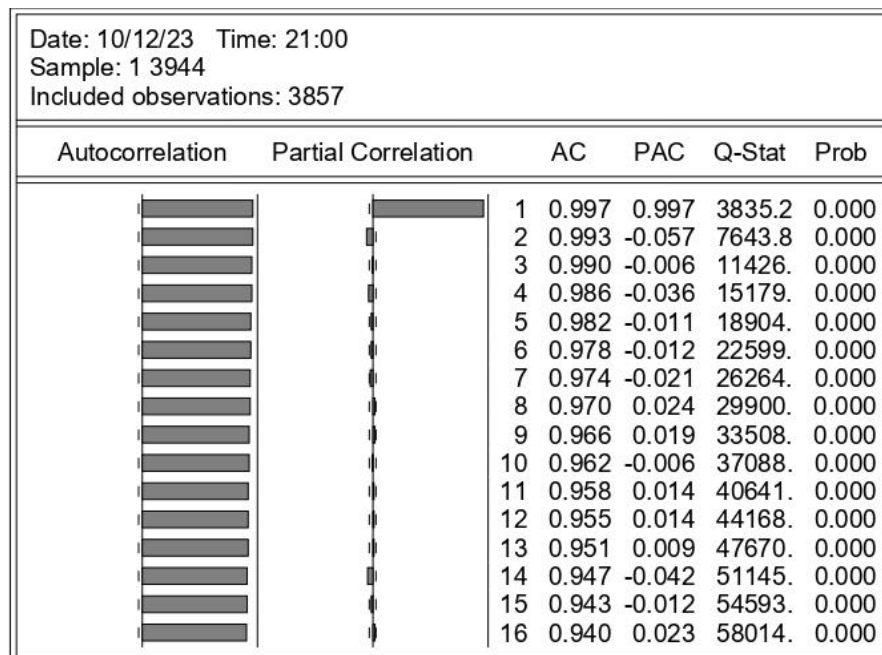


Figure 16: RTSI Index Correlations

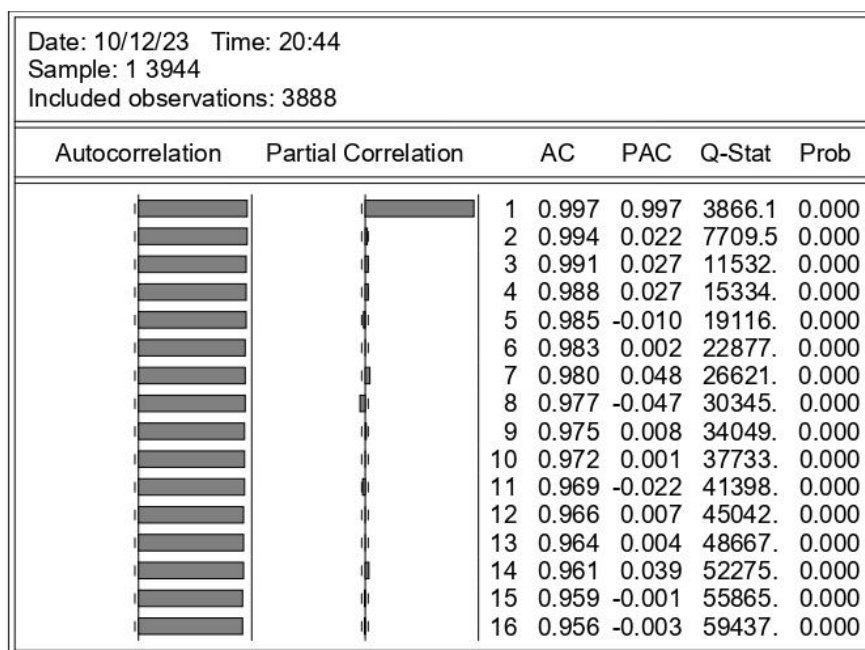


Figure 17: FTSE Index Correlations

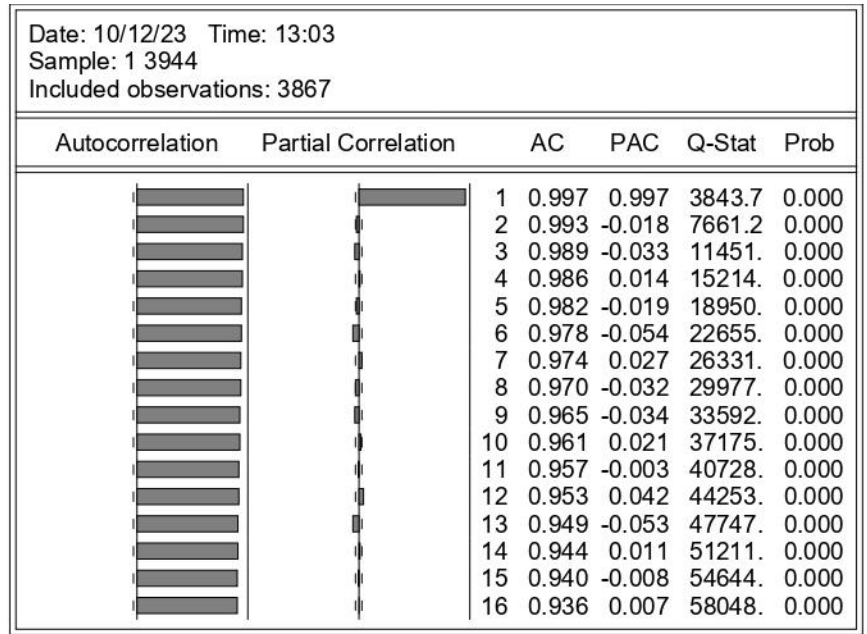


Figure 18: STI Index Correlations

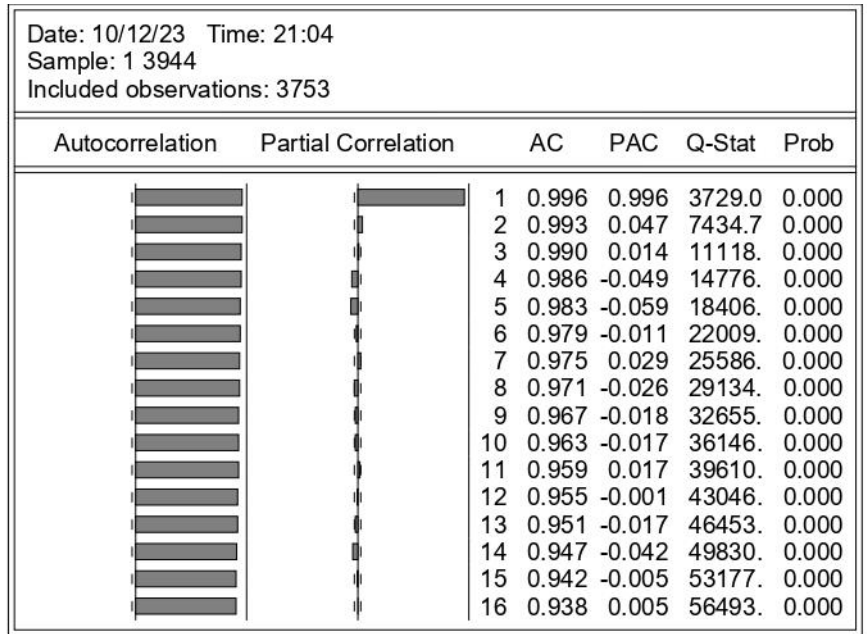


Figure 19: SHANGN-COMP Index Correlations

Unit root test

Index DAX

Null Hypothesis: DAX has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic - based on SIC, maxlag=3)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-1.020938	0.7479
Test critical values:		
1% level	-3.431839	
5% level	-2.862083	
10% level	-2.567103	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(DAX)

Method: Least Squares

Date: 10/12/23 Time: 20:41

Sample (adjusted): 2 3906

Included observations: 3905 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DAX(-1)	-0.000666	0.000652	-1.020938	0.3073
C	8.224483	6.720314	1.223824	0.2211

R-squared	0.000267	Mean dependent var	1.689575
Adjusted R-squared	0.000011	S.D. dependent var	127.9335
S.E. of regression	127.9328	Akaike info criterion	12.54140
Sum squared resid	63879604	Schwarz criterion	12.54461
Log likelihood	-24485.08	Hannan-Quinn criter.	12.54254
F-statistic	1.042314	Durbin-Watson stat	2.015832
Prob(F-statistic)	0.307347		

Index STI

Null Hypothesis: STI has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic - based on SIC, maxlag=3)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-2.574543	0.0984
Test critical values:		
1% level	-3.431856	
5% level	-2.862091	
10% level	-2.567106	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(STI)

Method: Least Squares

Date: 10/12/23 Time: 13:05

Sample (adjusted): 2 3867

Included observations: 3866 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
STI(-1)	-0.003311	0.001286	-2.574543	0.0101
C	9.970029	3.918916	2.544078	0.0110

R-squared	0.001712	Mean dependent var	-0.046661
Adjusted R-squared	0.001454	S.D. dependent var	29.22530
S.E. of regression	29.20405	Akaike info criterion	9.587009
Sum squared resid	3295514.	Schwarz criterion	9.590247
Log likelihood	-18529.69	Hannan-Quinn criter.	9.588159
F-statistic	6.628269	Durbin-Watson stat	1.963644
Prob(F-statistic)	0.010074		

Index CAC40

Null Hypothesis: CAC40 has a unit root
 Exogenous: Constant
 Lag Length: 0 (Automatic - based on SIC, maxlag=3)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-1.620019	0.4722
Test critical values:		
1% level	-3.431824	
5% level	-2.862076	
10% level	-2.567099	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
 Dependent Variable: D(CAC40)
 Method: Least Squares
 Date: 10/12/23 Time: 20:39
 Sample (adjusted): 2 3943
 Included observations: 3942 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
CAC40(-1)	-0.001565	0.000966	-1.620019	0.1053
C	7.527758	4.625546	1.627431	0.1037
R-squared	0.000666	Mean dependent var		0.207879
Adjusted R-squared	0.000412	S.D. dependent var		62.16169
S.E. of regression	62.14888	Akaike info criterion		11.09745
Sum squared resid	15218186	Schwarz criterion		11.10064
Log likelihood	-21871.07	Hannan-Quinn criter.		11.09858
F-statistic	2.624462	Durbin-Watson stat		2.046842
Prob(F-statistic)	0.105308			

Index FTSE100

Null Hypothesis: FTSE100 has a unit root
 Exogenous: Constant
 Lag Length: 0 (Automatic - based on SIC, maxlag=3)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-2.276107	0.1799
Test critical values:		
1% level	-3.431847	
5% level	-2.862087	
10% level	-2.567104	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
 Dependent Variable: D(FTSE100)
 Method: Least Squares
 Date: 10/12/23 Time: 20:45
 Sample (adjusted): 2 3888
 Included observations: 3887 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
FTSE100(-1)	-0.002836	0.001246	-2.276107	0.0229
C	18.40064	8.025608	2.292741	0.0219
R-squared	0.001332	Mean dependent var		0.309015
Adjusted R-squared	0.001075	S.D. dependent var		69.23256
S.E. of regression	69.19535	Akaike info criterion		11.31226
Sum squared resid	18601367	Schwarz criterion		11.31548
Log likelihood	-21983.38	Hannan-Quinn criter.		11.31340
F-statistic	5.180664	Durbin-Watson stat		2.052441
Prob(F-statistic)	0.022894			

Index BOVESPA

Null Hypothesis: BOVESPA has a unit root
 Exogenous: Constant
 Lag Length: 1 (Automatic - based on SIC, maxlag=3)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-1.262221	0.6492
Test critical values:		
1% level	-3.431912	
5% level	-2.862115	
10% level	-2.567120	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(BOVESPA)

Method: Least Squares

Date: 10/12/23 Time: 20:33

Sample (adjusted): 3 3743

Included observations: 3741 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
BOVESPA(-1)	-0.001052	0.000833	-1.262221	0.2069
D(BOVESPA(-1))	-0.080056	0.016310	-4.908308	0.0000
C	90.90251	63.78917	1.425046	0.1542

R-squared	0.006920	Mean dependent var	13.34174
Adjusted R-squared	0.006389	S.D. dependent var	1219.006
S.E. of regression	1215.106	Akaike info criterion	17.04385
Sum squared resid	5.52E+09	Schwarz criterion	17.04885
Log likelihood	-31877.52	Hannan-Quinn criter.	17.04563
F-statistic	13.02370	Durbin-Watson stat	1.997044
Prob(F-statistic)	0.000002		

Index NIKIKEI225

Null Hypothesis: NIKKEI_225 has a unit root
 Exogenous: Constant
 Lag Length: 0 (Automatic - based on SIC, maxlag=3)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-0.733053	0.8366
Test critical values:		
1% level	-3.431901	
5% level	-2.862110	
10% level	-2.567117	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(NIKKEI_225)

Method: Least Squares

Date: 10/12/23 Time: 20:49

Sample (adjusted): 2 3767

Included observations: 3766 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
NIKKEI_225(-1)	-0.000450	0.000613	-0.733053	0.4636
C	10.14068	11.23904	0.902272	0.3670

R-squared	0.000143	Mean dependent var	2.419116
Adjusted R-squared	-0.000123	S.D. dependent var	240.5199
S.E. of regression	240.5347	Akaike info criterion	13.80414
Sum squared resid	2.18E+08	Schwarz criterion	13.80745
Log likelihood	-25991.19	Hannan-Quinn criter.	13.80531
F-statistic	0.537367	Durbin-Watson stat	2.058344
Prob(F-statistic)	0.463572		

Index RTSI

Null Hypothesis: RTSI has a unit root

Exogenous: Constant

Lag Length: 1 (Automatic - based on SIC, maxlag=3)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-2.630216	0.0869
Test critical values:		
1% level	-3.431861	
5% level	-2.862093	
10% level	-2.567108	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(RTSI)

Method: Least Squares

Date: 10/12/23 Time: 21:01

Sample (adjusted): 3 3857

Included observations: 3855 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
RTSI(-1)	-0.003075	0.001169	-2.630216	0.0086
D(RTSI(-1))	0.075809	0.016058	4.720850	0.0000
C	3.818955	1.600653	2.385873	0.0171

R-squared	0.007326	Mean dependent var	-0.261077
Adjusted R-squared	0.006810	S.D. dependent var	26.41740
S.E. of regression	26.32729	Akaike info criterion	9.379867
Sum squared resid	2669922.	Schwarz criterion	9.384736
Log likelihood	-18076.69	Hannan-Quinn criter.	9.381596
F-statistic	14.21334	Durbin-Watson stat	2.000413
Prob(F-statistic)	0.000001		

Index SP/TSX

Null Hypothesis: S_P_TSX has a unit root

Exogenous: Constant

Lag Length: 1 (Automatic - based on SIC, maxlag=3)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-1.120537	0.7099
Test critical values:		
1% level	-3.431861	
5% level	-2.862093	
10% level	-2.567108	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(S_P_TSX)

Method: Least Squares

Date: 10/12/23 Time: 21:03

Sample (adjusted): 3 3857

Included observations: 3855 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
S_P_TSX(-1)	-0.000957	0.000854	-1.120537	0.2626
D(S_P_TSX(-1))	-0.047783	0.016099	-2.968155	0.0030
C	15.48022	12.69043	1.219835	0.2226

R-squared	0.002667	Mean dependent var	1.445214
Adjusted R-squared	0.002149	S.D. dependent var	149.6448
S.E. of regression	149.4839	Akaike info criterion	12.85303
Sum squared resid	86074647	Schwarz criterion	12.85790
Log likelihood	-24771.22	Hannan-Quinn criter.	12.85476
F-statistic	5.150418	Durbin-Watson stat	1.996247
Prob(F-statistic)	0.005837		

Index SHANG-COMP

Null Hypothesis: SHANG_COMP has a unit root
 Exogenous: Constant
 Lag Length: 0 (Automatic - based on SIC, maxlag=3)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-2.873814	0.0485
Test critical values:		
1% level	-3.431907	
5% level	-2.862113	
10% level	-2.567119	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
 Dependent Variable: D(SHANG_COMP)
 Method: Least Squares
 Date: 10/12/23 Time: 21:04
 Sample (adjusted): 2 3753
 Included observations: 3752 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
SHANG_COMP(-1)	-0.003593	0.001250	-2.873814	0.0041
C	10.31182	3.814707	2.703176	0.0069
R-squared	0.002198	Mean dependent var	-0.374267	
Adjusted R-squared	0.001931	S.D. dependent var	52.21420	
S.E. of regression	52.16375	Akaike info criterion	10.74719	
Sum squared resid	10203963	Schwarz criterion	10.75051	
Log likelihood	-20159.72	Hannan-Quinn criter.	10.74837	
F-statistic	8.258809	Durbin-Watson stat	2.062685	
Prob(F-statistic)	0.004078			

Index SP500

Null Hypothesis: SP500 has a unit root
 Exogenous: Constant
 Lag Length: 1 (Automatic - based on SIC, maxlag=3)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-0.141039	0.9432
Test critical values:		
1% level	-3.431847	
5% level	-2.862086	
10% level	-2.567104	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
 Dependent Variable: D(SP500)
 Method: Least Squares
 Date: 10/12/23 Time: 21:06
 Sample (adjusted): 3 3890
 Included observations: 3888 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
SP500(-1)	-6.37E-05	0.000452	-0.141039	0.8878
D(SP500(-1))	-0.107784	0.015955	-6.755599	0.0000
C	0.815342	1.096506	0.743582	0.4572
R-squared	0.011634	Mean dependent var	0.608873	
Adjusted R-squared	0.011125	S.D. dependent var	28.85894	
S.E. of regression	28.69796	Akaike info criterion	9.552301	
Sum squared resid	3199581.	Schwarz criterion	9.557135	
Log likelihood	-18566.67	Hannan-Quinn criter.	9.554017	
F-statistic	22.86429	Durbin-Watson stat	1.992263	
Prob(F-statistic)	0.000000			

ADF Test

Null Hypothesis: Unit root (individual unit root process)

Series: BOVESPA-BOVESPA(-1), CAC40-CAC40(-1), DAX-DAX(-1),
 NIKKEI_225-NIKKEI_225(-1), FTSE100-FTSE100(-1), RTSI-RTSI(-1),
 SHANG_COMP-SHANG_COMP(-1), S_P_TSX-S_P_TSX(-1),
 SP500-SP500(-1), STI-STI(-1)

Date: 10/13/23 Time: 20:18

Sample: 1 3943

Exogenous variables: Individual effects

User-specified maximum lags

Automatic lag length selection based on SIC: 0

Total number of observations: 38451

Cross-sections included: 10

Method	Statistic	Prob.**
ADF - Fisher Chi-square	184.207	0.0000
ADF - Choi Z-stat	-11.7606	0.0000

** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

Intermediate ADF test results UNTITLED

Series	Prob.	Lag	Max Lag	Obs
BOVESPA-BOVESPA(-1)	0.0001	0	3	3741
CAC40-CAC40(-1)	0.0001	0	3	3941
DAX-DAX(-1)	0.0001	0	3	3904
NIKKEI_225-NIKKEI_225(-1)	0.0001	0	3	3765
FTSE100-FTSE100(-1)	0.0001	0	3	3886
RTSI-RTSI(-1)	0.0001	0	3	3855
SHANG_COMP-SHANG_COMP(-1)	0.0001	0	3	3751
S_P_TSX-S_P_TSX(-1)	0.0001	0	3	3855
SP500-SP500(-1)	0.0001	0	3	3888
STI-STI(-1)	0.0001	0	3	3865

Estimation by OLS with constant

Dependent Variable: SP500

Method: Least Squares

Date: 10/13/23 Time: 22:08

Sample (adjusted): 1 3743

Included observations: 3743 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-703.4465	31.59417	-22.26507	0.0000
STI	-0.220337	0.016192	-13.60760	0.0000
SHANG_COMP	-0.125754	0.005387	-23.34567	0.0000
S_P_TSX	0.147000	0.003272	44.92083	0.0000
RTSI	0.004913	0.011607	0.423280	0.6721
NIKKEI_225	0.021613	0.001594	13.55890	0.0000
FTSE100	-0.114763	0.009314	-12.32135	0.0000
DAX	0.133613	0.004227	31.61206	0.0000
CAC40	0.095350	0.006589	14.47036	0.0000
BOVESPA	0.005229	0.000197	26.49160	0.0000
R-squared	0.973527	Mean dependent var	2136.589	
Adjusted R-squared	0.973463	S.D. dependent var	979.5654	
S.E. of regression	159.5732	Akaike info criterion	12.98555	
Sum squared resid	95055635	Schwarz criterion	13.00219	
Log likelihood	-24292.46	Hannan-Quinn criter.	12.99147	
F-statistic	15253.03	Durbin-Watson stat	0.068500	
Prob(F-statistic)	0.000000			

Estimation the dynamic

Dependent Variable: SP500
 Method: Least Squares
 Date: 10/14/23 Time: 00:43
 Sample (adjusted): 4 3743
 Included observations: 3740 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-26.74789	5.571937	-4.800465	0.0000
SP500(-1)	0.851694	0.016365	52.04272	0.0000
SP500(-2)	0.172350	0.021324	8.082373	0.0000
SP500(-3)	-0.030559	0.016416	-1.861535	0.0627
BOVESPA	7.17E-05	3.57E-05	2.007709	0.0447
CAC40	-0.004305	0.001137	-3.785877	0.0002
DAX	-0.002698	0.000808	-3.338475	0.0009
FTSE100	0.007496	0.001599	4.689404	0.0000
NIKKEI_225	0.000959	0.000271	3.537468	0.0004
RTSI	-0.000212	0.001927	-0.110207	0.9123
S_P_TSX	0.002788	0.000673	4.140492	0.0000
SHANG_COMP	0.000187	0.000961	0.194333	0.8459
STI	-0.007435	0.002752	-2.702266	0.0069
R-squared	0.999272	Mean dependent var	2137.134	
Adjusted R-squared	0.999269	S.D. dependent var	979.7690	
S.E. of regression	26.48528	Akaike info criterion	9.394525	
Sum squared resid	2614380.	Schwarz criterion	9.416170	
Log likelihood	-17554.76	Hannan-Quinn criter.	9.402224	
F-statistic	426084.6	Durbin-Watson stat	1.993566	
Prob(F-statistic)	0.000000			

Dependent Variable: SP500
 Method: Least Squares
 Date: 10/14/23 Time: 01:32
 Sample (adjusted): 4 3744
 Included observations: 3741 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-21.33753	5.601695	-3.809121	0.0001
SP500(-1)	0.852776	0.016414	51.95390	0.0000
SP500(-2)	0.171133	0.021378	8.005066	0.0000
SP500(-3)	-0.031003	0.016515	-1.877253	0.0606
BOVESPA(-1)	6.53E-05	3.58E-05	1.821147	0.0687
CAC40(-1)	-0.003857	0.001138	-3.388678	0.0007
DAX(-1)	-0.002150	0.000806	-2.668738	0.0076
FTSE100(-1)	0.004559	0.001600	2.850082	0.0044
NIKKEI_225(-1)	0.001092	0.000272	4.010846	0.0001
RTSI(-1)	4.56E-06	0.001932	0.002362	0.9981
S_P_TSX(-1)	0.002618	0.000677	3.870127	0.0001
SHANG_COMP(-1)	-0.000573	0.000963	-0.594860	0.5520
STI(-1)	-0.004205	0.002762	-1.522829	0.1279
R-squared	0.999268	Mean dependent var	2137.679	
Adjusted R-squared	0.999266	S.D. dependent var	980.2054	
S.E. of regression	26.55936	Akaike info criterion	9.400110	
Sum squared resid	2629729.	Schwarz criterion	9.421750	
Log likelihood	-17569.91	Hannan-Quinn criter.	9.407807	
F-statistic	424200.8	Durbin-Watson stat	1.995997	
Prob(F-statistic)	0.000000			

Estimation by the ARCH model

Dependent Variable: SP500

Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)

Date: 10/14/23 Time: 13:39

Sample (adjusted): 1 3743

Included observations: 3743 after adjustments

Convergence not achieved after 0 iterations

Coefficient covariance computed using outer product of gradients

Presample variance: backcast (parameter = 0.7)

GARCH = C(11) + C(12)*RESID(-1)^2 + C(13)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-703.4465	71.02795	-9.903798	0.0000
BOVESPA	0.005229	0.000445	11.75558	0.0000
CAC40	0.095350	0.013537	7.043876	0.0000
DAX	0.133613	0.009122	14.64673	0.0000
FTSE100	-0.114763	0.020142	-5.697649	0.0000
NIKKEI_225	0.021613	0.003288	6.572302	0.0000
RTSI	0.004913	0.024928	0.197085	0.8438
S_P_TSX	0.147000	0.007104	20.69221	0.0000
SHANG_COMP	-0.125754	0.010962	-11.47188	0.0000
STI	-0.220337	0.034889	-6.315297	0.0000

Variance Equation

C	16507.12	9292.718	1.776350	0.0757
RESID(-1)^2	0.150000	0.069484	2.158756	0.0309
GARCH(-1)	0.600000	0.216556	2.770650	0.0056

R-squared	0.973527	Mean dependent var	2136.589
Adjusted R-squared	0.973463	S.D. dependent var	979.5654
S.E. of regression	159.5732	Akaike info criterion	13.05412
Sum squared resid	95055635	Schwarz criterion	13.07575
Log likelihood	-24417.79	Hannan-Quinn criter.	13.06182
Durbin-Watson stat	0.068500		

Short-term ARDL model

Dependent Variable: SP500

Method: ARDL

Date: 10/14/23 Time: 13:00

Sample (adjusted): 3 3743

Included observations: 3741 after adjustments

Dependent lags: 2 (Fixed)

Dynamic regressors (2 lags, fixed):

Fixed regressors: BOVESPA CAC40 DAX STI SHANG_COMP S_P_TSX

RTSI NIKKEI_225 FTSE100 C

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
SP500(-1)	0.847183	0.016200	52.29681	0.0000
SP500(-2)	0.146827	0.016300	9.007581	0.0000
BOVESPA	7.09E-05	3.57E-05	1.983855	0.0473
CAC40	-0.004532	0.001133	-3.998927	0.0001
DAX	-0.002857	0.000802	-3.561004	0.0004
STI	-0.007547	0.002752	-2.742087	0.0061
SHANG_COMP	0.000280	0.000961	0.291280	0.7709
S_P_TSX	0.002786	0.000673	4.137740	0.0000
RTSI	-0.000278	0.001928	-0.144200	0.8854
NIKKEI_225	0.000958	0.000271	3.533993	0.0004
FTSE100	0.007808	0.001591	4.908233	0.0000
C	-27.01351	5.571106	-4.848860	0.0000

R-squared	0.999271	Mean dependent var	2136.946
Adjusted R-squared	0.999268	S.D. dependent var	979.7056
S.E. of regression	26.49747	Akaike info criterion	9.395178
Sum squared resid	2618189.	Schwarz criterion	9.415152
Log likelihood	-17561.68	Hannan-Quinn criter.	9.402282
F-statistic	464456.0	Durbin-Watson stat	1.985949
Prob(F-statistic)	0.000000		

*Note: p-values and any subsequent tests do not account for model selection.

Long-term ARDL model

ARDL Long Run Form and Bounds Test
 Dependent Variable: D(SP500)
 Selected Model: ARDL(2)
 Case 2: Restricted Constant and No Trend
 Date: 10/16/23 Time: 00:42
 Sample: 1 3944
 Included observations: 3741

Conditional Error Correction Regression				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-27.01351	5.571106	-4.848860	0.0000
SP500(-1)*	-0.005990	0.002752	-2.176187	0.0296
D(SP500(-1))	-0.146827	0.016300	-9.007581	0.0000
BOVESPA	7.09E-05	3.57E-05	1.983855	0.0473
CAC40	-0.004532	0.001133	-3.998927	0.0001
DAX	-0.002857	0.000802	-3.561004	0.0004
FTSE100	0.007808	0.001591	4.908233	0.0000
NIKKEI_225	0.000958	0.000271	3.533993	0.0004
RTSI	-0.000278	0.001928	-0.144200	0.8854
S_P_TSX	0.002786	0.000673	4.137740	0.0000
SHANG_COMP	0.000280	0.000961	0.291280	0.7709
STI	-0.007547	0.002752	-2.742087	0.0061

* p-value incompatible with t-Bounds distribution.

Levels Equation				
Case 2: Restricted Constant and No Trend				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-4510.117	1971.651	-2.287482	0.0222

EC = SP500 - (-4510.1167)

F-Bounds Test

Null Hypothesis: No levels relationship

Test Statistic	Value	Signif.	I(0)	I(1)
Asymptotic: n=1000				
F-statistic	11.94141	10%	3.8	3.8
k	0	5%	4.6	4.6
		2.5%	5.39	5.39
		1%	6.44	6.44
Finite Sample: n=80				
Actual Sample Size	3741	10%	3.87	3.87
		5%	4.725	4.725
		1%	6.695	6.695

NARDL**NARDL : Short-terme**

Dependent Variable: SP500

Method: ARDL

Date: 10/16/23 Time: 01:15

Sample (adjusted): 3 3890

Included observations: 3888 after adjustments

Dependent lags: 2 (Fixed)

Dynamic regressors (2 lags, fixed):

Fixed regressors: BOVESPA_POS BOVESPA_NEG CAC40_POS

CAC40_NEG DAX_POS DAX_NEG FTSE100_POS

FTSE100_NEG NIKKEI_225_POS NIKKEI_225_NEG RTSI_POS

RTSI_NEG S_P_TSX_POS S_P_TSX_NEG SHANG_COMP_POS

SHANG_COMP_NEG STI_POS STI_NEG C

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
SP500(-1)	0.856360	0.015960	53.65817	0.0000
SP500(-2)	0.119744	0.016116	7.430320	0.0000
BOVESPA_POS	-7.08E-05	8.52E-05	-0.830831	0.4061
BOVESPA_NEG	-0.000129	7.17E-05	-1.805347	0.0711
CAC40_POS	-0.007055	0.002950	-2.391865	0.0168
CAC40_NEG	0.001174	0.002023	0.580444	0.5616
DAX_POS	-0.002712	0.001327	-2.043912	0.0410
DAX_NEG	-0.001601	0.001066	-1.501667	0.1333
FTSE100_POS	0.024630	0.002838	8.679696	0.0000
FTSE100_NEG	0.008467	0.002184	3.877282	0.0001
NIKKEI_225_POS	-5.39E-05	0.000394	-0.136908	0.8911
NIKKEI_225_NEG	-6.74E-06	0.000379	-0.017781	0.9858
RTSI_POS	-0.014904	0.004110	-3.626330	0.0003
RTSI_NEG	-0.005070	0.002973	-1.705088	0.0883
S_P_TSX_POS	0.003218	0.000828	3.887580	0.0001
S_P_TSX_NEG	0.002025	0.000798	2.538498	0.0112
SHANG_COMP_POS	-1.34E-05	0.001190	-0.011235	0.9910
SHANG_COMP_NEG	-0.001130	0.001325	-0.852397	0.3940
STI_POS	-0.005619	0.004070	-1.380766	0.1674
STI_NEG	0.011039	0.004337	2.545179	0.0110
C	38.04282	7.154618	5.317240	0.0000

R-squared 0.999238 Mean dependent var 2204.092

Adjusted R-squared	0.999234	S.D. dependent var	1019.489
S.E. of regression	28.22145	Akaike info criterion	9.523428
Sum squared resid	3079872.	Schwarz criterion	9.557270
Log likelihood	-18492.54	Hannan-Quinn criter.	9.535442
F-statistic	253430.9	Durbin-Watson stat	1.987276
Prob(F-statistic)	0.000000		

*Note: p-values and any subsequent tests do not account for model selection.

NARDL : Long-terme

ARDL Long Run Form and Bounds Test

Dependent Variable: D(SP500)

Selected Model: ARDL(2)

Case 2: Restricted Constant and No Trend

Date: 10/16/23 Time: 03:03

Sample: 1 3944

Included observations: 3888

Conditional Error Correction Regression				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	38.04282	7.154618	5.317240	0.0000
SP500(-1)*	-0.023896	0.004319	-5.533166	0.0000
D(SP500(-1))	-0.119744	0.016116	-7.430320	0.0000
BOVESPA_POS	-7.08E-05	8.52E-05	-0.830831	0.4061
BOVESPA_NEG	-0.000129	7.17E-05	-1.805347	0.0711
CAC40_POS	-0.007055	0.002950	-2.391865	0.0168
CAC40_NEG	0.001174	0.002023	0.580444	0.5616
DAX_POS	-0.002712	0.001327	-2.043912	0.0410
DAX_NEG	-0.001601	0.001066	-1.501667	0.1333
FTSE100_POS	0.024630	0.002838	8.679696	0.0000
FTSE100_NEG	0.008467	0.002184	3.877282	0.0001
NIKKEI_225_POS	-5.39E-05	0.000394	-0.136908	0.8911
NIKKEI_225_NEG	-6.74E-06	0.000379	-0.017781	0.9858
RTSI_POS	-0.014904	0.004110	-3.626330	0.0003
RTSI_NEG	-0.005070	0.002973	-1.705088	0.0883
S_P_TSX_POS	0.003218	0.000828	3.887580	0.0001
S_P_TSX_NEG	0.002025	0.000798	2.538498	0.0112

SHANG_COMP_POS	-1.34E-05	0.001190	-0.011235	0.9910
SHANG_COMP_NEG	-0.001130	0.001325	-0.852397	0.3940
STI_POS	-0.005619	0.004070	-1.380766	0.1674
STI_NEG	0.011039	0.004337	2.545179	0.0110

* p-value incompatible with t-Bounds distribution.

Levels Equation
Case 2: Restricted Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1592.002	115.9299	13.73246	0.0000

EC = SP500 - (1592.0021)

F-Bounds Test Null Hypothesis: No levels relationship

Test Statistic	Value	Signif.	I(0)	I(1)
F-statistic	15.45835	10%	3.8	3.8
		5%	4.6	4.6
		2.5%	5.39	5.39
		1%	6.44	6.44
k	0	10%	3.87	3.87
		5%	4.725	4.725
		2.5%	5.39	5.39
		1%	6.695	6.695

Wald Test:

Equation: NARDL01

Test Statistic	Value	df	Probability
F-statistic	13984.65	(12, 3867)	0.0000
Chi-square	167815.8	12	0.0000

Null Hypothesis: C(1)=0,C(2)=0,C(3)=0,C(4)=0,C(5)=0,C(6)=0,C(7)=0,C(8)=0,C(9)=0,C(10)=0,C(11)=0,C(12)=0

Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(1)	0.856360	0.015960
C(2)	0.119744	0.016116
C(3)	-7.08E-05	8.52E-05
C(4)	-0.000129	7.17E-05
C(5)	-0.007055	0.002950
C(6)	0.001174	0.002023
C(7)	-0.002712	0.001327
C(8)	-0.001601	0.001066
C(9)	0.024630	0.002838
C(10)	0.008467	0.002184
C(11)	-5.39E-05	0.000394
C(12)	-6.74E-06	0.000379

Restrictions are linear in coefficients.

Heteroskedasticity Test: Breusch-Pagan-Godfrey

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	56.91915	Prob. F(20,3867)	0.0000
Obs*R-squared	884.2546	Prob. Chi-Square(20)	0.0000
Scaled explained SS	6110.914	Prob. Chi-Square(20)	0.0000

Test Equation:

Dependent Variable: RESID^2

Method: Least Squares

Date: 10/16/23 Time: 05:35

Sample: 3 3890

Included observations: 3888

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	8462.226	661.5910	12.79072	0.0000
SP500(-1)	-5.339209	1.475787	-3.617873	0.0003
SP500(-2)	0.306436	1.490214	0.205632	0.8371
BOVESPA_POS	0.001582	0.007875	0.200843	0.8408
BOVESPA_NEG	0.005880	0.006626	0.887416	0.3749
CAC40_POS	0.729472	0.272764	2.674367	0.0075
CAC40_NEG	2.008536	0.187070	10.73679	0.0000
DAX_POS	0.851885	0.122712	6.942131	0.0000
DAX_NEG	0.611140	0.098558	6.200827	0.0000
FTSE100_POS	-1.810526	0.262400	-6.899882	0.0000
FTSE100_NEG	-1.554647	0.201931	-7.698893	0.0000
NIKKEI_225_POS	0.070483	0.036413	1.935653	0.0530
NIKKEI_225_NEG	-0.041368	0.035049	-1.180271	0.2380
RTSI_POS	2.376562	0.380057	6.253167	0.0000
RTSI_NEG	1.193077	0.274951	4.339230	0.0000
S_P_TSX_POS	-0.154014	0.076553	-2.011865	0.0443
S_P_TSX_NEG	-0.266529	0.073750	-3.613953	0.0003
SHANG_COMP_POS	-0.368919	0.110013	-3.353417	0.0008
SHANG_COMP_NEG	-0.013608	0.122539	-0.111052	0.9116
STI_POS	0.254425	0.376321	0.676086	0.4990
STI_NEG	-0.623869	0.401064	-1.555537	0.1199

R-squared 0.227432 Mean dependent var 792.1482

Adjusted R-squared	0.223436	S.D. dependent var	2961.378
S.E. of regression	2609.651	Akaike info criterion	18.57721
Sum squared resid	2.63E+10	Schwarz criterion	18.61105
Log likelihood	-36093.09	Hannan-Quinn criter.	18.58922
F-statistic	56.91915	Durbin-Watson stat	1.619588
Prob(F-statistic)	0.000000		

Breusch-Godfrey Serial Correlation LM Test

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	9.266636	Prob. F(1,3866)	0.0023
Obs*R-squared	9.297084	Prob. Chi-Square(1)	0.0023

Test Equation:

Dependent Variable: RESID

Method: ARDL

Date: 10/16/23 Time: 05:43

Sample: 3 3890

Included observations: 3888

Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
SP500(-1)	-0.387087	0.128155	-3.020468	0.0025
SP500(-2)	0.376046	0.124577	3.018591	0.0026
BOVESPA_POS	-2.99E-05	8.56E-05	-0.349143	0.7270
BOVESPA_NEG	-5.10E-05	7.35E-05	-0.693535	0.4880
CAC40_POS	-0.003023	0.003109	-0.972141	0.3310
CAC40_NEG	0.000231	0.002022	0.114072	0.9092
DAX_POS	-0.000306	0.001329	-0.230020	0.8181
DAX_NEG	-4.76E-07	0.001065	-0.000447	0.9996
FTSE100_POS	0.008443	0.003966	2.128981	0.0333
FTSE100_NEG	0.002828	0.002371	1.192853	0.2330
NIKKEI_225_POS	-1.67E-05	0.000393	-0.042445	0.9661
NIKKEI_225_NEG	-4.86E-05	0.000379	-0.128173	0.8980
RTSI_POS	-0.004559	0.004370	-1.043264	0.2969
RTSI_NEG	-0.001273	0.003000	-0.424403	0.6713
S_P_TSX_POS	0.001137	0.000907	1.253331	0.2102

S_P_TSX_NEG	0.000692	0.000829	0.835608	0.4034
SHANG_COMP_POS	-0.000163	0.001190	-0.137381	0.8907
SHANG_COMP_NEG	-0.000436	0.001331	-0.327411	0.7434
STI_POS	-0.001756	0.004106	-0.427600	0.6690
STI_NEG	0.003931	0.004521	0.869458	0.3847
C	17.41551	9.154762	1.902344	0.0572
RESID(-1)	0.393184	0.129162	3.044115	0.0023
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R-squared	0.002391	Mean dependent var	-6.27E-13	
Adjusted R-squared	-0.003028	S.D. dependent var	28.14875	
S.E. of regression	28.19133	Akaike info criterion	9.521548	
Sum squared resid	3072508.	Schwarz criterion	9.557002	
Log likelihood	-18487.89	Hannan-Quinn criter.	9.534134	
F-statistic	0.441268	Durbin-Watson stat	1.999455	
Prob(F-statistic)	0.986850			
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