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Impact of G8 Stock Markets on Chinese Stock Market

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Abstract: We extend the stock market integration research by exploring the linkages among nine large stock markets that include former G8 nations (current G7 and Russia) and China. We use a crisis-free period of 2009-2019 to avoid detecting linkages caused by interdependencies created by a major crisis. Our major purpose is to examine the impact of G8 stock markets on China's market. We use standard time series methods: stationarity tests (ADF and PP unit root); long-run correlation tests (Johansen integration involving trace and maximum eigenvalue); impact of G8 markets on China's market (VECM test); influence of G8 markets on volatility in China's market (variance decomposition analysis); and, effect from shocks in G8 markets on China's market (impulse response function). Major findings include the following. *First*, except for Germany and Russia, all markets have a significant causal influence on China with UK's market having the greatest influence. *Second*, G8 markets are not the major source of short-run fluctuation in China's market but over time can exercise a noteworthy impact with the UK market manifesting the largest impact. *Third*, there are occasions for international portfolio diversification with China's market providing the greatest potential. *Fourth*, all markets provide a short-run window of profit opportunity.

Keywords: G7 stock markets; China stock market; Cointegration; Time series; VECM

JEL Classification: C32 • F65 • G11 • G15

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1. Introduction

In this paper, we extend the stock market integration research. We use stock market indexes (or indices) to represent international stock markets. A nation's stock market index is a hypothetical portfolio of individual public stock holdings that represents a segment of its domestic financial market. Stock market indexes are calculated by tracking prices of its selected stocks using a weighted average scheme. Two common weighted average schemes are capitalization-weighted and price-weighted. Since companies with larger market capitalizations typically have higher prices, both weighting schemes give greater weight to larger firms. A nation can have more than one stock market index that can be viewed as representative of its public stocks. For example, the Nasdaq 100 (NDX 100) and S&P 500 are two of the more popular stock market indexes used to represent stocks with ties to the United States (US). Compared to the S&P 500 index, the NDX 100 index is more heavily allocated towards top performing industries such as technology, consumer services, and health care. This allocation can explain why the NDX 100 index has outperformed the S&P 500 index by a noticeable margin for the past fifteen years.

While perfect stock market globalization assimilates all international stock markets, the ultimate success of stock market globalization depends on the desire of stock market participants to move beyond an investment strategy that consists only of a portfolio that is largely domestic stocks. The desire to move away from the latter strategy is evident as different players (professional investors, financial economists, and investment researchers) have responded with intense interest not only to the notion of international portfolio diversification but also to the broader notion of general global integration that includes many areas of globalization such as product standardization, technology development, transportation, and banking services. The overall global interest stems from the belief that worldwide integration leads to growth in businesses and governments for all nations. Given this interest, research of the stock market globalization topic is important. In this paper, we examine this topic by using a sample of nine of the more important stock markets in the world, namely, those for the former G8 and China (where G8 includes the current G7 nations and Russia). In fact, as reported by the World Bank (2022), this group contains the five largest international stock markets in terms of total market capitalization: US, China, Japan, United Kingdom (UK), and Canada. In addition, France and Germany are in the top ten with Spain and Russia in the top twenty. These nine nations contain 77.4% of the total market capitalization of the largest 100 nations.

Given the importance of globalization to international economic growth and the role that stock market globalization plays, the general goal of this study is to investigate the dynamic linkages among the stock markets of nine large industrialized nations that control over ¾ of the world's total market capitalization. Within this general goal, the main purpose is to explore the impact of G8 stock markets on the Chinese stock market. We further aim to understand if the linkages between these nine international stock markets can enable investors to construct more diversified portfolios. In the process of doing this, we focus on the role of China in portfolio diversification. Unlike Russia, China has never been offered membership into the G7 despite having the second largest economy in the world. Regardless, the Chinese stock exchange has grown rapidly in the past few decades and has attracted the attention of investors around the world. The size factor of China's economy alone raises questions about the role played by the Chinese stock market in the integration and diversification of world markets.

As discussed in more detail in Section 2.4, Erdem and Ulucak (2016) overview much of the G7 time series data research with their focus on market efficiency. For the most part, they look at studies that consider at least one G7 nation in combination with non-G7 nations. They note that market efficiency is supported under the following circumstances: stock prices follow a random walk (this implies stock markets also follow a random walk); stock markets move together in the long run (e.g., are cointegrated); and, stock markets have no causal influence on one another. Erdem and Ulucak document that G7 studies offer mixed results on the existence of market efficiency. By our count, they cite eight papers that support market efficiency and five papers that do not. In this paper, we extend this line of G7 research and, to our knowledge, offer the first study that includes all current G7 members, Russia and China as a group. Thus, our study is unique in documenting the impact of the G8 stock markets on the Chinese stock market as well as on the diversification possibilities offered by including the Chinese stock market in a portfolio represented by the traditional and largest industrialized nations of the world. Noteworthy, our period of examination consists of the most recent ten-year period (from the first trading day in July of 2009 through the last trading day in June 2019) which is largely free of any impact from a major crisis. Thus, our examination takes place during a period where large world-wide shocks are less likely to influence stock price comovements and cointegration. In brief, this period is largely removed from the real estate bubble that was prominent from December 2007 to June 2009 and the pandemic that began having an impact around March 2019. As indicated by Chen et al. (2002), world calamities create dependencies in prices across countries bolstering the discovery of linkages. Thus, if a testing period is not free from a major crisis, then linkages could be found that otherwise may not exist.

As just described, Erdem and Ulucak (2016) find differences in prior G7 findings. In response, we build on this research by using more recent data to investigate the following five research hypotheses. *First*, we test if nine stock markets (that represent nine of the most important international stock markets) are non-stationary over a recent ten-year period. *Second*, we investigate if a long-run dynamic relation exists among the nine stock markets. In other words, we hypothesize that we can offer solid statistical evidence that one cointegration vector exists for the nine time series. *Third*, we examine if the G8 stock markets exercise a long-run causal influence on China's stock market. *Fourth*, we investigate if the volatility in the Chinese stock market is due primarily to its own fluctuation or that of the other eight stock market indexes that we use to represent world markets. *Fifth*, we examine if shocks in the stock markets of the G8 nations can influence the Chinese stock market.

Our findings are as follow. After establishing that the time series data for all nine stock market indexes are non-stationary at the level (indicating market efficiency) and stationary at the first difference, trace and maximum eigenvalue tests reveal that the time series data for the nine international stock indexes experience a high degree of integration with one cointegration vector existing for the nine time series (indicating market efficiency). Thus, we find support for our first two research hypotheses.

The vector error correction model (VECM) reveals that short-run and long-run dynamic relations exist among the nine indexes with UK's stock market having the most influential impact on China's stock market where an increase in the UK stock market (as represented by the FTSE 100 index) by 1% is associated with a decrease in the Chinese stock market (as represented by the CSI 300 index) of 7.62%. Furthermore, the VECM test reveals that all stock markets provide changes in the short-run to adjust for any deviation from the long-run common drift. Thus, we detect support for our third research hypothesis as well as the possibility for abnormal profits since all indexes are slightly removed from equilibrium and so offer a short-run window of profit opportunity that can earn an abnormal rate of return before moving to the equilibrium.

A variance decomposition analysis suggests that the G8 stock markets are not the major source of fluctuation in Chinese stock market in the short run as the major source is the China market itself as represented by the CSI 300. However, in the long run, the UK and US stock markets (as represented by FTSE 100 index and NDX 100 index, respectively) become ever increasing sources of fluctuation in CSI 300 index. This is especially true for UK. Thus, we obtain some support for our fourth research hypothesis.

The impulse response function (IRF) indicates that a change in the English, Italian, and US stock market indexes lead to a negative change in the Chinese index, while the French, German, and Japanese indexes elicit a positive change. Thus, we find support for our fifth research hypothesis. In addition, our results suggest that investors still have a small opportunity to diversify their portfolio by investing across nations with the Chinese index providing more potential for international portfolio diversification. All indexes indicate a short-run window of profit opportunity reflective of transitory market inefficiency.

The remainder of this paper is as follows. Section 2 provides a literature review covering four areas of research related to our study: internationalization of stock markets; comovement among stock markets; global stock markets integration; and, G7-related studies. Section 3 presents our hypotheses, data, and methodology that respectively include: five hypotheses; nine nations tested; nine indexes used to represent the nine nations; two unit root tests; two cointegration tests; VECM assessment; variance decomposition analysis; and IRF examination. Section 4 reports our results. Sections 5, 6, and 7 offers materials and methods, a discussion of finding, and conclusions, respectively.

2. Literature Review

This section provides a literature review covering four areas of research related to our study. *First*, we review the research on the internationalization of stock markets. *Second*, we overview comovement among international stock markets. *Third*, we look at the literature on global stock markets integration. *Fourth*, we summarize the G7-related research that is most germane to this study.

2.1. Internationalization of Stock Markets

The internationalization of stock markets refers to the process whereby entities (issuers, investors, broker-dealers, and financial marketplaces) cross national borders seeking a transaction in equity securities. As noted by Al Janabi et al. (2010), this process offers benefits for all participants. They state that their findings on the internationalization of stock market (using the Gulf Cooperation Council equity markets) have important policy implications and should be of interest not only to policymakers but to investors, researchers, and regulators. While studies can show the wisdom of combining international markets, it should also be pointed out that the internationalization of stock markets can indirectly occur within domestic markets as evident in the amount of business conducted worldwide by large domestic companies. As of the end of 2017, Brzenk (2018) reports that nearly forty percent of the revenue by firms in the US S&P 500 Index came from nations outside the US with China accounting for ten percent. In addition, domestic investors can purchase mutual funds that include an array of international stocks or international exchange-traded funds (ETFs).

Regardless of the capacity for a domestic stock market to contain companies with large international revenue, the internationalization of stock markets is still relevant as it aids financial advisors and investment companies to improve portfolio diversification for their clients. The major benefit of improved diversification is a further reduction in the risk associated with unwanted price variability. Risk reduction occurs because investments in different sovereign nations are less correlated compared to those within a nation. The end product of diversification is an optimal outcome in terms of return and risk. There is an abundant of research that shows the benefits from diversification across stock markets of different nations. For example, Sharma and Bodla (2011) demonstrate that there exists opportunities for diversification for investors among the stock exchanges of India, Pakistan and Sri Lanka. More recently, Salahuddin et al. (2021) identify the diversification opportunities and association between correlation and integration among 62 international stock markets.

Diversification goes hand in hand with the integration of international stock markets as perfect integration allows any domestic investor to invest in any foreign market and any foreign investor to invest in any domestic market. Bekaert and Harvey (2003) explore the financial effects of market integration and diversification benefits from investing in emerging markets. They note that markets are considered integrated when assets of identical risk command the same expected return irrespective of their domicile. In agreement, Korajczyk (1999) adds that if stock markets are interconnected, risk sharing should be the same across markets. This sameness results from the same patterns of positive correlation of returns that occur among portfolios across different nations. For these portfolios, all investors can own the same world market portfolio. This portfolio is efficient if the prices of all portfolio stocks reflect all relevant information. To the extent current prices embody all information contained in past prices (so that no technical analysis can aid investors), the portfolio is weak form efficient. If the current prices reflect all public information (so that no technical or fundamental analysis can aid investors), the portfolio is semi-strong form efficient. Finally, to the extent the current price contains all public and private information, the portfolio is strong form efficient.

Market efficiency research covers a wide array of international markets. Findings differ over time with the differences evident from the early studies. The seminal study by Fama (1965) uses a serial correlation model, run tests, and Alexander's filter technique on a sample of 30 large US companies stocks. For all tests and for all differencing intervals, the amount of dependence in the daily price data is interpreted as either extremely slight or else non-existent. Fama's investigation supports weak form market efficiency, also known as random walk theory. This theory emphasizes that historical stock price behavior cannot be used to predict future prices and achieve abnormal returns. Conrad and Jutter (1973) examine random walk theory by performing parametric and non-parametric tests using German stock prices. Their results do not fully support weak form market efficiency. Chan et al. (1992) examine major Asian and US stock markets and offer support for market efficiency.

2.2. *Comovement among Stock Markets*

Comovement is the subject of the research project by Baur (2004) who attempts to define and measure comovement. Comovement can be used to describe the strong positive correlation among stock returns where a stock return embodies the change in price from one period to another. Unlike individual stocks, the correlations among international stock markets are relatively low. While there was a steady and somewhat modest increase in the correlation of international stock markets for fifteen years prior to the global financial crisis of 2007-2008, Rabener (2021) notes there have been no significant change since then. While this can suggest that stock market globalization has peaked, Rabener argues that peaking is unlikely because China has been more integrated into the global economy since the financial crisis.

The vector error correction model (VECM) is used to discover comovements in short-run and long-run stock prices among international exchanges (or indexes representing those exchanges). Gerrits and Yuce (1999) utilize the VECM to detect comovements in stock prices among the stock exchanges in the US, UK, and Netherlands. Yang et al. (2003) apply the VECM to examine the impact of the European Monetary Unit (EMU) on the integration of European equity markets. They find that the comovement among the stock indexes increases after the establishment of EMU (which was introduced in 1979 and replaced by the euro in 1999). Using daily returns from 1980-2006, Johnson and Soenen (2009) discover a significant contemporaneous association between Germany's equity market and all other European Union (EU) stock markets. However, they detect no significant indication that the German market leads or lags the movements in the other EU markets. Three factors have positive effects on stock market comovements between the German market and other EU markets: difference in equity market capitalization; the greater foreign direct investment by Germany; and, membership in the eurozone (by adopting the euro). Two factors have negative effects: a higher share of imports by Germany from other EU nations and fluctuations and volatility in the exchange rate. Karamanou and Nishiotis (2005) find that the announcement of International Accounting Standards (IAS) adoption has an economically significant long-run reduction in the cost of capital indicating comovement acceleration in the European equity markets.

2.3. *Global Stock Markets Integration*

Raju and Pavto (2019) review the literature on global stock market integration which they define as stock markets of different regions marching together in the same direction to ensure identical returns on assets for a particular risk factor. They note that opening the doors of financial markets to foreign capital (through the relaxation of the various rules and regulations) has helped advance global stock market integration. They gather 223 research papers on stock market integration for a period ranging from 1972 to 2018. China is mentioned fifteen times in their synopsis of the findings for these 223 papers. They report mixed findings concerning the integration of the China stock market with other stock markets. This indicates there is potential for portfolio diversification by adding Chinese stocks to a portfolio. Noteworthy for our purposes, we find no indication from Raju and Pavto's literature review that prior stock market integration research deals with our sample of nations and even less indication with our time period. In brief, we can find no studies that parallel this paper's study of G8 nations and China.

Among global stock market integration researchers that examine China are Karim and Majid (2010) and Nishimura and Men (2010). As described below, these two studies are relevant to this paper's research. *First*, Karim and Majid investigate the stock market integration and short-run dynamic interactions between the Malaysian stock market and the stock markets of its major trading partners consisting of the US, Japan, Singapore, China and Thailand. For a period from January 1992 to May 2008, they find that the stock markets of Malaysia and its major trading partners are found to be integrated. To some extent, they show that trade does matter for stock market integration. In addition, geographical proximity and the close association between nations further contribute to a greater integration between nations. In order to achieve a greater financial integration among countries, they argue that trade liberalization (including the reduction or removal of trade and investment barriers) is necessary. Of importance, our study (compared to the Karim and Majid study) includes a more current period where trade liberalization has been more prevalent even in spite of large geographical differences that can exist between G8 nations and China. *Second*, Nishimura and Men (2010) examine common stock prices between China and G5 countries of Japan, US, UK, Germany and France from January 5, 2004 to December 31, 2007. They discover that the China stock market had a significant influence on the larger stock markets of US, UK, Germany and France but the latter stock markets do not significantly influence the smaller China market. They interpret this outcome as a particular phenomenon that can be attributed to the rapid economic development and severe capital regulation in China. As the integration of stock markets evolves among nations, equity capital becomes more mobile across nations eventually becoming available on a full global scale. In this paper, we include the same G5 nations in our sample of G8 nations enabling us to determine if a reversal has taken place where stock markets of major nations can now influence China's market.

One outcome for a group of nations (such as G5 or G7 or G8) is to create stability among nations and thus influence stability in the world. However, the outflow of funds from a nation's capital market can create instability. For example, instability results from a shortage of liquidity in a domestic nation's long-run investments. This illiquidity affects (i) the economic system composed of the organization of resources, services, and goods and their distribution within a nation and (ii) the financial system consisting of banks, insurance companies, and stock exchanges. An aid to maintaining stability involves stock exchanges entering alliances such as through cooperative agreements, mergers, and joint ventures. Researchers (Al Janabi, et. al., 2010; Cybo-Ottone, et. al, 2000; Domowitz, 1995; Hasan and Schmiedel, 2004; Xiao and Wang, 2020) confirm that such alliances reflect a new strategy to enhance the value of stock markets. In addition to stock market alliances, nations all over the world enter into various economic agreements and form associations that further bring stability to the economic and financial systems of the association's nations. These agreements and associations support the removal of legal and cultural barriers in order to mobilize the flow of funds between member nations (Alexakis and Vasila, 2013; Batten, *et. al.*, 2006; Mariani, *et. al.* 2020).

One of the best examples of a group of nations (joined to accelerate the economic development of its members) is G7. This is seen by its history as now briefly described. In 1973, the original group (G4) consisted of only four members: US, France, Germany, and UK. Japan was added shortly after and group was called G5. Italy and Canada were added later so that by 1976 it was G7. In 1998, Russia officially joined the group (G8). By 2014, Russia was on its way out after its invasion of Crimea and so G8 was back to G7. The global financial crisis (from December 2007 through June 2009) negatively affected the stock markets of G8 nations that existed at that time. The crisis challenged investors to revisit their investment strategy. Such a strategy includes examining the merit of international diversification when constructing a portfolio. Such a strategy is consistent with studies such as those that examine the benefits of diversification between multiple exchanges and stock market comovements (Agyei-Ampomah, 2011; Johnson and Soenen, 2009). Given the importance of building international diversified portfolios that decrease volatility, the study of stock markets integration among the largest industrial nations is important both for individual and institutional investors. In this paper, we address this issue by examining the integration of nine large stock markets.

2.4. G7-Related Studies

Erdem and Ulucak (2016) overview the literature on market efficiency in G7 nations and note that the research on G7 nations is limited. Based on twelve G7 studies, they offer mixed results on market efficiency. For the most part, these twelve studies consider one or more G7 nations in combination with non-G7 nations. To illustrate support for market efficiency among these twelve studies, Morley and Pentecost (2000) use a cointegration test for G7 nations for 1982-1994 and detect support for market efficiency as the time series data move together in the long run. In addition, Narayan and Smyth (2007) apply unit root tests with structural breaks to G7 nations for 1975-2003 and find evidence of market efficiency. In regard to market inefficiency, Balvers et al. (2000) test market efficiency by employing panel unit root for 18 developed nations including G7 nations in the period of 1969-1996 and offer evidence that markets are inefficient. Furthermore, Saramat and Dima (2011) apply unit root test to UK, Japan, and USA for 1995-2010 and discover support for market inefficiency.

In their own study, Erdem and Ulucak (2016) note that they first test market efficiency by unit root tests and find support for the weak form of market efficiency for each G7 nation. They next perform the causality test in paired samples and find support for semi-strong form of market efficiency. Thus, they conclude that any investor who takes a position in the G7 stock exchange markets can not gain abnormal profit by using past information and any new publicly available information. Finally, they contend that there are international portfolio benefits in that investors can reduce the risk of their investment for the same expected returns if they establish portfolios that consist of more than one G7 stock market.

Hardouvelis et al. (2006) include G7 members in their study that examines the hypothesis that the prospect of the Economic and Monetary Union was the causal driver behind the observed increase in stock market integration among Eurozone nations that adopted the euro as its currency during the 1990s. They find that the degree of integration had ups and downs, but in the second half of the 1990s the stock markets converged toward full integration with expected returns becoming increasingly determined by Eurozone-wide market risk and less by local risk. They offer two main reasons for this integration. *First*, the experience in UK, an European Union (EU) nation that chose not to join the Eurozone, showed no signs of increased integration with the EU stock market. *Second*, the integration in Europe appears to be a Eurozone-specific phenomenon, independent of a possible simultaneous world-market integration.

In another EU study, Alexakis and Vasila (2013) investigate European equity market integration by analyzing volatility spillover effects between selected indexes of high liquidity from the major regulated European equity markets (Euronext-Paris, Deutsche Boerse, London stock exchange, Euronext-Amsterdam, Borsa Italiana and OMX Stockholm stock exchange). They examine each pair of indexes using the conditional variance of the VAR-GARCH model. Their results provide evidence on strong EU equity market integration. They argue that the high degree of market interconnection among the EU stock markets exerts significant influence on the efficient operation of each market and on asset and index pricing, which has therefore to be taken into account by investors and traders as market prices are set in common.

Seth and Sharma (2015) use various econometric tests to analyze the informational efficiency and integration between the US and a set of major Asian stock market for the years from 2000 to 2010. They find that the markets under consideration are weak-form inefficient providing the opportunity for abnormal returns for investors. The results also suggest that international markets are integrated in the long run making international portfolio diversification insignificant. In addition, Dunis et al. (2013) investigate the empirical dimensions of correlation by pitting the stock markets of the five newest EU members (Estonia, Cyprus, Malta, Slovenia, and Slovakia) with the remainder of the stock markets in EU nations. They detect an increasing trend of integration between the stock markets of newest member nations with the stock markets for the remainder of European nations. Hamao et al. (1990) find that price volatility spillovers effects for the US, Japan, and UK depend on the period examined. In agreement with other studies such as Chen et al. (2002), their results are robust to stock prices being denominated in either US dollars or the nation's currency.

3. Hypotheses, Data, and Methodology

This section begins by presenting our five research (or alternative) hypotheses from which null hypotheses are formed. Next, we describe the nine nations, the nine stock markets indexes, and the data source to get price data for these indexes. We then provide information on the methodology used when testing our research hypotheses.

3.1. Research Hypotheses

From what we can decipher, the literature reveals a lack of research on testing the dynamic linkages among the stock markets of large industrial nations and their impact on the Chinese stock market. This is especially true for periods after the 2007-2008 global financial crisis. Our major purpose (of examining the impact of large industrialized stock markets on China's market) addresses this void in the research. To achieve our major purpose, we lay out an agenda with a number of goals. The initial goal is to determine the degree of integration among world stock markets represented by stock market indexes for nine of the largest industrial nations. The latter consists of the G8 nations and China. The ultimate goal involves investigating the impact of large world stock markets (as represented by the markets for G8 nations) on the Chinese stock market. In this investigative process, we examine both the speed of adjustment in stock markets toward the equilibrium in the long run and also the volatility in the Chinese stock market. In regard to the latter, we want to know if China's stock market volatility is due to its own fluctuations or if its volatility is generated by other major stock markets. We also want to understand the nature of any shocks from major world stock markets that might influence China's market. Finally, we want to find out if the outcomes of our agenda can help managers and practitioners implement strategies involving portfolio diversification as well as aid researchers in their understanding of world stock market efficiency.

In terms of formal testing, the above agenda forms the foundation for five alternate or research hypotheses. *First*, world stock markets represented by our nine stock markets and their corresponding indexes are stationary. *Second*, a long-run dynamic relation exists among the nine indexes as they experience integration. In other words, we can offer solid statistical evidence that at least one cointegration vector exists for the nine time series that cover stock markets for nine of the more important industrialized nations. *Third*, G8 stock markets exercise a long-run causal influence on China's stock market. As indicated in our literature review, Nishimura and Men (2010) find that a smaller version of today's China influences four other major stock markets (namely, US, UK, Germany and France) but those major stock markets do not influence China. Our third research hypothesis will examine if the latter holds for a much more recent period that we test. *Fourth*, the volatility of the Chinese stock market can be attributed to G8 stock markets. To illustrate, tests can be conducted to reject any hypotheses that states fluctuations in the Chinese stock market is caused internally. *Fifth*, shocks in world stock markets can influence one another. In particular, given our China focus, we want to know if the impulse response function (IRF) is able to document the impact of shocks in G8 stock markets on the Chinese market.

Given our five research hypotheses, we formulate five corresponding null hypotheses that we seek to reject. These null hypotheses are as follow where "world stock markets" are represented by G8 and China stock markets in ***NH1*** and ***NH2*** and by only G8 stock markets in ***NH3***, ***NH4***, and ***NH5***.

Null Hypothesis 1 (*NH1*): World stock markets are non-stationary.

Null Hypothesis 2 (*NH2*): A long-run dynamic relation among world stock markets does not exist as world stock markets are not integrated. (No cointegration vector exists among the nine time series representing world stock markets.)

Null Hypothesis 3 (*NH3*): World stock markets do not exercise a long-run causal impact on China's stock market.

Null Hypothesis 4 (*NH4*): The volatility in the Chinese stock market is due to its own fluctuation as opposed to that generated by world stock markets.

Null Hypothesis 5 (*NH5*): Shocks in world stock markets do not influence the Chinese stock market.

3.2. Nine Nations Tested

This study examines stock markets for nine nations that include China, the current seven nations in G7, and Russia. As described earlier, G7 was formed in 1976 with the following seven members: France, Germany, UK, Italy, US, Japan, and Canada. Of importance, G7 consists of the world's largest International Monetary Fund (IMF) advanced economies in terms of per capita income. While G7 contains only 10% of the world's population, it has 50% of the global net worth. G7 is perceived as a prestigious backdrop for debating and providing answers to the most important global issues, especially in the areas of trade, security, economics, and climate change. As indicated earlier, G7 was G8 from 1998 through 2014 when Russia was a member. However, as judged by democratic and humanitarian standards, Russia had ongoing problems with fitting in politically and ethically. These problems reached a climax in 2014 when Russia violated the international law that prohibits the acquisition of part or all of another state's territory through coercion or force. Consequently, this violation led to Russia's ouster from G8 in 2014. Russia invaded Ukraine in February of 2022 causing a month's shut down of its stock market and the lost of over one-third of its value. From the response to the invasion (largely from Democratic nations), Russia is facing its first default on its foreign debt in over one hundred years. Unlike Russia, other large territorial nations like Brazil, India, and China have never been members of G7. Compared to Russia, these three nations are generally further removed geographically from G7 nations.

In regard to China (which is a focus of this study), it had an economy in 1979 that was smaller than that of Italy. However, since opening up to foreign investment and introducing market reforms, China has become the world's second-largest economy and is a global leader in a range of new technologies. As measured by GDP, Ross (2022) notes that China was expected to produce 8% of the world's output in 2021. Despite having the second largest economy and greatest population, China has not been invited to join G7. Two reasons can be given for lack of an invitation. *First*, China is not perceived as an advanced economy like G7 nations because it has a relatively low level of wealth per person and is even 18% below that for Russia. *Second*, China does not fit in politically and so, like Russia, would likely have ongoing problems if admitted into G7. These problems stem from the reality that China has been accused of human violations, suppression of media, and religious freedoms. In political leadership terms, Russia and China share one major problem in that antagonists view their leaders as narcissistic autocrats who operate without strong checks and balances from judicial and legislative branches. While leaders in democratic nations can also exhibit similar narcissistic and autocratic tendencies, they are seen as less threatening due to a strong judicial system and/or legislative system that limit and control the acting out of these tendencies. Terms of office can also limit the ability of a leader with an autocratic personality to gain total control in a democratic nation with strong checks and balances.

3.3. Nine Stock Market Indexes

A major purpose of this study is to investigate how the Chinese stock market index is influenced by stock market indexes for eight industrialized nations consisting of the current G7 nations and Russia. By main exchange, index, nation, weighting, and brief description, we describe below the nine stock markets that we study.

(1) Shanghai stock exchange; CSI 300 (refers to *China Securities Index*); China; capitalization weighting; blue-chip stock index for mainland Chinese stocks designed to replicate the performance of the top 300 stocks traded on the Shanghai and Shenzhen Stock Exchanges.

(2) Paris stock exchange; CAC 40 (refers to *Cotation Assistée en Continu*); France; uses capitalization weighting; made up of the largest 40 French companies.

(3) Frankfurt stock exchange; DAX 40 (refers to *Deutscher Aktienindex*); Germany; capitalization weighting; consists of the 40 major German blue chip companies.

(4) London stock exchange; FTSE 100 (refers to *Financial Times Stock Exchange*); UK; capitalization weighting; consists of 100 companies with the highest market capitalization.

(5) Borsa Italiana stock exchange; MIB 40 (refers to *Milano Indice di Borsa*); Italy; capitalization weighting; the benchmark stock market index for 40 of the biggest companies chosen to represent 10 economic sectors.

(6) Moscow stock exchange; MOEX (refers to *Moscow Exchange*); Russia; capitalization-weighting; use to consist of 50 Russian blue chip companies but now the number varies and was at 62 as of April 2022. (While MOEX resulted when MICEX merged with the Russian Trading System, RTS, in 2011, it was not renamed as MOEX until November 27, 2017.)

(7) Nasdaq stock exchange; NDX100 (refers to *Nasdaq Exchange* and often called Nasdaq 100); United States (US); modified capitalization weighting (largest companies have a cap); made up of 101 equity securities issued by 100 of the largest non-financial companies listed on the Nasdaq stock exchange.

(8) Tokyo stock exchange; NI225 (refers to *Nikkei Index* and often called Nikkei 225); Japan; price weighting; consists of 225 large companies from a wide array of industry sectors.

(9) Toronto stock exchange; TSX 250 (refers to *Toronto Stock Exchange*); Canada; float-adjusted capitalization weighting; contains about 250 of the over 1,500 companies but represents 70% of the exchange's market capitalization (TSX composite index is now called S&P/TSX composite index).

The stock market indexes in this study (i) manifest some form of capitalization weighting (or weighting where more value is given to larger companies), (ii) include total returns with cash distributions and capital gains, and (iii) consist of larger companies (and so are more likely to have an international presence and be listed on exchanges in different nations). The daily closing prices (denominated in US dollars for all nine indexes) are collected from investing.com, which is a financial portal that reports global financial information on a daily basis including index price data on the major stock market indexes throughout the world. With daily data, we are able to examine daily price fluctuations. Our investigation analyzes both the short-run and the long-run dynamic relation among this study's nine major stock market indexes. The period examined is from the first trade day in July 2009 through the last trade day in June 2019. This is a period largely removed from any major global financial crisis or drawn-out stock market collapse. Finally, index names and symbols are subject to change and, as noted above, Russia and Canada have experienced changes since 2009, which is the first year for which we gather data. The main change with Russia is the addition of about a dozen companies over time. However, most (if not all) indexes will replace companies over time and in the case of TSX250, the number of stocks can vary slightly and be below or above 250.

3.4. Unit Root Tests

Generally, time series data are non-stationary. A time series is stationary if a shift in time does not modify the shape of the distribution. Unit roots are one cause for non-stationarity. A unit root is a stochastic trend in a time series that is sometimes called a random walk with drift. If a time series has a unit root, it demonstrates a pattern that is random in nature.

The test for stationarity in time series data is the unit root test. The null hypothesis is that a unit root is present so that non-stationarity occurs. The alternative hypothesis is either stationarity or a variant of stationarity (such as trend stationarity). When the null is rejected, a time series has no unit root indicating it is integrated of order zero, referred to as I (0). If the time series is not integrated of I(0), then non-stationarity is present with an order that is typically one, referred to as I(1). When a time series is integrated of I(1), we say that it is no longer non-stationary but stationary at the first difference for a designated period.

In this paper, we use two unit root tests: the Augmented Dickey-Fuller test (ADF) and Phillips-Perron test (PP). The ADF test examines the presence of a unit root in an autoregressive model. A basic autoregressive model is $Z_t = \alpha Z_{t-1} + u_t$ where Z_t is a time series variable examined at period t, α is the coefficient, and u_t is the error term. If a time series generates a unit root ($\alpha = 1$), the time series data is non-stationary. The autoregressive model that tests the stationary at the first difference is:

$$Z_t - Z_{t-1} = \alpha Z_{t-1} - Z_{t-1} + u_t \tag{1}$$

$$Z_t - Z_{t-1} = (\alpha - 1) Z_{t-1} + u_t \tag{2}$$

$$\Delta Z_t = \delta Z_{t-1} + u_t \tag{3}$$

where ΔZ_t is the first difference operator represented as $Z_t - Z_{t-1}$. This model's assessment of a unit root is like testing the null hypothesis that $\delta = 0$.

ADF is based on the assumption that error terms are distributed independently and generate a constant variance. The assumption might not be true for all time series data. In contrast, PP relaxes this assumption and permits the testing of a time series under a heterogeneous distribution (nonconstant variance). In essence, PP is a modification of the ADF test that corrects for unspecified autocorrelation and heteroscedasticity in the disturbance process. The mathematical expression for the PP model is:

$$Z_t = \alpha_o + \alpha_1 Z_{t-1} + \alpha_t \left\{ t - \frac{T}{2} \right\} + u_t. \tag{4}$$

Critical values have to be computed for unit root tests. Critical values are essentially cut-off values that define regions where the test statistic is unlikely to lie; for example, a region where the critical value is exceeded with probability p if the null hypothesis is true. The null hypothesis is rejected if the test statistic lies within this region which is often referred to as the rejection region. For this study, we examine test statistics for the regression coefficients under the null hypothesis that the data is generated by $Z_t = Z_{t-1} + u_t$ where $E(u_t) = 0$. The unit root test is applied on the daily change in prices of the nine indexes, namely, CSI 300, CAC 40, DAX 40, FTSE 100, MIB 40, MOEX, NDX100, NI225, and TSX 250.

3.5. Cointegration Test

For this study, we utilize the Johansen cointegration test (Johansen, 1991) to examine for the presence of cointegrating vectors in a set of non-stationary time series data. This test has its origins in the maximum likelihood cointegration procedure of Johansen (1988) and Johansen and Juselius (1990). The Johansen (1991) test permits more than one cointegrating association so is more generally applicable than the Engle–Granger test which is based on the Dickey–Fuller (or the augmented) test for unit roots in the residuals from a single (estimated) cointegrating association. The Johansen multivariate cointegration equitation can be expresssed as:

$$Z_t = K_0 + K_1 \Delta Z_{t-1} + K_2 \Delta Z_{t-2} + \ldots\ldots + K_{p-1} \Delta Z_{t-p} + Z_{t-p} + V_t \quad (5)$$

where Z_t is a 9 × 1 vector of variables that are integrated of I(1); K is a 9 × 9 matrix coefficients for each difference lag; and, V_t is a 9 × 1 error vector. The matrix K contains information about the long-run properties of the model. If K has rank zero ($r = 0$), where r is the number of cointegrating relations, then the system is not cointegrated. If K has rank p ($r = p$ is full rank), all the variables in Zt are stationary and are all cointegrated, indicating a long-run association between the variables.

There are two types of Johansen tests. They are the trace test (λ_{Trace}) and the maximum eigenvalue test (λ_{Max}). The null hypothesis is that the number of cointegration vectors is $r = r^* < k$ versus the alternative that $r = k$. Johansen's cointegration requires a time series lag length to estimate the cointegrating vector. We use five criteria to determine the lag length. They are: the sequential modified likelihood ratio test statistic criterion (LRC); the final prediction error criterion (FPC); the Akaike information criterion (AIC); the Schwarz information criterion (SIC), and Hannan-Quinn information criterion (HQC). The time series lag length estimated under these five criteria will determine the appropriate lag selection use in cointegration tests and vector error correction estimation.

3.6. Vector Error Correction Model

The vector autoregressive (VAR) model is a general framework used to describe the dynamic interrelation among stationary variables. To use this framework for time series analysis, a first step is to decipher if the levels of the data are stationary. If the levels (or log-levels) of a time series are not stationary, then we take the first differences of the time series and try again. If the time series are not stationary then the VAR framework needs to be modified to allow consistent estimation of the relations among the time series being tested. The vector error correction model (VECM) is just a special case of the VAR for variables that are stationary in their differences by being integrated of I(1). The VECM can also take into account any cointegrating relations among the variables.

The VECM is typically used for estimating systems of integrated time series and for examining the dynamic impact of random disturbance terms on the system of variables. The VECM approach considers each endogenous variable in the equation to be a function of the lagged values of all of the other endogenous variables in the equation. In this paper, we use the Engle and Granger (1987) VECM to examine the long-run dynamic relation among the variables. The mathematical expression is:

$$y_t = A_1 y_{t-1} + \ldots\ldots + A_P y_{t-1} + B x_t + \varepsilon_t \quad (6)$$

where y_t is a vector of endogenous variables; x_t is a vector of exogenous variables; $A_1, \ldots, A_P$ and B are matrixes of coefficients to be estimated, and ε_t is a vector of error terms that might be contemporaneously correlated but are uncorrelated with their own lag values and uncorrelated with all exogenous variables.

In our study, we run the variance decomposition analysis under the VECM to investigate the effects of other selected stock market indexes on the Chinese stock market index. The variance decomposition indicates the amount of information each variable contributes to the other variables in the autoregression. It determines how much of the forecast error variance of each of the variables can be explained by exogenous shocks to the other variables. Finally, we apply the impulse response function (IRF) to examine how a shock to one endogenous variable impacts the other variables under a VECM environment. For this test, we use impulse responses to Cholesky one standard deviation innovations.

4. Results

This section presents results using the methodology discussed in the previous section. Results are contained in six tables and one figure. The results also include our comments on the level of support for our five research hypotheses.

4.1. Unit Root Test

Before we can directly investigate the short-run and the long-run dynamic relations among the nine international stock indexes, we must perform preliminary tests. To begin this process, we first check the stationary of the time series data for each stock market index. For this purpose, we perform ADF and PP tests to determine the presence of a unit root and thus non-stationarity. For these two tests, we use the logarithmic form for each index. Table 1 reports results for the ADF and PP tests.

As given in the first nine rows of the "Ln Stock Market Index" column of Table 1 (where "Ln" denotes logarithmic form), the nine stock market indexes are: CSI 300, CAC 40, DAX 40, FTSE 100, MIB 40, MOEX, NDX100, NI225, and TSX 250. These indexes were described in Section 3.3. The second and third columns provide statistical results for ADF tests and the last two columns report results for PP tests. The bottom three rows of the last four columns provide critical values.

Table 1. Unit Root Test.

Ln Stock Market Index	ADF - Level	ADF – 1st Difference	PP - Level	PP – 1st Difference
Ln CSI 300	1.7458	-5.4835	-1.9225	-9.4401
Ln CAC 40	-1.9706	-5.7987	-2.3842	-9.5301
Ln DAX 40	-2.6255	-6.9701	-3.0001	-10.159
Ln FTSE 100	-2.9295	-5.8282	-3.0101	-11.093
Ln MIB 40	-1.5924	-5.3236	-1.8555	-9.1899
Ln MOEX	-3.0008	-9.1541	-3.0021	-13.261
Ln NDX100	-2.9211	-7.6357	-3.1002	-13.404
Ln NI225	-2.6656	-8.8190	-2.8976	-10.568
Ln TSX 250	-2.6456	-5.5125	-2.8403	-11.183
0.01 Critical Value	-4.0620	-4.0632	-4.0597	-4.0608
0.05 Critical Value	-3.4599	-3.4601	-3.4588	-3.4594
0.10 Critical Value	-3.1562	-3.1564	-3.1555	-3.1558

NOTE: Ln refer to the logarithmic form.

The values in the "ADF-Level" and "PP-Level" columns demonstrate that the nine time series for the corresponding nine stock market indexes are non-stationary at the level for both ADF and PP tests. This is because the ADF and PP level values are all higher (less negative or positive) than the three negative critical values and so fall outside the rejection region. Thus, we can not reject our first null hypothesis (*NH1*) at the level. We conclude that all nine indexes are non-stationary at the level. However, as shown in the "ADF-1st Difference" and "PP-1st Different" columns, the nine time series for the nine indexes become stationary at the first difference for ADF and PP tests as all values fall below the critical values. In conclusion, the results from Table 1 indicate that the time series for the nine stock market indexes are integrated of I(1) and so need to be differenced once to obtain stationarity. Thus, we reject ***NH1*** at the first difference level and offer evidence for our first research hypothesis that world stock markets represented by our nine indexes are stationary.

4.2. Lag Length Criteria

The next step in the process is to identify the optimal lag length, which is required to perform the cointegration equitation and utilize the VECM. To determine the optimal lag length, we use the five criteria described in Section 3.5. These five criteria are given in the first row of the last five columns of Table 2. They are: the sequential modified likelihood ratio test statistic criterion (LRC); the final prediction error criterion (FPC); the Akaike information criterion (AIC); the Schwarz information criterion (SIC), and Hannan-Quinn information criterion (HQC).

Table 2. Lag Selection Criteria.

Lag (in days)	LogL	LRC	FPC	AIC	SIC	HQC
0	1965.14	NA	6.42	-43.44	-43.16	43.33
1	2654.73	1210.84	1.97	-56.27	-50.54	53.32
2	2742.53	134.62*	1.32*	-56.60*	-53.44*	55.93*
3	2819.59	101.03	3.83	-55.76	-47.15	52.29
4	2921.25	110.71	6.66	-55.80	-44.42	51.22

* Indicates lag order selected by the criteria at 0.05 level.
NOTE: LogL is loglikelihood values derived from fitting different models to data, and given the corresponding number of estimated model parameters LRC is sequential modified likelihood ratio test statistic criterion; FPC is final prediction error criterion; AIC is Akaike information criterion; SIC is Schwarz information criterion; and, HQC is Hannan-Quinn information criterion.

Table 2 shows the results of the five methods when applied to the time series data for the nine stock market indexes. As given earlier, these indexes in acronym form are: CSI300, CAC40, DAX40, FTSE100, MIB40, MOEX, NDX100, NI225, and TSX250. As seen in the "Lag" column for row "2", the values for LRC, FPC, AIC, SICK, and HQC all have an asterisk (*) indicating that the lag order of two is selected by the criteria at the 0.05 level. Thus, we should use lag 2 during the cointegration analysis and VECM estimation procedures.

4.3. Cointegration Analysis

Having completed the prerequisite tests, we run the Johansen (1991) test to investigate the cointegration relation among our sample of nine stock market indexes. The Johansen test examines the null hypothesis (which is our *NH2*) that no cointegration vector exists among the time series for these indexes. The research or alternative hypothesis is that a long-run dynamic relation exists, e.g., at least one cointegration vector exists.

Table 3. Cointegration Trace Test.

Hypothesized No of CE(s)	Eigenvalue	Trace Statistics	Critical Value	Prob
None*	0.4856	202.16	197.37	0.0283
At most 1	0.3489	141.66	159.52	0.3061
At most 2	0.2797	102.62	125.62	0.5188
At most 3	0.2101	72.75	95.75	0.6263
At most 4	0.1823	51.29	69.82	0.5809
At most 5	0.1468	32.97	47.85	0.5582
At most 6	0.1144	18.53	29.79	0.5273
At most 7	0.0784	7.4629	15.49	0.5246
At most 8	0.0038	0.0348	3.42	0.8519

* Denotes the rejection of our second null hypothesis (*NH2*) that there is no cointegration at 0.05 significance level. Thus, consistent with our second research hypothese, the trace test indicates one cointegration equation (CE) at 0.05 significance level.

The two cointegration tests utilized in this study are the trace test (λ_{Trace}) and the maximum eigenvalue test (λ_{Max}). The results for the trace test are given in Table 3 and those for the maximum eigenvalue test (λ_{Max}) are found in Table 4. As seen in these tables, both cointegration tests are significant at the 0.05 level. Thus, they offer solid statistical evidence that one cointegration vector exists in the long run for the nine time series that we examine for our nine sample nations.

In conclusion, given the results in Tables 3 and 4, we reject *NH2* that no cointegration vector exists among the nine time series. Thus, we accept our research hypothesis that a long-run dynamic relation exists among these time series. These results are generally consistent with other researchers (Alexakis and Vasila, 2013; Dorodnykh, 2014; Seth and Sharma, 2015; Yang, *et al.*, 2003) in terms of cointegration among international stock markets. In addition, Gagnon *et al.* (2016) derive similar results from exploring the long-run dynamic relation among international stock markets using stock option data.

Table 4. Cointegration Max-Eigenvalue Test.

Hypothesized No of CE(s)	Eigenvalue	Trace Statistics	Critical Value	Prob
None*	0.4856	60.49	58.44	0.0341
At most 1	0.3489	39.05	52.36	0.5544
At most 2	0.2797	29.86	46.23	0.7881
At most 3	0.2101	21.45	46.23	0.9348
At most 4	0.1823	18.32	33.87	0.8612
At most 5	0.1468	14.44	27.58	0.7901
At most 6	0.1144	11.65	21.13	0.6402
At most 7	0.0784	7.43	14.26	0.4399
At most 8	0.0038	0.03	3.84	0.8519

* Denotes the rejection of our second null hypothesis (*NH2*) that there is no cointegration at 0.05 significance level. Thus, consistent with our second research hypothesis, the max-eigenvalue test indicates one cointegration equation (CE) at 0.05 significance level.

4.4. VECM Estimation

If a set of variables are found to have one or more cointegrating vectors then a suitable estimation technique for investigating long-run causal influences among stock market indexes is the VECM (Vector Error Correction Model). The appropriateness of this model lies in its capacity to adjust for short run changes in variables as well as deviations from equilibrium. With this in mind, we use the VECM to further investigates the dynamic relations among our sample of nine stock market indexes and whether or not they can influence one another. Given this paper's purpose, our application of the VECM test focuses on how the time series data for the G8 stock markets impact the time series for China's market. The results for the VECM test are reported in Table 5 and described below.

First, Table 5 shows that the UK stock market (as represented by the FTSE 100 index) has a large influence in the long run on the Chinese stock market (as represented by CSI 300 index). For example, as seen in the "*Coefficient*" column, an increase of 1% in the FTSE 100 index (as given by the coefficient 1.00000) results in a change of about -7.62% in the CSI 300 index (as given by the coefficient -7.62025). As seen in the "*P-Value*" column, UK has the lowest value indicating the greatest significance. Similarly, the results for the Italian and US stock markets (as represented by the MIB 40 and NDX 100 indexes, respectively) also manifest a significant negative relation with the Chinese stock market.

Second, in contrast to the negative coefficient for the UK stock market, Table 5 reports that the French and Canadian stock markets have large positive coefficents where a 1% increase in the CAC 40 and TXS 250 indexes cause respective increases of 4.65% and 3.99% in the CSI 300 index. The results for the Japanese stock market (as represented by the Nikkei 225) also manifest a significant positive relation with the Chinese stock market in the long run.

Third, Table 5 reveals that the Russian and German stock markets (as represented by the MOEX and DAX 40 indexes) have insignificant long-run relations with CSI 300 index.

Fourth, as seen in the final cell of Table 5, the α coefficient is significantly different from zero. This reveals that all variables bring change in the short run to adjust for any deviation from the long-run common drift.

In conclusion, we cannot reject *NH3* for the German and Russian stock markets. For the other six national stock markets, our results indicate rejection of *NH3*. Thus, for France, UK, Italy, US, Japan, and Canada, we accept the general research hypothesis that world stock markets exercise a long-run causal impact on China's stock market.

Table 5. Vector Error Correction Estimates.

Nation	Stock Market Index	Coefficient	Standard Error	*P*-Value
China	CSI 300 (-1)	1.00000		
France	CAC 40 (-1)	4.64916	-1.63467	0.022*
Germany	DAX 40 (-1)	0.59403	-0.81410	0.487
UK	FTSE 100 (-1)	-7.62025	-1.07212	0.000**
Italy	MIB 40 (-1)	-2.60375	-0.82880	0.014*
Russia	MOEX (-1)	-0.37861	-0.30953	0.256
US	NDX100 (-1)	-1.17890	-0.40434	0.019*
Japan	NI 225 (-1)	0.66316	-0.21404	0.015*
Canada	TSX 250 (-1)	3.99288	-0.88183	0.002**
	α			0.000**

* Indicate 0.05 significance level. ** Indicates 0.01 significance level. One-tail test.

4.4.1. Variance Decomposition Analysis

Table 6 reports the results from the variance decomposition analysis. This analysis indicates the amount of information each stock market index contributes to the other indexes in the autoregression. In brief, it determines how much of the forecast error variance of each of the variables can be explained by exogenous shocks to the other variables. For Table 6, we report results to address our fourth research hypothesis: the volatility in the Chinese stock market is due to its own fluctuation as well as that generated by world stock markets (as represented by the G8 stock markets).

In Table 6, the "Period" column represents the ten years from July 2009 through June 2019. For our period of study, we consider any length of time that is four years or less as "short run". Thus, tests greater that four years (e.g., five years or more) are "long run". For the first four years, Table 6 shows that the eight other stock markets cannot explain one-fourth of the short-run fluctuation in Shanghai stock exchange (CSI 300 index). This suggests that other stock market indexes are not the major source of the short-run fluctuations. In fact, Table 6 reveals that 100% of the volatility generated within the CSI 300 index in period one is due to its own internal dynamics as represented by the inner shocks specific to the CSI 300 index and thus largely specific to the nation of China where the index resides. The 100% is denoted in the value given as 100.00 in the cell where the row for period 1 and the column for CSI300 intersect. Similarly, for periods 2, 3, and 4, we find large volatility from internal shocks. Table 6 reports that 93.66%, 82.62%, and 76.17% of the volatility occur for these three respective periods.

In looking at periods 5 through 10, we discover that a large source of long-run fluctation in the CSI 300 index is still mostly internally generated. For example, even after ten years, 57.27% of the fluctuation can be assigned to random internal shocks. Regardless, other stock exchange indexes can also exercise an influence on long-run fluctuation in the CSI 300 index. This is especially true for the London stock exchange represented by the FTSE 100 index where its contribution to fluctuation ranges from 15.15% to 24.45% for long-run periods ranging from 5 to 10 years. The impact on the CSI 300 index from NDX 100 and NI 225 are the next two indexes with the greatest influence on fluctuation in index prices for the CSI 300. In contrast, Table 6 indicates that the TSX 250 index has a very little contribution in fluctuation of CSI 300 index.

Table 6. Variance Decomposition Analysis.

Period	S.E.	CSI300	CAC40	DAX40	FTSE100	MIB40	MOEX	NDX100	NI225	TSX250
1	0.03	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.04	93.66	1.10	0.34	2.79	0.82	0.69	0.11	0.49	0.00
3	0.05	82.62	1.25	0.22	8.15	3.36	0.45	2.12	1.72	0.11
4	0.06	76.17	0.98	0.26	11.58	3.46	0.37	4.52	2.55	0.10
5	0.07	71.33	0.82	0.37	15.15	3.33	0.35	5.81	2.73	0.10
6	0.07	66.76	0.73	0.47	18.09	3.45	0.31	6.71	3.38	0.09
7	0.08	63.23	0.64	0.55	20.34	3.43	0.28	7.42	4.02	0.07
8	0.08	60.84	0.58	0.60	22.04	3.35	0.28	7.95	4.30	0.07
9	0.09	58.89	0.52	0.65	23.37	3.30	0.27	8.32	4.61	0.06
10	0.09	57.27	0.48	0.68	24.45	3.29	0.25	8.61	4.91	0.06

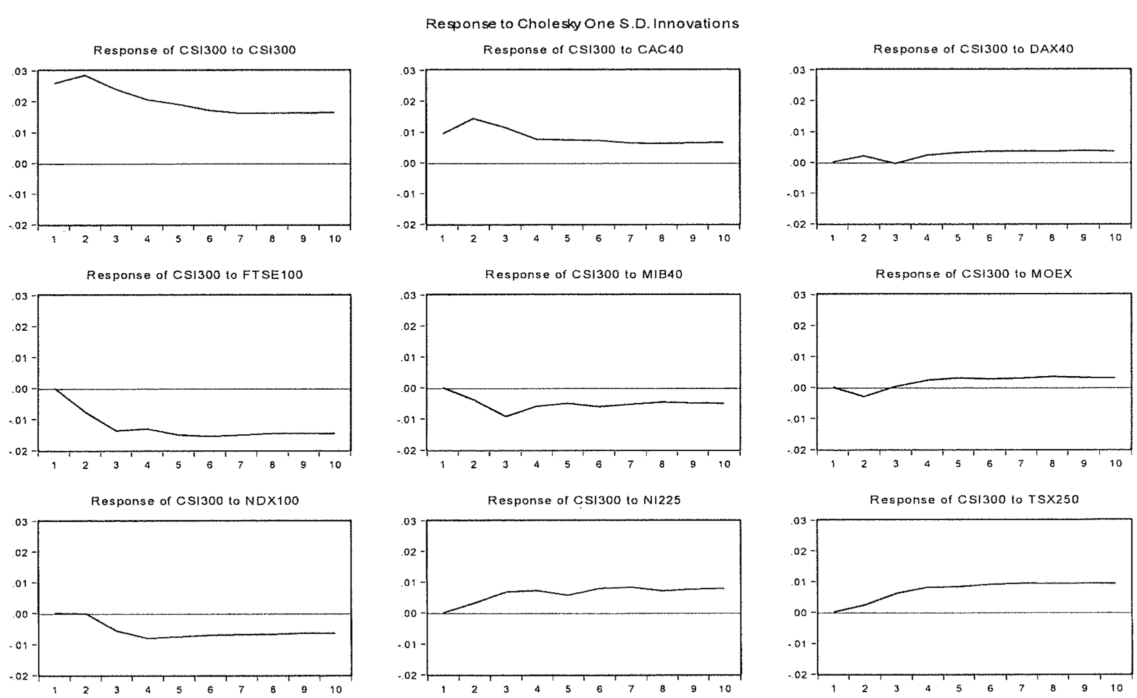
NOTE: Values in percentage form. Period 1 covers the first trading day in July of 2009 through the last trading day in June 2010 and so forth for the other nine periods.

4.4.2. Impulse Response Functions

Impulse response functions (IRFs) sketch the dynamic impact to a system of a "shock" or "innovation" that involves a change to an input. IRFs describe the reaction of endogenous variables at the time of the shock and over subsequent points in time. Figure 1 shows the impulse response of the Chinese stock market (represented by the CSI 300 index) from a one standard deviation shock. The upper left diagram shows the response of CSI 300 to CSI 300. Like the results from the variance decomposition analysis, the impulse response function results show that major fluctuations arise in the CSI 300 index due to its own dynamic in the short run.

The other eight diagrams in Figure 1 reveal the response of CSI 300 to each of the G8 stock markets (as represented by their stock indexes). The statistical significance of IRF has been examined at 95% confidence interval. These eight diagrams show that a one standard deviation change in the French CAC 40, German DAX 40, Russian MOEX, Japanese NI225, and Canadian TSX 250 lead to an increase in the Chinese CSI 300 with DAX and MOEX increases smaller. In contrast, a one standard deviation change in the English FTSE 100, Italian MIB 40, and US NDX 100 indexes lead to a decrease in the Chinese CSI 300 index with the FTSE 100 decrease larger.

Figure 1. Impulse Response Function (IRF).



5. Materials and Methods

All material and methods are described in our paper. As noted Section 3.3, the daily closing prices we use is from investing.com at https://www.investing.com/indices/. It is supplied free for academic researchers.

6. Discussion

We extend international stock market linkage research by exploring the dynamic relation among stock market indexes in the G8 nations (current G7 nations and Russia) and China. The major purpose is to investigate the impact of the G8 stock markets on the Chinese stock market. To our knowledge, this is the first times series study that includes these nine nations. Our study is unique in documenting the impact of the stock markets of G8 nations on China's stock market. Our period of examination consists of the most recent ten-year period that is largely (if not totally) removed from the impact of a major crisis. Thus, our results should be largely free from the interference of crises like the real estate bubble (December 2007 through June 2009) and the pandemic that began shortly before July 2009. As noted by Chen et al. (2002), economic contagions and spillovers create dependencies in prices across countries and they bias results towards finding linkages.

To achieve our purpose, we first perform preliminary tests. These include establishing that the time series data for all nine stock market indexes are non-stationary at the level and stationary at the first difference. For the latter, trace and maximum eigenvalue tests reveal that one cointegration vector exists for the nine time series. The VECM test reveals that short-run and long-run dynamic relations exist among the nine indexes with UK's stock market having the most influential impact on China's stock market where as increase in the FTSE 100 index price by 1% is associated with a decrease in the CSI 300 index of 7.62%. In particular, for France, UK, Italy, US, Japan, and Canada, we accept the general research hypothesis that world stock markets exercise a long-run causal impact on China's stock market. These results supplement prior research (that includes G7 nations) performed on earlier time series data. For example, Nishimura and Men (2010) examine common stock prices between China and G5 countries. They discover that the China stock market had a significant influence on the larger stock markets of US, UK, Germany and France but the latter stock markets do not significantly influence the smaller China market. Thus, our results indicate how the direction of influence has changed over time.

Furthermore, we find that all indexes provide changes in the short-run to adjust for any deviation from the long-run common drift. A variance decomposition analysis suggests that other stock exchange indexes are not the major source of fluctuation in CSI 300 index in the short run. However, in the long run, the FTSE 100 index and NDX 100 index are the two major sources of fluctuation in CSI 300 index.

The IRF indicates that a change in the English, Italian, and USA indexes lead to a negative change in the Chinese Index, while the opposite reaction occurs for the French, German, Russian, Japanese, and Canadian indexes. Our results suggest that investors still have a small opportunity to diversify their portfolio to invest across the nations with the Chinese index providing more potential for international portfolio diversification. All provide a short-run window of profit opportunity.

In the broadest context, our results bear similarities to prior studies of international stock market indexes. Like our study, prior studies can include some of the same nine nations we include as well as other nations. Like our study, prior studies often show non-stationarity at the level and stationarity at the first difference; find a cointegration vector for the time series data that they examine; document the sources of fluctuation in stock market indexes; and show the value of international portfolio diversification while commenting on profit opportunities that might exist. Thus,the results of the hypotheses that we test can can be found when other groups of nations are examined. Given the totality of prior research, our study is different in terms of its focus on how industrialized nations influence China's stock market.

By including the current G7 nations, our study covers the pillars of the most industrialized and *democratic* nations. By including Russia and China, our study covers the pillars of the most industrialized and *autocratic* nations. Thus, two types of governments are represented: democratic and autocratic. The implications from these two political types is that both similarities and dissimilarities can exist in time series data when comparing democratic and autocratic governments. For example, the autocratic nation of Russia and the democratic nation of Germany had little impact on the autocratic nation of China while the democratic nation of UK has a great impact. However, more research is needed before we can say that the greatest stock markets impacts are related the government types.

In highlighting future research, there are several areas that can be explored. *First*, our research can expand to include different indexes for the same nations. For example, how would our results change if had included the S&P 500 index instead of the NDX 100 index? In addition, an explanation for the greater impact of the FTSE 100 index is that many of its companies have an international focus. Future research can test the FTSE 250 Index as it contains a smaller proportion of international companies. *Second*, our research can expand by attempting to filter out companies. For example, how would our results change by choosing an index with fewer companies with greater amounts of foreign revenue? Similarlity, how would our results change if an index was filtered to take out companies where most of its revenue comes from nations with large foreign endeavors?

7. Conclusions

In this paper, we extend international stock market linkage research by exploring the dynamic relation among stock market indexes in G7 nations, Russia, and China. G7 linkage research is limited. In addition, this limited research if further constrained by often focusing on the linkage among G7 nations and non-G7 nations including emerging market nations. To our knowledge, this is the first G7 study that includes all seven members of G7 as well as both Russia and China. Furthermore, our study is unique in documenting the impact of the Chinese stock market on the stock markets of Russia and G7 nations. In addition, our period of examination consists of a recent ten-year period (from July 2009 through June 2019) that is removed from a major crisis. This period begins after the end of the the real estate crisis (June 2009) and ends shortly after the pandemic crisis began (March 2019).

We initiate our empirical testing by establishing that the time series for all nine stock market indexes are non-stationary at the level and stationary at the first difference. Next, we proceed to examine the degree of integration among the indexes using the Johansen cointegration method. This method involves trace and maximum eigenvalue tests. These two tests reveal that the time series data for the nine international stock indexes experience a high degree of integration. In brief, we offer solid statistical evidence that one cointegration vector exists for the nine time series that cover nine of the more important industrialized nations.

We next examine the relation among this study's nine stock market indexes using the vector error correction model (VECM). The VECM test reveals that both a short-run and a long-run dynamic relation exist among these indexes. Of importance, the VECM test further indicates that UK's stock market has an influential impact on China's stock market in the long run. For example, an increase in the FTSE 100 index price by 1% is associated with a decrease in the CSI 300 index of 7.62%. When applying the VECM, the α coefficient is 10.43276, which is significantly different from zero. This result indicates that all variables provide changes in the short-run to adjust for any deviation from the long-run common drift.

Finally, we perfom a variance decomposition analysis. This analysis suggests that other stock exchange indexes are not the major source of fluctuation in the CSI 300 index in the short run. However, in the long run, indexes for G8 nations can become an ever increasing source to explain fluctuation. This is especially true for the FTSE 100 index and, to a lesser extent, for the NDX 100 index. The findings of the impulse response function (IRF) suggest that a one standard deviation change in the indexes of FTSE 100, MIB 40, and NDX 100 lead to a noticeable decrease in the CSI 300 index. In contrast, a one standard deviation change in the indexes of CAC 30, DAX 40, and Nikkei 225 lead to a noteworthy increase in the CSI 300 index. The TSX 250 and MOEX indexes have very little impact on the CSI 300 index. Overall, our results suggest that investors still have a small opportunity to diversify their portfolio to invest across nations. In particular, the CSI 300 index provides a better chance of international portfolio diversification. All indexes are also a bit removed from equilibrium and so provide a short-run window of profit opportunity that can earn an abnormal rate of return before moving to the equilibrium.

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