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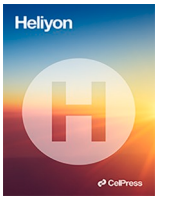

Research article

Chinese stock market integration with developed world: A portfolio diversification analysis

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ABSTRACT

This study investigates integration dynamics between the Chinese stock market and major developed counterparts—Australia, Germany, Japan, the UK, and the US—focusing on portfolio diversification. Using a comprehensive analytical approach from 2012 to 2022, encompassing events like the Belt and Road Initiative, the Shanghai market crash, US-China trade tensions, and the COVID-19 pandemic, the research employs descriptive statistics, unit root tests, cointegration analysis, and VECM-based Granger Causality Tests. Findings indicate modest integration, endorsing diversified portfolios for developed country investors due to higher returns in China with acceptable risk. Unit root analysis confirms cointegration with developed indices, indicating relatively low integration. Granger Causality Tests reveal bidirectional causality, emphasizing mutual influence. Notably, no causal link exists between the US and China, possibly due to regulatory disparities and the trade war. The study enhances understanding of Chinese stock market dynamics, supporting global economic intertwining and urging further openness of China's domestic shares for economic growth.

1. Introduction

The integration and portfolio diversification between Chinese and developed world stock markets represent a nuanced and intricate relationship [1]. This study specifically explores the linkages between China's stock markets and its significant trading partners: Australia, Germany, Japan, the UK, and the USA. These countries were selected based on their substantial trade volume with China and their role as major sources of foreign investment. As the world's leading exporter, boasting a positive trade balance of $458.93 billion, China's economic fortunes are closely entwined with these key partners [2–4].

The integration of China's economy with developed nations, particularly in the financial realms, introduces potential challenges stemming from varying regulatory systems and market structures [5]. However, investors from developed countries have already demonstrated substantial exposure to Chinese equities, emphasizing the need for a nuanced understanding of global equity market integration, moving beyond broad generalizations [6]. The relationships between China's equity market and those of its counterparts fluctuate across periods, demanding an exploration of the underlying factors influencing these dynamics. Regulatory forces, economic performance, and financial aspects directly shape the extent of integration and diversification among these markets, with foreign investment playing a pivotal role facilitated through offshore funds and direct participation in Chinese stocks [7]. The ongoing

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internationalization of China's market has injected new capital, enhanced liquidity, and broadened equity ownership structures [8]. However, the study emphasizes the necessity to strike a balance between the benefits of foreign investment and potential vulnerabilities to sudden macroeconomic and regulatory shifts.

Globalization, a prominent trend fostering economic growth and investment flows, has significantly increased connectivity in the world economy [9]. This trend, beneficial for emerging economies like China, has propelled the nation into a central role in the international financial landscape [10–12] The integration of the Chinese stock market with other nations has been further fortified by trade openness and increased investment [13]. Despite this growth, challenges, including heightened volatility, have emerged [14]. While economic globalization has witnessed an overall slowdown since the 2008 financial crisis, China's "Going Global" policy has played a pivotal role in expanding Chinese businesses globally, establishing it as the world's largest emerging market with rapidly growing stock markets [15–17]. Alongside other BRICS economies, China has experienced substantial growth rates, averaging 6.2 % annually compared to 1.9 % in the US [18,19]. This growth prompted a closer examination of interrelationships between world financial markets, with advancements in information technology contributing to increased market correlation [20–22]. In recent years, the Chinese government has undertaken significant steps to liberalize its capital markets, encouraging foreign investment through various reforms, including issuing B- and H-shares, improving accounting standards, and linking the Shanghai and Shenzhen markets to Hong Kong [23,24]. These reforms, initiated in 2012, aimed to deepen China's financial markets and enhance its role in financing investments, contributing to the "going global" process of Chinese stock markets [13,24]. As a result, China's stock market secured inclusion in the MSCI Global Stock Index, generating interest from foreign institutional investors [25].

China's emergence as a global leader in promoting openness and integration, as demonstrated by initiatives such as the "One Belt and One Road," which involves infrastructure development and investments in 70 countries, highlights its expanding involvement in international trade [26,27]. While skepticism exists regarding the primary benefits of this initiative for China, the inclusion of the Chinese currency (RMB) in the basket of Special Drawing Rights by the IMF in 2015 acknowledges China's increasing role in international trade [28]. Advances in China's monetary, foreign exchange, and financial systems demonstrate its growing influence and positive strides in implementing reform measures [29]. Over the past decade, China's revolutionary reforms have opened up its global market, fostering economic growth, development, and increased reserves. This transformation has elevated China's global influence, positioning it as the world's second-largest economy and a significant recipient of foreign direct investment (FDI). The World Investment Report 2021 reveals a 6 % increase in FDI in China in 2020, reinforcing China's reform agenda and growth strategy [30]. The global economy's shift towards China has created opportunities for enterprises to enter the Chinese market, signaling anticipated changes in economic integration [31].

The concept of cointegration among equity markets has recently gained attention due to its profound impact on portfolio diversification. As capital markets become increasingly integrated, achieving diversification weakens, necessitating domestic investors to comprehend the relationship between international financial markets and their domestic counterparts for favorable portfolio performance [6]. The growing interconnectedness of stock markets further diminishes the effect of diversification, compelling foreign investors to understand how Chinese equity markets respond to global shocks [32]. The crashes of the Shanghai stock market in 2007 and 2016 underscored the potential impact of emerging economies' stock markets on a global scale, causing temporary financial instability worldwide, including in the United States, Australia, Japan, and several ASEAN countries [13,33,34]. Given China's significant role in the global economy, a financial crisis could considerably influence its trading partners, particularly in the East Asia Pacific region and countries integrated into China's supply chains [13,35]. Factors contributing to the integration of international stock markets include mutual trade, globalization of financial markets, increased capital mobility, and advancements in communication and transportation technologies [36].

Extensive research has been conducted on the dynamic relationship between China and the world's developed and developing stock markets. These studies, yielding mixed findings, have contributed to early perceptions that the Chinese equity market may not necessarily correlate with global market trends [37,38]. However, other arguments assert its increasing integration with the global market [39–43]. Research by Refs. [13,44–52] have also indicated growing integration between China and its Asian neighbors' stock markets. International fund managers recognize the potential for diversification and increased returns by including investments in China and ASEAN countries within their portfolios [38,53–56]. As the Chinese authorities continue their economic reforms, financial integration between China and the rest of the globe is expected to continue its upward trajectory [5]. Examining stock market integration in finance is paramount, directly influencing asset allocation and portfolio diversification strategies. Highly integrated stock markets may lead to reduced advantages of international diversification, while fragmented markets offer opportunities for diversification and potential market variation gains [57,58]. Thus, the exploration of the benefits of international portfolio diversification has sparked significant interest in the realm of international finance.

This study comprehensively examines the integration and portfolio diversification between Chinese stock markets and its major trading partners in the developed world. Understanding the dynamics between these markets is crucial for investors and policymakers. The research delves into the changing landscape of Chinese financial markets, analyzing price and volatility transmissions before and during the 2015–2016 crash and the impact of subsequent events like the US-China tariff war of 2018 and the COVID-19 pandemic. A key objective is assessing potential portfolio diversification opportunities within these alliances. This research distinguishes itself by focusing on how Chinese stocks respond to evolving market dynamics in the countries they are traded with. Additionally, the study explores the influence of financial turmoil on Chinese and other stock markets, analyzing a sample period that includes these pivotal events. This research makes a noteworthy contribution to the existing literature through its correlation research of multivariate time series analysis of financial markets. Notably, it represents the first attempt to investigate the integration and portfolio diversification between Chinese stock markets and these selected developed world markets. The research aims to bridge a gap by examining both short- and long-term aspects of stock market integration and the potential for portfolio diversification between Chinese and developed

world stock markets. Moreover, while existing research has focused on comovements during the global financial crisis, this study uniquely investigates the consequences of significant post-crisis shocks. Specifically, the study analyzes the impact of the global crash of Shanghai's stock exchange during 2015–2016, the US-China tariff conflicts in 2018, and the outbreak of COVID-19 on stock market disruptions.

2. Literature review

This paper endeavors to scrutinize stock market comovements and explore portfolio diversification opportunities within collaborative alliances, aiming to contribute valuable insights to the existing academic literature. The integration of the Chinese stock market with the developed world is a dynamic area of research intricately linked to economic integration and interdependence. Understanding the current dynamics of these markets and the potential for efficient capital allocation through international diversification is of paramount significance to investors. Consequently, this study seeks to provide a comprehensive analysis of stock market relationships, shedding light on potential portfolio diversification strategies.

2.1. Introduction to portfolio diversification and integration

The stock market's pivotal role in economic development cannot be overstated, providing a crucial avenue for businesses to secure funds and fostering overall economic growth [59,60]. Within the financial realm, diversification and integration are vital strategic tools involving astute fund allocation across diverse assets or markets to mitigate risk [61]. Integration, a key element of this strategy, entails interlinking stock markets, exchanging crucial information, and sharing experiences of market shocks [12,62].

This review analyzes the intricate connection between Chinese stock markets and major trading partners, including Australia, Germany, Japan, the UK, and the US. Understanding the evolving relationships between Chinese and global stock markets is imperative, especially in an era where interconnectedness may threaten diversification advantages [63–65]. The current state of the global economy, especially within stock markets, showcases varying degrees of interdependence, with some markets exhibiting high levels of interconnectedness while others maintain more limited connections [66–70].

Empirical literature scrutinizes the escalating trend of financial integration among nations, particularly evident in China's stock markets after liberalization policies in 2001 [71–74]. This review tracks the evolving relationship between Chinese stock markets and counterparts in the developed world, recognizing the imperative need for making informed decisions and implementing effective risk management strategies.

2.2. Review of Chinese stock market developments

The journey of China's stock market since its initiation in 1990 unfolds a narrative of profound transformations shaped by strategic financial reforms [24]. These reforms, not merely administrative, embody a narrative of evolution with regulatory measures attracting foreign investors. These deliberate steps trigger substantial shifts in interconnectivity and diversification potential between Chinese and developed world stock markets, marking a paradigmatic shift [37,65,75].

In the intricate tapestry of global finance, emerging markets like China present a mosaic of varying integration degrees with global counterparts, necessitating further research [76,77]. Peeling back the layers of this complex relationship becomes essential to unveil the factors shaping integration dynamics, providing a roadmap for investors and policymakers navigating these uncharted waters.

China's gradual embrace of international financial markets has expanded economic horizons and woven tighter connections between its stock markets and major trading partners. Understanding the ebb and flow of these relationships is crucial for effective risk management and seizing investment opportunities within this evolving landscape [13,34,42,78].

2.3. Comparative analysis: Chinese and developed world stock markets

The integration of the Chinese stock market with developed economies has been a focal point of academic research, especially concerning portfolio diversification. Empirical studies investigating the correlation and diversification of investment portfolios involving Chinese stock markets and their developed world counterparts reveal a growing integration and interdependence between China and the global financial markets [76,77,79].

In the dramatic storyline of the COVID-19 pandemic [80], uncovered a riveting chapter, exposing the transmission of financial contagion between China and G7 countries. China and Japan emerged as central characters, acting as both transmitters and recipients of spillovers, casting a spotlight on their pivotal roles in the interconnected web of global finance. Positive connections and bidirectional causality between Chinese and developed markets signify a reciprocal influence [81,82]. Moreover, the study conducted by Ref. [74] on market integration and interdependence following the implementation of financial liberalization policies identified a notable increase over the study period. Notably, empirical research has delved into the integration between China's stock market and various counterparts in the developed world, encompassing Australia, Germany, Japan, the UK, and the US [83]. A study conducted by Refs. [84,85] suggests a demand for increased integration between China and Japan's stock markets, possibly indicating a form of market isolation for China. While existing studies suggest potential integration needs between China and Japan, these findings are not exhaustive, necessitating further research for a comprehensive understanding of the relationship between Chinese stock markets and their major trading partners.

2.4. Exploring the connection between the Chinese and Australian stock market

The integration between the Chinese and Australian stock markets is a subject of extensive scholarly inquiry driven by the increasing interconnectedness of global financial markets. This analysis aims to navigate the intricacies of their integration and assess implications for portfolio diversification, fortifying our arguments for the chosen research analysis method. Empirical studies have explored the evolving integration between these markets, influenced by economic, regulatory, and geographical factors. Economic ties and China's global prominence deepen the interdependence of their financial markets [86]. found co-movements, indicating integration, while [87,88] highlight interdependence, especially compared to the United States. Geographical proximity, notably with nearby Asian countries, has a substantial impact on the dependence effect. The importance of portfolio diversification arises from the fundamental principle of risk management, leveraging correlations between markets. The integration between the Chinese and Australian markets directly influences the effectiveness of diversification strategies [74]. research explores integration's extent and potential benefits for portfolio diversification, emphasizing existing opportunities and impact on correlation dynamics. A robust research analysis method is imperative, with cointegration analysis, as employed by Refs. [86,87], offering valuable insights into the long-term relationship between financial markets. Drawing parallels to existing research methodologies, such as [74] enhances comprehensiveness, ensuring robust findings across different statistical approaches. Identifying gaps and areas necessitating further investigation is crucial. Regulatory changes, economic policy shifts, and global market dynamics significantly impact integration [83]. research explores integration between China's stock market and various developed counterparts, underlining the need to address these gaps for a comprehensive understanding of Chinese-Australian stock market integration. In conclusion, the integration between the Chinese and Australian stock markets is complex with profound implications for portfolio diversification. Referencing scholarly insights and drawing parallels to diverse research methodologies fortifies our analytical approach. The selected research analysis method, encompassing cointegration analysis, dynamic conditional correlation models, and insights from studies like [86,89], positions us to unravel integration's intricacies comprehensively. Ongoing research and methodological refinement remain imperative for a nuanced understanding of Chinese-Australian stock market dynamics and their implications for portfolio management as global financial markets continue to evolve.

2.5. Analysis of Chinese-German market correlations

Empirical studies extensively explore the evolving correlation between the Chinese and German stock markets, considering economic ties, regulatory frameworks, and global economic dynamics [90–92]. An examination of German stock markets after China's financial liberalization suggests a strengthening correlation, indicating increased interconnectedness over time. Similarly, studies by Refs. [93–95] provide evidence supporting a growing relationship between the Chinese and German stock markets. However, contrasting perspectives from Refs. [96–98] propose a limited impact of China's stock market on Germany's market performance, implying a weaker correlation.

In a recent study [99], investigated the dynamics of the Chinese-German stock market relationship. Using wavelet analysis, they identified time-varying correlations, suggesting evolving linkages. The study proposed that Chinese stocks could serve as effective diversifiers for German investors, especially during times of economic uncertainty. Despite these insights, the study emphasized the need for further research to understand short-term and long-term dynamics in this integration. Consequently, whether a significant correlation or connection exists remains uncertain, necessitating further research to gain a comprehensive understanding of their relationship.

In conclusion, the correlation between the Chinese and German stock markets is a complex phenomenon with significant implications for portfolio diversification. Referencing existing scholarly insights and drawing parallels to diverse research methodologies fortifies our analytical approach. The selected research analysis method, encompassing cointegration analysis, dynamic conditional correlation models, and insights from studies by Refs. [27,39] and others, positions us to understand the intricacies of this relationship comprehensively. As global financial markets continue to evolve, ongoing research and methodological refinement are imperative for a nuanced understanding of Chinese-German stock market dynamics and their implications for portfolio management.

2.6. In-depth study: Chinese market's relationship with Japan's stock market

China and Japan share a significant trading relationship, leading to extensive academic research on their stock market connections. While early studies suggested a limited correlation between the Chinese equity market and global trends, recent research, including works by Refs. [39,41–43] indicates an increasing integration with the worldwide market, reflecting the evolving nature of this relationship [100,101]. study reveals information transfer from the Chinese to the Japanese stock market, indicating integration and influence [102]. have emphasized understanding dynamics among neighboring markets, highlighting stock market interdependence [38]. In a recent study by, Recent study by Ref. [99] focused on the linkages between the Chinese and Japanese stock markets. Employing a dynamic conditional correlation model, they found short-term contagion during COVID-19 but remained low during normal periods. The study suggested that Japanese investors could benefit from diversifying their portfolios with Chinese assets, especially during turbulent market conditions. However, the research indicated the need for further investigation into the impact of economic events on this integration.

Existing literature presents a consensus on the growing integration between the Chinese and Japanese stock markets. Studies by Refs. [13,38,46,47,49,51,52,103] demonstrate the increasing interdependence of stock markets within Asia, indicating reduced diversification benefits as integrated markets tend to move in tandem. Integrated markets might pose challenges to diversification

strategies, a pivotal element in risk management.

The economic ties between China and Japan, substantial global roles, and geographical proximity contribute to the deepening interdependence of their financial markets [104]. The integration of China and Japan, as major economic players in the Asian region, has been accentuated by strengthening economic ties. Understanding this relationship is crucial for comprehending bilateral relations and broader dynamics in the Asian region, with significant implications for investors and policymakers [49,52].

The implications of Chinese-Japanese stock market co-movements are crucial for portfolio diversification. Integrated stock markets tend to reduce diversification benefits, while fragmented markets offer variation gains and diversification opportunities. Global investors need to understand the dynamics of co-movements between these markets to formulate effective diversification strategies [46,49].

Identifying gaps and areas for further investigation is integral to advancing our understanding of Chinese-Japanese stock market co-movements. Changes in regulatory environments, geopolitical events, and macroeconomic shifts may significantly impact market dynamics over time. Continuous monitoring of these factors and refining research methodologies are essential for staying ahead of evolving trends in the Chinese-Japanese stock market integration landscape.

2.7. Exploring the UK as a major trading partner in China's stock market

The exploration of the integration between the Chinese and UK stock markets and its implications for portfolio diversification stands as a critical domain within the scholarly inquiry, driven by the escalating interconnectedness of global financial markets. Empirical studies have extensively delved into the correlation between Chinese and UK stock markets, particularly in terms of yield and volatility [105,106]. identified a link between US and UK stock markets post-European Monetary Union, suggesting a connection with China, especially in yield and volatility [72,93]. highlighted interdependence among China, Hong Kong, Japan, Germany, the UK, and the US during the 2008 financial crisis, indicating a connection between the UK and Chinese markets through volatility transmission [103]. identified long-term relations between the Greater China region and the UK and US stock markets. However, the strength of these relationships may vary. Diverse findings, such as those by Ref. [107] exploring the impact of global financial crises on UK-China stock market connections, and [88] showing that the UK and US stock markets do not significantly impact China's market performance, underscore the complexity and variability of the relationship, necessitating a nuanced and thorough analysis.

[103] employed a conditional correlation GARCH model to investigate the integration between the Chinese and UK stock markets, revealing time-varying correlations and suggesting potential benefits for UK investors through portfolio diversification. This approach emphasizes the importance of considering economic events in understanding integration dynamics. However, the research also noted the need for further investigation into the impact of geopolitical factors and market regulations, underlining the continuous evolution and complexity of market relationships.

The implications of Chinese-UK stock market integration for portfolio diversification are pivotal, as integrated markets may reduce diversification benefits while fragmented markets offer variation gains and diversification opportunities [13,44,46,49]. demonstrate through their studies on Asian stock markets that integrated markets tend to move in tandem, indicating reduced diversification benefits. Global investors must comprehend the dynamics of integration between Chinese and UK stock markets to formulate effective diversification strategies.

2.8. Chinese stock market and US stock market: an analytical relationship

The examination of Chinese-US stock market integration reveals a complex landscape shaped by economic, regulatory, and geopolitical factors [108,109]. Empirical studies shed light on the profound interdependence arising from substantial economic ties and China's ascendance as a global economic force. Noteworthy variations in research findings, with [4] challenging a long-term connection and contrasting perspectives presented by Refs. [41,96], and [80], underscore the evolving nature of this relationship, demanding a sophisticated analysis.

Understanding the portfolio diversification implications stemming from Chinese-US stock market integration is indispensable for crafting effective risk management strategies. A profound comprehension of correlation dynamics between these markets is paramount for global investors seeking to diversify risks strategically. Credible references, such as [110], illuminate the intricate association between China's stock market and its global counterparts, emphasizing the interconnected nature of portfolios. Insights from Ref. [108] accentuate that changes in China's stock market conditions could intricately influence sales and subsequent movements, introducing layers of complexity to portfolio management strategies.

The chosen research analysis method should be robust and tailored to capture the nuanced dynamics of integration. Methodologies like cointegration analysis, as employed by Ref. [41] prove essential for scrutinizing the long-term relationship between these financial markets. Dynamic conditional correlation models and GARCH models emerge as valuable tools for gaining insights into the evolving correlations over time. Aligning our approach with existing research methodologies, especially those utilized by Ref. [110], enhances the depth and comprehensiveness of our analysis, ensuring the robustness of our findings across diverse statistical approaches.

Acknowledging valuable insights from existing research is pivotal in identifying gaps and areas necessitating further investigation. Regulatory changes, geopolitical events, and macroeconomic shifts emerge as critical factors impacting market dynamics. References such as [108,109] underscore dissimilar regulatory environments and ownership structures between Chinese and US markets, underscoring the continuous reassessment of the chosen research analysis method in light of evolving market conditions.

In conclusion, the integration between Chinese and US stock markets unfolds as a multifaceted and evolving phenomenon with profound implications for portfolio diversification. Anchoring our analysis with existing scholarly insights and aligning with diverse

research methodologies fortify our analytical approach. The selected research analysis method, incorporating cointegration analysis, dynamic conditional correlation models, and insights from studies like [110], positions us to unravel the intricacies of this integration comprehensively. As global financial markets continue to evolve, ongoing research and methodological refinement remain imperative for a nuanced understanding of Chinese-US stock market dynamics and their implications for portfolio management.

2.9. Implications of the integrated stock market for global traders

The correlation between Chinese stock markets and those in developed countries holds profound implications for global traders [83,111]. However, it is essential to recognize that Chinese stock markets exhibit unique dynamics that only partially align with developments observed in developed countries [76]. Consequently, global traders must conduct a nuanced analysis of the Chinese market, accounting for specific regulatory policies and unique economic indicators. Relying solely on global market trends may not capture the intricacies of investing in Chinese stocks effectively.

The diverse levels of integration and interdependencies underscore the strategic advantages of portfolio diversification between Chinese and developed world stock markets. Allocating investments across these markets can effectively reduce risk and potentially enhance returns, given the varying degrees of integration observed [37,112,113]. However, it is crucial to acknowledge that integration with developed markets may introduce heightened volatility and contagion effects. Therefore, close monitoring of both domestic and international market conditions is imperative for global traders to manage risks effectively [65,114–117].

The integration with developed markets opens up appealing opportunities for implementing cross-border investment strategies. Global traders can explore arbitrage opportunities by capitalizing on price discrepancies between markets [76,113,118–120]. Moreover, this integration enables investors to diversify portfolios across different regions, potentially mitigating risk and optimizing returns [121–124].

To effectively navigate the implications of integrating stock markets with developed ones, global traders must meticulously consider the level of integration and associated risks and opportunities [122]. Access to comprehensive data on the relationship between Chinese stock markets and significant trading partners is crucial for making informed investment decisions and implementing effective portfolio management strategies in today's interconnected global financial system [118].

2.10. Future trends and predictions of Chinese stock market integration

The exploration of future trends and predictions in Chinese stock market integration stands as a pivotal area of research, particularly in light of ongoing globalization and the increasing openness of China's financial markets to international investors [50,122]. The heightened accessibility of the Chinese stock market to global markets, alongside cross-border investments, technological advancements, and financial liberalization initiatives by Chinese authorities, has substantially fortified its linkages with crucial trading partners [24,83,122]. As China's economy expands and exerts global influence, investor interest in incorporating Chinese stocks into their portfolios has surged [122]. The deepening interconnectivity between Chinese stock markets and developed nations magnifies the impact of international market fluctuations on the Chinese market [125]. This investigation contributes valuable insights to the literature on global stock market integration by scrutinizing the relationship between China and its primary trading partners in developed countries. A pivotal objective is to assess potential opportunities for portfolio diversification within these alliances, concentrating on the behavioral aspects of Chinese stocks amid evolving market dynamics in their trading markets with other countries. This underscores the imperative for further research to comprehensively fathom the relationship between Chinese stock markets and their major trading partners.

The examination of future trends and predictions in Chinese stock market integration with global investors assumes significance due to China's expanding economic influence and its heightened receptivity to international markets. The augmented connectivity with key trading partners, propelled by cross-border investments and financial reforms, necessitates vigilant monitoring of global trends for effective risk management. Empirical evidence suggests varying degrees of integration and interdependencies with developed nations, underscoring the necessity for nuanced analyses grounded in specific trading partnerships. This study adds valuable insights by evaluating existing evidence of both long-term associations and short-term connections, utilizing diverse methodologies that extend beyond traditional sample periods. Sustained scholarly attention and methodological innovation are imperative for comprehending the evolving dynamics of Chinese stock market integration.

3. China's global trade: a study of top partners in developed countries

As the world's largest trading nation, China has established solid financial collaborations with key global partners, such as Australia, Germany, Japan, the UK, and the USA. These nations' significant roles in various industries and their diverse geographical locations across America, Europe, the Pacific, and Asia make them crucial influencers in shaping the Chinese economy. As a result, these partnerships have far-reaching effects, contributing to stable economic conditions on a global scale.

One of the ways these collaborations achieve mutual benefits is evident in the trade between China and Australia. The increasing demand for Australian goods, particularly raw materials, creates a robust market for Chinese exports, fostering a mutually beneficial relationship. German engineering and manufacturing products also contribute to modernizing Chinese infrastructure and industries, driven by increased German investment initiatives. Likewise, Japan, the UK, and the USA serve as vital benchmarks for the progress of developing economies while promoting competitive policies that benefit all stakeholders involved.

In summary, China's financial ties with these vital global partners are pivotal in shaping local and international economic

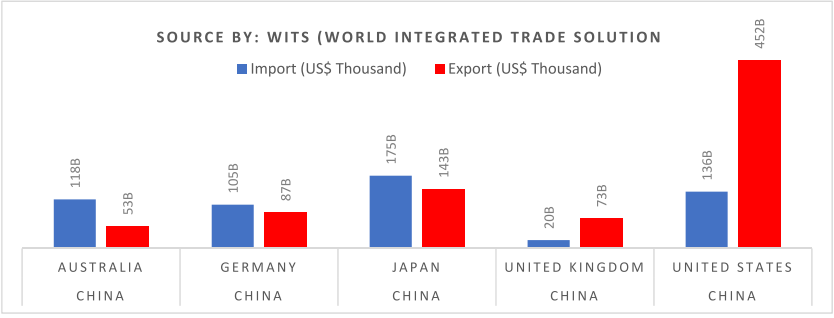

Fig. 1. China's Trade Dynamics with its Major trading Partners in the Developed World (2020–21).
CHINA IMPORTS-EXPORTS UNDER STUDY COUNTRIES 2020–21.
Source: China trade balance, exports, imports by country and region 2020 | WITS Data (worldbank.org)

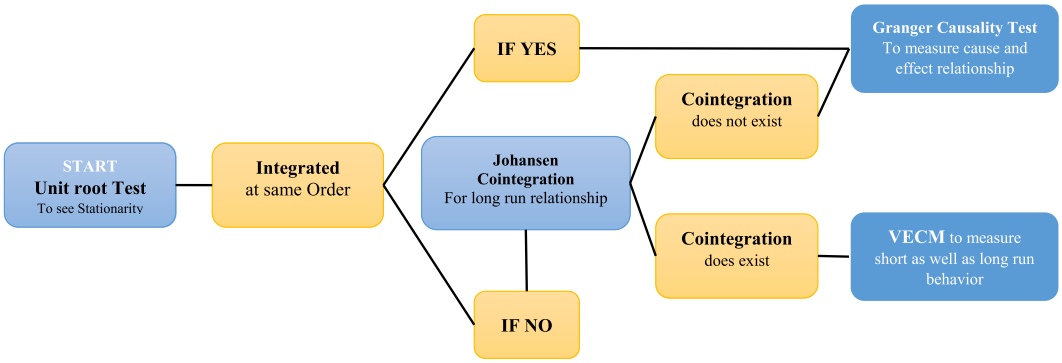

Fig. 2. The process of cointegration, Granger causality, and VECM model. (Source: Created by the author).

conditions, fostering growth and stability across various sectors.

Fig. 1 depicts the bilateral trade dynamics, encompassing both imports and exports, between China and its respective trading partners. In 2022, China's global trade reached an impressive $6.3 trillion, boasting a positive trade balance of $458.93 billion, making it the world's leading exporter despite trade tensions and COVID-19's economic impact. The United States is China's top export destination, while other significant trading partners include Australia, Germany, Japan, and the UK, which were China's major Foreign Direct Investment (FDI) sources in 2019. Notably, the United States invested $14.3 billion, followed by Japan with $10.8 billion, and Germany with $9.9 billion, highlighting the significant economic connections between China and these developed countries. However, it is crucial to recognize that current circumstances may have been influenced by the COVID-19 pandemic and the emergence of trade tensions [126].

Integrating stock markets among nations is pivotal, demonstrating economic interdependence and facilitating informed decision-making for investors, traders, and policymakers. Understanding these linkages is essential for identifying promising investment opportunities and contributing to a stable global financial system.

4. Methodology

The study employed the following research methodologies to achieve the results:

- Descriptive statistics
- Unit root tests (Augmented Dickey-Fuller test, Phillips and Perron test)
- Cointegration tests (Johansen's bivariate and multivariate tests)
- Granger Causality tests Based on VECM (Vector Error Correction Model)

The empirical steps of this paper are organized and written serially in Figure 2.

4.1. Calculation of the mean

The mean, denoted as x, signifies the average value within a set of observations. This is determined by dividing the sum of all values

by the total number of observations (n). The formula for the mean (x) is expressed as:

$$x = \frac{1}{n}\sum_{i=1}^{n} x_i \tag{1}$$

Here, In Eq. (1) x represents the sample mean, x_i denotes the ith observation, n indicates the sample size, and the summation notation $\sum_{i=1}^{n}{}'$ signifies the accumulation or summation of all observations from the first ($i = 1$) to the last (n).

4.2. Calculation of standard deviation

The standard deviation (SD) is a statistical measure that quantifies the extent to which individual data points within a dataset deviate from the mean, serving as an indicator of the data's dispersion. The formula for standard deviation is given by:

$$\sigma = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_1 - \overline{x})^2} \tag{2}$$

Here, In Eq. (2) σ denotes the standard deviation, $\overline{x}$ represents the sample mean, x_1 is the i th observation, n is the sample size, and the summation notation $\sum_{i=1}^{n}{}'$ signifies the sum of squared deviations from the sample mean for each observation, ranging from the first ($i = 1$) to the last (nth) observation.

4.3. Analysis of skewness

In the realm of financial analysis, skewness stands as a pivotal metric for discerning the asymmetry inherent in a distribution. At its core, skewness reveals which side of the distribution's tail is more extended. When skewness is positive, often referred to as rightward skewness, it signifies that the distribution boasts a lengthier tail on the right. Conversely, negative skewness, or leftward skewness, indicates a more extensive tail on the left. This nuanced conceptualization of skewness provides profound insights into the contours and tendencies of the distribution, thereby enriching our comprehension of its asymmetrical characteristics. In the context of our investigation into the integration of the Chinese stock market with developed economies, understanding the skewness of the portfolio diversification potential becomes imperative, offering a refined lens through which to assess the market dynamics and optimize investment strategies.

4.4. Examination of kurtosis

Kurtosis, a vital statistical measure, unveils the "tailedness" of a probability distribution, enriching our understanding of financial data. A mesokurtic distribution aligns with normalcy (kurtosis = 3), while shifts in kurtosis alter the distribution's shape—decreasing kurtosis broadens the peak and thickens tails, and increasing kurtosis (>3) crafts a thin-bell distribution. Recognizing leptokurtic (>3) and platykurtic (<3) distinctions is pivotal. This nuanced grasp of kurtosis amplifies our analytical prowess, which is crucial in interpreting probability distribution intricacies within the Chinese Stock Market Integration with the Developed World framework.

4.5. Unit root tests

Assessing the stationarity of the data series is imperative to analyze cointegration. Stationarity refers to when a time series's mean and standard deviation remain constant over time. Conversely, non-stationary data exhibits a time-varying mean or standard deviation [127]. To determine stationarity, it is crucial to specify the order of integration. A time series that evolves stationary after differencing d times is considered integrated of order d, or I(d). A variable with an integration order equal to or higher than 1 will exhibit non-stationarity. The unit root test is commonly utilized to examine an index series's stationarity and cointegration relations' existence. In this research, the ADF test (Augmented Dickey-Fuller 1981) and PP test (Phillips-Perron, 1988) will be used, as supported by previous studies conducted by Refs. [41,128–131].

Below are the ADF test equations for log level and first Difference:

$$y_t = \rho y_{t-1} + u_t \tag{3}$$

$$\Delta y_t = \delta y_{t-1} + u_t \tag{4}$$

In Equation (3), " y_t" represents the value at the time 't', " y_{t-1}" means the value from the previous time point ('t-1'), "ρ" is a projected parameter utilized to decide the stationarity of the series, and " u_t" is a random noise series with an average of 0 and a variance of 2. Rejecting the null hypothesis indicates stationarity. In practice, method (3) is rarely utilized, and instead, method (4) is employed to test for the existence of a unit root in the data, where $\delta = 0$ is tested instead of $\rho = 1$.

4.6. Cointegration test

According to economic theory, two or more economic variables are believed to have a long-term connection, despite short-term fluctuations. These variables are assumed to be cointegrated, with economic forces eventually restoring the original equilibrium between them. To decide the cointegration connection between the selected variables, both integrated in the same order, two commonly used tests are the Engle and Granger two-step cointegration test and the Johansen cointegration test. The Engle and Granger test is less effective when analyzing multivariate models. This analysis will utilize the Johansen cointegration test to investigate the long-term association among the data series. This procedure includes two types of tests: the trace test statistic and the maximum eigenvalue test statistic. Many previous studies have also used these techniques [106,130].

Following is the equation for the Johansen test:

$$x_t = A_0 + A_1 \Delta x_{t-1} + A_2 \Delta x_{t-2} + ... + A_{k-1} \Delta x_{t-k} + \prod x_{t-k} + \varepsilon_t \quad (5)$$

In the first step, the order of integration is tested; in the second, the lag length is selected; finally, in the third stage, the Cointegrating vectors are decided. This test presents two likelihood ratio tests for this objective, the "trace test" and the "maximum Eigenvalue test".

$$\lambda_{trace}(r) = -T \sum_{i=r+1}^{n} \ln(1+\lambda) e_t \quad (6)$$

$$\lambda_{max}(r, r+1) = -T \ln(1-\lambda_r+1) \quad (7)$$

H_0: $\Pi = r$.

H_1: $\Pi = r+1$.

In this context, In Eq. (6) the symbol "r" signifies the count of cointegrating vectors assumed in the null hypothesis, and "λ_i" denotes the estimated value of the "ith" ordered eigenvalue of the matrix "Π." Notably, as the magnitude of "λ_i" increases, the value of ln (1- λ_i) becomes more negative, leading to a higher test statistic.

Equation (6) presents a test that considers all eigenvalues collectively and is based on the null hypothesis (H0) that the number of cointegrating vectors is equal to or less than "r." In contrast, the alternative assumption suggests a greater number of cointegrating vectors. On the other hand, equation (7) is applied to each eigenvalue individually. It assumes a null hypothesis that the number of cointegrating vectors equals "r," with the alternative assumption indicating that it is equal to "r+1." When the test statistic exceeds the critical level determined by Johannsen's tables, the null hypothesis is rejected for both tests in favor of the alternative hypothesis.

The process of checking follows a sequential approach starting with the null hypothesis of "$r = 0''$ and then proceeding with "r = 1, …, r = g-1," representing a rank of zero for the matrix "Π." If this null hypothesis is not rejected, it concludes that there are no cointegrating relations among the variables in the VAR model, and the assessment is considered complete. However, if the null hypothesis is rejected, it leads to investigating whether the matrix "Π" rank equals 1. Accepting this hypothesis suggests only one cointegrating connection among the variables in the model, and the process continues for subsequent hypotheses.

4.7. Granger Causality Tests based on VECM

The advantages of employing Granger Causality Tests based on VECM for studying integration and portfolio diversification in financial markets are manifold. Firstly, these tests are particularly suitable for analyzing time series data commonly observed in stock markets, allowing the exploration of temporal interactions between variables over different periods. Secondly, the combination of VECM and Granger Causality Tests enables the examination of dynamic relationships between stock markets, revealing short-term and stable long-term causal links. Such insights help in understanding the direction of causality between markets, essential for informed decision-making by investors and policymakers.

Moreover, the tests offer valuable information on portfolio diversification opportunities. Detecting significant causality between certain markets indicates potential benefits in diversifying investments to reduce overall portfolio risk. Additionally, Granger Causality Tests assist in assessing the level of interdependence between stock markets, indicating the extent of market integration and guiding investment strategies and risk management.

VECM with Granger Causality Tests also proves beneficial for analyzing the impact of specific events on stock market interactions, such as economic shocks or policy changes. Understanding how global events influence market behavior is crucial for decision-makers. Moreover, the model allows researchers to test specific hypotheses related to stock market integration and portfolio diversification, investigating if one country's market movements cause changes in another country's market.

In addition, VECM accounts for cointegration among variables, particularly vital in financial markets where some assets may have long-term relationships. By distinguishing short-term causality from long-term relationships, the model provides robust and reliable results.

In conclusion, Granger Causality Tests based on VECM offer valuable insights into causal relationships between stock markets, aiding researchers, investors, and policymakers in understanding market integration and portfolio diversification dynamics. By identifying interconnectedness and causality between markets, this model supports well-informed investment decisions and risk management in a globalized financial landscape. However, it is essential to interpret the results cautiously, considering other factors and theories to draw meaningful conclusions about stock market behavior.

The Granger representation theorem states that in the case of cointegrated series CI (1,1), it is essential to incorporate an error correction term into the model to account for the long-term association between the variables; failure to include this term leads to model misspecification as posited by Engle and Granger (1987) and Toda and Phillips (1993). Previous studies have also used these techniques [130–133].

Hence, this model, commonly known in the literature as a VECM (Vector Error Correction Model), is utilized:

$$\Delta Y_{it} = \alpha + \xi' Z_{t-1} + \sum_{t=1}^{m} a_i \Delta Y_{1,t-i} + \sum_{t=1}^{m} b_i \Delta Y_{2,t-i} + \sum_{t=1}^{m} c_i \Delta Y_{3,t-i} + \sum_{t=1}^{m} d_i \Delta Y_{4,t-i} + \sum_{t=1}^{m} e_i \Delta Y_{5,t-1} + \varepsilon_t \quad (8)$$

In Eq. (8) the stock price index series for China and its trading partners, including Australia, Germany, Japan, the UK, and the USA, are denoted as Y. The long-term equilibrium connection between these five stock markets is reflected in the $\xi' Z_{t-1}$, which encompasses r cointegrating terms. Granger-causality tests are performed by assessing whether the coefficients of $\Delta Y_{1,t-i}, \Delta Y_{2,t-i}, \Delta Y_{3,t-i}, \Delta Y_{4,t-i}$, and $\Delta Y_{5,t-i}$ significantly deviate from zero using an F-test. The significance of the error correction term is evaluated using a T-test. When the variables are cointegrated, OLS regression provides "super-consistent" estimates of the cointegrating parameters, as Enders (1995) indicated. Furthermore, Stock (1987) determines that OLS estimates of parameters converge more rapidly than in OLS models involving stationary variables.

5. Data preliminaries

This research paper analyzed the stock markets of China, Australia, Japan, Germany, the United States, and the United Kingdom from January 04, 2012, to December 30, 2022, using publicly available daily data such as stock market indices and financial reports. The study looked at how these markets' cointegration and portfolio diversification were affected by four events that happened after the global financial crisis: The Belt and Road Initiative, the Shanghai stock market crash, US-China trade tensions, and the COVID-19 pandemic, with a focus on how these events affected the Chinese stock market. The study used the Shanghai and Shenzhen stock exchange composite indices as the dependent variable and the AORD (Australia), DAX 30 (Germany), Nikkei 225 (Japan), FTSE 100 (UK), and S&P 500 (USA) indices as the independent variables. The indexes used in this study are denominated in local currency and were sourced from the database www.econstats.com. After adjusting for certain factors, each country's total observations amounted to 2266. Furthermore, all the indexes were measured in natural logarithms. The stock prices for each country appear to move together over time, which is confirmed through cointegration. Source: [41].

Fig. 3 show that the stock prices of all indices are non-stationary and that Chinese markets, such as Shanghai and Shenzhen, tend to move together over time. In 2014, market capitalization in these markets saw a 150 % increase, making them some of the highest-performing in the world [134]. However, in July and February of 2015 and 2018, respectively, there were significant drops in stock prices. The decline in China's markets also affected global markets, resulting in a 30 % decrease in Chinese shares since June 2016. Despite these drops, the market has frequently returned to a stable range with government intervention.

5.1. Graphical representation of stationarity

Fig. 3 demonstrates non-stationarity across all data series at the level, while Fig. 4 reveals stationary time series after the first difference. This also supports the ADF and PP test results, indicating integration of order (I (1)).

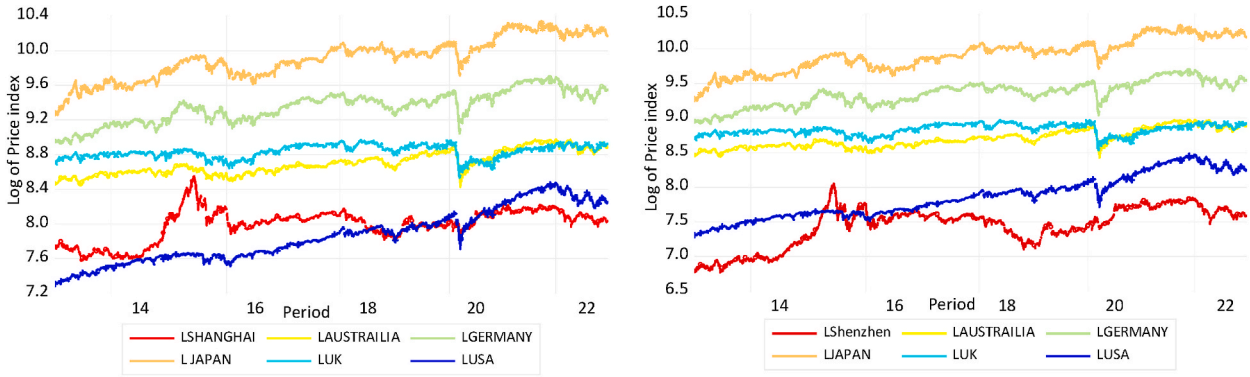

Fig. 3. Stock price indexes for selected countries: January 04, 2012–December 30, 2022.

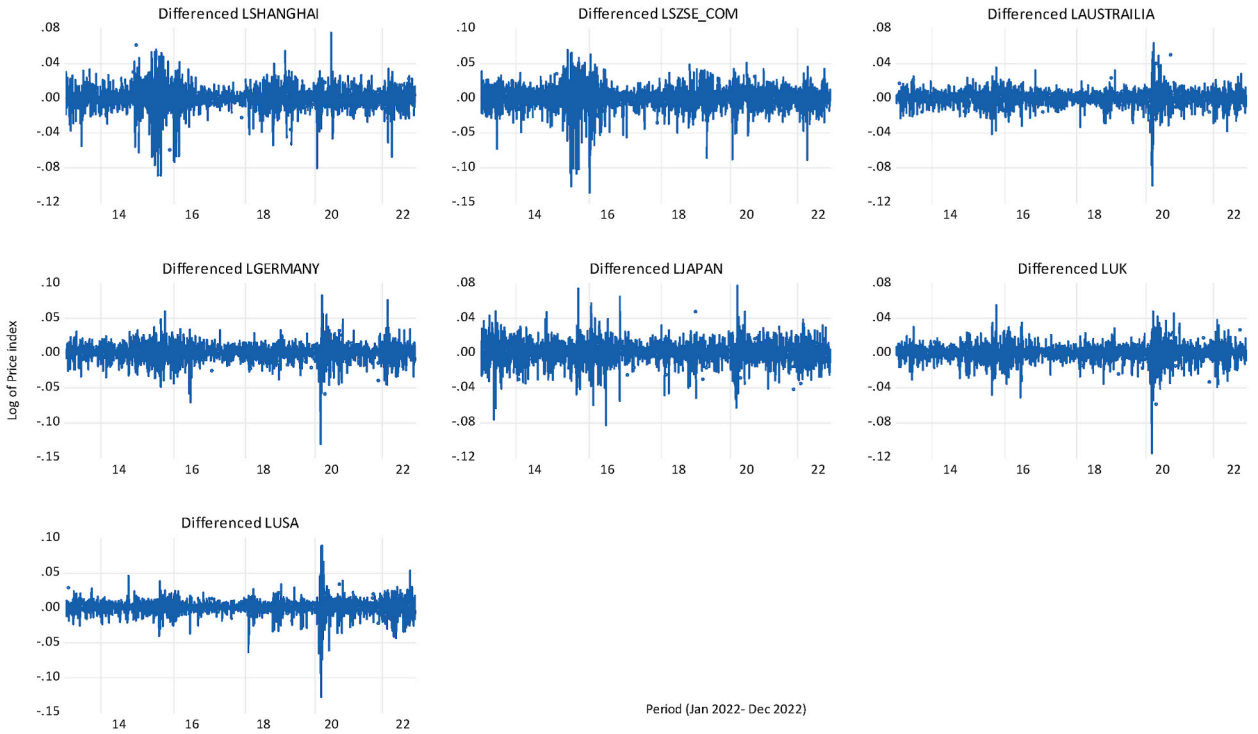

Fig. 4. Volatility clustering plot of daily returns. (Source: author's calculations).

6. Results and discussions

The descriptive statistics provide a comprehensive exploration of the performance of key stock indices, offering nuanced insights into the dynamics of Chinese Stock Market Integration with Developed World: A Portfolio Diversification Analysis. Daily returns were calculated by taking the logarithmic Difference of the indices, as shown in Table 1. Examining the mean returns, it is evident that the Shenzhen Stock Exchange in China exhibits the highest mean return, signaling a potential area of interest for investors seeking favorable returns within the context of the broader study. However, the modest mean returns across all indices underscore the need for a diversified approach to portfolio construction.

Turning to the volatility, as captured by standard deviations, a notable contrast emerges. Developed countries, exemplified by the USA and Germany, showcase lower volatility in comparison to China's stock exchanges. This variance in volatility levels underscores the importance of understanding and managing risk when considering portfolio diversification strategies, especially in the context of Chinese stocks.

The skewness values provide additional depth to our analysis, revealing distinctive distribution shapes. Australia and the UK display negative skewness, indicative of distributions skewed towards lower returns. On the contrary, China's stock exchanges exhibit negative skewness, suggesting distributions skewed towards higher returns. This skewness pattern suggests potential opportunities and risks associated with investments in these respective markets, contributing valuable information for investors aiming to diversify their portfolios.

Delving further into the statistical measures, kurtosis values illuminate the extent of outliers and heavy tails in return distributions. The diverse kurtosis values across all indices underscore the varying degrees of risk and potential outliers present in each market. This information is crucial for investors considering the implications of extreme events and tail risks in the context of their portfolio

Table 1
Descriptive statistics.

	Rtn- SSE China	*Rtn*-SZSE China	*Rtn*-Australia	*Rtn*-Germany	*Rtn*-Japan	*Rtn*-UK	*Rtn*-USA
Mean	0.000229	0.000509	0.000235	0.000342	0.000486	0.000145	0.000481
Std Error	0.000288	0.000369	0.000208	0.000271	0.000285	0.000218	0.000242
Median	0.000494	0.001229	0.000748	0.000807	0.00079	0.000631	0.000635
Std Deviation	0.013724	0.017562	0.009891	0.012897	0.013556	0.010368	0.011527
Kurtosis	6.279371	6.202872	10.54584	7.631257	3.790094	9.653318	15.5248
Skewness	−0.712960	−1.007209	−0.745004	−0.517863	−0.163192	−0.865092	−0.66447
Minimum	−0.084906	−0.126653	−0.095247	−0.122386	−0.079216	−0.108745	−0.11984
Maximum	0.078403	0.072123	0.065611	0.086417	0.080381	0.056598	0.093828

management strategies.

In summary, the descriptive statistics unveil a multifaceted landscape in the integration of the Chinese stock market with the developed world. The high mean returns in the Shenzhen Stock Exchange captures attention, while the nuanced volatility, skewness, and kurtosis patterns across different markets provide a holistic understanding of the risks and opportunities associated with portfolio diversification. These detailed findings contribute to the overarching objective of our research, guiding investors in formulating informed decisions within the evolving dynamics of Chinese stock market integration.

To examine cointegration, we first assess the stationarity of the data series to avoid spurious regression effects. The unit root test, including the Augmented Dickey-Fuller and Phillips-Perron tests, is employed for this purpose. Table 2 indicates that all series have unit roots at a level I (0), requiring transformation into stationary series through first-order differencing (I (1)). Consequently, the daily closing values of stock price indices become stationary in their first difference form, enabling the application of the cointegration procedure. Moreover, the Durbin-Watson statistic for each variable is approximately 2.0, indicating no autocorrelation issues in the time series data.

When employing the Johansen-Juselius cointegration technique, two potential issues should be considered. Firstly, the test results may be sensitive to the chosen lag order. Including at least two lags in cointegration analysis with daily stock market data in EViews is generally recommended. The optimal number of lags can vary based on the data and research question, aiming to confirm uncorrelated residuals without unnecessary complexity. In this study, five different criteria were used to determine the optimal lag length, with the Akaike Information Criteria (AIC) guiding the selection for conducting the cointegration test. Visual inspection of residuals is also advised to detect correlations or patterns, leading to the inclusion of additional lags if necessary.

The researchers found that using "6″ lags in the VAR system yielded the most accurate results for all selected equity markets. Therefore, all further analyses were conducted with "6″ lags (see Table 3).

The multivariate cointegration test conducted by Johansen (1988) and Johansen and Juselius (1990) reveals one cointegration between China, Australia, Germany, Japan, the UK, and the US stock markets over the studied period. The analysis employs original data, considering the long-term relationship's presence. Both the Trace and Maximum Eigenvalues likelihood ratio tests in Table 4 confirm this result, and different information criteria for lags yield the same outcome of one cointegration vector. These findings suggest a relatively low degree of integration among these markets, presenting opportunities for long-term portfolio diversification in Chinese stock markets for investors from Australia, Germany, Japan, the UK, and the US. Additionally, Chinese investors can manage risk by investing in these developed stock markets. However, it's crucial to consider the cointegration test results within the sample period and account for any economic or political events during that time. Further analysis using different methods and an extended sample period is recommended to validate these results.

Table 5 part I: The Vector Error Correction Model (VECM) Granger causality test reveals significant relationships between the Shanghai Stock Exchange in China and the stock markets of Australia (AORD), Germany (DAX 30), Japan (Nikkei 225), the UK (FTSE 100), and the USA (S&P 500). Notably, AORD, DAX 30, and Nikkei 225 exhibit strong bidirectional causality with Shanghai, indicating mutual influence. Additionally, FTSE 100 shows significant causality, while the S&P 500 does not exhibit a significant impact, likely

Table 2
Unit root analysis.

Test Variables	Augmented Dickey-Fuller			Phillip-Perron		
	Level	1st Difference	Durbin-Watson statistic	Level	1st Difference	Durbin-Watson statistic
	t-statistic	t- statistic		t- statistic	t- statistic	
SHANGHAI (CHINA)	−2.164087	−49.28640	1.993744	−2.199320	−49.31016	1.993944
SHENZHEN (CHINA)	−2.444015	−49.85401	1.997429	−2.574793	−49.99252	1.997429
AORD (AUSTRALIA)	−1.342416	−35.79309	1.997665	−1.357988	−54.99936	1.994019
DAX30 (GERMANY)	−1.532239	−51.33699	1.999421	−1.555206	−51.33559	1.999421
NIKKEI225 (JAPAN)	−1.203697	−34.98652	1.993933	−1.134905	−54.09697	1.995145
FTSE100 (UK)	−2.680014	−52.17009	1.999621	−2.606269	−52.24529	1.997902
S&P500 (USA)	−0.734322	−35.86244	1.995824	−0.699444	−58.37252	1.981263

The critical values for t-ratio at 1 %, 5 %, and 10 % are −3.432547, −2.862396, and −2.567270, respectively.

Table 3
Optimal lag-lengths of the VAR.

Lag	LogL	LR	FPE	AIC	SC	HQ
0	14722.93	NA	8.94e-14	−13.01807	−13.00288	−13.01253
1	41614.29	53616.21	4.31e-24	−36.77336	−36.66704	−36.73457
2	42125.83	1017.213	2.83e-24	−37.19402	−36.99656*	−37.12196
3	42239.35	225.1143	2.64e-24	−37.26258	−36.97400	−37.15727*
4	42309.82	139.3860	2.56e-24	−37.29307	−36.91336	−37.15451
5	42338.04	55.66149	2.58e-24	−37.28619	−36.81534	−37.11437
6	42382.27	87.02530	2.56e-24*	−37.29347*	−36.73150	−37.08841
7	42404.49	43.58548	2.59e-24	−37.28128	−36.62817	−37.04296
8	42441.54	72.48946*	2.59e-24	−37.28221	−36.53797	−37.01063

* Indicates lag order selected by the criterion

Table 4
Johansen Cointegration test.

Shanghai Stock market		Unrestricted Cointegration Rank Test (Trace)		Unrestricted Cointegration Rank Test (Maximum Eigenvalue)	
Hypothesized No. of CE(s)	**Eigenvalue**	**Trace Statistic**	**0.05 Critical Value**	**Max-Eigen Statistic**	**0.05 Critical Value**
None[a]	0.025125	142.0023***	117.7082	57.66050***	44.49720
At most 1	0.014281	84.34185	88.80380	32.59438	38.33101
At most 2	0.011520	51.74747	63.87610	26.25473	32.11832
At most 3	0.006461	25.49273	42.91525	14.68855	25.82321
At most 4	0.003384	10.80419	25.87211	7.681645	19.38704
At most 5	0.001377	3.122542	12.51798	3.122542	12.51798
Shenzhen Stock market		Unrestricted Cointegration Rank Test (Trace)		Unrestricted Cointegration Rank Test (Maximum Eigenvalue)	
Hypothesized No. of CE(s)	**Eigenvalue**	**Trace Statistic**	**0.05 Critical Value**	**Max-Eigen Statistic**	**0.05 Critical Value**
None[a]	0.023305	140.0135***	117.7082	53.43483***	44.49720
At most 1	0.016051	86.57872	88.80380	36.66583	38.33101
At most 2	0.010314	49.91289	63.87610	23.49225	32.11832
At most 3	0.006394	26.42064	42.91525	14.53432	25.82321
At most 4	0.003531	11.88632	25.87211	8.014591	19.38704
At most 5	0.001707	3.871732	12.51798	3.871732	12.51798

**MacKinnon-Haug-Michelis (1999) p-values.
Max-eigenvalue indicates 1 cointegrating eqn(s) at the 0.05.
**MacKinnon-Haug-Michelis (1999) p-values.
* denotes rejection of the hypothesis at the 0.05 level.
* denotes rejection of the hypothesis at the 0.05 leve
Note: *** denotes rejection of null hypothesis at 5 % level of significance.
Trace test indicates 1 cointegrating eqn(s) at the 0.05 level.
[a] denotes rejection of the hypothesis at the 0.05 level.

due to differences in regulatory environments, ownership structures, and the ongoing impact of the trade war. These results suggest a complex yet interconnected relationship between China and these developed markets, with varying degrees of influence.

Moving to the AORD Australia results, bidirectional causality is observed between AORD and all other markets, including Shanghai. The significance levels are generally high, indicating a robust influence. However, the USA's S&P 500 displays a relatively lower significance level compared to other markets, suggesting a nuanced relationship. Overall, the findings in Table 1 highlight both similarities and differences in the causal relationships between Shanghai, AORD, and other major developed markets.

Turning to Table 5 Part II, the Granger Causality Tests for Shenzhen Stock Exchange China demonstrate significant relationships

Table 5
Granger causality tests based on VECM.

VEC Granger Causality/Block Exogeneity Wald Tests						
ΔShanghai China		ΔAustralia	ΔGermany	ΔJapan	ΔUK	ΔUS
Wald X^2 Statistics						
ΔShanghai	–	0.0021	0.0656	0.7511	0.5488	0.6644
		18.78903***	10.36221	2.667581	4.004568	3.231089
ΔAustralia	0.0000	–	0.0738	0.8144	0.1166	0.0005
	28.54278***		10.05247	2.244484	8.816930	22.19963***
ΔGermany	0.0001	0.0000	–	0.0000	0.0110	0.0104
	25.49772***	38.76741***		89.80590***	14.86405***	14.99161***
ΔJapan	0.0000	0.0000	0.0198	–	0.0024	0.0036
	30.35006***	75.77771***	13.40960***		18.48404***	17.50525***
ΔUK	0.0032	0.0000	0.2830	0.0383	–	0.0000
	17.82507***	152.1695***	6.246059	11.75209***		47.60979***
ΔUS	0.3797	0.0000	0.0000	0.1499	0.0000	–
	5.305873	55.83943***	29.46571***	8.117875	38.65470***	
ΔShenzhen	–	0.0756	0.8907	0.3660	0.9837	0.7960
		9.986449	1.685505	5.427376	0.686176	2.369644
ΔAustralia	0.0371	–	0.0474	0.8184	0.1265	0.0017
	11.83433***		11.20752***	2.216638	8.592545	19.31654***
ΔGermany	0.0041	0.0000	–	0.0000	0.0168	0.0055
	17.21066***	38.17678***		85.03285***	13.81295***	16.51223***
ΔJapan	0.0009	0.0000	0.0162	–	0.0020	0.0026
	20.76192***	76.43182***	13.91608***		18.88733***	18.24943
ΔUK	0.7144	0.0000	0.3056	0.0375	–	0.0000
	2.906629	146.9467***	6.006367	11.80758***		45.54983***
ΔUS	0.6535	0.0000	0.0000	0.1777	0.0000	–
	3.302032	51.58269***	28.88466***	7.632843	38.38782***	

Note: ***,* *and * indicates significance at the 1, 5 and 10 % levels.

with AORD, DAX 30, Nikkei 225, FTSE 100, and S&P 500. Similar to Shanghai, Shenzhen exhibits bidirectional causality with DAX 30, Nikkei 225, and FTSE 100, indicating potential mutual influence. However, the USA's S&P 500 displays a lower significance level, suggesting a less pronounced impact.

In the case of AORD Australia, bidirectional causality is observed with Shenzhen, emphasizing reciprocal influence. The significance levels are generally high, but, similar to Table 1, the USA's S&P 500 shows a relatively lower impact compared to other markets.

The outcomes derived from the Granger Causality Tests utilizing VECM to assess the integration of the Chinese stock market with developed countries reveal several noteworthy implications. The observed significant interdependencies between the Shanghai and Shenzhen stock exchanges and global markets suggest that these Chinese markets are intricately linked to the broader international financial landscape rather than being isolated. The consistent causality patterns across both exchanges, particularly with the Australian and German markets, underscore a coherence that could be advantageous for investors seeking diversified portfolios responsive to global economic trends.

Furthermore, the variations in significance levels and causality strength underscore nuanced relationships between the Chinese exchanges and individual developed countries. Notably, the Japanese market exerts a substantial impact on both exchanges, with differing significance levels. Similarly, the influence of the UK, as measured by the FTSE 100, is more pronounced on the Shanghai Stock Exchange compared to Shenzhen. These distinctions emphasize the importance of a nuanced approach to portfolio diversification, considering the specific dynamics between the Chinese markets and each developed country.

The limited observed causality between the Chinese exchanges and the S&P 500 suggests a potential divergence in their responses to US market movements. This finding could be particularly relevant for investors considering exposure to the Chinese market for diversification against the backdrop of the US market. In summary, the comparative analysis of the study provides valuable insights for investors and policymakers, emphasizing the necessity for a nuanced and globally informed approach to decision-making in the interconnected landscape of international financial markets.

As indicated by the Granger causality test, the absence of a causal relationship between the US and Chinese stock markets is unexpected and contradicts intuitive assumptions. Economic theory would posit that events and developments in the US economy should influence the Chinese stock market, and vice versa, given the close economic interactions between the two countries.

Several factors may potentially explain this result, including differing regulatory environments, ownership structures, and the impact of the ongoing trade war between the US and China. These complexities and unique dynamics may contribute to the lack of observable causality between their stock markets, contrary to conventional economic expectations.

It is crucial to note that the absence of causality between the US and Chinese stock markets does not imply a complete lack of relationship or correlation; rather, it suggests that changes in one market do not consistently predict changes in the other market over the examined period. Further research and analysis are necessary to comprehend the factors contributing to this unexpected finding and assess the potential implications for investors and policymakers.

The relationship between China and Australia, Germany, Japan, the UK, and the USA holds unique significance. Australia serves as a crucial supplier of natural resources, while Germany provides opportunities for technology collaboration. Japan stands as a vital trade partner, and the UK functions as a financial center for China. Despite existing political tensions, the USA remains a significant market for Chinese exports and a source of investment. Collectively, these countries significantly impact China's economic growth, industrial development, and global engagement strategies. Fig. 5 illustrates the Granger Causality Tests Based on VECM, shedding light on temporal relationships between all the Stock Markets.

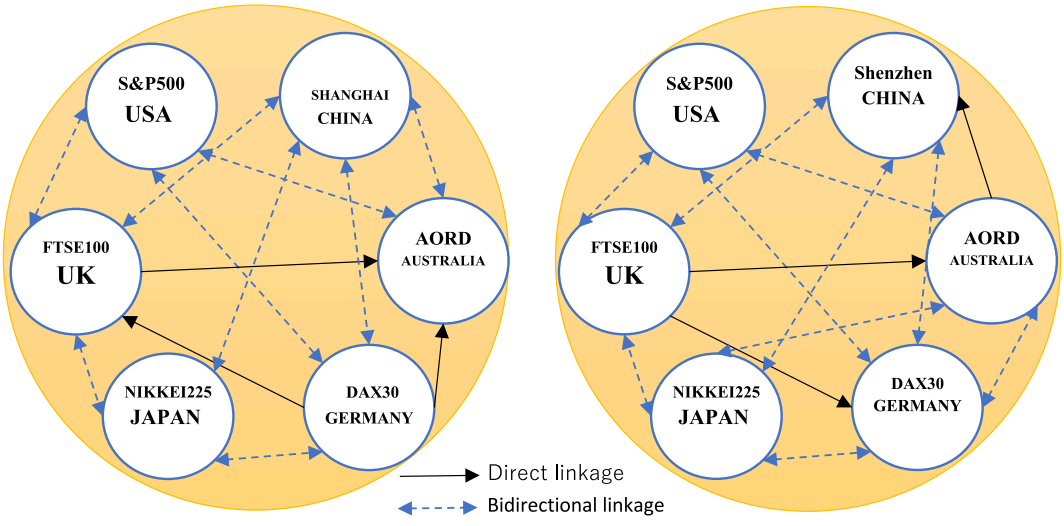

Fig. 5. | illustrates the Chinese Stock Market's links with trade partners using VECM Granger Causality Results (Table 5).

7. Summary and conclusion

In conclusion, our research aimed to shed light on the integration dynamics between the Chinese stock market and major developed world counterparts: Australia, Germany, Japan, the UK, and the US, with a specific focus on portfolio diversification. The findings, derived from a comprehensive analysis of descriptive statistics, unit root tests, cointegration analysis, and Granger Causality Tests based on VECM, provide valuable insights for investors and policymakers. Analyzing daily data from 2012 to 2022, this study examines the impact of key events, such as the Belt and Road Initiative, the Shanghai stock market crash, US-China trade tensions, and the COVID-19 pandemic, on market dynamics and diversification opportunities.

In the first phase, the descriptive statistics unveiled a multifaceted landscape, emphasizing the need for a diversified approach to portfolio construction. Notably, the Shenzhen Stock Exchange exhibited the highest mean return, drawing attention as a potential area of interest for investors seeking favorable returns. The nuanced volatility, skewness, and kurtosis patterns across different markets underscored the complex risks and opportunities associated with portfolio diversification.

The unit root analysis confirmed the presence of cointegration among the Chinese stock market and major developed world indices. The optimal lag lengths determined through the VAR system facilitated accurate cointegration tests. The results revealed one cointegration vector, indicating a relatively low degree of integration among these markets. This finding presents opportunities for long-term portfolio diversification in Chinese stock markets for investors from developed countries, while Chinese investors can manage risk by investing in these developed stock markets. However, it is essential to acknowledge that while cointegration testing plays a vital role in analyzing stock market performance and informing investment decisions, practitioners must also consider other critical factors, including economic variables such as political stability and firm-specific information, to develop a comprehensive strategy. In conclusion, our findings align with previous research conducted by Refs. [37,135–137].

In the second phase, Granger Causality Tests based on VECM further illuminated the interconnected relationships between the Shanghai and Shenzhen stock exchanges with global markets. The bidirectional causality observed with major developed markets, such as Australia, Germany, and Japan, suggested mutual influence, providing consistent patterns across both Chinese exchanges. However, distinctions in the strength and significance of causality underscored the need for a nuanced approach to portfolio diversification, accounting for specific dynamics between the Chinese markets and each developed country.

The observed limited causality between the Chinese exchanges and the S&P 500 highlighted potential divergence in their responses to US market movements. This insight is crucial for investors considering exposure to the Chinese market for diversification against the backdrop of the US market. The study findings suggest that the Chinese, Japanese, and US economic systems are so intertwined with the global economic system that any changes in these financial markets would significantly affect each other's stock market. The study findings support [137–139].

In essence, our research contributes to a deeper understanding of Chinese stock market dynamics and their implications for global investors. By emphasizing the importance of nuanced decision-making and a globally informed approach, our findings empower stakeholders to navigate the ever-interconnected landscape of international financial markets effectively. Further research, especially considering extended sample periods and alternative methodologies, is recommended to validate and build upon these insights.

The interconnection between China's stock markets and those of developed countries highlights significant disparities, including regulations, market structures, and risk levels within a complex framework. Despite strong economic relations, these markets exhibit variations in returns. Foreign investment plays a vital role in supporting diversification and strengthening integration efforts. Continual efforts to further open China's domestic shares will improve transparency and governance and provide valuable insights for policymakers. Lifting restrictions will enhance the prospects of increased Chinese listings on developed platforms, fostering bilateral understanding and contributing to a thriving economy.

7.1. Policy implications

Our study presents compelling policy implications to foster international collaboration and enhance investment strategies. Policymakers should actively encourage cross-border investments, leveraging the identified opportunities for long-term portfolio diversification in Chinese stock markets for investors from developed countries. Initiatives aimed at promoting information sharing and regulatory cooperation can contribute to market transparency and facilitate a conducive environment for global investors. Moreover, crafting tailored risk management guidelines based on the nuanced relationships revealed in the study can empower investors to make more informed decisions in an ever-interconnected financial landscape.

7.2. Limitations

Despite its valuable insights, our study has certain limitations that should be considered in future research. The findings are sensitive to the selected sample period, emphasizing the need for studies that explore the implications of extending the analysis timeframe to encompass a broader range of market conditions. Additionally, while the methodologies employed are widely accepted, researchers are encouraged to explore alternative approaches for cointegration and causality analysis to ensure a more robust understanding. The influence of economic and political factors, not fully captured in our analysis, should be acknowledged, prompting future studies to incorporate a broader set of variables for a comprehensive view.

7.3. Future directions

Our study suggests key paths for future research to enhance comprehension of the complex dynamics between Chinese and developed world stock markets. Extending analysis periods can yield a more comprehensive view of market dynamics, capturing the influence of economic cycles, geopolitical events, and policy changes. Researchers are urged to explore alternative methodologies, fostering comparative studies with diverse statistical techniques. Additionally, integrating macroeconomic factors, such as interest rates and trade policies, into the analysis can provide a more holistic perspective. In the evolving landscape of financial markets, investigating the impact of innovations like blockchain and digital currencies on integration dynamics is essential. In conclusion, our study not only illuminates the current state of integration but also propels future research, addressing limitations and guiding researchers toward a nuanced understanding. This contributes actionable insights for investors, policymakers, and stakeholders navigating the complexities of global finance.

Data availability statement

The data employed in this research paper have been sourced from publicly available reputable platforms including **Bloomberg Inc.** and **investing.com,** both renowned for their comprehensive and reliable financial datasets.

CRediT authorship contribution statement

Azmat Sher: Formal analysis. **An Haizhong:** Project administration. **Muhammad Kaleem Khan:** Conceptualization. **Judit Sági:** Investigation.

Declaration of competing interest

The authors declare there is no conflict of interest.

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