



Can artificial intelligence and green finance affect economic cycles?

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ARTICLE INFO

Keywords:

Economic cycles
Artificial intelligence
Green finance
Quantile coherence method
Machine learning
Panel QQRRLS method

ABSTRACT

The COVID-19 recession and the Ukraine-Russia War (URW) crisis have added a new layer of complexity to global economic cycles, necessitating the evolution of economic systems and proactive responses to emerging economic challenges. In this context, the recent article introduces artificial intelligence (AI) as a new driver of economic cycles and analyzes its dynamic role alongside the Belt and Road Initiative (BRI), the Paris Agreement (PA), green finance (GB), and economic shocks (ES) in determining global economic cycles. The article employs novel econometric tools, namely the CAViaR-TVP-VAR model, the Quantile Coherence method, panel Quantile on Quantile Kernel-Based Regularized Least Squares (PQQRRLS), and the Quantile-Quantile Granger causality (QQGC) test for robust findings. The outcomes reveal that AI influences economic cycles in the short run while significantly mitigating these cycles in the medium and long run. Furthermore, the BRI exhibits a positive link with economic cycles during the short and medium run; however, it can contribute to economic stability in the long run by impeding economic fluctuations. Similarly, green finance and the PA show mixed influences across various time horizons, except for the long run, which confirms their negative association with economic cycles. Additionally, ES has a direct link with economic cycles across most periods. The robustness check based on the QQGC test and PQQRRLS method supports the main results. Our results identify AI, BRI, and the PA as new drivers of economic cycles with the potential to counter global economic cycles. Therefore, based on these findings, the study proposes several policy implications tailored to different time horizons.

1. Introduction

Global Economic history unfolds as a complex tapestry, with growth, recession, and crisis cycles shaping the global landscape. From the great depression of the 1920s to the financial crisis of 2007–2008 and the more recent convulsions of the COVID-19 pandemic, each period of upheaval has left an indelible mark on the trajectory of economies as Fig. 1 visualizes the global economic shocks (Yu and Qayyum, 2023). The Great Depression from 1929 to 1939 stands as a seminal chapter in economic history (Borazan, 2023), a time of unprecedented global economic downturn that reshaped the fabric of societies—subsequent decades witnessed the ebb and flow of economic cycles from the 2000s energy crisis, i.e., the oil price bubble (2003–2008) to the 2007–2008 world financial crisis, exposing vulnerabilities in global supply chains (Espinosa-Gracia and Sánchez-Chóliz, 2023). The financial crisis of 2007–2008 and its aftermath, known as the great recession from 2007 to 2009, underscored the limitations of existing economic models (Bessler

et al., 2023). The subsequent COVID-19 recession (2020–2022) and the Ukraine-Russia War (URW) crisis (2022–2024) added a new layer of complexity (Cherbib, 2024). This alarming global economic situation has caught the attention of policymakers, prompting them to coordinate and take immediate action. Also, global economists believe it is crucial to understand the trends of global economic cycles (World Bank, 2022), particularly through the lens of new technologies such as artificial intelligence. Therefore, understanding global economic shocks through the lens of the latest technologies is the core agenda of the current study.

In the context above, the economic literature underlines several factors for economic (business) cycles.¹ Among them, the most emphasized factor is technological progress, which is linked significantly with economic development and cycles (Lau et al., 2023; Wei et al., 2023; Ahmad and Zheng, 2023). The last two decades are essential for economic history, in which most global nations are blessed with enormous technological development that is diffused in various sectors of the economy. The main stream economic theories of technological progress

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¹ A state in which an economy endures fluctuations such that the economy expands, peaks, contracts, and troughs. These fluctuations might be termed as economic cycles (Wallerstein, 1984).

and its link with economic cycles can be divided into two categories. For instance, Schumpeterian Theory and Real Business Cycle (RBC) theory suggests that, among other real economic variables, oscillations in technological progress influence the production possibilities of firms, leading to fluctuations in output and employment, which ultimately causes the economic cycles (Cakici, 2024; Ahmad et al., 2023; Nikiforos et al., 2023). On the other hand, Endogenous Growth Theory determines that technological improvements tend to enhance the labour market's efficiency, which eventually leads to fostering stability in economic growth (Zhou et al., 2023; Kruse-Andersen, 2023) and decreases the possibility of economic cycles. This scholarly contradiction emphasizes further exploration for analyzing the contribution of recent technological innovations to global economic cycles, specifically in the era of current global economic shocks.

Most global nations have recently benefitted from the fast-spinning pace of new technological innovation (viz, artificial intelligence (AI)) and its diffusion in various economic sectors. AI can produce novel outputs rather than merely foretelling from already available data. Furthermore, this is an accessible technology that can be used by all nations in diverse sectors and industries through natural language interfaces (Zhang, 2023). Also, the future trends in the generative AI industry may result in new ideas for innovation, increased productivity, and new business opportunities. The IMF has recognized AI as a means of lifting global growth rates, wage levels, and output per person (International Monetary Fund, 2021). McKinsey predicts that by 2030, artificial intelligence may deliver approximately \$13 trillion of additional global economic activity (McKinsey Global Institute, 2017). Based on this discourse, it might be inferred that AI can significantly trigger international economic development by enhancing economic activities in various economic sectors, disrupting the possibilities of detrimental repercussions of economic cycles.

Contemporarily, global green financing in the form of green bonds, economic development projects like the Belt and Road Initiative (BRI), and environmental sustainability agreements such as the Paris Agreement (PA) and their contribution towards globalizing the new technologies, i.e., AI across the world cannot be overlooked. Green financing might enhance green technological innovation projects like AI for sustainable development by providing access to finance (Xu et al., 2023). Similarly, the BRI project, which has 151 member nations, might increase the access to AI by transferring it from developed nations to

developing nations (Wang et al., 2023). In a similar fashion, the PA strongly endorses the developed nations supporting the underdeveloped countries through sharing new technologies and knowledge (Chishti et al., 2024). At the same time, the influence of global economic shocks (ES) can also be not neglected. The recent literature (Xu et al., 2024; Pata et al., 2024; Hossain et al., 2024) reports the devastating effects of current ES, such as COVID-19 and URW, by disrupting the global economic supply chain and trade.

The above discourse induces the hypothesis that AI might play a critical role in determining the global economic cycles. Also, we can hypothesize that the BRI, the PA, and green finance can handle the exigency of global economic cycles by expanding the AI market worldwide. Economic shocks can also be assumed to influence the association between AI, BRI, PA, green finance, and economic cycles. Therefore, it is rational to assume that the disruption exerted by economic shocks might be dynamic, and thus, it can affect the global economic cycles. The recent study's focal point is exploring these issues, and therefore, we posit the following query:

Research Query: How can AI tackle the exigency of global economic cycles with the role of BRI, PA, and green finance amid global economic shocks over time?

In the context of the above query, our study extends the prior literature in the following ways. First, to the best of our humble understanding, this article introduces AI as a new driver to assess how it can assist in handling the economic cycles for economic sustainability. The diffusion of AI in most developed nations' global economic sectors might play a crucial role, specifically in the era of COVID-19 and URW. Hence, it is important to divulge the expected role of AI in determining global economic shocks. Second, the study extends the pertinent literature by testifying the RBC and Endogenous Growth theories empirically. Schumpeterian Theory and Real Business Cycle (RBC) theory suggests that, among other real economic variables, technological progress oscillations influence firms' production possibilities, leading to fluctuations in output and employment, which ultimately causes economic cycles. On the other hand, Endogenous Growth theory determines that technological improvements tend to enhance the labour market's efficiency, which eventually leads to fostering stability in economic growth and decreases the possibility of economic cycles. Hence, analyzing how and why AI support either RBC or Endogenous growth theory is imperative. Third, this is the first study that investigates how BRI and

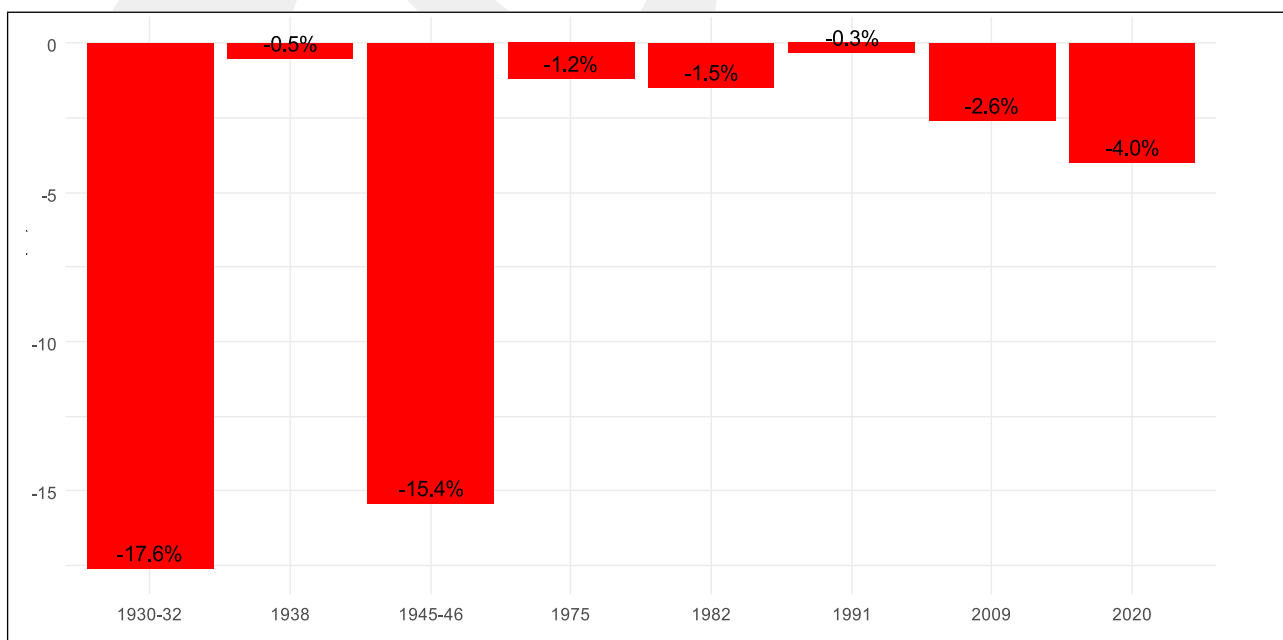


Fig. 1. Global per capita GDP growth during global economic recessions. Source: World Bank Blogs (2022).

the PA can play a role in influencing economic shocks. These variables might play a considerable role in enhancing global economic globalization; thus, assessing their effect on global economic shocks might be advantageous for policymakers.

Fourth, our study expects that the influence of AI, BRI, PA, and other variables might be nonlinear and dynamic. Thus, the study tends to deploy advanced econometric tools to handle the issue of nonlinearity and attain robust policy-oriented findings. To do so, the study relies on the CAViaR-TVP-VAR model to confirm the dynamic connectedness level. The study uses the Quantile Coherence (QC) approach to measure the marginal effects, producing outcomes for various market conditions and time horizons. The article deploys the Quantile-on-Quantile Granger causality (QQGC) test for robustness check. Notably, the study introduces a novel machine learning-based panel, Quantile on Quantile Kernel-Based Regularized Least Squares (PQQKRLS), deployed to perform further robustness check analysis.

The upcoming sections of the article possess the following order. [Section 2](#) focuses on the pertinent literature review, and [Section 3](#) covers the theoretical underpinning for econometric modelling. [Section 4](#) covers the deployed methodology and data sources. [Section 5](#) documents the findings and discussion. The [last section](#) concludes the study and suggests policy implications.

2. Literature

To deal with the economic cycles depends on how global authorities strive to grasp the complexities relevant to global economic cycles. Their understanding is highly associated with the policy tools used to tackle this issue. These tools might be in the form of local strategies such as advanced technologies and pertinent finance. Also, these economic cycles might be associated with global developmental steps such as economic development projects and environmental development organizations. At the same time, the global economic shock cannot be neglected. Thus, this part of the article reviews the pertinent literature in the context of the above perspective and endeavours to divulge the rational literature gaps to be addressed.

2.1. Economic cycles and artificial intelligence

One way to view the economic expansion over the past 150 years is to say that the rise of automation brought it about. As a result of the Industrial Revolution, many production processes were automated through steam and, later, electricity. This pattern was maintained as switches, semiconductors, and transistors continued to emerge. It is possible that artificial intelligence is not a departure from the past but rather a new step in this process ([Morikawa, 2017](#)). Self-driving automobiles and AI radiology reports are the next logical step after computer-controlled automotive engines, autopilots, and magnetic resonance imaging (MRI) devices. However, until now, automation has primarily impacted routine tasks or requires modest competence. According to [Goertzel et al. \(2017\)](#), AI may eventually be able to automate non-routine cognitive tasks that highly competent humans perform.

The overall productivity of the manufacturing sector in the United Kingdom, Germany, and Japan may increase by 8 % to 22 %, respectively. [Dinlersoz and Wolf \(2024\)](#) take advantage of the constant elasticity of the replacement production function in conjunction with endogenous technology choice to build the relationship model that describes the relationship between automation and relative factor consumption. Some scholars believe that AI positively affects the expansion of the economy. On the other hand, a few restrictions come with earlier studies. This is because they incorporated certain aspects of AI into preexisting theories, also known as classical theoretical models. The only degree of validation for these results is the academic level; there is no data validation. As a result, the empirical analysis of the consequences of AI on economic growth (EG) will be the primary focus of this section. In addition, [Brynjolfsson and Hitt \(1995\)](#) conducted an

empirical study to investigate the impact of computerization on productivity. For example, they used a sample of 527 American companies with eight-year stock data. The results demonstrate that implementing computerization has a beneficial impact on productivity and increases EG. [Dinlersoz and Wolf \(2024\)](#) also developed a model that explains how automation affects relative capital intensity within industries. According to this model, a higher degree of automation means the labour force shares in production decrease, and a much more significant part is allocated to capital. Thus, this results in a lower percentage of highly paid workers. This implies that productivity goes up because of automation. In his study on US macroeconomics, [He \(2019\)](#) views artificial intelligence as an additional input to production. The vector error correction model and empirical analysis show that EG rises as AI inputs increase.

The previous discussion has shown the importance of AI in automation and its capability to improve efficiency and result in enhanced productivity. This can also be viewed as a way AI might hasten output growth. However, limited attention is paid to this side, which requires more exploration in this era of AI. *Thus, it is appropriate to hypothesize that "AI might contribute to tackling the exigency of economic cycles by fostering economic growth."*

2.2. Economic cycles and BRI

In 2013, China launched the Silk Road Economic Belt and the 21st Century Maritime Silk Road initiative, viz., Belt and Road Initiative (BRI) in order to enhance global regional connectivity, specifically among Asia, Africa, and Europe ([World Bank, 2018](#)). Interconnectivity is the key to BRI development, and infrastructure construction is the basis for interconnectivity. The BRI mainly focuses on infrastructure connectivity among BRI countries to realize coordinated development for shared prosperity in the global economy.

After decades of expansion, China has achieved the most infrastructural stock compared to other nations. Infrastructure development is central to China's transformation from a weak economy into the world's second-largest economy over the last forty years. China's experience can provide important insights for BRI countries and contribute to shaping a community of shared future for global development. According to the Asian Development Bank (ADB), Asia requires \$26tn worth of investments by 2030 to bridge their infrastructure gaps ([Shang, 2020](#)). Even though significant improvements have been made over the past few decades, Asian infrastructures are still lagging behind economic, population, and urban changes. This leaves opportunities open for large-scale investment in transportation, electric power, water, and health sectors, and China currently possesses a comparative advantage in those fields. Interconnection within BRI constructs bridges between relevant states' interests and world economic progress.

In the context of economic development, trade and economic data related to BRI have been investigated extensively by scholars. [Zhang et al. \(2018\)](#) estimated that while accessing China's industrial manufacturing production capacity and urban development expertise for planning purposes, these countries will explore new ideas, thereby leading them to achieve more significant gains through enhanced trade." Regarding industrial structure, [Yao et al. \(2018\)](#) reveals that compared to other Belt Road partner members' labour, China's intensive manufacturing sector has a competitive edge compared with capital-intensive manufacturing and producer services. [Zhang et al. \(2022\)](#) used social network analysis to show that China is an intermediate link in international trade, having close ties with developing and developed countries. However, only a few academic researchers have been studying the effects of BRI project. [Berger et al. \(2020\)](#) researched the contribution of BRI-financed infrastructure projects to economic growth, especially among countries with limited existing infrastructure.

Limited literature is available to assess how BRI affects economic development and confirms that BRI has a significant potential to either directly or indirectly promote economic growth or speed up

development processes. This positive association might assist in dwindling the adverse influence of global economic cycles by enhancing regional and global economic connectivity. *Thus, it would be reasonable to put forward the hypothesis that BRI might play an auxiliary role in tackling global economic shocks for sustainable growth.*

2.3. Economic cycles and Paris agreement

The Paris Agreement, adopted in 2015 under the United Nations Framework Convention on Climate Change (UNFCCC), aims to combat climate change and accelerate actions and investments needed for a sustainable low-carbon future. The main objectives of PA are limiting global warming, improving adaptive capacity by strengthening the ability of countries to deal with the impacts of climate change, providing financial support, regular reporting on emissions and progress towards targets by all parties, conducting a global stock take every five years to assess the collective progress towards achieving the goals of the agreement, outlining the efforts and progress through NDCs, and facilitating international cooperation through mechanisms such as carbon markets and other voluntary cooperative approaches (UNFCCC, 2024). Several aspects are involved in the intersection between the Paris Agreement and economic development in countries participating in China's BRI, which include energy transition, infrastructure investments, and Sustainable Development Goals. The Chinese government has provided guidance documents that set a time-bound Paris-aligned plan for China's overseas investment, focusing on supporting energy transition and green transport, which enhances socioeconomic development (Chinadialogue, 2019a, 2019b). However, Chinese investments in BRI countries result in higher carbon emissions pathways, mainly in developing nations where BRI investments are most increased, thus meaning that BRI will also have an outsized influence on emissions (Chinadialogue, 2019a, 2019b). Considering these concerns, the Chinese government established the BRI International Green Development Coalition (BRIGC), whose primary purpose is to foster international consensus, understanding, cooperation, and concerted actions towards green development of the BRI (Boston University Global Development Policy Center, 2020). The BRIGC has initiated various initiatives, including the BRI Green Development Report, Joint Research on "Green Development Guidance on BRI Projects," and a joint study on BRI Green Development Case Studies.

In addition, this literature review examines some risks associated with the implementation of the project under study, such as legal restrictions, environmental hazards, governance risks, social risks etc., which can contribute to the success or failure of a project (Scientific Research Publishing, 2019). Examples include sustainable practices like renewable energy and efficient transport. Clean energy investments can significantly enhance economic growth while promoting climate-resilient development via green infrastructure. Thus, encouraging low-carbon trade and investment is one way for the PA. For instance, technology transfer means accessing advanced technologies for sustainable development. Another driver is attracting investors who need climate-friendly projects. Improving skills plus knowledge relating to climate action through Capacity Building (Sharif et al. (2023) when scrutinizing the effects of energy tax.

Nonetheless, some policymakers argue that regional-level regulations can be instrumental in advancing ET, though this stimulates economic development. Many studies (Pan et al., 2023; Liu et al., 2022; Ahmed et al., 2022) have recognized the Paris Agreement's role in economic development and climate action balance for BRI economies. These countries can contribute to global efforts while pursuing growth by incorporating sustainable practices into BRI projects. *Consequently, the study conjectures that the PA can be a paramount driver in addressing the economic cycles.*

2.4. Economic cycles and green finance

So far, the pertinent literature reports that the connection between

economic growth and financial development is positive (King and Levine, 1993; Beck et al., 2000), especially in developed nations (Marques et al., 2013) and emerging as well as developing economies (Bittencourt, 2012). As the financial market matures, the research on this issue becomes more comprehensive. For example, scholars have examined various channels through which financial development can enhance economic growth (Gazdar et al., 2019; Bucci et al., 2019) and found that different proxies of finance display divergent roles in fostering economic growth (Wang et al., 2019a, 2019b; Adu et al., 2013), and explored how financial regulatory policies affect the linkage between financial development and economic growth (Bernier and Plouffe, 2019). Thus, green finance is a recently introduced financing method to address environmental problems, which represents a financial invention in the field of environmental protection (Wang et al., 2019a, 2019b). Traditional finance has similar traits to green finance.

Consequently, just like in the case of financial development, green finance can also support economic progress. However, only some present studies on green finance exist due to its short existence. He et al. (2019) indicated that investment into renewable resources has double threshold effects on green economy development; in the future, it takes green investment into renewable energy to ensure the growth of a green economy to happen effectively. Pradhan et al. (2018) noted that the government should support green financing mechanisms by investing in clean energy areas such as natural gas, contributing to environmental conservation and growth. *"Therefore, we can infer the hypothesis that green finance can promote economic growth and curb the economic cycles."*

2.5. Economic cycles and economic shocks

Economic shocks are sudden and massive interruptions in the global economy that have a widespread impact. These shocks can come from many causes, such as geopolitical events, financial crises, natural calamities, and epidemics (Aastveit et al., 2017; Gök et al., 2022). In this part of the literature, these shocks are examined to how they affect economic growth and development in countries and how they cause global economic cycles. The occurrence of economic shocks causes uncertainty among investors and firms, thus leading to postponed investment and spending. For example, there was a credit crunch and reduced investments due to the global financial crisis that occurred in 2008, causing enormous decreases in output and employment (Reinhart and Rogoff, 2009). Equally, natural calamities such as the earthquake and tsunami disaster experienced by Japan in 2011 had a severe impact on supply chains across the region, reducing their output (Cavdur et al., 2016). Different transmission mechanisms through which crises spread include the finance, trade, confidence, and policy uncertainty channels that bring about variation between sectors and regions (Blanchard and Summers, 2017).

Nevertheless, factors such as shock intensity, effectiveness of policy responses, and underlying structural characteristics have long-term effects on economic shocks. While some shocks can lead to permanent adverse effects on growth, others may cause innovation, resulting in different structures that eventually become more resilient over time (Aghion et al., 2021; Yang et al., 2024; Kafka and Kostis, 2024). For instance, the COVID-19 pandemic has led to significant declines in GDP through supply shocks, reductions in employment levels, lower production levels and exports, and lockdown restrictions (Ahangar and Kim, 2022). Any worldwide domestic economic disaster can negatively influence GDP and cause economic cycles. Economic shocks can increase uncertainty within the economy, limiting its output growth.

The above literature-based debate on economic shocks indicates that their effects are averse to output growth and can result in economic fluctuations. It can also be deduced that such shocks speed up volatility in business cycles. *Thus, we can assume that global economic shocks stimulate business cycles worldwide.*

2.6. Literature gap

Based on the above review, the following gaps in the pertinent literature can be identified. For example, economists contradict while considering the main stream economic theories of technological progress and its link with economic cycles. For instance, Schumpeterian Theory and Real Business Cycle (RBC) theory suggests that, among other real economic variables, oscillations in technological progress influence the production possibilities of firms, leading to fluctuations in output and employment, which ultimately causes the economic cycles (Cakici, 2024). However, Endogenous Growth Theory determines that technological improvements tend to enhance the labor market's efficiency, which eventually leads to fostering stability in economic growth (Zhou et al., 2023) and decreases the possibility of economic cycles. Also, the pertinent literature failed to provide empirical evidence on how AI, BRI, GF, and the Paris Agreement (PA) influence the economic cycles. At the same time, the dynamic influence of GPR on global economic cycles could not be undermined. Based on the gaps mentioned above in the literature, it is essential to explore the dynamic effects of AI, BRI, PA, and GF on economic cycles in the era of global economic shocks to further explore the nature of economic cycles. Also, it is crucial to understand whether the advanced form technologies "AI" can tackle the exigency of economic cycles. To fill these considerable literature gaps, the recent study examines the dynamic effects of AI, BRI, PA, GF, and ES on economic cycles to draw suitable policy suggestions for pertinent authorities.

3. Theoretical underpinning

Economic cycles (EC) can be referred to as a state in which an economy endures fluctuations such that the economy expands, peaks, contracts, and troughs. These fluctuations might be termed as economic cycles (EC). Understanding the nature of EC and its factors is a crucial but critical area of economic literature. The economic literature underlines several factors contributing to economic (business) cycles. Among them, the most emphasized factor is technological progress, which is linked significantly with economic development and cycles (Ahmad and Zheng, 2023).

Most global nations have recently benefitted from the fast-spinning pace of technological innovations like artificial intelligence (AI) and its diffusion in various economic sectors. AI can produce novel outputs rather than merely foretelling from already available data. Furthermore, this is an accessible technology that can be used by all people in diverse sectors and industries through natural language interfaces (Zhang, 2023). Further, the IMF has recognized AI as a means of lifting global growth rates, wage levels, and output per person (International Monetary Fund, 2021). McKinsey predicts that by 2030, AI may deliver approximately \$13 trillion of additional global economic activity (McKinsey Global Institute, 2017). Therefore, AI can significantly improve labour productivity by automating routine tasks and freeing workers to focus on more complex or value-added activities. In addition, it would help generate insights based on data, enabling businesses to unfold what is happening with them in terms of identifying consumer patterns and developing new product lines or services using these results. This means countries can leverage AI to improve their global competitiveness and attract investors who want to create a vibrant startup ecosystem for tech firms (Chen et al., 2024).

Based on the above discussion, it can be argued that AI might be a crucial driver in supporting and fostering economic growth and dwindling the uncertainties related to global economic development, which might cause the EC. Therefore, AI might play a critical role in determining the EC, and it is rational to express this theory-based association mathematically as follows:

$$EC_t = (AI_t) \quad (1)$$

Like AI, another likely important driver of EC is the global grand

development project "BRI" initiated by Chinese authorities. It focuses on improving connections using roads, trains, harbours, and power lines. This type of investment promotes trade, cuts down on transportation costs, and integrates the national economies of the participating countries—a possible outcome (Yu et al., 2024). Also, suppose such BRI transport projects were implemented. In that case, they may shorten journey times in economic corridors by 12 %, enhance trade from 2.7 % up to 9.7 %, and take out of extreme poverty about 7.6 million people (Nanwani, 2020). Chinese foreign aid, including other BRI-related funding, facilitated overcoming infrastructure gaps, thereby developing host countries' economies (Chen et al., 2021). At this moment, May Petry's (2020) investigation reveals that Chinese financing, as opposed to traditional development finance institutions, is more directed towards industry and infrastructure loans. For instance, over the last decade, BRI has attracted approximately 1 trillion dollars in investments across global economies through over three thousand projects (Chen et al., 2021).

Also, Von Bogdandy (2017) shows that a new model of a south-south corporation was co-created by BRI. China raised the Global South profile within global economic governance by increasing its role in liquidity provision and development finance. Southern-led alternative organizations provide additional possibilities for much-needed funds, empowering developing nations. The BRI's emphasis on infrastructure aligns with Sustainable Development Goal Number Nine of the United Nations, which aspires to have sustainable industrialization for all countries with resilient infrastructures while promoting innovation (Ruta et al., 2019). In summary, the connectivity emphasis proposed by BRI, resulting in infrastructure improvement, can help stimulate economic growth while addressing the volatile nature of economic shocks, leading to job creation and enhancing overall well-being. Based on the above arguments, it seems rational to consider BRI as a vital driver of EC, and the prior mathematical model can be extended as:

$$EC_t = (AI_t, BRI_t) \quad (2)$$

Also, a global environmental accord, i.e., the Paris Agreement (PA), a revolutionary contract accepted by 197 nations, can be considered a vital driver of international sustainable development to counter global economic uncertainty challenges. The main goal of this agreement is to reduce CO2 emissions significantly by committing countries to specific greenhouse gas (GHG) reduction targets, providing for environmental sustainability, and increasing economic productivity (Chishti et al., 2024). Additionally, the PA allows the world economies to attract green investments and stimulate future innovation through upgrading infrastructure such as renewable energy grids, efficient transportation, and resilient urban planning. Additionally, it might allow developed and developing countries to venture into new markets for renewable energies, green finance, or eco-products, escalating sustainable growth worldwide (Lu et al., 2020). Similarly, the PA might help in improving collaboration among the developing and developed world to address various global challenges related to a sustainable environment by transferring technology, knowledge, and joint research while also serving as a comprehensive framework for sustainable development that links environmental objectives with economic prosperity (International Renewable Energy Agency, 2020). Eventually, this process might foster sustainable economic growth worldwide, countering EC issues effectively. Hence, it seems rational to consider PA as a crucial driver of economic cycles, and Eq. (2) can be extended as:

$$EC_t = (AI_t, BRI_t, PA_t) \quad (3)$$

Green finance (GF) is a field that seeks to merge financial operations, environmental protection, and ecological equilibrium. It consists of financial tools and mechanisms that aid environmentally conscious projects and sustainable growth by assigning funds to clean energy, energy efficiency, and environmental preservation. Additionally, GF is synonymous with allocating funds towards green infrastructure, which enhances economic development, promotes job creation, and fosters

technological advancements in line with the United Nations Sustainable Development Goals (SDGs) for promoting inclusive and sustainable economic growth (Puaschunder, 2023). By investing in projects like renewable energy, public transportation systems, or eco-friendly buildings that combine ESG factors, we can reduce risks of climate change and resource depletion using green finance.

In addition, when it comes to sustaining agriculture, clean energy generation, or circular economy, they help attract private investments into sustainable projects such as “green bonds,” thus driving market innovation and growth (De La Orden and De Calonje, 2022). According to De La Orden and De Calonje (2022), green finance complements national policies that meet global climate goals by encouraging financial system transparency, disclosure, and accountability. A study conducted by Liang and Song (2022) on panel data from Chinese provinces showed how green finance promotes economic development while reducing emissions of industrial pollutants, thereby handling economic shocks. However, Zhang et al. (2021) find that there are different impacts on environmental quality due to differing levels of economic development, indicating that green finance may enhance sustainable economic growth, creating a win-win situation in that way. Accordingly, the Eq. (3) can be extended as:

$$EC_t = (AI_t, BRI_t, PA_t, GF_t) \tag{4}$$

Nevertheless, Ignoring the economic shocks resulting from geopolitical risks (GPR) and other sources is unsuitable. This progress in global geopolitics may produce the continued political wrangling around various regions with China and Russia at its centre, influencing investment ratio GDP growth and increasing business cycle dislocations. For example, according to a report by the United Nations (2022), the Ukraine–Russia War affected the green transition by causing disruptions in global trade and investment ratios, leading to a giant swing in economic activity.

Moreover, due to inconsistent international trade patterns, several regional and global investment sectors were negatively affected by the

China-US trade war, leading to high inflation rates (Centre for Economic Policy Research, 2023). A worldwide economic or geopolitical shock could reduce the flow of international investing across countries, causing a halt in rapid changes involving business cycles. Hence, it might be critical to consider GPR as a representative of economic shocks that might cause the global EC, and the final form of the model can be written as:

$$EC_t = (AI_t, BRI_t, PA_t, GF_t, ES_t) \tag{5}$$

In the above expression, EC, AI, BRI, PA, GF, and ES exhibit the economic cycles, artificial intelligence, the Belt and Road Initiative, the Paris Agreement, green finance, and economic shocks. Based on the above discourse, we expect the positive influence exerted from AI, BRI, PA, and GF, with adverse effects stemming from ES. Further, the graphical representation of the above nexus is sketched in Fig. 2.

4. Econometric tools and data

For empirical analysis, the study tends to utilize the advanced econometrics tool. For instance, the study first confirms whether the total and directional connectedness among the opted series exists. Secondly, the Quantile Coherence method measures the marginal effects of various market conditions across different time horizons. Thirdly, the QQGC test is deployed to assess the various time horizon-wise Granger causality between independent and dependent series. Also, the study deploys the PQQKRLS method for robustness check. Besides, Fig. 3a visualizes the sequence of the deploy methods for analysis. It shows that the study firstly confirms the total and directional connectedness among the selected series. Subsequently, the marginal effects are computed by using the Quantile Coherence method. Finally, the results’ validation is checked by deploying the QQGC test and PQQKRLS method.

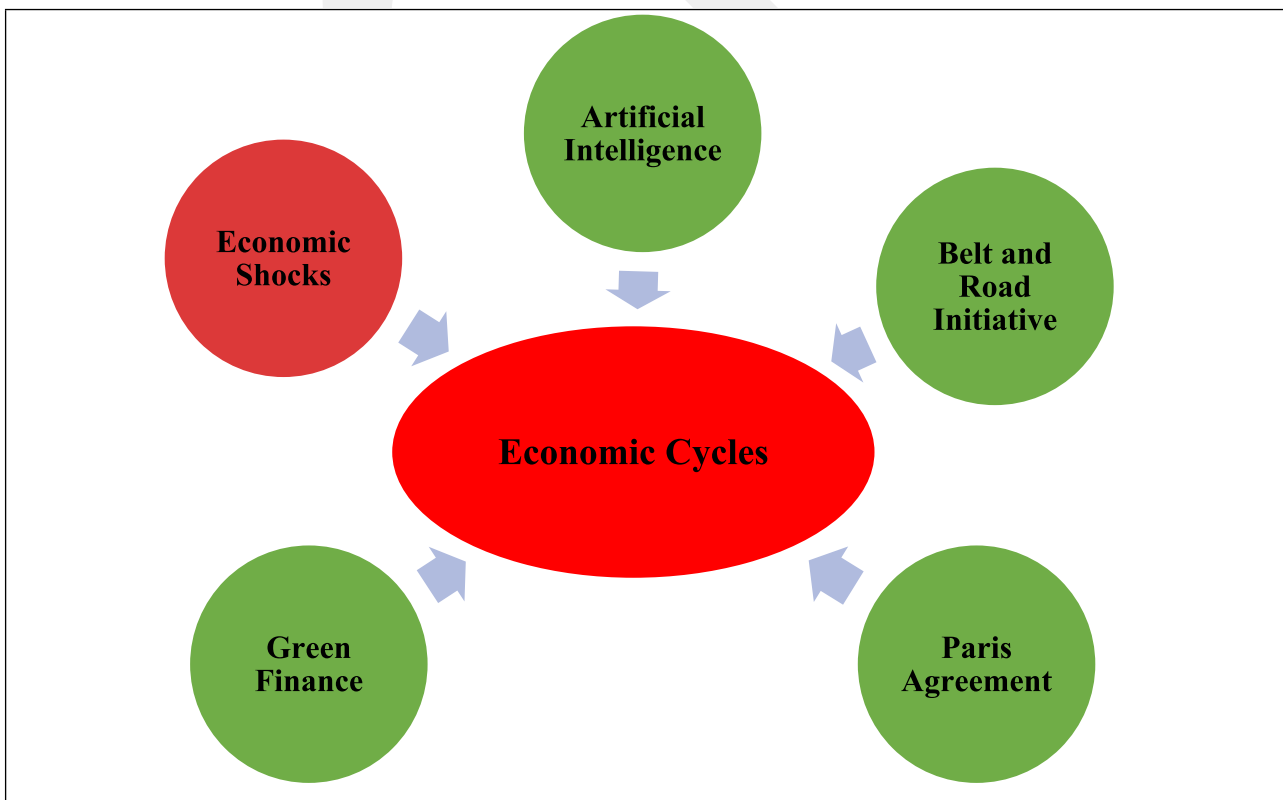


Fig. 2. Theory-based nexus between AI, BRI, PA, GF, ES, and EC.

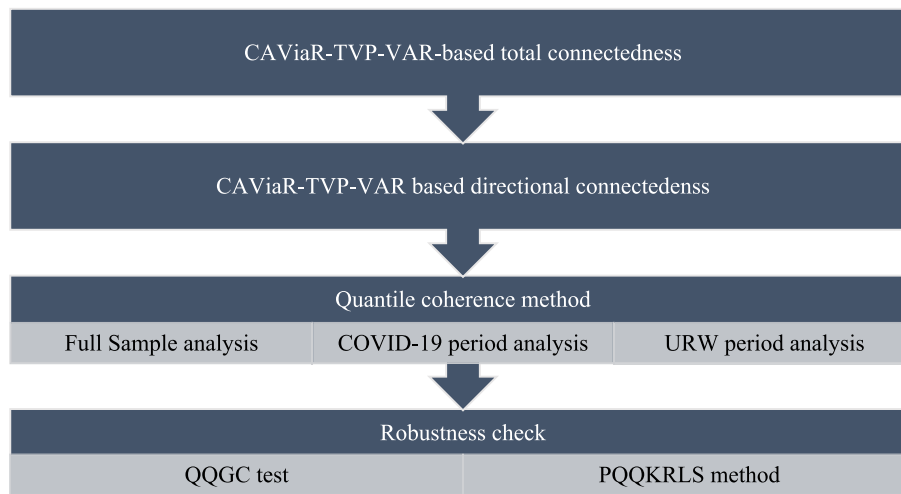


Fig. 3a. Flow chart of deployed econometric methods.

4.1. CAViaR-TVP-VAR model

To measure the risk-based connectedness and to explore the risk transmission, the study follows Naeem et al. (2023a) and utilizes the Conditional autoregressive value-at-risk (CAViaR) model propounded by Engle and Manganelli (2004). Also, the article deploys the TVP-VAR method by Antonakakis et al. (2020). The combination of both approaches, viz., the CAViaR-TVP-VAR technique, is mainly utilized to assess the level of risk transmission, which also gives the benefit of divulging the level of tail risk-based connectedness. The mathematical form of the above model can be expressed as:

$$f_{a,t}(\gamma) = \gamma_0 + \gamma_1 f_{a,t}(\gamma) + \gamma_2 x_{t-1}^+ + \gamma_3 x_{t-1}^- \tag{6}$$

The study utilized the VAR at 5% quantile, which is captured by $f_{a,t}$. Further, γ_0 is the constant, and γ_2 and γ_3 are the VAR-based returns. Besides, t exhibits the time in order to capture the time-varying effects. Among the various advantages, the notable benefit of the CAViaR model is that it can capture the nonlinear dependencies among the opted series while measuring the connectedness risk. Also, its capability to measure the risk transmission directly is a unique characteristic as compared to the VAR model (Naeem et al., 2023a, 2023b).

4.2. Quantile coherence method

After confirming the total and directional connectedness based on the CAViaR-TVP-VAR methodology, the study tends to measure the marginal effects. The study utilizes the quantile coherence (QC) approach propounded by Baruník and Kley (2019). The article advocates for adopting the QC approach due to several advantages. The QC method effectively addresses the impact of outliers within the data and is equipped to handle potential nonlinearities in the series by presenting results across different quantiles. Additionally, the QC technique offers comprehensive dynamic insights by generating results based on distinct time horizons, as highlighted by Khalfaoui et al. in 2022. Also, the QC method visualizes the outcomes for various (bearish, normal, and bullish) market conditions to understand the series' behaviour in the context of policy implications. To write the mathematical expression of the QC method, Baruník and Kley (2019) suggest the following equation:

$$\tilde{\rho}_{n,R}^{j_1 j_2}(\omega, \tau_1, \tau_2) = \frac{\tilde{Y}_{n,R}^{j_1 j_2}(\omega, \tau_1, \tau_2)}{\sqrt{\tilde{Y}_{n,R}^{j_1 j_1}(\omega, \tau_1, \tau_1) \tilde{Y}_{n,R}^{j_2 j_2}(\omega, \tau_2, \tau_2)}} \tag{7}$$

The above expression is utilized to compute the marginal influence of independent series on dependent series, and the QC approach visualizes its outcome in heatmaps. Subsequently, our article tends to deploy the

novel quantile-on-quantile Granger causality (QQGC) test erected by Adebayo and Özkan (2024) for robustness check. Among the numerous benefits, QQGC reports the causality-based outcome for various quantiles which are categorized as short, medium, and long-run quantiles to grasp the causality level for different time horizons. Also, the QQGC test can handle nonlinearity issues in the opted series. Besides, this method can tackle the influence of outliers stemming from various economic shocks such as COVID-19 and URW by providing the results in different quantiles and reliable results for policymakers (Adebayo and Özkan, 2024).

For further robustness checks, the recent study takes the panel data of 16 countries based on the availability of data restrictions. For empirical analysis, the article tends to propound a novel machine learning-based method, viz., panel Quantile on Quantile Kernel-Based Regularized Least Squares (PQQKRLS) method that is the extended form of QKRLS by Adebayo et al. (2024). Adebayo et al. (2024) utilize the KRLS (Kernel Regularized Least Squares), introduced by Hainmueller and Hazlett (2014) and integrate it with the Quantile-Quantile regression method developed by Sim and Zhou (2015) and the quantile estimation method by Li et al. (2015) in order to measure the marginal influence of independent series on explained series.

In order to compute the marginal influence of an independent series on the explained variable, Hainmueller and Hazlett (2014) suggest the following mathematical expression:

$$E_N \left[\frac{\beta \hat{Y}}{\beta X_k} \right] = \frac{-2}{\sigma^2 N} \sum_k \sum_i j_i e^{\frac{\|X_i - X_k\|^2}{\sigma^2}} (X_i - X_k) \tag{8}$$

The above mathematical equation demonstrates that $E_N \left[\frac{\beta \hat{Y}}{\beta X_k} \right]$ shows the change in dependent series due to independent series, viz., it measures the marginal effects. Further, N denotes the sample size, and k indicates the single observation. In order to develop the PQQKRLS method, we follow Adebayo et al. (2024) and amalgamate the KRLS with the quantile-quantile regression method developed by Sim and Zhou (2015) and the quantile estimation method by Li et al. (2015). The mathematical expression of the PQQKRLS method can be written as follows:

$$E_N \left[\frac{\beta \hat{QY}_\tau}{\beta \hat{QX}_{\theta k}} \right] = \frac{-2}{\sigma^2 N} \sum_k \sum_i \sum_t j_{it} e^{\frac{\|X_{\theta it} - X_{\theta kt}\|^2}{\sigma^2}} (X_{\theta it} - X_{\theta kt}) \tag{9}$$

In the above equation, $E_N \left[\frac{\beta \hat{QY}_\tau}{\beta \hat{QX}_{\theta k}} \right]$ indicates the change in dependent series due to independent series. Further, t implies the time, i shows the cross-sections, j_{it} represents the weight associated with each cross

section at time t . Besides, X is the independent variable, and θ is the parameter. Among the notable benefits, the PQQKRLS method can handle the issue of outliers by producing the outcomes for various quantiles. Hence, the quantile-wise results can also tackle the basic problems pertinent to panel data, such as autocorrelation and heteroscedasticity. Also, this method can capture the effects of economic shocks by reporting the marginal effects in different quantiles. Additionally, this method can also handle the likely asymmetries in the data. Since the PQQKRLS technique considers each cross-section while computing the marginal effects, it can tackle cross-sectional dependence and heterogeneity. This method is based on bivariate modelling, insensitive to model misspecification. Besides, the PQQKRLS method is based on machine learning and other advanced tools; it is more powerful and reliable for analysis.

4.3. Data and preliminary analysis

In order to assess how artificial intelligence (AI) with the consort of the Belt and Road Initiative (BRI), the Paris Agreement (PA), green bonds (GB), and economic shocks (ES) affect global economic cycles (EC), our study retrieves the data for modelled series from various authentic sources. For instance, the data for AI (proxied by the Global Artificial Intelligence Index), the PA (proxied by Net Zero 2050 Paris-Aligned Index), and GB (proxied by the Green Bonds Index) are obtained from the source of S&P Dow Jones Indices (<https://www.spglobal.com/spdji/en/>). The study selects AI as an important determinant of economic growth, as suggested by [Zarova et al. \(2023\)](#) and [Ma et al. \(2023\)](#). Hence, it is rational to consider AI as a new driver of economic cycles. Also, [Guzović et al. \(2023\)](#), [Ottonelli et al. \(2023\)](#), and [Alessi et al. \(2024\)](#) suggest that PA can play a critical role in order to determine economic development. Therefore, it might contribute to determining the economic cycles. Additionally, we use GB, which has a significant role in boosting economic development, following [Dong et al. \(2023\)](#), [Asl et al. \(2023\)](#), and [Tiwari et al. \(2023\)](#). Further, the study follows [Cheng et al. \(2023\)](#) and [Tang et al. \(2023\)](#) and utilizes geopolitical risk, i.e., GPR ([Caldara and Iacoviello, 2022](#)), to capture the influence of global economic shocks (ES). [Che et al. \(2023\)](#) and [Salisu et al. \(2023\)](#) identify that GPR significantly causes financial and economic shocks. Thus, it is rational to consider GPR a salient factor in economic cycles. To measure the global economic cycles, the study takes the data for global sustainable economic growth (proxied by the World Sustainability Index) from S&P Dow Jones Indices. We deploy the Markov switching Bayesian Vector Autoregressive Model (MS-BVAR) to compute the filtered probability, which can be utilized to measure economic cycles ([Maneejuk et al., 2024](#)).

Additionally, our study deploys a newly developed Belt and Road index by [Chishti et al. \(2024\)](#) to measure the effects of the global economic development project “Belt and Road Initiative” (BRI). The data utilized for the analysis covers the period 06-04-2018 to 10-27-2023, as per availability conditions. This period covers two global economic and geopolitical shocks, respectively. For instance, the global pandemic “COVID-19” occurred at the beginning of 2020, significantly disrupting international economic activities. Another economic shock, the “Ukraine-Russia War,” was observed at the start of 2022, considerably deteriorating the global economic supply chain. The study also performs data analysis for robustness checks. The study retrieves the data from various authentic sources for panel annual data analysis, which ranges from 2014 to 2020. For instance, we download the GDP per capita data from [World Development Indicators \(2024\)](#) and apply the MS-BVAR model to measure the EC. The data for China’s FDI to BRI economies for the BRI project is taken from the [Chinese National Bureau of Statistics \(2024\)](#) and used to capture the BRI’s effects. We used dummy variables to capture PA’s influence. Since PA was adopted by the end of 2015, we have kept its value at zero for the years before 2016. We use data for environmental taxes as a proxy for GB retrieved from the [OECD database \(2024\)](#). Besides, the data for geopolitical risk as a proxy for ES

is taken from ([Caldara and Iacoviello, 2022](#)).

[Table 1](#) documents the preliminary analysis for the opted series. It can be noted that ES has the most enormous variance, followed by BRI, and EC possesses the most negligible variance. Further, the series are significantly skewed; some are positively skewed, while others are negatively skewed. The presence of significant skewness confirms that all modelled series are asymmetrically distributed. Further, the significance of the Kurtosis and Jarque-Bera test also asserts that all series have a nonlinear distribution. The presence of asymmetric distribution requires the application of nonlinear methods to tackle the asymmetries in the series and obtain unbiased outcomes ([Razzaq et al., 2023](#)). Thus, the recent article opts to deploy several nonlinear methods such as the CAViaR-TVP-VAR model, quantile coherence (QC) approach, and Quantile-on-Quantile Granger causality (QQGC) test to attain robust outcomes. Further, the outcomes based on the ERS unit root test verify that all modelled series are pure from the non-stationarity. All modelled series are transformed into percentage change ([Lau et al., 2023](#); [Gozgor and Istiak, 2023](#)), and their trends are reported in [Fig. 3b](#). Besides, [Fig. 4](#) depicts the correlations matrix for opted series to understand the correlation level among these series.

5. Results and discussion

5.1. Tail risk-based connectedness

This subsection explores the total and directional connectedness between the modelled series and economic cycles while analyzing the 5 % Value at Risk (VaR) based on the asymmetric CAViaR model. Before delving into the interpretation, it is worth noting that the higher the spikes in the series, the greater the tail risk. Additionally, the comovement among the series indicates their connectedness. Examining the total tail risk connectedness reported in [Fig. 5](#), it can be inferred that ES exhibits several significant peaks, especially after 2020 and 2022, making it the riskiest series. Similarly, BRI emerges as the riskiest series, with considerable peaks observed after 2020 and 2022. AI also shows significant peaks among the other selected series, particularly after 2020 and 2022. PA and GB also demonstrate notable peaks during 2020 and 2022. These conspicuous tail risks in the form of high spikes after 2020 and 2022 can be attributed to COVID-19 and URW, which significantly affected global economic and financial markets by escalating uncertainty. These findings align with the earlier research by [Xu et al. \(2024\)](#) and [Hossain et al. \(2024\)](#).

Interestingly, all the modelled series exhibit a consistent pattern, indicating a robust tail risk-based connectedness. This suggests that each series responds significantly to global economic shocks, resulting in exposure to tail risk. After confirming this overall tail risk-based connectedness, we further assess directional connectedness using the network spillover, employing the CAViaR-TVP-VAR model.

Looking at the directional connectedness for the entire sample period depicted in [Fig. 6](#), it can be seen that all the selected series exhibit a substantial tail risk spreading from one series to the other. Assuming that the risk-taker series is a risk recipient and the risk-spreading series is the risk transmitter, it can be inferred that all modelled series are significant risk recipients and transmitters, indicating a strong tail risk connectedness among them. Notably, ES appears to be a predominant risk transmitter. Additionally, EC acts as both a recipient and transmitter, indicating a strong link with other variables in the model. The above outcomes suggest that, due to the impact of COVID-19 and URW, all series have to endure significant risk, which is transmitted to other series. The evidence of each series acting as both a recipient and transmitter indicates that all series are interconnected and significantly interlinked. Similar outcomes are also reported by [Chen et al. \(2024\)](#), confirming the influence of economic shocks on other financial markets.

Focusing on the directional connectedness for the COVID-19 sample period presented in [Fig. 7](#), we observe significant interconnectedness among all selected series. This implies that all chosen series exhibit

Table 1
Descriptive statistics.

Averaged dynamic connectedness table						
	AI	BRI	PA	GB	ES	EC
Mean	0.039	0.093	0.035	-0.012	0.09	0.037
Variance	3.297	175.86	1.881	0.214	571.315	0.013
Skewness	-0.512***	0.829***	-0.662***	-0.194***	-0.140**	5.016***
Ex.Kurtosis	4.067***	4.711***	12.706***	4.669***	1.895***	25.115***
JB	1027.510***	1457.030***	9533.475***	1282.324***	214.417***	42,725.634***
ERS	-5.593***	-4.825***	-12.631***	-6.678***	-3.222***	-8.000***
Q(10)	30.360***	315.997***	119.878***	47.210***	301.868***	2278.268***
Q2(10)	669.921***	64.795***	1109.471***	332.087***	169.397***	1673.567***

Note: ***, **, and * show the significance level at 1 %, 5 %, and 10 %, correspondingly.

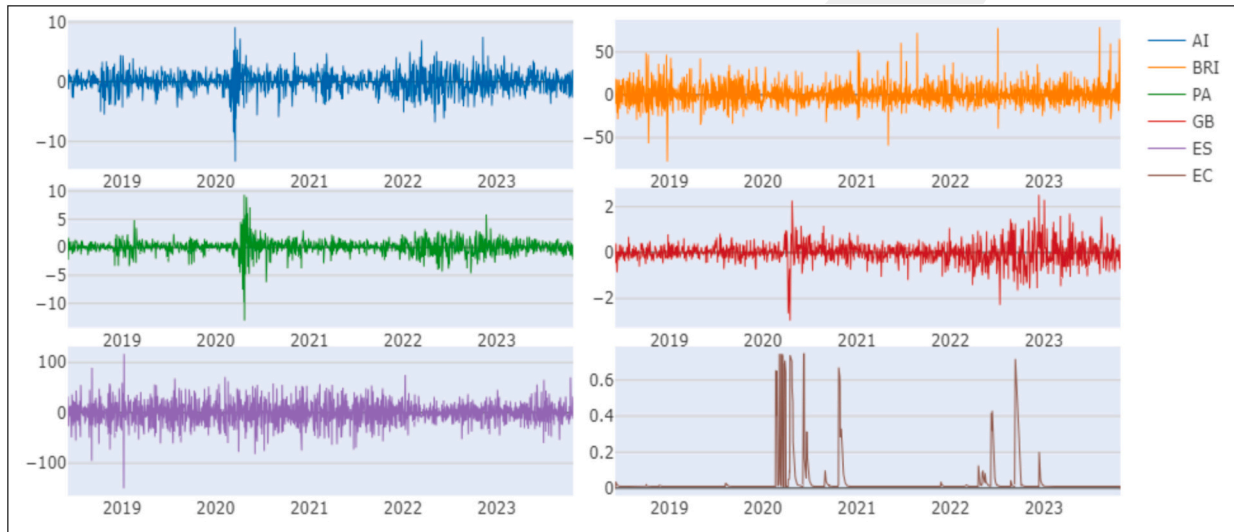


Fig. 3b. Trends in the selected series.

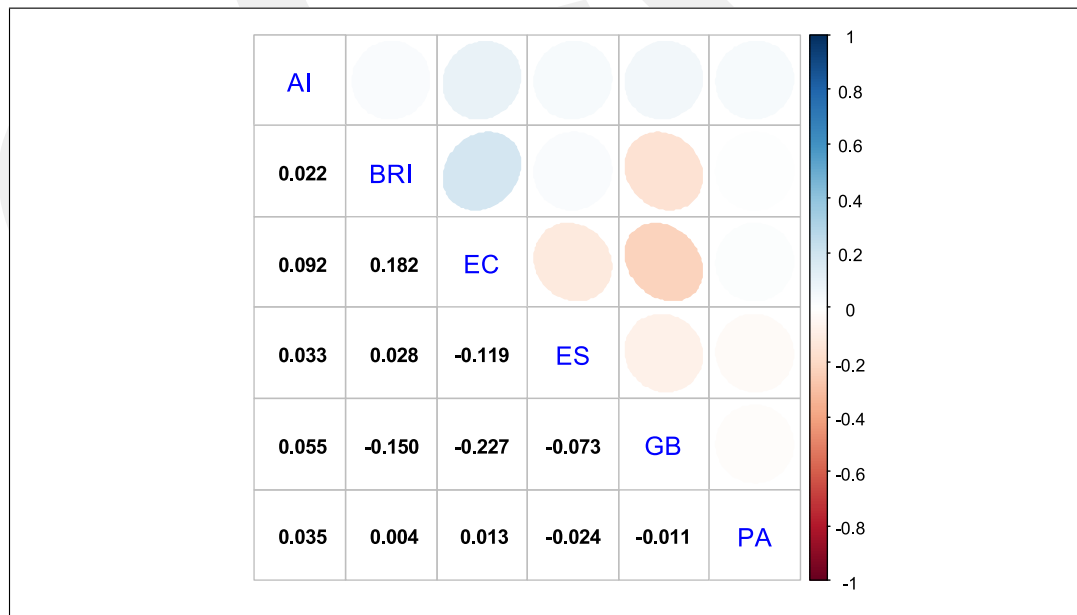


Fig. 4. Correlation matrix of the modelled series.

strong interconnectedness during the COVID-19 period. Given the significant losses endured by global economic and financial markets due to uncertainty stemming from COVID-19, the strong connectedness is

evidence of considerable spillover tail risk. Notably, ES (a representative variable of economic shocks such as COVID-19) shows the predominant behaviour of a transmitter, specifically to AI, BRI, and GB, indicating

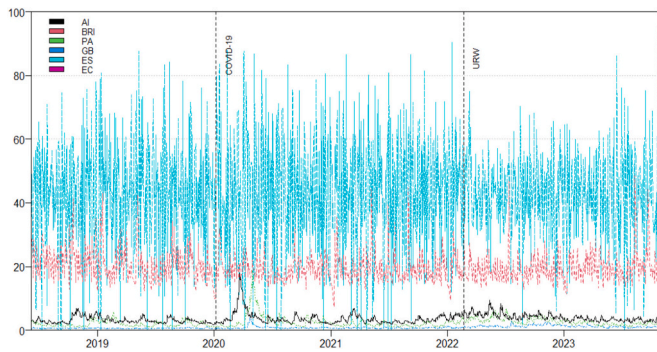


Fig. 5. Tail risk-based connectedness among the opted series. Note: In the above Fig., 5 % VaR based on the asymmetric-slope CAViaR model is represented. Note: AI = Artificial intelligence, BRI = Belt and Road Initiative, PA = Paris Agreement, GB = Green bonds, ES = Economic shocks, and EC = Economic Cycles. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

that these series faced significant risk due to COVID-19. Furthermore, these series have a strong interlink with EC, implying that economic cycles significantly rose due to the direct and indirect spillover influence of COVID-19.

Another important finding is that EC has relatively weak direct connectedness with ES; however, it behaves as a strong recipient while exhibiting connections with other series. This unique outcome confirms that economic shocks significantly responded to the indirect spillover effects of COVID-19 through AI, GB, PA, and BRI channels. Similar results are observed in the case of the URW sample period analysis, as reported in Fig. 8. These unique findings affirm that economic cycles are significant recipients of tail risk from other modelled series caused by global economic shocks such as COVID-19 and URW. Summing up, it is evident that the modelled series exhibits robust tail risk-based total and directional connectedness with EC. Consequently, it is logical to investigate the marginal influence of AI, BRI, PA, GB, and ES on EC.

5.2. Quantile coherence (QC) analysis

This subsection is divided into three sections: full sample, COVID-19,

and URW period analysis. Before commencing the interpretation and discussion of the results, it is worth noting that the QC method provides the outcomes for various time horizons for the full sample period. Further, the results based on the QC method are computed for various market conditions, such as bearish, normal, and bullish, as well as different time horizons, such as short, medium, and long run. Additionally, the colour bar provided along with each results matrix indicates the significance level and magnitude of the computed coefficients.

5.3. Full sample analysis

Before interpreting the full sample analysis, it is important to highlight that short-run results for various market conditions are reported in Fig. 9. Similarly, the medium and long-run outcomes for different market conditions are reported in Figs. 10 and 11, respectively. Looking at the short-run influence of AI, it can be seen that AI has a significantly positive link with the economic cycles across most of the market conditions except for the normal market condition, which shows a negative association. It implies that AI predominantly causes economic cycles in the short run. Further, in the medium run, the bearish and bullish market situations indicate the negative link of AI with economic cycles but insignificantly. However, normal market conditions signify AI's positive influence on economic cycles. Overall, the medium-run findings suggest that AI impedes the economic cycles but insignificantly.

Interestingly, our long-run results for all market conditions exhibit the significantly negative impacts of AI on economic cycles. It suggests that AI's long-run influence can dramatically disrupt the adverse repercussions of global economic cycles. Based on the above findings, it can be claimed that AI causes global economic cycles in the short and medium run across most market conditions; however, in the long run, it has significant potential to support international economic development by curtailing the economic cycles. Logically, the above unique outcomes support the two main economic theories related to technological innovation and economic cycles. The short and medium-run findings are backed by Schumpeterian Theory and Real Business Cycle (RBC) theory, which suggests that, among other real economic variables, oscillations in technological progress influence the production possibilities of firms, leading to fluctuations in output and employment, which ultimately causes the economic cycles (Cakici, 2024; Ahmad et al., 2023; Nikiforos et al., 2023). On the other hand, the long run results back the

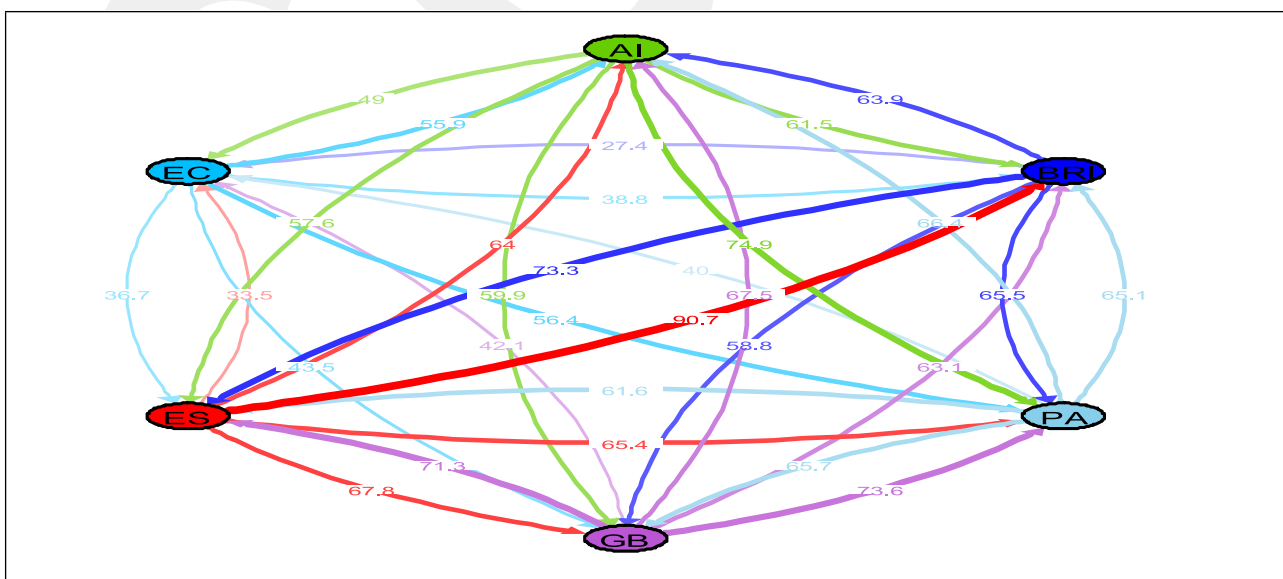


Fig. 6. Directional connectedness among the opted series based on network spillover for the Full sample. Note: A CAViaR-TVP-VAR model with 1st lag is utilized. Note: In the above Fig., AI = Artificial intelligence, BRI = Belt and Road Initiative, PA = Paris Agreement, GB = Green bonds, ES = Economic shocks, and EC = Economic Cycles. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

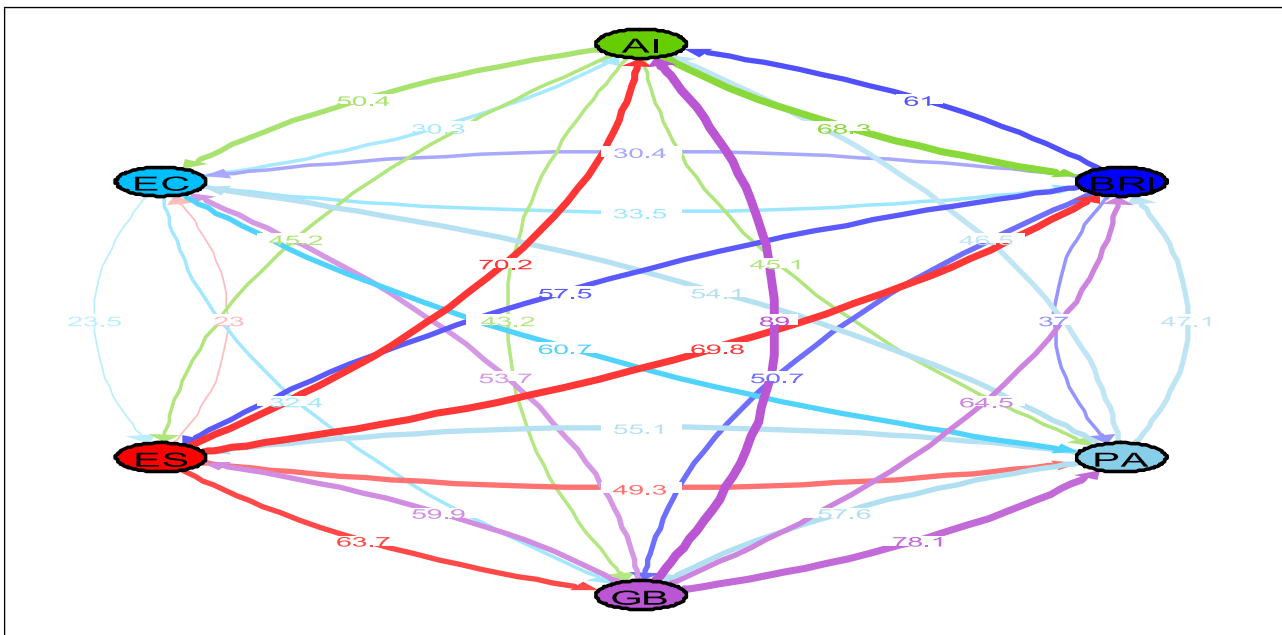


Fig. 7. Directional connectedness among the opted series based on network spillover for the COVID-19 period. Note: A CAViaR-TVP-VAR model with 1st lag is utilized. Note: In the above Fig., AI = Artificial intelligence, BRI = Belt and Road Initiative, PA = Paris Agreement, GB = Green bonds, ES = Economic shocks, and EC = Economic Cycles. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

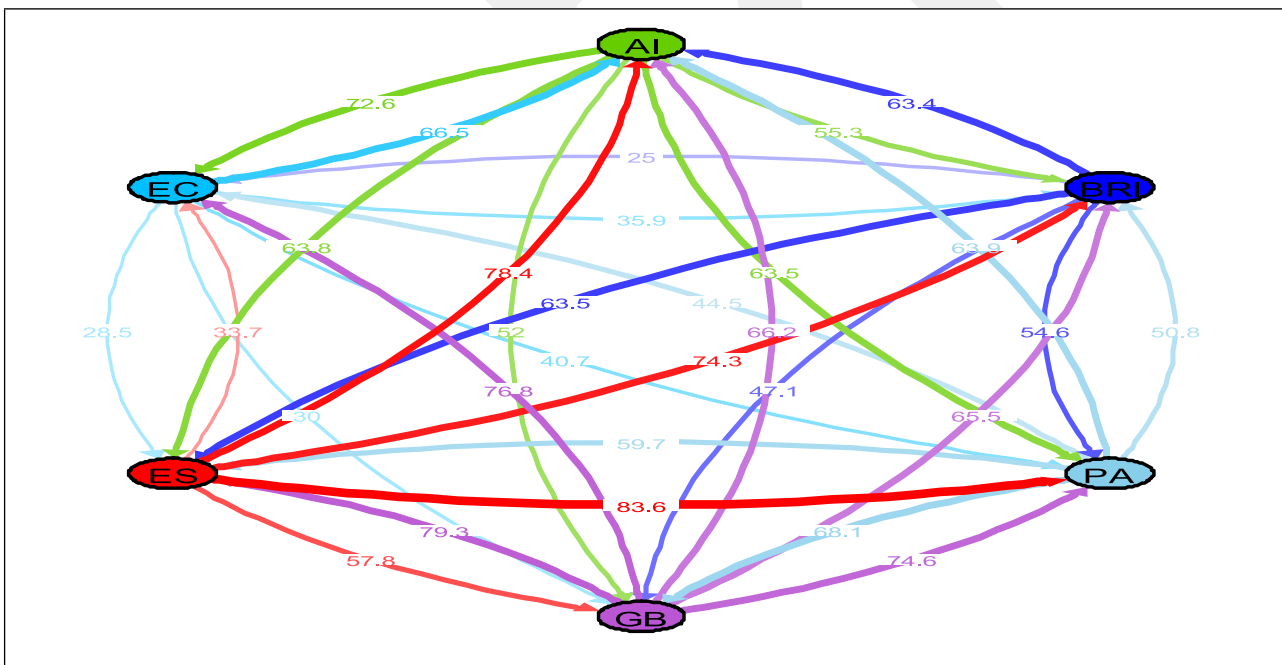


Fig. 8. Directional connectedness among the opted series based on network spillover for the Ukraine-Russia War period. Note: A CAViaR-TVP-VAR model with 1st lag is utilized. Note: In the above Fig., AI = Artificial intelligence, BRI = Belt and Road Initiative, PA = Paris Agreement, GB = Green bonds, ES = Economic shocks, and EC = Economic Cycles. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Endogenous Growth Theory that determines that technological improvements tend to enhance the labour market’s efficiency, which eventually leads to fostering stability in economic growth (Zhou et al., 2023; Kruse-Andersen, 2023) and decrease the possibility of economic cycles.

Focusing on the role of BRI, it is noticed that BRI possesses a significantly positive link with economic fluctuations during the short run when the market situation is bearish. This indicates that BRI seems to increase the economic cycle in the short run when the market is

bearish. However, the normal and bullish markets during the same time horizon demonstrate the negative influence of BRI. The same pattern of impact exerted by BRI on economic cycles is witnessed across all time horizons during the medium and long run. This implies that BRI’s medium and long influence dwindles the economic cycles by showing a negative association. The findings determine that BRI significantly contributes to global economic development by cutting the detrimental effects of economic cycles. This is another notable outcome of the recent study, which identifies BRI as a crucial driver of economic cycles.

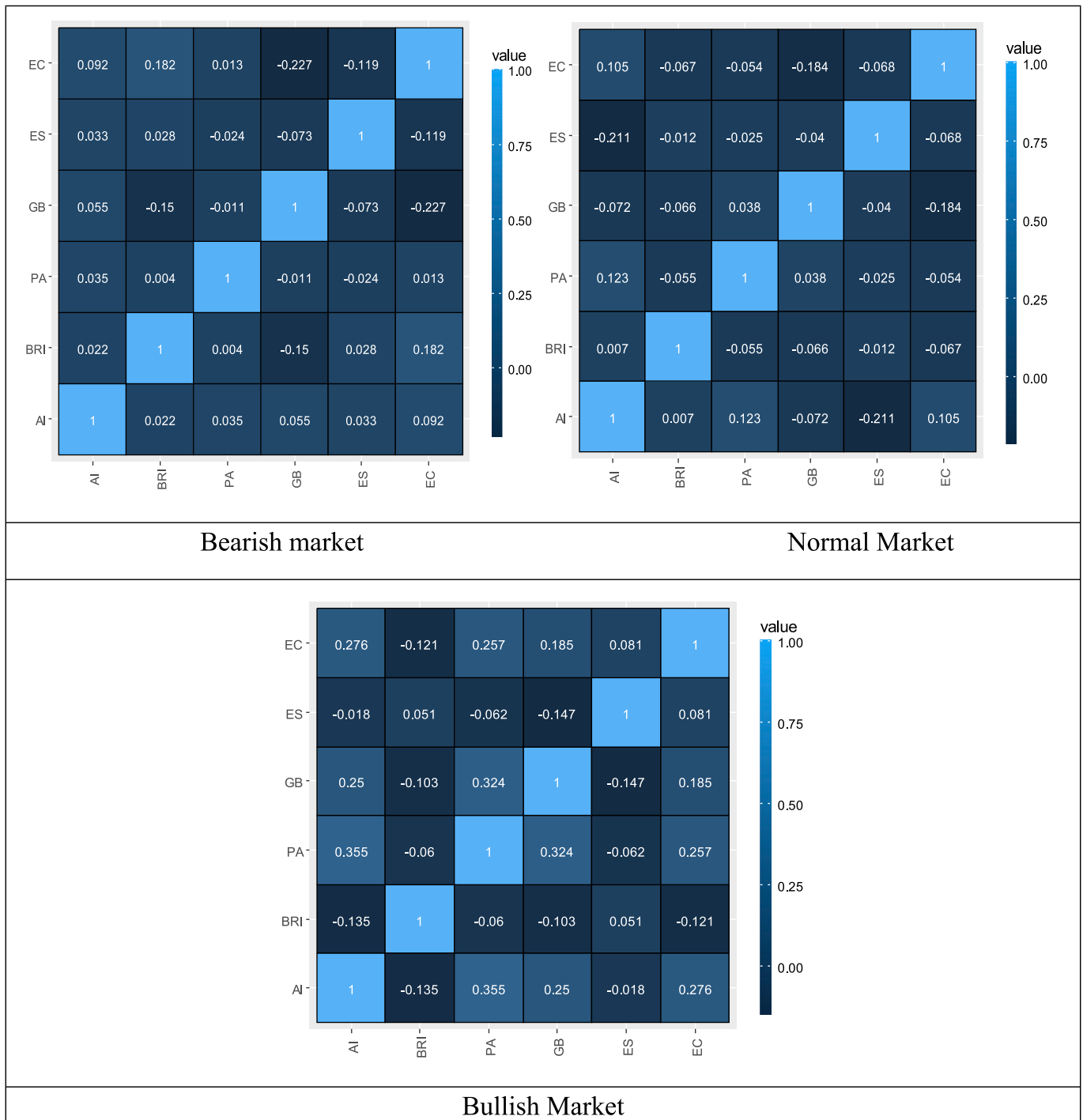


Fig. 9. Quantile coherence-based results for short-run. Note: In the above Fig., AI = Artificial intelligence, BRI = Belt and Road Initiative, PA = Paris Agreement, GB = Green bonds, ES = Economic shocks, and EC = Economic Cycles. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Whereas the influence of PA is concerned, the outcomes suggest that, in the short-run, PA shows a predominantly positive link with economic fluctuations across most market conditions. At the same time, the medium and long-run effects of PA seem to slow down the economic cycles across most market situations by exhibiting an adverse influence. The results indicate that, in the short term, PA causes an increase in the economic cycles. However, in the medium and long, it has the potential to shrink the business cycles and contribute to global economic growth. This is the unique outcome of the recent study, which confirms how PA can play a critical role in determining global economic cycles.

Regarding the effects of green bonds (GB), the short and medium-run findings suggest that GB has a mixed influence on the economic cycles across various market conditions. For example, the short-run market conditions show a negative influence of GB except for the bullish market condition, which signifies green finance's significant and positive impact on economic cycles. Similarly, a positive link of GB with economic oscillations is observed across the bearish and normal market conditions, while a negative association is witnessed for the bullish market situation. Ironically, the long-run outcomes affirm the adverse link of GB with economic cycles across all market conditions. The

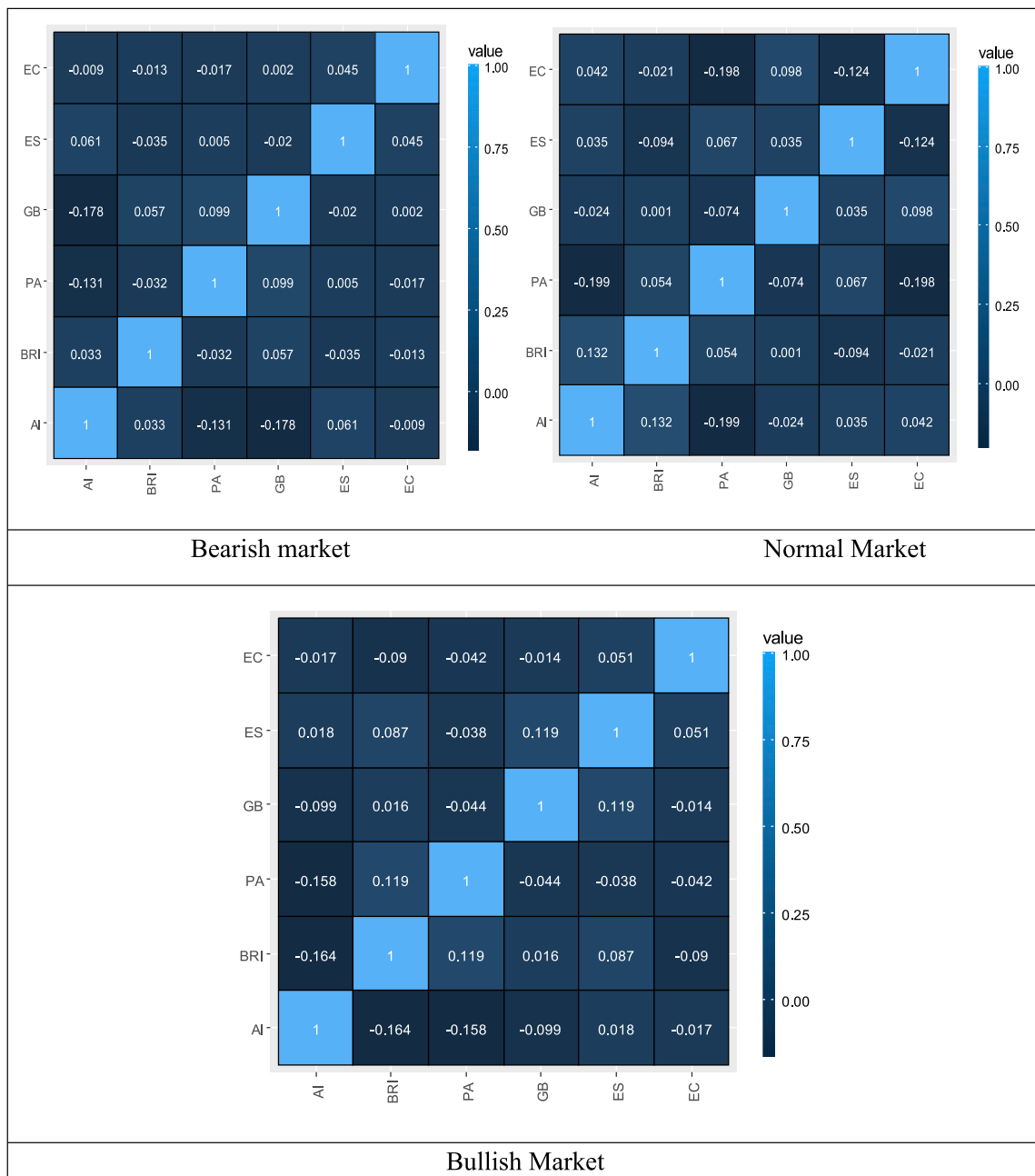


Fig. 10. Quantile coherence-based results for medium-run. Note: In the above Fig., AI = Artificial intelligence, BRI = Belt and Road Initiative, PA = Paris Agreement, GB = Green bonds, ES = Economic shocks, and EC = Economic Cycles. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

findings imply that, in the short run, GB possesses a mixed influence; however, the long-run influence exerted by GB on economic cycles assures that GB can play a pivotal role in decreasing the economic cycles.

Focusing on how economic shocks (ES) affect the economic cycles, we observed that in the short run, ES exhibits mixed effects on economic cycles. The same pattern of influence is noticed for the medium run. This means that ES can increase and decrease the economic cycles across various market situations during short and medium runs. This is another unique outcome of the study, which confirms the negative link between ES and economic cycles. This negative influence can be attributed to effective policy measures by global policymakers to disrupt the ratio of economic shocks, which ultimately tends to impede the economic cycles (Li et al., 2024; Guinea et al., 2024) as the economic shocks have the direct link with the economic cycles (Linsenmeier, 2024). In the long

run, it can be seen that ES possesses a predominantly positive link with the economic cycles. It implies that ES causes economic cycles on account of demand-side shocks, the decline in investment, technology-based shocks, war, changes in the money supply, changes in production, and population changes (Chatterjee, 2024; Kanzola et al., 2023; Umar et al., 2021).

5.4. COVID-19 period analysis

The study also performs the analysis for the period of COVID-19 in order to assess how modelled series influence the economic cycles during the global economic shock of COVID-19. The outcome is depicted in Fig. 12. The findings suggest that AI and PA have a significantly positive link with economic cycles, implying that economic cycles

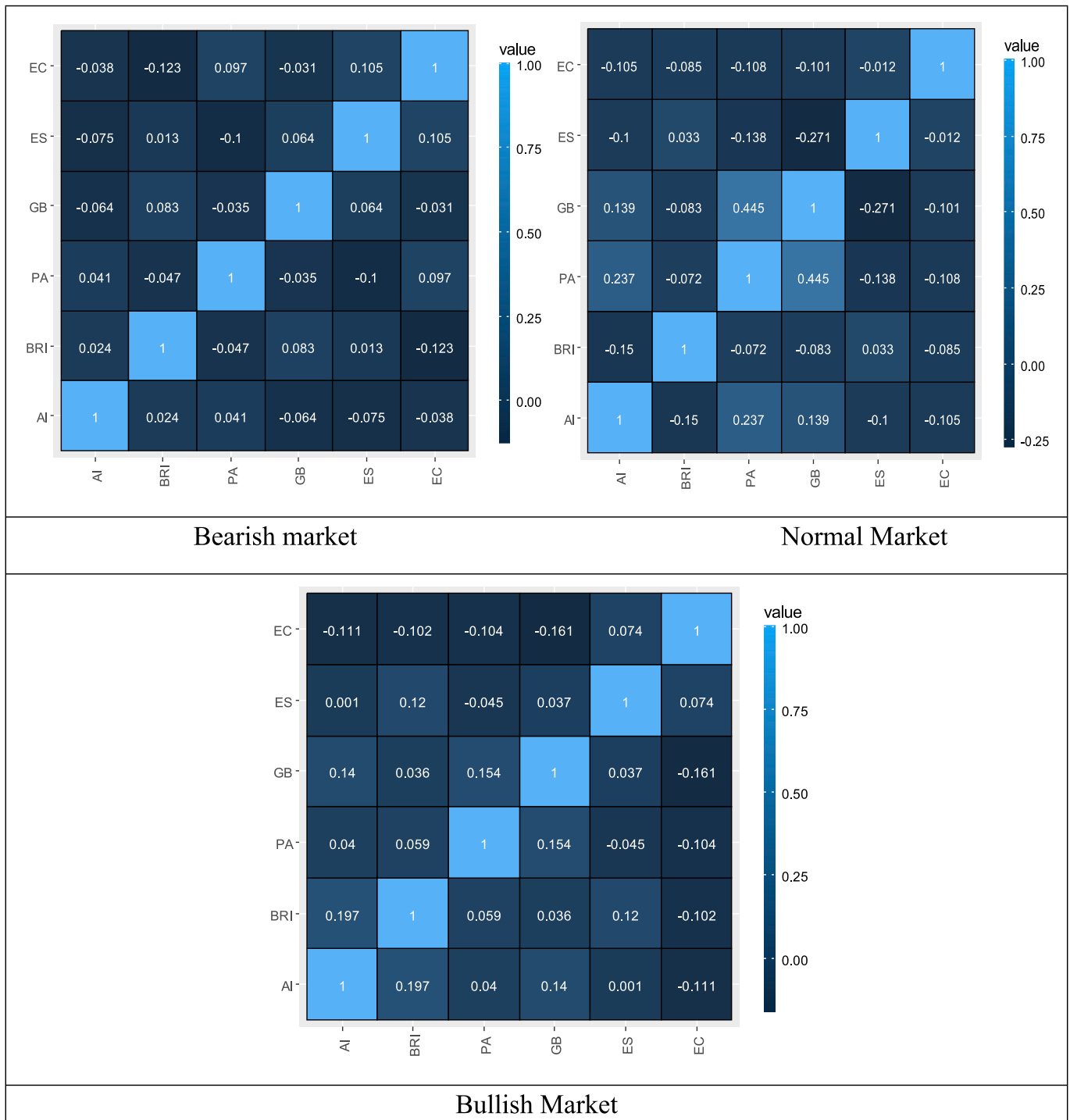


Fig. 11. Quantile coherence-based results for long-run. Note: In the above Fig., AI = Artificial intelligence, BRI = Belt and Road Initiative, PA = Paris Agreement, GB = Green bonds, ES = Economic shocks, and EC = Economic Cycles. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

tended to increase because of AI and PA during COVID-19. However, BRI and GB signify the adverse association with economic fluctuations, indicating that both variables played a crucial role in dwindling the detrimental repercussions of economic shocks even during COVID-19. The findings suggest that only AI and PA's influence on EC changed, so these variables seemed to increase the economic cycles, while BRI and GB significantly reduced the detrimental effects of EC during COVID-19. Since COVID-19 caused global supply chain disruption (Zhao et al., 2024; Wang et al., 2024), it might slow down the process of achieving

the objectives of PA. Also, the disruption in the global supply chain seemed to cause a downfall in the AI market, which tended to increase the rise in international economic shocks. Another possible reason is that PA also works as a globalization force indirectly by integrating the global economies under the agenda of SDG 13, and it also encourages the share of knowledge and experience. Thus, inferring that COVID-19 also deteriorated AI by affecting the PA is rational. Therefore, AI seemed to trigger the economic cycles by creating uncertainty.

Also, the negative influence of BRI and GB on EC reveals that these

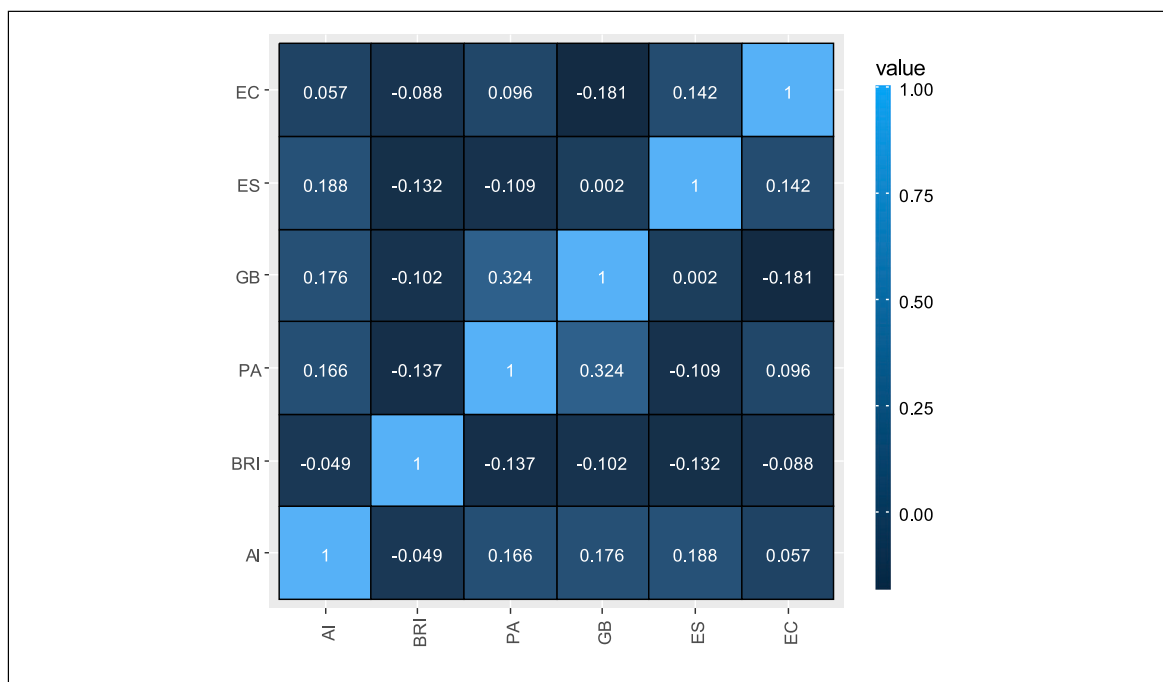


Fig. 12. Quantile coherence-based results for COVID-19 period. Note: In the above Fig., AI = Artificial intelligence, BRI = Belt and Road Initiative, PA = Paris Agreement, GB = Green bonds, ES = Economic shocks, and EC = Economic Cycles. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

can be significantly resilient to adverse influences of the global pandemic, and therefore, they could be important determinants to cut down the harmful impacts of global economic shocks.

5.5. Ukraine-Russia War (URW) period analysis

Revealing how the selected series influence economic cycles during the URW period, the outcomes based on QC are reported in Fig. 13. The

results indicate that AI, PA, and GB exhibit an adverse relationship with business cycles, suggesting that these variables play a significant role in influencing global economic cycles even during the URW period. In contrast, BRI shows a significantly positive correlation with economic cycles, implying that BRI contributed to global economic fluctuations during URW. Unlike the outcomes for the COVID-19 period, AI, PA, and GB seem to support global economic sustainability by decreasing the EC during URW. It implies that these markets could not be influenced by the

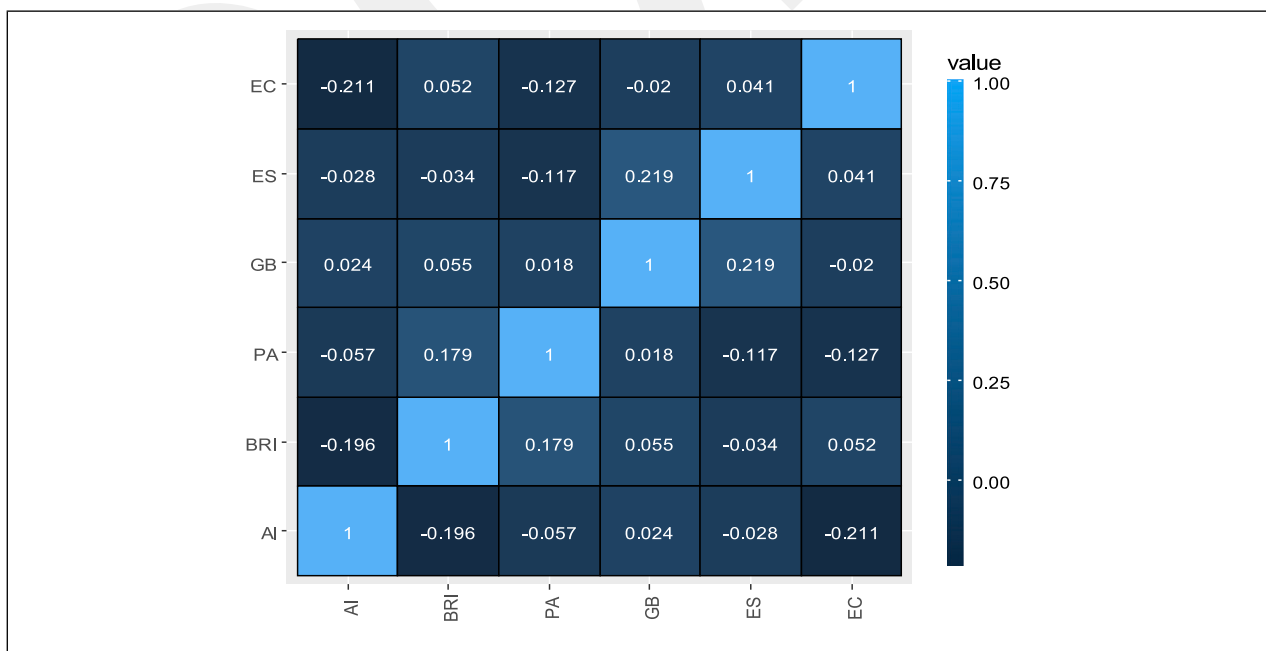


Fig. 13. Quantile coherence-based results for the URW period. Note: In the above Fig., AI = Artificial intelligence, BRI = Belt and Road Initiative, PA = Paris Agreement, GB = Green bonds, ES = Economic shocks, and EC = Economic Cycles. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

uncertainties stemming from URW. However, BRI seemed to be influenced by the adverse effects of URW; therefore, it tended to increase the EC during this period. Additionally, economic shocks also appear to exacerbate economic cycles during URW.

From the above findings, it can be inferred that AI, PA, and GB are observed as significantly resilient to the adverse influences of the global pandemic, and therefore, they could be essential determinants in mitigating the harmful impacts of global economic shocks. However, BRI seems to be influenced by URW and consequently exhibits a positive correlation with economic cycles.

5.6. Robustness check

The article tends to deploy a new quantile-quantile Granger causality (QQGC) by Adebayo and Özkan (2024) for the purpose of robustness checks. The outcomes are visualized in Fig. 14. Before elaborating on the results, it is worth noting that the QQGC test produces the outcome in the heatmap for the 0.05th to 0.95th quantiles. Further, the horizontal axis exhibits the quantiles for the independent variable, while the vertical axis reports the dependent variable's quantile. The colour, along with each heatmap, indicates the level of significance. Also, the lower quantiles (0.05 to 0.30) show the short run, the medium quantiles (0.4 to 0.6) show the medium run, and the higher quantiles (0.7 to 0.95) imply the long run.

As for the effects of AI, the QQGC test confirms that AI significantly granger causes economic cycles across all time horizons (short to long run). This outcome implies that any policy shock in the AI market can substantially influence economic fluctuations across various time horizons. Further, BRI could not significantly cause economic cycles across most of the short-run quantiles; however, it substantially causes economic fluctuations during the medium and long run. The same pattern of Granger causality is observed in the case of PA. Interestingly, GB significantly granger causes the economic cycles across most periods. In the case of ES, significant quantiles of economic cycles across all time horizons seem to be granger caused by ES.

Based on the outcomes above, it can be inferred that all modelled series significantly Granger cause economic cycles, thereby supporting the study's main findings. This signifies that any policy changes to these

variables could substantially affect global economic shocks. In summary, all selected series are considerable drivers of economic shocks. Therefore, international authorities should carefully consider the potential response to global economic fluctuations when proposing any policy changes in these variables.

Also, the study performs another robustness check by deploying a novel machine learning-based PQQRLS method. The results are visualized in Fig. 15. Before delving into interpretation, it is imperative to highlight that 0.10 to 0.3 quantiles show the short-run, 0.4 to 0.6 quantiles indicate the medium-run, and the rest denote the long-run. The findings significantly support our main findings. For instance, across the short to long run, AI predominantly minimizes the adverse effects of EC by showing the negative influence. However, an insignificant association is also observed across some quantiles. Similarly, PA reduces the EC across most short to long run quantiles, except for the short and long run quantiles of PA, which shows the positive link with the short-run quantiles of EC. In the case of BRI, it is observed that short to long-run quantiles of BRI boost the EC in the short to medium-run quantiles of EC. However, the same quantiles of BRI have a predominantly negative link with long-run quantiles of EC. Further, GB has the significant ability to dwindle EC as GB demonstrates a positive link with EC across most of the quantiles. Besides, ES seems to increase the EC during the short to long run, except for the long-run quantiles of ES, which have a negative link with the same quantiles of ES. To recapitulate, the PQQRLS method-based results support the results of the QC approach.

5.7. Comparison with conventional methods'-based results

The study also compares the advanced methods'-based results with the outcome of conventional methods. To do so, the study deploys two famous conventional methods, DOLS and FMOLS, which can handle several basic econometric issues (viz., autocorrelation and heteroscedasticity). The results are documented in Table 2. It can be observed that only AI and PA have a significant and negative influence on EC, supporting the long-run results of the QC approach. However, the remaining variables have no significant association with EC. Also, the adjusted R-squared of both conventional methods is significantly low,

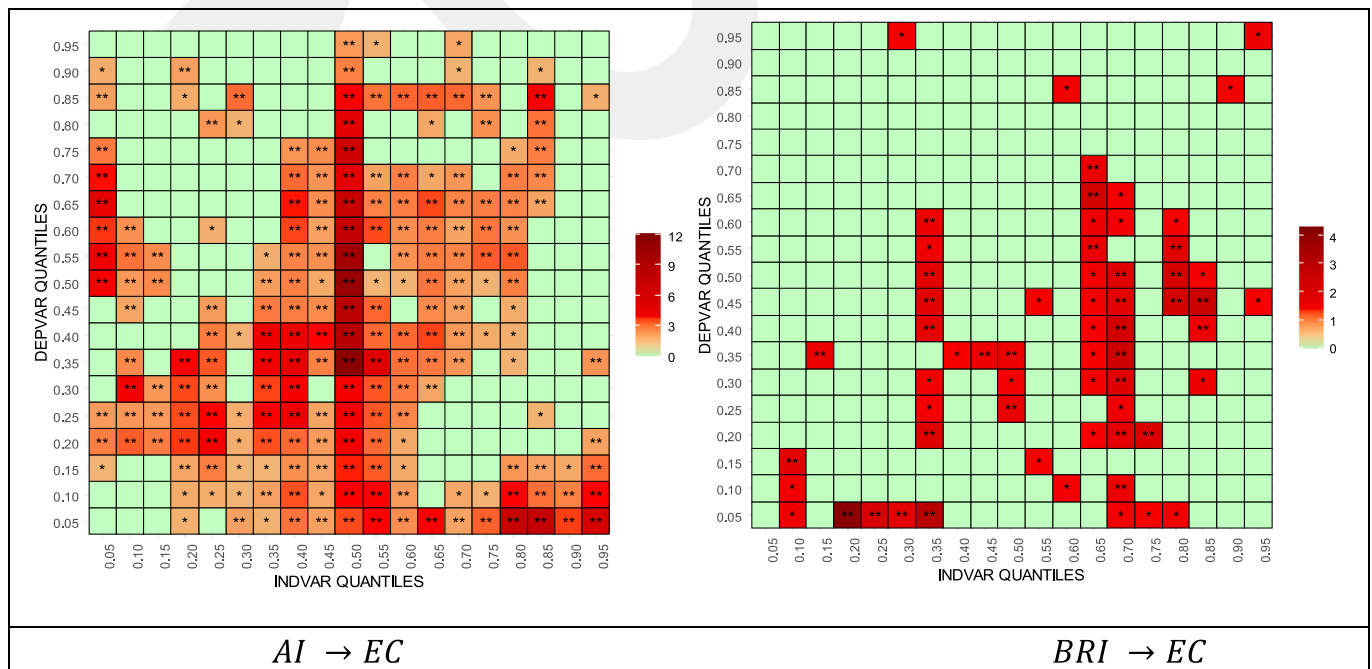


Fig. 14. Results based on Quantile-on-Quantile Granger Causality test.

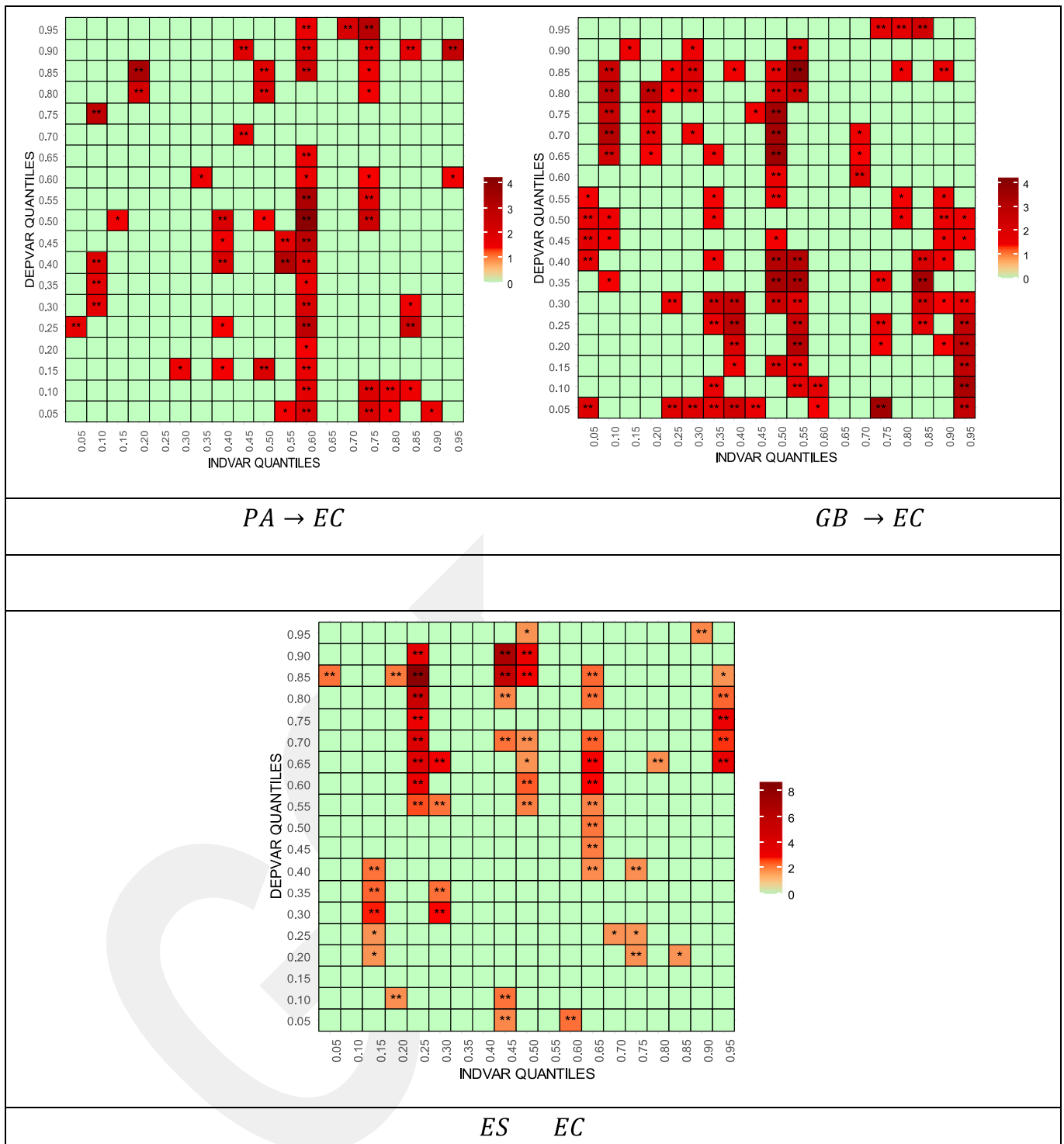


Fig. 14. (continued).

employing the lower power of the explained variation of the model. However, the outcome of the advanced method clearly shows that the effects of all independent series on EC are significant and vary across various time horizons. Based on the above discussion, it seems rational to argue that the conventional methods'-based results might be biased and misleading.

6. Conclusion

The recent study extends the pertinent academic literature by

introducing artificial intelligence (AI) with the consort of the Belt and Road Initiative (BRI), the Paris Agreement (PA), and green bonds (GB) as novel drivers of global economic cycles. Also, the study investigates the influence of global economic shocks (ES) on economic cycles. For robust analysis and comprehensive policy suggestions, the study tends to deploy advanced statistical tools such as the CAViaR-TVP-VAR based connectedness model, quantile coherence (QC) approach, and quantile-quantile Granger causality (QQGC) test and explore the dynamic influence of modelled series for various time horizons. We also deploy our novel PQQKRLS method for robustness check. The results-based

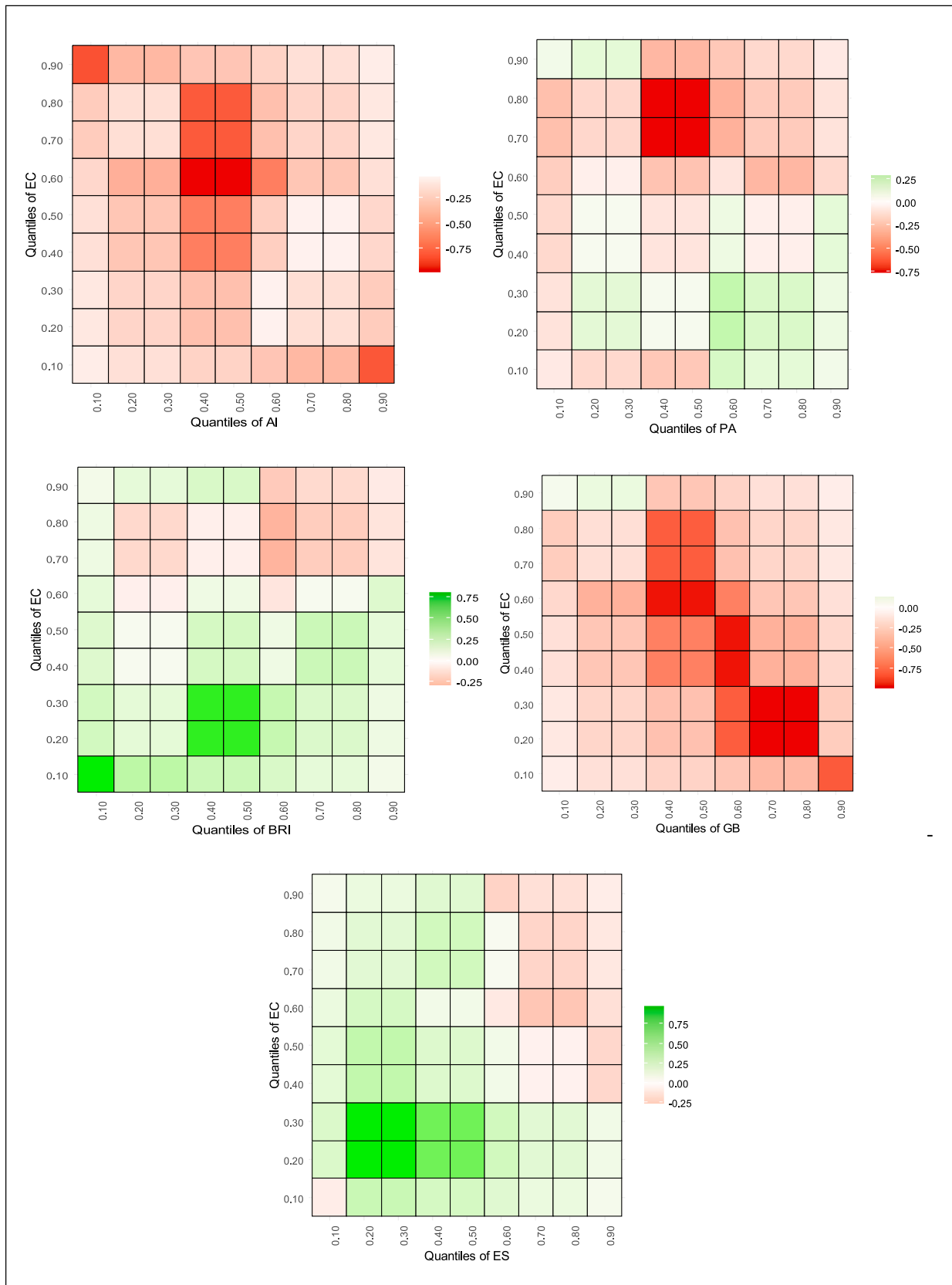


Fig. 15. Panel QQRLS method-based results.

Table 2
conventional methods'-based results.

Variable	Coefficient (DOLS)	Coefficient (FMOLS)
AI	-0.022***	-0.006*
BRI	0.0003	9.59E-05
GB	-0.0280	-0.009
PA	-0.026***	-0.008*
ES	-0.0001	7.50E-05
C	0.036***	0.036***
R-squared	0.070	0.007
Adjusted R-squared	0.056	0.003

Note: *, **, and *** show the significance level at 10 %, 5 %, and 1 %, respectively. Note: Dependent variable is EC.

CAViaR-TVP-VAR-based connectedness confirms significant total connectedness over time. Also, network-based connectedness was witnessed for the whole sample during COVID-19 and URW periods. Subsequently, the application QC method confirms the impact of AI, BRI, PA, GB, and ES on economic cycles across different market conditions and time horizons. In the short run, AI is found to have a significantly positive association with economic cycles in most market conditions, except for normal market situations, where a negative correlation is observed. However, in the medium run, AI shows a negative link with economic cycles during bearish and bullish market conditions, while normal conditions exhibit a positive influence. Notably, the long-run results indicate a consistently negative impact of AI on economic cycles across all market conditions, suggesting that AI has the potential to support global economic development by curbing adverse repercussions in the long term. The short and medium-run findings are backed by RBC theory, which suggests that, among other real economic variables, technological progress oscillations influence firms' production possibilities, leading to fluctuations in output and employment, which ultimately causes the economic cycles. However, the long run results back the Endogenous Growth Theory that determines that technological improvements tend to enhance the labour market's efficiency, eventually fostering stability in economic growth and decreasing the economic cycles.

In the case of BRI, it is observed that in the short run, BRI shows a positive link with economic fluctuations during bearish market situations but a negative influence during normal and bullish markets. This pattern continues in the medium and long run, indicating that BRI significantly contributes to global economic development by reducing the detrimental effects of economic cycles. Concerning the influence of PA, short-term results reveal a predominantly positive link with economic fluctuations across various market conditions. However, in the medium and long run, PA appears to slow down economic cycles, contributing to global economic growth by reducing business cycles. Green finance proxied by GB exhibits mixed effects on economic cycles in the short and medium run across various market conditions. GB shows positive and negative influences in the short run, but it consistently has an adverse link with economic cycles in the long run. This implies that GB can play a pivotal role in decreasing economic cycles in the long term.

The global economic shocks (ES) have mixed effects on economic cycles in the short and medium run, with both increasing and decreasing impacts. However, in the long run, ES has a predominantly positive link with economic cycles, attributed to various factors such as demand-side shocks, declines in investment, technology-based shocks, war, money supply changes, production changes, and population changes.

During COVID-19, AI and PA exhibit a significantly positive link with economic cycles, indicating increased economic cycles during the pandemic. This is attributed to disruptions in the AI market and PA authorities neglecting global green and sustainable development projects. In contrast, BRI and GB show an adverse association with economic fluctuations during this period, suggesting their resilience to damaging influences and their role in mitigating the harmful impacts of

global economic shocks. Furthermore, AI, PA, and GB exhibit an adverse relationship with business cycles during the URW. However, BRI shows a significantly positive correlation with economic cycles during URW, suggesting its susceptibility to the war's impact. Economic shocks also exacerbate economic cycles during URW, highlighting their continued influence on global economic conditions even during geopolitical crises. The summary of the findings is visualized in Fig. 16. Also, the study performs another robustness check by deploying a novel machine learning-based PQQKRLS method. The PQQKRLS method-based results support the results of the QC approach.

6.1. Policy suggestions

Based on the results of the study, here are detailed policy recommendations. In the short run, based on the significantly positive association of AI with economic cycles in most market conditions, it can be suggested that global policymakers should consider monitoring and regulating the AI market during normal conditions to prevent potential negative impacts. At the same time, the positive influence exerted by BRI on economic cycles during bearish market situations and negative influence during normal and bullish markets during the short to medium run, policymakers should carefully evaluate the economic conditions when engaging in BRI projects. This can be done by adapting BRI strategies to enhance their positive impact during normal and bullish market conditions. The PA shows a predominantly positive link with economic fluctuations in various market conditions in the short run. Policymakers should continue promoting policy advocacy while considering the medium- and long-term effects. The mixed effects on economic cycles stemming from GB are observed. Global policymakers can be encouraged to consider specific market conditions when promoting green bonds, emphasizing their positive influences. The mixed effects of ES during the short and medium run require that policymakers should be vigilant during economic shocks and prefer to implement targeted policies to mitigate adverse impacts and enhance positive outcomes.

In the medium and long run, based on the consistently negative impact of AI on economic cycles, policymakers should focus on long-term strategic planning and global collaboration to harness AI's potential for supporting economic development while mitigating adverse repercussions. Global authorities should aim to balance AI development to avoid exacerbating economic cycles during these periods. Further, the witnessed downfall in economic cycles on account of PA suggests that sustained policy advocacy efforts can contribute to global economic growth. Hence, the pertinent authorities should continue and enhance efforts to advocate for stable economic policies and reforms. Similarly, the adverse link of GB with economic cycles suggests the need for ongoing evaluation and potential adjustments in green bond policies to align them with long-term economic stability goals. Contemporarily, the economic shocks have a predominantly positive link with economic cycles in the long run; policymakers should suggest building resilience and implementing measures to withstand and recover from various shocks, such as investing in diversified industries and fostering innovation to minimize the detrimental effects of economic shocks.

6.2. Policy suggestions for short-run

Since in the short-run, AI has a significantly positive association with economic cycles in most market conditions except for normal market situations; the following policy implications might be suitable. On the one hand, policymakers should provide incentives such as tax breaks, grants, and subsidies to companies investing in AI technologies, especially during economic volatility. At the same time, the authorities should practice strict ethical guidelines and regulatory frameworks for AI deployment to avoid market distortions and ensure fair competition to minimize the negative correlation of AI with economic cycles during normal market conditions. Besides boosting innovation and economic

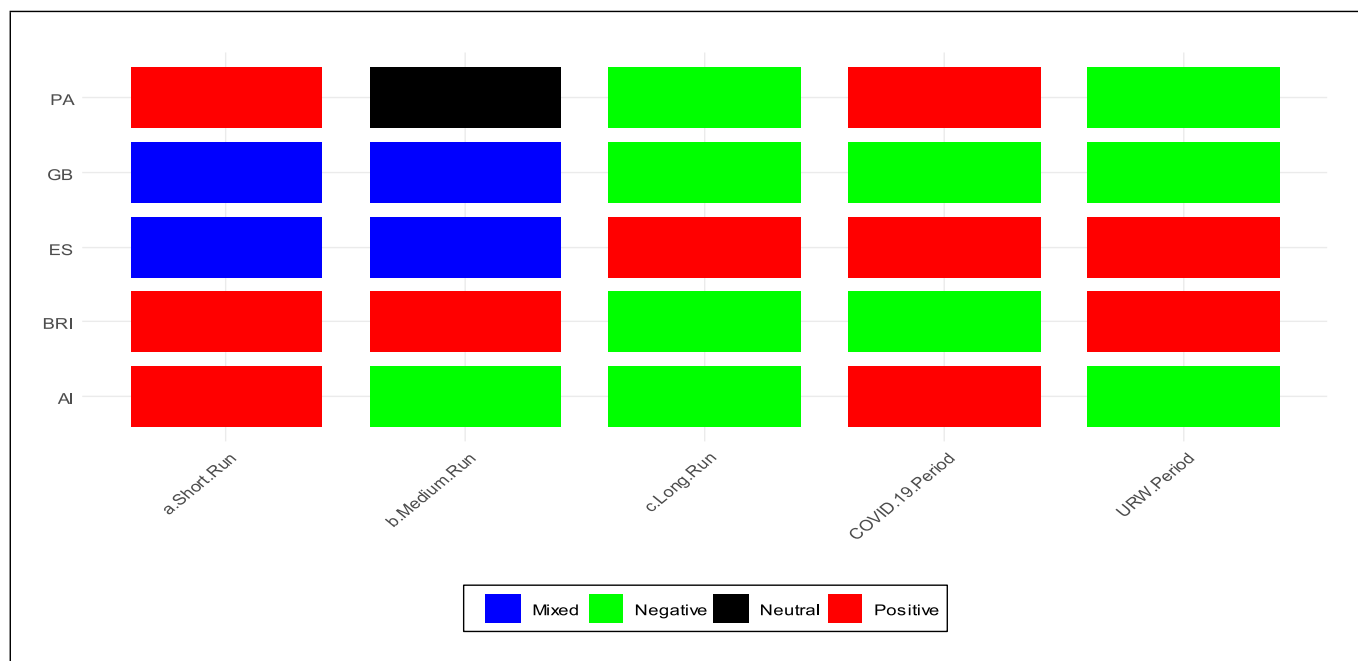


Fig. 16. Graphical conclusion.

resilience, creating a favourable regulatory environment for AI startups can be beneficial to reducing AI’s positive link with EC. Additionally, global authorities should promote AI in different sectors, such as healthcare, logistics, and manufacturing, which might assist in triggering economic growth and stability in normal market conditions.

6.3. Policy suggestions for medium-run

In the medium-run, the policy makers should focus on practicing the stabilization policies. For instance, counter-cyclical fiscal policies and monetary measures can be applied to smooth out economic cycles influenced by AI. The global nations also enhance AI adoption through public-private partnerships and innovation clusters to obtain sustained growth. Further, the deployment of flexible regulatory frameworks regarding AI, such as periodic reviews and updates of AI-related regulations, can assist in reducing the detrimental effects of economic cycles. Contemporarily, the authorities should promote research and development in AI through international cooperation on AI regulations. It will also help in understanding the cross-border challenges and opportunities of reading AI.

6.4. Policy suggestions for long run

In the long run, AI possesses a consistently negative impact on economic cycles across all market conditions, implying that AI has the significant potential to promote global economic growth by disrupting the harmful influence of economic cycles. Thus, in the long run, policymakers should consider integrating AI into national and international development plans. Also, AI can be integrated in environmental management, smart cities, and sustainable industries. These steps might help minimize the economic cycles and enhance sustainable development worldwide. Before deploying AI in various sectors of an economy, the authorities should consider strengthening the global standards and cooperation frameworks by international treaties and agreements on AI ethics, data sharing, and best practices to understand the loopholes pertinent to AI. It might assist in reducing the adverse aspects of AI to foster sustainable growth. Also, global governments should provide grants, retraining programs, and transitional assistance, which might help industries and workers transition to AI-driven economies. The final

and important step is to practice robust monitoring and evaluation mechanisms to assess the long-term impacts of AI in order to ensure the benefits of AI for the global economy. To do so, policymakers should develop institutions that assess AI implementation and its economic implications to ensure long-term economic benefits.

6.5. Policy recommendations for Crisis (COVID-19 and URW)

Our results suggest that global authorities should focus on careful policy suggestions regarding some of our chosen series and their role in the global economic cycles during the global crisis. To handle this exigence, policymakers should address disruptions in the AI market and prioritize global green and sustainable development projects during crises to prevent increased economic cycles. Also, policymakers should develop strategies to mitigate susceptibility, such as the positive link between BRI and economic cycles during the crisis, possibly by diversifying economic dependencies and strengthening global cooperation.

6.6. Limitations

Though the recent study identifies AI, BRI, and PA as the new determinants of global economic cycles, it has some limitations. First, future studies can attain more exciting results by analyzing Asia, Africa, and Europe globally. Second, analyzing selected advanced economies regarding AI might provide more policy-oriented results. Third, due to data limitation, the recent could analyze global country-wise analysis, expecting more directional and detailed outcomes for international policymakers. Fourth, the current econometric model can be improved by including more global variables such as circular economy, global value chain, financial crisis, technological innovation, and weather shocks for more exciting findings. Lastly, it is highly anticipated that changes in the sampled data might lead to different results. Therefore, it is rational for future scholars to expand the data period in order to attain more interesting findings.

CRedit authorship contribution statement

Muhammad Zubair Chishti: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Data curation,

Writing – original draft. **Eyup Dogan:** Supervision, Software, Methodology. **Rima H. Binsaeed:** Writing – review & editing.

Data availability

Data will be made available on request.

Acknowledgment

This work has been supported by the Researchers Supporting Project RSP2024R203, King Saud University, Saudi Arabia.

References

- Aastveit, K.A., Natvik, G.J., Sola, S., 2017. Economic uncertainty and the influence of monetary policy. *J. Int. Money Financ.* 76, 50–67.
- Adebayo, T.S., Özkan, O., 2024. Evaluating the role of financial globalization and oil consumption on ecological quality: a new perspective from quantile-on-quantile granger causality. *Heliyon* 10 (2).
- Adebayo, T.S., Meo, M.S., Eweade, B.S., Özkan, O., 2024. Examining the effects of solar energy innovations, information and communication technology and financial globalization on environmental quality in the United States via quantile-on-quantile KRLS analysis. *Sol. Energy* 272, 112450.
- Adu, G., Marbuah, G., Mensah, J.T., 2013. Financial development and economic growth in Ghana: does the measure of financial development matter? *Rev. Dev. Finance* 3, 192–203.
- Aghion, P., Bloom, N., Lucking, B., Sadun, R., Van Reenen, J., 2021. Turbulence, firm decentralization, and growth in bad times. *Am. Econ. J. Appl. Econ.* 13 (1), 133–169.
- Ahangar, R.G., Kim, M., 2022. The impact of COVID-19 shocks on business and GDP of global economy. *Am. Bus. Rev.* 25 (2), 5.
- Ahmad, M., Zheng, J., 2023. The cyclical and nonlinear impact of R&D and innovation activities on economic growth in OECD economies: a new perspective. *J. Knowl. Econ.* 14 (1), 544–593.
- Ahmad, M., Haq, Z.U., Iqbal, J., Khan, S., 2023. Dating the business cycles: research and development (R&D) expenditures and new knowledge creation in OECD economies over the business cycles. *J. Knowl. Econ.* 14 (4), 3929–3973.
- Ahmed, Z., Ahmad, M., Murshed, M., Shah, M.I., Mahmood, H., Abbas, S., 2022. How do green energy technology investments, technological innovation, and trade globalization enhance green energy supply and stimulate environmental sustainability in the G7 countries? *Gondw. Res.* 112, 105–115.
- Alessi, L., Battiston, S., Kvedaras, V., 2024. Over with carbon? Investors' reaction to the Paris Agreement and the US withdrawal. *J. Financ. Stab.* 71, 101232 and Road." *World Economic Research*, 1: 122-133+136.
- Antonakakis, N., Cunado, J., Filis, G., Gabauer, D., de Gracia, F.P., 2020. Oil and asset classes implied volatilities: investment strategies and hedging effectiveness. *Energy Econ.* 91, 104762.
- Asl, M.G., Rashidi, M.M., Tiwari, A.K., Lee, C.C., Roubaud, D., 2023. Green bond vs. Islamic bond: which one is more environmentally friendly? *J. Environ. Manag.* 345, 118580.
- Baruník, J., Kley, T., 2019. Quantile coherency: A general measure for dependence between cyclical economic variables. *Econom. J.* 22 (2), 131–152.
- Beck, T., Levine, R., Loayza, N., 2000. Finance and the sources of growth. *J. Financ. Econ.* 58, 261–300.
- Berger, A., Blümer, D., Brandi, C., Chi, M., 2020. Towards Greening Trade? Environmental Provisions in Emerging Markets' Preferential Trade Agreements. In: *Sustainability Standards and Global Governance: Experiences of Emerging Economies*, pp. 61–81.
- Bernier, M., Plouffe, M., 2019. Financial innovation, economic growth, and the consequences of macroprudential policies. *Res. Econ.* 73, 162–173.
- Bessler, W., Gonenc, H., Tinoco, M.H., 2023. Information asymmetry, agency costs, and payout policies: an international analysis of IFRS adoption and the global financial crisis. *Econ. Syst.* 47 (4), 101129.
- Bittencourt, M., 2012. Financial development and economic growth in Latin America: is Schumpeter right? *J. Policy Model.* 34, 341–355.
- Blanchard, O., Summers, L., 2017. Rethinking Stabilization Policy. Back to the future. Peterson Institute for International Economics, p. 8.
- Borazan, A., 2023. Setting the record straight on the recovery from the 1920–1921 recession. *Camb. J. Econ. Dev.* 47 (2), 289–308.
- Boston University Global Development Policy Center, 2020. Greening the Belt and Road Initiative and the 2020 Agenda for Sustainable Development. Retrieved from. <https://www.bu.edu/gdp/files/2020/09/SPS-4-1-Green-BRI-and-2020-Agenda-for-Sustainable-Development.pdf>.
- Brynjólfsson, E., Hitt, L., 1995. Information technology as a factor of production: the role of differences among firms. *Econ. Innov. New Technol.* 3 (3–4), 183–200.
- Bucci, A., La Torre, D., Liuzzi, D., Marsiglio, S., 2019. Financial contagion and economic development: an epidemiological approach. *J. Econ. Behav. Organ.* 162, 211–228.
- Cakici, S.M., 2024. Risk premium in a real business cycle framework. *Int. Rev. Econ. Finance* 91, 111–122.
- Caldara, D., Iacoviello, M., 2022. Measuring geopolitical risk. *Am. Econ. Rev.* 112 (4), 1194–1225.
- Cavdur, F., Kose-Kucuk, M., Sebatli, A., 2016. Allocation of temporary disaster response facilities under demand uncertainty: an earthquake case study. *Int. J. Disaster Risk Reduct.* 19, 159–166.
- Centre for Economic Policy Research, 2023. The Centre for Economic Policy Research (CEPR). Available at: [https://cepr.org/voxeu/columns/bystander-effect-us-china-trade-war#:~:text=US%20tariffs%20affected%20around%2018,the%20US%20\(Figure%201\)](https://cepr.org/voxeu/columns/bystander-effect-us-china-trade-war#:~:text=US%20tariffs%20affected%20around%2018,the%20US%20(Figure%201)).
- Chatterjee, P., 2024. Uncertainty shocks, financial frictions, and business cycle asymmetries across countries. *Eur. Econ. Rev.* 162, 104646.
- Che, M., Zhu, Z., Li, Y., 2023. Geopolitical risk and economic policy uncertainty: different roles in China's financial cycle. *Int. Rev. Financ. Anal.* 90, 102867.
- Chen, M., Wang, S., Wang, X., 2024. How does artificial intelligence impact green development? Evidence from China. *Sustainability* 16 (3), 1260.
- Chen, H., Li, L., Chen, Y., 2021. Explore success factors that impact artificial intelligence adoption on telecom industry in China. *J. Manag. Anal.* 8 (1), 36–68.
- Cheng, J., Mohammed, K.S., Misra, P., Tedeschi, M., Ma, X., 2023. Role of green technologies, climate uncertainties and energy prices on the supply chain: policy-based analysis through the lens of sustainable development. *Technol. Forecast. Soc. Change* 194, 122705.
- Cherbib, J., 2024. Exploring the interplay between entrepreneurial orientation, causation and effectuation under unexpected COVID-19 uncertainty: insights from large French banks. *Technol. Forecast. Soc. Change* 200, 123090.
- Chinadialogue, 2019a. Belt and Road countries will make or break the Paris Agreement. Retrieved from. <https://chinadialogue.net/en/energy/11509-belt-and-road-countries-will-make-or-break-the-paris-agreement/>.
- Chinadialogue, 2019b. Belt and Road must align with Paris Agreement, say experts. Retrieved from. <https://chinadialogue.net/en/business/belt-and-road-must-align-n-paris-agreement-government/>.
- Chinese National Bureau of Statistics, 2024. Available at: <https://www.stats.gov.cn/english/>.
- Chishti, M.Z., Xia, X., Dogan, E., 2024. Understanding the effects of artificial intelligence on energy transition: the moderating role of Paris Agreement. *Energy Econ.* 131, 107388.
- De La Orden, R., De Calonje, I., 2022. Sustainability-Linked Finance.
- Dinlersoz, E., Wolf, Z., 2024. Automation, labor share, and productivity: plant-level evidence from US manufacturing. *Econ. Innov. New Technol.* 33 (4), 604–626. <https://doi.org/10.1080/10438599.2023.2233081>.
- Dong, X., Xiong, Y., Nie, S., Yoon, S.M., 2023. Can bonds hedge stock market risks? Green bonds vs conventional bonds. *Financ. Res. Lett.* 52, 103367.
- Engle, R.F., Manganelli, S., 2004. CAViaR: conditional autoregressive value at risk by regression quantiles. *J. Bus. Econ. Stat.* 22 (4), 367–381.
- Espinosa-Gracia, A., Sánchez-Chóliz, J., 2023. Long waves, paradigm shifts, and income distribution, 1929–2010 and afterwards. *J. Evol. Econ.* 33 (5), 1365–1396.
- Gazdar, K., Hassan, M.K., Safa, M.F., Grassa, R., 2019. Oil price volatility, Islamic financial development and economic growth in Gulf Cooperation Council (GCC) countries. *Borsa Istanbul Rev.* 19, 197–206.
- Goertzel, B., Goertzel, T., Goertzel, Z., 2017. The global brain and the emerging economy of abundance: mutualism, open collaboration, exchange networks and the automated commons. *Technol. Forecast. Soc. Change* 114, 65–73.
- Gök, R., Bouri, E., Gemic, E., 2022. Can twitter-based economic uncertainty predict safe-haven assets under all market conditions and investment horizons? *Technol. Forecast. Soc. Change* 185, 122091.
- Gozgor, G., Istiak, K., 2023. Relationship between economic policy uncertainty and domestic credits: evidence from the long-span time series for the UK and the USA. *Appl. Econ.* 1–18. <https://doi.org/10.1080/00036846.2023.2279038>.
- Guinea, L., Puch, L.A., Ruiz, J., 2024. Energy news shocks and their propagation to renewable and fossil fuels use. *Energy Econ.* 130, 107289.
- Guzović, Z., Duić, N., Piacentino, A., Markovska, N., Mathiesen, B.V., Lund, H., 2023. Paving the way for the Paris Agreement: contributions of SDEWES science. *Energy* 263, 125617.
- Hainmueller, J., Hazlett, C., 2014. Kernel regularized least squares: Reducing misspecification bias with a flexible and interpretable machine learning approach. *Polit. Anal.* 22 (2), 143–168.
- He, L., Liu, R., Zhong, Z., Wang, D., Xia, Y., 2019. Can green financial development promote renewable energy investment efficiency? A consideration of bank credit. *Renew. Energy* 143, 974–984.
- He, Y., 2019. The importance of artificial intelligence to economic growth. *Korea J. Artif. Intell.* 7 (1), 17–22.
- Hossain, A.T., Masum, A.A., Saadi, S., 2024. The impact of geopolitical risks on foreign exchange markets: evidence from the Russia–Ukraine war. *Finance Res. Lett.* 59, 104750.
- International Monetary Fund, 2021. World Economic Outlook: Recovery during a Pandemic—Health Concerns, Supply Disruptions, Price Pressures.
- International Renewable Energy Agency, 2020. Available at: <https://www.irena.org/>.
- Kafka, K.L., Kostis, P.C., 2024. Unravelling the innovation puzzle: the interplay between uncertainty, economic institutions, and innovation performance in advanced and developing economies. *Technol. Forecast. Soc. Change* 198, 123027.
- Kanzola, A.M., Papaioannou, K., Petrakis, P.E., 2023. Environmental behavioral perceptions under uncertainty of alternative economic futures. *Technol. Forecast. Soc. Change* 190, 122428.
- King, R.G., Levine, R., 1993. Finance, entrepreneurship and growth. *J. Monet. Econ.* 32, 513–542.
- Kruse-Andersen, P.K., 2023. Testing R&D-based endogenous growth models. *Oxf. Bull. Econ. Stat.* 85 (5), 1083–1110.

- Lau, C.K., Gozgor, G., Mahalik, M.K., Patel, G., Li, J., 2023. Introducing a new measure of energy transition: green quality of energy mix and its impact on CO₂ emissions. *Energy Econ.* 122, 106702.
- Li, G., Li, Y., Tsai, C.L., 2015. Quantile correlations and quantile autoregressive modeling. *J. Am. Stat. Assoc.* 110 (509), 246–261.
- Li, J., Nie, H., Ruan, R., Shen, X., 2024. Subjective perception of economic policy uncertainty and corporate social responsibility: evidence from China. *Int. Rev. Financ. Anal.* 91, 103022.
- Liang, J., Song, X., 2022. Can green finance improve carbon emission efficiency? Evidence from China. *Front. Environ. Sci.* 10, 955403.
- Linsenmeier, M., 2024. Seasonal temperature variability and economic cycles. *J. Macroecon.* 79, 103568.
- Liu, H., Alharthi, M., Atil, A., Zafar, M.W., Khan, I., 2022. A nonlinear analysis of the impacts of natural resources and education on environmental quality: green energy and its role in the future. *Res. Policy* 79, 102940.
- Lu, Q., Fang, K., Heijungs, R., Feng, K., Li, J., Wen, Q., Huang, X., 2020. Imbalance and drivers of carbon emissions embodied in trade along the belt and road initiative. *Appl. Energy* 280, 115934.
- Ma, X., Hao, Y., Li, X., Liu, J., Qi, J., 2023. Evaluating global intelligence innovation: an index based on machine learning methods. *Technol. Forecast. Soc. Change* 194, 122736.
- Maneejuk, P., Kaewtathip, N., Yamaka, W., 2024. The influence of the Ukraine-Russia conflict on renewable and fossil energy price cycles. *Energy Econ.* 129, 107218.
- Marques, L.M., Fuinhas, J.A., Marques, A.C., 2013. Does the stock market cause economic growth? Portuguese evidence of economic regime change. *Econ. Model.* 32, 316–324.
- May Petry, L., Soares, A., Bogorny, V., Brandoli, B., Matwin, S., 2020. Challenges in vessel behavior and anomaly detection: From classical machine learning to deep learning. In: *Advances in Artificial Intelligence: 33rd Canadian Conference on Artificial Intelligence, Canadian AI 2020, Ottawa, ON, Canada, May 13–15, 2020, Proceedings 33*. Springer International Publishing, pp. 401–407.
- McKinsey Global Institute, 2017. Jobs lost, jobs gained: Workforce transitions in a time of automation.
- Morikawa, M., 2017. Firms' expectations about the impact of AI and robotics: evidence from a survey. *Econ. Inq.* 55 (2), 1054–1063.
- Naeem, M.A., Nguyen, T.T.H., Karim, S., Lucey, B.M., 2023a. Extreme downside risk transmission between green cryptocurrencies and energy markets: the diversification benefits. *Financ. Res. Lett.* 58, 104263.
- Naeem, M.A., Sadowsky, P., Karim, S., 2023b. Sailing across climate-friendly bonds and clean energy stocks: an asymmetric analysis with the Gulf cooperation council stock markets. *Energy Econ.* 126, 106911.
- Nanwani, S., 2020. The Belt and Road Initiative: an interface with multilateral development banks on international cooperation and global governance. In: *The Belt and Road Initiative and Global Governance*.
- Nikiforos, M., Santetti, M., Von Arnim, R., 2023. The Sraffian supermultiplier and cycles: theory and empirics. *Rev. Political Econ.* 1–20.
- OECD, 2024. Available at: <https://data.oecd.org/envpolicy/environmental-tax.htm>.
- Ottonelli, J., Lazaro, L.L.B., Andrade, J.C.S., Abram, S., 2023. Do solar photovoltaic clean development mechanism projects contribute to sustainable development in Latin America? Prospects for the Paris Agreement. *Energy Policy* 174, 113428.
- Pan, W., Cao, H., Liu, Y., 2023. "Green" innovation, privacy regulation and environmental policy. *Renew. Energy* 203, 245–254.
- Pata, U.K., Cevik, E.I., Destek, M.A., Dibooglu, S., Bugan, M.F., 2024. The impact of geopolitical risks on clean energy mineral prices: does the Russia-Ukrainian war matter? *Int. J. Green Energy* 21 (9), 2102–2116. <https://doi.org/10.1080/15435075.2023.2295867>.
- Pradhan, R.P., Arvin, M.B., Nair, M., Bennett, S.E., Hall, J.H., 2018. The dynamics between energy consumption patterns, financial sector development and economic growth in Financial Action Task Force (FATF) countries. *Energy* 159, 42–53.
- Puaschunder, J.M., 2023. The future of resilient green finance. In: *The Future of Resilient Finance: Finance Politics in the Age of Sustainable Development*. Springer International Publishing, Cham, pp. 185–210.
- Razzaq, A., Sharif, A., Afshan, S., Li, C.J., 2023. Do climate technologies and recycling asymmetrically mitigate consumption-based carbon emissions in the United States? New insights from quantile ARDL. *Technol. Forecast. Soc. Change* 186, 122138.
- Reinhart, C.M., Rogoff, K.S., 2009. The aftermath of financial crises. *Am. Econ. Rev.* 99 (2), 466–472.
- Ruta, M., Dappe, M.H., Lall, S.V., Zhang, C., Constantinescu, C., Lebrand, M., Churchill, E., 2019. Belt and Road Economics: Opportunities and Risks of Transport Corridors.
- Salisu, A.A., Omoke, P.C., Sikiru, A.A., 2023. Geopolitical risk and global financial cycle: some forecasting experiments. *J. Forecast.* 42 (1), 3–16.
- Scientific Research Publishing, 2019. Sustainable development and the role of China's Belt and Road Initiative in its economic growth: A review. Retrieved from: <https://www.scirp.org/journal/paperinformation?paperid=129292>.
- Shang, H., 2020. Analysis of Geopolitical Factors in the Promotion of the Belt and Road Initiative. *Front. Educ. Res.* 3 (9).
- Sharif, A., Ibrahim, M., Dogan, E., Tzeremes, P., 2023. Analysis of the spillover effects between green economy, clean and dirty cryptocurrencies. *Energy Econ.* 120, 106594.
- Sim, N., Zhou, H., 2015. Oil prices, US stock return, and the dependence between their quantiles. *J. Bank. Financ.* 55, 1–8.
- Tang, Y., Chen, X.H., Sarker, P.K., Baroudi, S., 2023. Asymmetric effects of geopolitical risks and uncertainties on green bond markets. *Technol. Forecast. Soc. Change* 189, 122348.
- Tiwari, A.K., Abakah, E.J.A., Adekoya, O.B., Hammoudeh, S., 2023. What do we know about the price spillover between green bonds and Islamic stocks and stock market indices? *Glob. Finance J.* 55, 100794.
- Umar, M., Su, C.W., Rizvi, S.K.A., Shao, X.F., 2021. Bitcoin: a safe haven asset and a winner amid political and economic uncertainties in the US? *Technol. Forecast. Soc. Change* 167, 120680.
- UNFCCC, 2024. Available at: <https://unfccc.int/process-and-meetings/the-paris-agreement>.
- United Nations, 2022. Global Impact of War in Ukraine: Energy Crisis. Available at: http://s://news.un.org/pages/wp-content/uploads/2022/08/GCRG_3rd-Brief_Aug3_2022_FINAL.pdf.
- Von Bogdandy, A., 2017. EU insights for political inclusion in international institutions. *Global Pol.* 8, 23–33.
- Wallerstein, I., 1984. Economic cycles and socialist policies. *Futures* 16 (6), 579–585.
- Wang, C., Zhang, X., Ghadimi, P., Liu, Q., Lim, M.K., Stanley, H.E., 2019b. The impact of regional financial development on economic growth in Beijing-Tianjin-Hebei region: a spatial econometric analysis. *Phys. A: Stat. Mech. Appl.* 521, 635–648.
- Wang, K., Tsai, S., Du, X., Bi, D., 2019a. Internet finance, green finance, and sustainability. *Sustainability-Basel* 11, 3856.
- Wang, M., Liu, J., Rahman, S., Sun, X., Sriboonchitta, S., 2023. The effect of China's outward foreign direct investment on carbon intensity of Belt and Road Initiative countries: A double-edged sword. *Econ. Anal. Policy* 77, 792–808.
- Wang, Q., Zhou, H., Zhao, X., 2024. The role of supply chain diversification in mitigating the negative effects of supply chain disruptions in COVID-19. *Int. J. Oper. Prod. Manag.* 44 (1), 99–132.
- Wei, P., Qi, Y., Ren, X., Gozgor, G., 2023. The role of the COVID-19 pandemic in time-frequency connectedness between oil market shocks and green bond markets: evidence from the wavelet-based quantile approaches. *Energy Econ.* 121, 106657.
- World Bank, 2018. Available at: <https://www.worldbank.org/en/topic/regional-integration/brief/belt-and-road-initiative>.
- World Bank, 2022. Available at: <https://www.worldbank.org/en/news/press-release/2022/09/15/risk-of-global-recession-in-2023-rises-amid-simultaneous-rate-hikes>.
- World Bank Blogs, 2022. Available at: <https://blogs.worldbank.org/opendata/understanding-depth-2020-global-recession-5-charts>.
- World Development Indicators, 2024. Available at: <https://databank.worldbank.org/source/world-development-indicators>.
- Xu, J., She, S., Gao, P., Sun, Y., 2023. Role of green finance in resource efficiency and green economic growth. *Resour. Policy* 81, 103349.
- Xu, Y., Liu, T., Du, P., 2024. Volatility forecasting of crude oil futures based on Bi-LSTM-attention model: the dynamic role of the COVID-19 pandemic and the Russian-Ukrainian conflict. *Resour. Policy* 88, 104319.
- Yang, J., Dong, D., Liang, C., 2024. Climate policy uncertainty and the US economic cycle. *Technol. Forecast. Soc. Change* 202, 123344.
- Yao, Xing, Wang, Bo, Yue, Pu, 2018. Network Structure and Influencing Factors of Intermediate Input in Countries along The 'Belt'.
- Yu, D., Gu, B., Zhu, K., Yang, J., Sheng, Y., 2024. Risk analysis of China's renewable energy cooperation with belt and road economies. *Energy* 293, 130664.
- Yu, Y., Qayyum, M., 2023. Impacts of financial openness on economic complexity: cross-country evidence. *Int. J. Finance Econ.* 28 (2), 1514–1526.
- Zarova, E., Abdurakhmanova, G., Tursunov, B., 2023, December. The relationship of the global index of artificial intelligence and the level of employment: a cluster approach in assessing cross-country differences. In: *Proceedings of the 7th International Conference on Future Networks and Distributed Systems*, pp. 682–688.
- Zhang, J., Ren, M., Lu, X., Li, Y., Cao, J., 2022. Effect of the belt and road initiatives on trade and its related LUCC and ecosystem services of central asian nations. *Land* 11 (6), 828.
- Zhang, S., Wu, Z., Wang, Y., Hao, Y., 2021. Fostering green development with green finance: an empirical study on the environmental effect of green credit policy in China. *J. Environ. Manage.* 296, 113159.
- Zhang, W., Alon, I., Lattemann, C., 2018. *China's Belt and Road Initiative*. Springer International Publishing.
- Zhang, Z., 2023. The impact of the artificial intelligence industry on the number and structure of employments in the digital economy environment. *Technol. Forecast. Soc. Change* 197, 122881.
- Zhao, G., Vazquez-Noguerol, M., Liu, S., Prado-Prado, J.C., 2024. Agri-food supply chain resilience strategies for preparing, responding, recovering, and adapting in relation to unexpected crisis: a cross-country comparative analysis from the COVID-19 pandemic. *J. Bus. Logist.* 45 (1), e12361.
- Zhou, Y., Tian, L., Yang, X., 2023. Schumpeterian endogenous growth model under green innovation and its enculturation effect. *Energy Econ.* 127, 107109.

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