Is green growth affected by financial risks? New global evidence from asymmetric and heterogeneous analysis

Jun Zhao [a], Kangyin Dong [b,c,*], Xiucheng Dong [b,c], Muhammad Shahbaz [d,e,*], Ioannis Kyriakou [f]

[a] *The College of Economics and Management, Beijing University of Chemical Technology, Beijing 100029, China*

[b] *School of International Trade and Economics, University of International Business and Economics, Beijing 100029, China*

[c] *UIBE Belt & Road Energy Trade and Development Center, University of International Business and Economics, Beijing 100029, China*

[d] *School of Management and Economics, Beijing Institute of Technology, Beijing 100081, China*

[e] *Department of Land Economy, University of Cambridge, Cambridge CB2 1TN, UK*

[f] *Bayes Business School, City, University of London, United Kingdom*

E-mail addresses: zhaojun4768@163.com (J. Zhao), dongkangyin@uibe.edu.cn (K.Y. Dong), dongxc@uibe.edu.cn (X.C. Dong), muhdshahbaz77@gmail.com (M. Shahbaz), ioannis.kyriakou.2@city.ac.uk (I. Kyriakou).

**Corresponding author: dongkangyin@uibe.edu.cn (K.Y. Dong)*

muhdshahbaz77@gmail.com (M. Shahbaz)

Abstract: In this paper, we aim to detect whether the instability of financial industry will restrict the global green evolution. To this end, by applying a sample dataset of 47 countries for the period 1996-2018, this study empirically examines the financial risk-green growth nexus, and also checks their regional heterogeneity as well as the impact of the financial crisis. We find that: (i) increased financial risks play an important role in restricting green growth across the globe; by implication, the instability of financial markets is an effective determinant hindering the global green evolution; (ii) significant regional heterogeneity exists in the financial risk-green growth nexus; only in regions with low green growth and high financial risks can financial risks affect green growth negatively; and (iii) the outbreak of the financial crisis in 2008 becomes a watershed in the impact of financial risks on green growth; after the crisis, the effective control of financial risks can facilitate the green economic recovery. Accordingly, some policy implications are put forward concerning the reform of the financial system and the establishment of early warning mechanism.

Keywords: Green growth; Financial risks; SYS-GMM technique; Heterogeneous and asymmetric analysis; Globe

JEL classification: C33; G32; O16; Q56

1. Introduction

The world economy has experienced unprecedented growth in the past few decades, thanks to the rapid evolution of industrialization and urbanization. According to statistics from the World Development Indicators (WDI) published by the World Bank (2021), the world's total gross domestic product (GDP) has more than doubled, from USD 40,916.72 billion (constant 2010 dollars) in 1994 to USD82,892.75 billion in 2018. However, this prosperity comes at the cost of environmental degradation, with an increase in extreme weather such as drought, floods, and heat waves. These climate changes can be attributed mainly to greenhouse gas emissions. As the main component of greenhouse gases, global carbon dioxide (CO_2) emissions grew from 21,652.92 million tons (Mt) in 1994 to 33,890.84 Mt in 2018, a 56% increase. The rapidly growing amount of CO_2 emissions has become a primary problem restricting the long-term development of the global economy (Umar et al., 2021).

To address mounting CO_2 emissions and the associated global warming caused by conventional economic growth, sustainable development has been proposed to address the adverse environmental by-products of economic growth. The proposals were well defined in the Brundtland report and were embraced by many developed economies around the world (Brundtland, 1987; Kim et al., 2014). However, many developing countries believe that environmental protection policies will be expensive since they may slow their economic growth rates and even lead to unemployment problems poor countries cannot afford. Accordingly, a green growth strategy, representing a paradigm shift from the traditional green growth mode, emerged as an essential component of sustainable evolution (Alkemade and Hekkert, 2010; Hallegette et al., 2012). Different from the concept of sustainability, green growth seeks to pursue environmentally sustainable growth without slowing down the economic growth rate (UNESCAP, 2012). Thus, green growth is considered as an effective low-carbon framework as well as a feasible path towards sustainable development (OECD, 2011a; Wang and Shao, 2019). Since green growth entails short-term economic growth and long-term environmental sustainability, to achieve this goal, multi-sectoral efforts must be employed to catalyze investment and innovation that consolidates new resources and stimulates economic growth (Huang and Quibria, 2013; OECD, 2011b). To this end, green growth, identified as an alternative growth path requiring policy instruments such as fiscal and monetary policies, has become an important agenda facing the international community, and has greatly spurred research into its determinants (Hickel and Kallis, 2020; Kim et al., 2014; Wang et al., 2020; Zhao et al., 2022).

Since green growth is a feasible and valid way to achieve sustainable development, massive scholars have dedicated their efforts to an in-depth investigation of the nexus between green growth and its driving factors, such as technical innovation (Cheng et al., 2021; Mensah et al., 2019; Wang et al., 2021), environmental tax (Hao et al., 2021; Lin and Chen, 2020; Wang et al., 2019; Zhao et al., 2020), and renewable energy use (Ackah and Kizys, 2015; Dai et al., 2016; Dong et al., 2018a, 2020; Sohag et al., 2021). However, the impact of financial risks on green growth has received little attention from researchers. On the one hand, financial risks, the possibility of a government's monetary policy getting out of control, can greatly influence the stability and efficiency of an economy's financial system (Greenwood, 2013; Molyneaux et al., 2016). High financial risks will also hinder the development of national direct and indirect investment, thus impeding the country's economic growth. On the other hand, scholars have confirmed that financial risks can affect environmental quality, which provides a new insight for studies on how financial risks affect green growth. Using the amount of CO_2 emissions as a proxy for environmental degradation, for example, many studies focus on checking the underlying impact of increased financial risks on greenhouse effect; however, their conclusions are inconsistent (Le et al., 2020; Zhang and Chiu, 2020; Zhao et al., 2021) (see Section 2.2 for detailed information). Therefore, the effect of financial risks on green growth may be strong and significant. An explicit nexus between financial risks and green growth not only helps us to better realize the drivers of green growth, but also makes a great contribution to formulate policies that help avert financial risks and promote green growth. This motivates us to investigate the impact of financial risks on green growth.

Notably, to date, although ample studies have discussed the measurement of green growth, no unified indicator framework has been established in these studies. And the extant literature focuses mainly on the progress of green growth at the national level or regional level, very few scholars discuss the issue related to green growth from a global perspective, especially evaluating the effect of financial risks on green growth, figuring out the nexus between financial risks and green growth is imperative, since it helps to better understand the determinants of green growth and can provide new insights to pursue a synergy of financial stability and green growth. Furthermore, the financial crisis of 2008 may have caused structural changes in the linkage between financial risks and green growth due to the different performances of monetary policy during the financial crisis (Mishkin, 2009), although this effect has rarely been discussed in the extant literature. In addition, regional differences in growth patterns and environmental performances may influence the underlying impact of financial risks on green growth. These may lead to heterogeneous impacts of financial risks on green growth (Dong et al., 2019, 2020; Wang and Shao, 2019), however, this is generally ignored in previous studies.

To address above issues, we first build an indicator system of green growth and use a novel technique – the improved entropy method (IEM) – to evaluate the national green growth level of 47 countries across the globe. Then, by applying the global data from 1996 to 2018, this study quantifies the underlying effect of financial risks on green growth. Given the possible impact of the 2008 financial crisis on the financial risk-green growth nexus, we divide our sample data into two subsamples around 2008, and re-estimate the model based on these two subsamples. In the end, the whole sample in this study is divided into four regions accordance with their financial risk levels and progress in accomplishing green growth to explore any possible regional heterogeneity between financial risks and green growth.

Our paper effectively complements the current related literature in the following three aspects. First, we think this paper is one of the few studies that investigates the direct impact of increased financial risks on green growth. This will greatly promote research on the determinants of green growth and effectively supplement the related literature. Second, this study creatively discusses the specific impact of the notorious 2008 financial crisis on the financial risk-green growth nexus. Identifying the impact of external shocks on the financial risks-green growth nexus can produce a clear understanding of the externalities of the financial crisis. Third, considering the differences of regional growth models and financial systems across various regions, we creatively gauge the regional heterogeneous effects of financial risks on green growth. This can provide effective reference for local governments to implement specific and appropriate policies to foster green growth according to the actual conditions.

We arrange the rest of our study as follows. The next section reviews the relevant literature on financial risks and green growth. Section 3 analyzes the conceptual and theoretical framework. Section 4 illustrates the model and data, followed by the empirical findings presented in Section 5. In Section 6, this study further discusses the shock of the 2008 financial crisis and examines the asymmetric effects between variables. Section 7 concludes the paper.

2. Literature review

2.1. An overview of green growth

In 2005, the United Nations Economic and Social Commission for Asia and the

Pacific (UNESCAP) first proposed the concept of "green growth." Green growth is defined as the development of a low-carbon and sustainable economic growth pattern to replace the conventionally extensive economic growth mode (ESCAP, 2005)[1]. Since then, as governments around the world have gradually acknowledged the importance of green and sustainable economic development, the concept of green growth has been highly extended. At the UNESCAP conference in 2006, the green growth paradigm was formalized as an approach that seeks to establish a synergy between environmental sustainability and efficient economic growth (ESCAP, 2006). As the Organization for Economic Cooperation and Development (OECD) underscored, green growth refers to the harmonious situation of rapid economic growth and ecological well-being while providing sufficient resources and services for current and future generations with the existing limited natural resource endowment (OECD, 2011b). This concept has been widely accepted by many scholars (Baniya et al., 2021; Hickel and Kallis, 2020; Jänicke, 2012).

In addition to the definitions by these organizations, several scholars have focused on defining green growth. For instance, Hallegatte et al. (2012) define green growth as a process of achieving clean, high-quality, efficient, and resilient economic growth without slowing down the growth rate. And Hickel and Kallis (2020) argue that green growth entails absolute decoupling of growth from resource use and undesirable environmental impacts. Although there has not been complete consensus on the concept

[1] The state of the environment in Asia and the Pacific 2005. https://www.unescap.org/resources/state-environment-asia-and-pacific-2005#.

on green growth, the consistent view is that green growth is about environmentally sustainable economic development, which requires decoupling sustainable economic growth from adverse environmental impacts and extensive resource use. Accordingly, it is necessary for governments to catalyze eco-innovation and efficient production, thus ensuring new resources for economic growth and long-term sustainable development (Engelmann et al., 2019; Kim et al., 2014; OECD, 2011b).

After clarifying the definition of green growth, a growing body of scholars has attempted to quantitatively assess green growth by using various indicators. The mainstream literature in this field is committed to constructing a unified framework or system of green growth indicators to make the status of green growth comparable across various countries (Baniya et al., 2021; Engelmann et al., 2019; Lin and Benjamin, 2017; Lyytimäki et al., 2018; Merino-Saum et al., 2018; Qu, 2012). However, no standard measurement of green growth has been established yet. To be more specific, the OECD outlined five crucial categories to measure green growth (i.e., environmental efficiency of consumption and production, residential environmental quality, stocks of natural capital, and responses to economic actors) (OECD, 2010). On this basis, Kim et al. (2014) selected 12 indicators to assess the progress of green growth for 30 countries; these indicators were compared with the 10th percentile of OECD countries and scored by 1–10. Then, by 2011, the OECD (2011c) developed 22 green growth indicators in the light of five categories, and these indicators were frequently used by researchers, such as Ates and Derinkuyu (2021) and Huang and Quibria (2013). Baniya et al. (2021)

chose six indicators from the set of green growth indicators proposed by the OECD (2017) to monitor the progress of green growth in Nepal and Bangladesh. Obviously, the viewpoints on evaluating the performance of green growth in an economy is not consistent.

2.2. The nexus between financial risk and green growth

Given the important role of green growth in the transformation of the conventional economic growth model, the determinants of green growth have attracted much attention from policymakers and scholars. Green growth is a comprehensive term that involves economic growth, people's livelihood, and environmental improvements simultaneously. Thus, achieving green growth requires multi-sectoral joint actions to foster investment, competition, and innovation, thus stimulating new resources of economic growth (Kim et al., 2014; OECD, 2011a).

Financial risk, however, is expected to be negatively correlated with green growth because it hampers national financial development. It has been confirmed that financial development is an important driving force for green growth due to its significant promotion effect on technological innovation (Abu-Bader and Abu-Qarn, 2008; Hassan et al., 2011; Mensah et al., 2019; Sohag et al., 2019; Ulucak, 2020; Valickova et al., 2015). Furthermore, financial development can provide enterprises, especially small and medium enterprises (SMEs), with substantial and stable financial funds to update their facilities and technology. This also reduces credit constraints confronting SMEs, thus enabling them to increase their investment in some high-profit projects and even expand their research and development (R&D) expenditure. These outcomes will lead to increased national green growth (Adejumo and Asongu, 2020; Hallegatte et al., 2012; Lorek and Spangenberg, 2014; Samad and Manzoor, 2015; Zhu and Ye, 2018).

Considering the adverse effects of financial risks on national financial development, these risks are very likely to be detrimental to green growth. However, despite an inherent linkage between financial risks and green growth, scant literature has been dedicated to an in-depth investigation of the impact of financial risks on green growth. Furthermore, regarding environmental degradation, scholars have investigated the impact of financial risks on greenhouse effect, but their conclusions are inconsistent. Some scholars hold that financial risks favor CO_2 emissions, and thus are not conducive to green growth (Abbasi and Riaz, 2016; Zhang and Chiu, 2020); in contrast, other scholars insist that financial risks can lead to a reduction in carbon emissions by destabilizing an economy's financial system and severely constraining the investment and production levels of enterprises (Zhang, 2011; Zhao et al., 2021). Dong et al. (2021) also investigate the greenhouse gas emission reduction effect of political risks and conclude that increased political risks can facilitate carbon reduction. Accordingly, the environmental impacts of financial risk are still inconclusive, implying an ambiguous nexus between financial risks and green growth.

3. Conceptual and theoretical framework

Finance is the core content of the modern economic system, and the financial market is the artery of the entire market economy (Li and Huang, 2020). Financial risks are the possibility that a certain amount of financial assets will suffer loss of expected income in the future period, which is an objective phenomenon (Sun et al., 2020; Zhao et al., 2021). Risks related to finance, such as risks in financial markets, institutions, and products, are all called financial risks. At present, as Kirikkaleli (2019) underscores, heightened currency expectations in major economies and divergent global economic recovery have become two fundamental risk factors constraining economic growth in all countries. Since April 2020, international commodities have risen for 19 consecutive months. Based on this, from January to September 2021, the consumer price index (CPI) in the United States (US) rose from 1.4% to 5.4%, from 0.9% to 3.4% in the euro zone, and from 0.7% to 3.1% in the United Kingdom (UK), far higher than the 2% target, triggering concerns about inflation expectations in the global market.

To this end, the rapid economic recovery and the persistent high inflation prompt the central banks of developed economies to begin to signal the shift of monetary policy. The US starts debt reduction in November, the European bond purchase slows down, and the central banks of the UK and Canada consider the withdrawal of quantitative easing, which becomes the uncertain factors promoting capital flows and exchange rate fluctuations. The current financial risks are the result of the superposition of cyclical and structural factors and the resonance of endogenous and external factors.

In the context of the current disconnect between the financial market and the real economy, if invertors' expectations and attitudes change, the price of risky assets may adjust again, financial fragility may be amplified, and financial conditions may be sharply tightened, thus restricting the flow of credit to the real economy and posing a threat to economic recovery. In particular, in the economic downturn, the negative feedback between financial risks and economic growth has been formed, and the virtuous circle has been broken (Batuo et al., 2018). In addition, the continuous expansion of financial risks will significantly affect the stability and socio-economic evolution, and it is difficult to provide a sound and complete capital base for social construction and production & operation activities, thus significantly inhibiting the green economic development (Zhao et al., 2021). Green growth focuses on advocating a low-carbon, green, and sustainable economic development model, which ensures the harmonious evolution of economy and environment under the premise of limited natural resources (Belmonte-Ureña et al., 2021). To this end, we put forward the following hypothesis:

Hypothesis 1: The growing financial risk is a stumbling block to the green growth of the global economy.

4. Model and data

4.1. Estimated model

To empirically check the proposed hypothesis — whether financial risk can hinder the green growth of the economy, we construct the following basic framework:

$$GG_{it} = f(FR_{it}, Pgdp_{it}, Tra_{it}, Cap_{it}, Pop_{it}) \quad (1)$$

where subscript *i* refers to the global 47 countries, and *t* indicates the time spanning 1996-2018. $f(\cdot)$ is a function. GG_{it} represents green growth. FR_{it}, $Pgdp_{it}$, Tra_{it}, Cap_{it}, and Pop_{it} indicate financial risks, economic growth, trade openness, capital, and the population of various countries of each year, respectively.

Due to the potential heteroscedasticity of the original panel data model framework, we conduct natural logarithm processing on the above equation to empirically eliminate data volatility. Accordingly, Eq. (1) can be rewritten as follows:

$$\begin{aligned} lnGG_{it} = \alpha_0 + \alpha_1 lnFR_{it} + \alpha_2 lnPgdp_{it} + \alpha_3 lnTra_{it} + \alpha_4 lnCap_{it} \\ + \alpha_5 lnPop_{it} + \eta_i + v_t + \varepsilon_{it} \end{aligned} \tag{2}$$

where α_0 represents the intercept term. η_i, v_t, and ε_{it} are the country-specific effect, year-specific effect, and random disturbance term, respectively. $\alpha_1 - \alpha_5$ indicate the parameters to be estimated. Increased international financial risks could undermine the integrity of financial markets, thereby inhibiting rapid economic growth, damaging the quality of residents' lives, and reducing global green growth. Therefore, we expect the coefficient of financial risks (i.e., α_1) to be negative.

4.2. Data

We employ a balanced panel dataset of 47 countries across the globe for the period 1996-2018 to check the underlying impact of financial risks on green growth, yielding a total of 1,081 observations. Notably, other countries are excluded due to missing data.

4.2.1 Explained variable

As the main core research variable, the measurement standard of green growth is not consistent, especially in the global sample. To this end, we develop an indicator system covering three dimensions — people's livelihood, economic growth, and resources and environment — to effectively and comprehensively measure green growth across the globe. To be specific, economic growth consists mainly of the growth rate of GDP and per capita GDP, the proportion of the total import and export trade to GDP, and the ratio of the output value of tertiary industry to GDP. People's livelihood includes three indicators: the number of hospital beds per thousand people, per capita wage level of the employed population, and the ratio of the total number of unemployed people to the total labor force. And resources and environment contains the proportion of the population with electricity to the total population, the ratio of forest area to land area, and the amount of CO_2 emissions. In addition to the data on CO_2 emissions from the former British Petroleum (BP, 2019), the data of other variables have been collected mainly from the World Bank (2021). We use the IEM to calculate the ten indicators listed in Table A1 of the Appendix to obtain the global green growth composite index. The specific procedures of the IEM are reported as follows:

(1) *The standardization of indicators*. We select the 47 countries and ten indicators across the globe to measure green growth. In Table A1, the indicators consist of two kinds of attributes: positive and negative. The standardization of the positive and negative indicators is presented in the following process, respectively:

$$x_{ij}^{'} = \frac{x_{ij} - \min(x_{1j}, \cdots, x_{nj})}{\max(x_{1j}, \cdots, x_{nj}) - \min(x_{1j}, \cdots, x_{nj})} \tag{3}$$

$$x_{ij}^{'} = \frac{\max(x_{1j}, \cdots, x_{nj}) - x_{ij}}{\max(x_{1j}, \cdots, x_{nj}) - \min(x_{1j}, \cdots, x_{nj})} \tag{4}$$

where x_{ij} refers to the value of the *j-th* indicator of the *i-th* country and $x_{ij}^{'}$ denotes the normalized value of x_{ij}. Max and min in the above equations refer to the maximum and minimum values of the original sequence values.

(2) *The calculation of entropy value*. In this procedure, the ratio of the normalized value of an indicator in the certain country to the value of that indicator in all countries is gauged, and the entropy value of the certain indicator is measured as follows:

$$e_j = -\frac{1}{Ln(n)} \sum_{i=1}^{n} \frac{x_{ij}^{'}}{\sum_{i=1}^{n} x_{ij}^{'}} Ln\left(\frac{x_{ij}^{'}}{\sum_{i=1}^{n} x_{ij}^{'}}\right) \tag{5}$$

(3) *Calculation of the green growth composite index*. Based on Eq. (5), we can gauge the green growth composite index across the globe (i.e., *GG*) in the following equation:

$$GG_i = \sum_{j=1}^{m} [(1-e_j) / \sum_{j=1}^{m} (1-e_j)] \cdot p_{ij} \tag{6}$$

Following the green growth composite index calculated above, we conduct a spatio-temporal analysis of global green growth. In the sample period, the green growth levels of Ireland, Poland, Germany, South Korea, the Czech Republic, Luxembourg, and Hungary show a significant upward trend, while other countries either maintain a relatively consistent level or exhibit a downward trend. Furthermore, we also draw the average trend chart of green growth from 1996 to 2018 (see the blue bar chart in Fig.1). We can see that the average level of global green growth does not show an increasing trend; on the contrary, it shows a downward trend of volatility and reaches its lowest point in 2015. The possible reason is that the potential driving force of economic growth is energy (Dong et al., 2018b). Rapid economic growth is usually accompanied by a large amount of energy consumption and environmental pollution emissions. When environmental quality improves significantly, the speed of economic growth is inhibited. Accordingly, how to realize the coordinated socio-economic evolution has become the primary concern of all countries.

Insert Fig. 1

In addition, we also plot the spatial pattern of green growth across the globe in some selected years (i.e. 1996, 2001, 2006, 2011, 2016, and 2018) due to the space limitations, which are presented in Fig. 2. European countries have the best level of green growth, followed by American countries, while Asian and African countries exhibit the worst level of green growth. Among the Asian countries, South Korea, with a high level of green growth, is an exception. European countries took the lead in completing the process of industrialization in the last century. With the rapid economic growth in Asia and other countries, European countries have begun to carry out green and low-carbon technical innovation to improve the environmental quality and residents' welfare.

Insert Fig. 2

4.2.2 Explanatory variable

The measurement of financial risks can refer to the work of Zhao et al. (2021). Following the statistical data of the International Country Risk Guide (ICRG) rating published by the Political Risk Services (PRS) group, we calculate the financial risks of 47 countries according to the IEM discussed above through five indicators, i.e., risk points of the proportion of foreign debt on GDP, risk points for exchange rate stability, risk points for the ratio of debt service to XGS, risk points for the current account as a percentage of XGS, and risk points for international liquidity. Thus, we obtain the corresponding composite index of financial risks across the globe.

Based on the financial risks composite index, we draw the time trend chart of the average values of financial risks for the period 1996-2018 (see also the red line in Fig. 1). Obviously, the global average value of financial risks peaked in 2002 and reached the minimum in 2008. We also draw the spatial distribution map of financial risks in selected years, i.e., 1996, 2001, 2006, 2011, 2016, and 2018. We find that the areas with the highest financial risk are distributed mainly in Asian and European countries, while American countries have the lowest financial risks.

Insert Fig. 3

4.2.3 Control variables

This study further introduces some control variables (i.e., economic growth, trade openness, capital, and population). The data on which are obtained from the World Bank (2021). The definition and descriptive statistics of all the used variables with the natural logarithm form are presented in Table 1.

Insert Table 1

5. Empirical findings

Technically, the estimated procedures of this study are as follows: (1) the cross-sectional correlation within the panel data is checked (see Section 5.1); (2) the benchmark regression is conducted to check the impact of financial risks on green growth (see Section 5.2); and (3) the regional heterogeneity is analyzed by dividing the full sample into four areas (see Section 5.3).

5.1. Cross-sectional correlation check

To the best of our knowledge, global countries are not independent entities, their development depends on connections with other countries, and is mutually reinforcing. Therefore, to choose an effective estimation method, the cross-sectional dependence of the panel data cannot be ignored, and may result in biased and invalid empirical results. Based on this, we utilize two methods, i.e., the Breusch-Pagan Lagrange multiplier (LM) test and the Pesaran cross-sectional dependence (CD) test to check cross-sectional dependence within the sample data. The results of Table 2 suggest the existence of cross-sectional correlation within the data. Accordingly, to effectively estimate the empirical results, estimation methods that can solve the cross-sectional dependence problem should be selected.

Insert Table 2

5.2. Benchmark regression

Table 3 exhibits the estimated findings of estimating Eq. (2) with the ordinary least square (OLS), fixed effect (FE), and two-step system generalized method of moments (SYS-GMM) techniques, which consists of the static and dynamic estimates simultaneously; thus, which method to choose as the benchmark regression becomes a crucial issue in this study. Notably, as Ullah et al. (2018) stress, testing the applicability of the methods requires certain steps: (1) We first perform OLS estimate and check whether the endogeneity problem of the core explanatory variables exists. If not, OLS estimate is valid; otherwise, the endogeneity problem needs to be solved; (2) the failure of FE estimate in dealing with endogeneity is emphasized in the next step; and (3) we address the endogeneity concerns by applying a rigorous two-way SYS-GMM method.

5.2.1 Step 1: OLS estimate

The OLS estimation technique is first applied to check the underlying impact of financial risks on green growth owing to its wide use in previous studies. The related results are shown in the first two columns of Table 3. Notably, it is imperative to test the endogeneity before interpreting the primary findings (Schultz et al., 2010; Wintoki et al., 2012). To address this issue, this study first selects an appropriate instrumental variable (i.e., risk value for exchange rate stability) to perform instrumental variable (IV) estimate, the statistic values of *K-P rk LM* and *K-P rk Wald* F in Table 3 indicate that our estimate does not have the problems of insufficient identification and weak identification of instrumental variables. On this basis, we apply the Durbin-Wu-Hausman (DWH) test to assess the endogeneity of individual regressors by referring to the test steps of Wintoki et al. (2012), Wooldridge (2010), and Ullah et al. (2018).

Obviously, the significant test value of the DWH implies that core explanatory variable exists endogeneity issue; thus, the OLS estimate is inapplicable.

5.2.2 Step 2: FE estimate

Since OLS strategy cannot effectively address endogeneity problems, we further choose the FE estimate. Under the strict exogenous assumption, this method can eliminate the potential influence of time variable by difference, and effectively control the non-observable regional or temporal heterogeneity (Hamilton and Nickerson, 2003). By implication, in the FE estimate, the impact of financial risks on green growth has no time lag effect, which is constant over time. However, this is not practical. Since the relationship between financial risks and green growth is dynamic, this may violate strict exogenous assumptions (Schultz et al.,2010). To this end, conventional static panel models with fixed and random effects can lead to inconsistent and biased estimates. Because two-step SYS-GMM method has a significant advantage in addressing the endogeneity problems, we finally choose to apply this technique as the benchmark regression, which will be discussed in detail in the next step.

5.2.3 Step 3: SYS-GMM estimate

In the last step, we proceed to apply the two-step SYS-GMM method to solve the endogeneity problem (Arellano and Bover, 1995; Blundell and Bond, 1998). During the process, it is necessary to conduct the non-autocorrelation and overidentification tests (i.e., the Arellano-Bond (A-B) and Sargan tests) (Ullah et al., 2018). As this table shows, the p-values of the two tests suggest that using this method is reasonable, which denotes the credibility and accuracy of the financial risk-green growth nexus.

In the last column of Table 3 with all the selected control variables, a 1% increase in financial risks can significantly reduce green growth by 0.008%. This suggests that the continuous expansion of global financial risks is a huge barrier to the sustainable socio-economic development of various countries, which is in line with the finding of Zhang and Chiu (2020): the growing financial risks worsen the ecological environment and restrict green and sustainable development. In recent years, as policy uncertainties have been rife, financial markets in emerging economies have fluctuated, global trade frictions have arisen, and financial conditions have tightened, the sustainability and inclusiveness of economic development across the globe have been severely hampered and challenged (Kunieda and Shibata, 2016). In addition, the US has intensified global unilateralism and trade protectionism, which have become a source of uncertainty in the world economy, and these will become the fuse for the reversal or outbreak of global financial risk appetite. Specifically, as the world's largest economy, the US still faces many risks. First, the foundation of the US economic recovery under the action of fiscal policy inertia is based more on the tax cut effect, stock market bubble expansion, and infrastructure stimulus. Second, if the trade frictions between China and the US continue to escalate, the uncertainty it creates will hurt economic growth in both the US and China (Shi et al., 2021). Third, a slowdown in the global economy could cause big losses in the US stock and bond markets.

In addition, given the uncertain international environment, Japan's economic growth may show a slight decline. Furthermore, as Tu (2020) and Urata (2020) stress, rising trade frictions between the US and China, the lack of confidence in domestic consumption and investment, the passive appreciation of the yen due to the demand for hedging, and the pressure of high government debt under the normalization of monetary policy in developed countries will threaten the slightly improved economic growth. More importantly, emerging market countries are important engines of global economic growth (Bakirtas and Akpolat, 2018). However, at the current stage, international trade and investment environment are increasingly uncertain, economic and political risks are mounting. Under the premise of insufficient development impetus of emerging economies, the economic trend of each country is significantly differentiated, and the uncertainty of financial policies and the aggravation of international trade friction hinder the sustainable evolution of emerging economies. This conclusion is also reached by Liu et al. (2020). For instance, Russia, Iran, Turkey, and other emerging economies are deeply affected by the international political crisis, and the slowdown of their economic growth has been a high-probability event. Moreover, China’s growth momentum will wane as it pursues high-quality, healthier economic growth (Kong et al., 2021). Based on the above discussion, we find that increasing global financial risks will seriously damage the sustainable and stable economic development of various countries and inhibit the improvement of residents’ living quality, which will slow down the pace of green growth.

Economic growth and capital are positively related to green growth. This is because economic growth and capital formation provide a solid economic foundation for green growth. Accelerated economic development can effectively improve people's livelihood and alleviate environmental pollution. On the contrary, trade openness and population affect green growth negatively across the globe. While promoting the flow of commodities, trade openness may also harm the quality of a country's environment due to the trade of polluting products. Population growth will reduce the per capita economic level and resource endowment, which will decrease residents' life satisfaction and not be conducive to green growth.

Insert Table 3

5.3. Regional heterogeneous analysis

As Fig. 2 displays, the spatial pattern of global green growth exhibits obvious regional heterogeneity. Accordingly, an interesting question ignites our interest: Will increased financial risk produce heterogeneous impacts on green growth across various regions? To effectively answer this question, we proceed to divide the 47 countries into four areas by expanding the work of Jiang et al. (2020): high green growth region, low green growth region, high financial risk region, and low financial risk region. The classification criteria comprise the following steps: (1) We first gauge the average value of financial risks and green growth in each country from 1996 to 2018, respectively; (2) then, this study evaluates the average values of financial risks and green growth for the whole panel during the sample period, respectively; and (3) finally, we classify the 47 countries into four areas: high green growth region, low green growth region, high financial risk region, and low financial risk region. The specific countries of each region are listed in Table A2 and are clearly shown in Fig. 4.

Insert Fig. 4

We use the SYS-GMM technique to detect the different impacts of financial risk on green growth across various regions; the corresponding results are presented in the first four columns of Table 4. In the high green growth and low financial risk regions, both financial risk and green growth show significant positive correlation. This implies that increased financial risk can promote green growth. When the regional level of green growth is high or the regional financial risk is low, this shows that regional economic development, people's livelihood and welfare, and resource and environment are in a superior state, and the region has the ability and strength to face and bear risks. Increased financial risk can improve the activity of the financial market, and the government and citizens can take advantage of this opportunity to further promote the country's level of green growth.

In the low green growth and high financial risk regions, we obtain the opposite conclusion: increased financial risk plays a negative role in reducing green growth. In these countries, especially in countries with high financial risks, it is easy to produce frequent fluctuations in financial markets or even the collapse of the financial system. This will inhibit the development of the national economy and even the global capital market, and, more importantly, it will significantly inhibit national stability.

Insert Table 4

6. Further discussion

6.1. The impact of the financial crisis in 2008

When it comes to financial risks, they will be unconsciously associated with the outbreak of a financial crisis. The most famous one in the sample period (i.e., 1996-2018) is the subprime financial crisis, which broke out in the US and spread to the whole world in 2008. This crisis results in a sustained global economic recession (Nelson and Katzenstein, 2014; Reinhart and Rogoff, 2008). To analyze whether potential differences existed between financial risks and green growth before and after the financial crisis, we divide the whole sample into two sub-panels (i.e., before 2008 and after 2008) for regression. Based on this, we conduct the relevant research and list the results in Table 4.

Before 2008, financial risks and green growth across the globe showed a significant positive correlation. An increase in financial risks by 1% can facilitate green growth by 0.033%. In the first few years of the sample period, the financial market of each country was in a stage of rapid development, and the governments of various countries were committed to accelerating the improvement of the financial system and promoting the active use of capital, which was conducive to promoting the rapid growth of the economy. In contrast, after the outbreak of the financial crisis (i.e., after 2008), financial risks had a negative impact on global green growth. After this financial crisis, various countries gradually realized the importance of controlling financial risks and taking measures to reduce the degree of financial risks, thus promoting the green recovery of their national economy.

6.2. Asymmetric analysis

After conducting regional heterogeneous analysis, this study further checks the asymmetric impacts of financial risks on global green growth by re-estimating Eq. (2) according to the two-step panel quantile regression at different quantiles of conditional green growth. We report the regression results in Table 5 and Fig. 5. Accordingly, it can be concluded that financial risks and green growth across the globe show a significant asymmetric relationship.

More specifically, the coefficients of financial risks are only significantly negative at the 10th and 25th quantiles, while at the 75th and 90th quantiles, increased financial risks are positively associated with global green growth. This finding is consistent with the results of regional heterogeneity. In other words, when a country's level of green growth is relatively low, the increase in financial risks is not conducive to regional green growth; on the contrary, increased financial risks will accelerate the process of green growth. In terms of the control variables, the impacts of economic growth and trade openness on global green growth are consistent at different quantiles. Capital formation shows a significant positive effect with green growth only at the 50th quantile, while the effect of population on green growth is significantly negative only at the 75th and

90th quantiles.

Insert Table 5

Insert Fig. 5

7. Conclusions and policy recommendations

7.1. Conclusions

To explore the potential role of financial industry development on global green growth from a risk perspective, this paper focuses on assessing the dynamic linkage between financial risks and green growth, as well as the characteristics of geographic heterogeneity and asymmetry. Furthermore, the impact of the financial crisis that broke out in 2008 on the financial risks-green growth nexus has also been highlighted. The main findings of this study are illustrated as follows:

(1) The negative impact of increased financial risks on green growth across the globe is the primary finding of our paper; more specifically, a 1% increase in financial risks can significantly reduce green growth by 0.008%. Put differently, the continuous growing of financial risks could seriously hamper the process of global green growth.

(2) Significant geographic heterogeneity and asymmetry exist in various countries. Only in high green growth and low financial risks regions can financial risks facilitate green growth, while in low green growth and high financial risks regions, increased financial risk is a stumbling block to the green socio-economic evolution. This finding is consistent with the empirical results of asymmetric analysis.

(3) The related analysis of the impact of the 2008 financial crisis emphasizes that increased financial risks will accelerate the process of global green growth before the outbreak of the financial crisis in 2008. However, after the financial crisis in 2008, as countries gradually realize the consequences of the financial crisis, the effective control of financial risks can facilitate the green recovery of the economy.

7.2. Policy recommendations

Based on the above three findings, we make the following policy suggestions. First, the negative financial risk-green growth nexus implies that it is imperative for countries to effectively manage and control financial risks to accelerate global green growth. All countries should accelerate the reform of the financial system and implement the innovation of domestic financial regulatory system. Eliminating all kinds of financial risks and hidden dangers to the greatest degree possible, and innovating and deepening the reform of the financial system are indispensable measures to reduce financial risks. More specifically, the fragility of financial system is a main reason for the outbreak of financial crisis. As countries with relatively high financial risk, Eurasia countries should actively improve their financial legal systems, strengthen supervision, and increase the resilience of financial markets. For example, governments should facilitate the division of labor and efficient operation of various institutions in the financial system, organically combine the internal control and external supervision, comprehensively maintain the completeness of the financial system, and prevent the impact of the outbreak of crisis. In addition, each country should improve the property rights structure of listed companies and the transparency of company information, and avoid insider trading. Countries also should establish institutional investor access systems to prevent price booms and crashes caused by market manipulation by institutional investors.

Second, in addition to strengthening financial regulation and control, another effective measure for reducing financial risks is to establish a financial risk-prevention and early warning mechanism. Financial crisis is usually the result of accumulation of financial risks, it is particularly imperative to establish a financial crisis early warning mechanism to resolve the financial crisis in advance. Building a set of early warning system including exchange rate, debt, inflation, and other indicators, and regularly gauging and evaluating the level and possibility of crisis are effective means to prevent the outbreak of crisis. On the one hand, various countries should actively establish an "identification, assessment, classification, control, monitoring, and reporting" early warning mechanism of risk management and control, improve credit files, and make a comprehensive and true record of the issuance, management, and recovery of loans. On the other hand, various countries should also pay close attention to early warning signs of risks, so as to prioritize problems and predict the development trend of loans. In addition, an analysis mechanism of risk prevention should be established to carry out risk analysis and prediction.

Third, the results of the regional heterogeneity and asymmetric analysis indicate the significant differences in the relationship between financial risks and green growth. Thus, when formulating the legal systems for financial supervision and early warning, as well as policies and regulation to achieve green growth, it is necessary to develop appropriate policies and measures in light of national and local realities. For instance, in the high green growth and financial risk regions, the national government should accelerate the activity of the financial market, expand its size, and clearly define its role. Furthermore, in the low green growth and high financial risk regions, the government should prioritize ways in which it can effectively reduce financial risks.

Notably, as one of the few articles that discusses the global green growth from the perspective of financial risks, this study only preliminarily analyzes the dynamic effect and heterogeneity of the relationship between financial risks and green growth. While supplementing relevant research, there are still the following research gaps. The first involves the issue of sample data. Due to the lack of data on green growth and financial risks, only 47 countries are selected. In future studies, we will continue to search for relevant databases to study green growth in more countries. The second is related to the transmission mechanism and internal pathways. We only focus on the geographical heterogeneity and asymmetry of the impact of global financial risks on green growth, and do not carry out in-depth research on how financial risks influence green growth. It is imperative to investigate the impact mechanism between financial risks and green growth in the future studies.

Acknowledgements

The article is supported by the National Social Science Foundation of China (Grant No. 20VGQ003). The authors gratefully acknowledge the helpful reviews and comments from the editors and anonymous reviewers, which improved this manuscript considerably. Certainly, all remaining errors are our own.

Disclosure statement

No potential conflict of interest was reported by the authors.

Inclusion and Diversity

While citing references scientifically relevant for this work, we also actively worked to promote gender balance in our reference list. The author list of this paper includes contributors from the location where the research was conducted who participated in the data collection, design, analysis, and/or interpretation of the work.

Appendix A.

Table A1. The indicator system of global green growth.

Category	Indicator	Attribute
Economic growth	Growth rate of total gross domestic product (GDP)	Positive
	Growth rate of per capita GDP	Positive
	Proportion of the total import and export trade to GDP	Positive
	Ratio of the output value of the tertiary industry to GDP	Positive
People's livelihood	The number of hospital beds per thousand people	Positive
	Per capita wage level of employed population	Positive
	Ratio of the total number of unemployed people to the total labor force	Negative
Resource and environment	Proportion of the population with electricity to the total population	Positive
	Ratio of forest area to land area	Positive
	The amount of carbon dioxide (CO_2) emissions	Negative

Table A2. The specific countries of the four sub-regions.

Region	Specific countries
High green growth region	Austria, Belgium, Bulgaria, Canada, Cyprus, Czech Republic, Finland, France, Germany, Hungary, Ireland, Japan, Luxembourg, Netherlands, Norway, Poland, Romania, Russian Federation, Singapore, Slovakia, South Korea, Sweden, Switzerland
Low green growth region	Australia, Brazil, Britain, Chile, China, Denmark, Egypt, Greece, India, Indonesia, Iran, Israel, Italy, Mexico, Morocco, Oman, Pakistan, Philippines, Portugal, Saudi Arabia, Spain, Turkey, United Arab Emirates, United States
High financial risk region	Chile, China, Denmark, India, Iran, Ireland, Israel, Japan, Morocco, Norway, Oman, Philippines, Russian Federation, Saudi Arabia, Singapore, South Korea, Switzerland, United Arab Emirates
Low financial risk region	Australia, Austria, Belgium, Brazil, Britain, Bulgaria, Canada, Cyprus, Czech Republic, Egypt, Finland, France, Germany, Greece, Hungary, Indonesia, Italy, Luxembourg, Mexico, Netherlands, Pakistan, Poland, Portugal, Romania, Slovakia, Spain, Sweden, Turkey, United States

Table A3. Abbreviation list.

Abbreviations			
A-B	Arellano-Bond	Mt	Million tons
BP	British Petroleum	OECD	Organization for Economic Cooperation and Development
CD	Cross-section dependence	OLS	Ordinary least square
CO_2	Carbon dioxide	PRS	Political Risk Services
CPI	Consumer price index	R&D	Research and development
DWH	Durbin-Wu-Hausman	SMEs	Small and medium enterprises
FE	Fixed effect	SYS-GMM	System generalized method of moments
GDP	Gross domestic product	UK	United Kingdom
ICRG	International Country Risk Guide	UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
IEM	Improved entropy method	US	United States
IV	Instrumental variable	WDI	World Development Indicators
LM	Lagrange multiplier		

Appendix B. Supplementary data

Supplementary data to this article can be found online at

References

Abbasi, F., Riaz, K., 2016. CO_2 emissions and financial development in an emerging economy: an augmented VAR approach. Energ. Policy 90, 102-114. doi: 10.1016/j.enpol.2015.12.017.

Abu-Bader, S., Abu-Qarn, A. S., 2008. Financial development and economic growth: The Egyptian experience. J. Policy Model. 30, 887-898. doi: 10.1016/j.jpolmod.2007.02.001.

Ackah, I., Kizys, R., 2015. Green growth in oil producing African countries: A panel data analysis of renewable energy demand. Renew. Sust. Energ. Rev. 50, 1157-1166. doi: 10.1016/j.rser.2015.05.030.

Adejumo, A. V., Asongu, S. A., 2020. Foreign direct investment, domestic investment and green growth in Nigeria: Any spillovers? In International Business, Trade and Institutional Sustainability (pp. 839-861). Springer, Cham. doi: 10.1007/978-3-030-26759-9_50.

Alkemade, F., Hekkert, M. P., 2010. Coordinate green growth. Nature 468, 897. doi: 10.1038/468897a.

Arellano, M., Bover, O., 1995. Another look at the instrumental variable estimation of error-components models. J. Econometrics 68, 29-51. doi: 10.1016/0304-4076(94)01642-D.

Ates, S. A., Derinkuyu, K., 2021. Green growth and OECD countries: measurement of country performances through distance-based analysis (DBA). Environ. Dev.

Sustain. 23, 15062–15073. doi: 10.1007/s10668-021-01285-4.

Bakirtas, T., Akpolat, A. G., 2018. The relationship between energy consumption, urbanization, and economic growth in new emerging-market countries. Energy 147, 110-121. doi: 10.1016/j.energy.2018.01.011.

Baniya, B., Giurco, D., Kelly, S., 2021. Green growth in Nepal and Bangladesh: Empirical analysis and future prospects. Energ. Policy 149, 112049. doi: 10.1016/j.enpol.2020.112049.

Batuo, M., Mlambo, K., Asongu, S., 2018. Linkages between financial development, financial instability, financial liberalisation and economic growth in Africa. Res. Int. Bus. Financ. 45, 168-179. doi: 10.1016/j.ribaf.2017.07.148.

Belmonte-Ureña, L. J., Plaza-Úbeda, J. A., Vazquez-Brust, D., Yakovleva, N., 2021. Circular economy, degrowth and green growth as pathways for research on sustainable development goals: A global analysis and future agenda. Ecol. Econ. 185, 107050. doi: 10.1016/j.ecolecon.2021.107050.

Blundell, R., Bond, S., 1998. Initial conditions and moment restrictions in dynamic panel data models. J. Econometrics 87, 115-143. doi: 10.1016/S0304-4076(98)00009-8.

BP, 2019. BP Statistical Review of World Energy 2019. http://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy/downloads.html.

Brundtland, G. H., 1987. World commission on environment and development: Our common future. New York: Oxford University Press.

Cheng, C., Ren, X., Dong, K., Dong, X., Wang, Z., 2021. How does technological innovation mitigate CO_2 emissions in OECD countries? Heterogeneous analysis using panel quantile regression. J. Environ. Manage. 280, 111818. doi: 10.1016/j.jenvman.2020.111818.

Dai, H., Xie, X., Xie, Y., Liu, J., Masui, T., 2016. Green growth: The economic impacts of large-scale renewable energy development in China. Appl. Energ. 162, 435-449. doi: 10.1016/j.apenergy.2015.10.049.

Dong, K., Dong, X., Dong, C., 2019. Determinants of the global and regional CO_2 emissions: what causes what and where? Appl. Econ. 51, 5031-5044. doi: 10.1080/00036846.2019.1606410.

Dong, K., Dong, X., Jiang, Q., 2020. How renewable energy consumption lower global CO_2 emissions? Evidence from countries with different income levels. World Econ. 43, 1665-1698. doi: 10.1111/twec.12898.

Dong, K., Dong, X., Jiang, Q., Zhao, J., 2021. Valuing the greenhouse effect of political risks: the global case. Appl. Econ. 53, 3604-3618. doi: 10.1080/00036846.2021.1883543

Dong, K., Hochman, G., Zhang, Y., Sun, R., Li, H., Liao, H., 2018a. CO_2 emissions, economic and population growth, and renewable energy: Empirical evidence across regions. Energ. Econ. 75, 180-192. doi: 10.1016/j.eneco.2018.08.017.

Dong, K., Sun, R., Li, H., Liao, H., 2018b. Does natural gas consumption mitigate CO_2

emissions: testing the environmental Kuznets curve hypothesis for 14 Asia-Pacific countries. Renew. Sust. Energ. Rev. 94, 419-429. doi: 10.1016/j.rser.2018.06.026.

Engelmann, J., Al-Saidi, M., Hamhaber, J., 2019. Concretizing green growth and sustainable business models in the water sector of Jordan. Resources 8, 92. doi: 10.3390/resources8020092.

ESCAP, 2005. The state of the environment in Asia and the Pacific 2005. https://www.unescap.org/resources/state-environment-asia-and-pacific-2005#.

ESCAP, 2006. Second green growth policy dialogue: Role of public policy in providing sustainable consumption choices: Resources saving society and green growth, Beijing. Standard Certification Centre.

Greenwood, J., Sanchez, J. M., Wang, C., 2013. Quantifying the impact of financial development on economic development. Rev. Econ. Dynam. 16, 194-215. doi: 10.1016/j.red.2012.07.003.

Hallegatte, S., Heal, G., Fay, M., Treguer, D., 2012. From growth to green growth-a framework (No. w17841). National Bureau of Economic Research. doi: 10.3386/w17841.

Hamilton, B. H., Nickerson, J. A., 2003. Correcting for endogeneity in strategic management research. Strateg. Organ. 1, 51-78. doi: 10.1177/1476127003001001218.

Hao, L. N., Umar, M., Khan, Z., Ali, W., 2021. Green growth and low carbon emission in G7 countries: how critical the network of environmental taxes, renewable energy and human capital is? Sci. Total Environ. 752, 141853. doi: 10.1016/j.scitotenv.2020.141853.

Hassan, M. K., Sanchez, B., Yu, J. S., 2011. Financial development and economic growth: New evidence from panel data. Q. Rev. Econ. Finance 51, 88-104. doi: 10.1016/j.qref.2010.09.001.

Hickel, J., Kallis, G., 2020. Is green growth possible? New Polit. Econ. 25, 469-486. doi: 10.1080/13563467.2019.1598964.

Huang, Y., 2010. Political institutions and financial development: an empirical study. World Dev. 38, 1667-1677. doi: 10.1016/j.worlddev.2010.04.001.

Huang, Y., Quibria, M. G., 2013. Green growth: theory and evidence (No. 2013/056). WIDER Working Paper.

Jänicke, M., 2012. “Green growth”: From a growing eco-industry to economic sustainability. Energ. Policy 48, 13-21. doi: 10.1016/j.enpol.2012.04.045.

Jiang, H., Dong, X., Jiang, Q., Dong, K., 2020. What drives China’s natural gas consumption? Analysis of national and regional estimates. Energ. Econ. 87, 104744. doi: 10.1016/j.eneco.2020.104744.

Kim, S. E., Kim, H., Chae, Y., 2014. A new approach to measuring green growth: Application to the OECD and Korea. Futures 63, 37-48. doi: 10.1016/j.futures.2014.08.002.

Kirikkaleli, D., 2019. Time–frequency dependency of financial risk and economic risk: evidence from Greece. J. Econ. Struct. 8, 1-10. doi: 10.1186/s40008-019-0173-z.

Kong, Q., Peng, D., Ni, Y., Jiang, X., Wang, Z., 2021. Trade openness and economic growth quality of China: Empirical analysis using ARDL model. Financ. Res. Lett. 38, 101488. doi: 10.1016/j.frl.2020.101488.

Kunieda, T., Shibata, A., 2016. Asset bubbles, economic growth, and a self-fulfilling financial crisis. J. Monetary Econ. 82, 70-84. doi: 10.1016/j.jmoneco.2016.07.001.

Le, T. H., Le, H. C., Taghizadeh-Hesary, F., 2020. Does financial inclusion impact CO_2 emissions? Evidence from Asia. Financ. Res. Lett. 34, 101451. 10.1016/j.frl.2020.101451.

Li, S., Huang, Y., 2020. Do cryptocurrencies increase the systemic risk of the global financial market?. China World Econ. 28, 122-143. doi: 10.1111/cwe.12314.

Lin, B., Benjamin, N. I., 2017. Green development determinants in China: A non-radial quantile outlook. J. Clean. Prod. 162, 764-775. doi: 10.1016/j.jclepro.2017.06.062.

Lin, B., Chen, X., 2020. Environmental regulation and energy-environmental performance—empirical evidence from China's non-ferrous metals industry. J. Environ. Manage. 269, 110722. doi: 10.1016/j.jenvman.2020.110722.

Liu, L. J., Creutzig, F., Yao, Y. F., Wei, Y. M., Liang, Q. M., 2020. Environmental and economic impacts of trade barriers: the example of China–US trade friction. Resour. Energy Econ. 59, 101144. doi: 10.1016/j.reseneeco.2019.101144.

Lorek, S., Spangenberg, J. H., 2014. Sustainable consumption within a sustainable economy–beyond green growth and green economies. J. Clean. Prod. 63, 33-44. doi: 10.1016/j.jclepro.2013.08.045.

Lyytimäki, J., Antikainen, R., Hokkanen, J., …, Seppälä, J., 2018. Developing key indicators of green growth. Sustain. Dev. 26, 51-64. doi: 10.1002/sd.1690.

Mensah, C. N., Long, X., Dauda, L., …, Tachie, A. K., 2019. Technological innovation and green growth in the Organization for Economic Cooperation and Development economies. J. Clean. Prod. 240, 118204. doi: 10.1016/j.jclepro.2019.118204.

Merino-Saum, A., Baldi, M. G., Gunderson, I., Oberle, B., 2018. Articulating natural resources and sustainable development goals through green economy indicators: A systematic analysis. Resour. Conserv. Recy. 139, 90-103. doi: 10.1016/j.resconrec.2018.07.007.

Mishkin, F. S., 2009. Is monetary policy effective during financial crises? Am. Econ. Rev. 99, 573-77. doi: 10.1257/aer.99.2.573.

Molyneaux, L., Brown, C., Wagner, L., Foster, J., 2016. Measuring resilience in energy systems: Insights from a range of disciplines. Renew. Sust. Energ. Rev. 59, 1068-1079. doi: 10.1016/j.rser.2016.01.063.

Nelson, S. C., Katzenstein, P. J., 2014. Uncertainty, risk, and the financial crisis of 2008. Int. Organ. 68, 361-392. doi: 10.1017/S0020818313000416.

OECD, 2010. Indicators for the green growth strategy: Meeting of the committee on statistics. Paris: OECD Conference Center.

OECD, 2011a. Towards Green Growth: A Summary for Policy Makers, May 2011. OECD, Paris, p. 50 https://doi.org/10.1787/9789264111318-en.

OECD, 2011b, Towards Green Growth, Green Growth Strategy Synthesis report, OECD, Paris.

OECD, 2011c. Towards Green Growth: Monitoring Progress. Paris: OECD.

OECD, 2017. Organization for Economic Cooperation and Development (OECD), 2017. Green Growth Indicators 2017. Paris, France.

Qu, J. J. R., 2012. Construction of green competitiveness analysis index-a case study of export procession zone. Int. J. Electron. Bus. Manage. 10, 140.

Reinhart, C. M., Rogoff, K. S., 2008. Is the 2007 US sub-prime financial crisis so different? An international historical comparison. Am. Econ. Rev. 98, 339-44. doi: 10.1257/aer.98.2.339.

Samad, G., Manzoor, R., 2015. Green growth: important determinants. Singap. Econ. Rev. 60, 1550014. doi: 10.1142/S0217590815500149.

Schultz, E. L., Tan, D. T., Walsh, K. D., 2010. Endogeneity and the corporate governance-performance relation. Aust. J. Manage. 35, 145-163. doi: 10.1177/0312896210370079.

Shi, B., Wang, X., Gao, B., 2021. Transmission and diffusion effect of Sino-US trade friction along global value chains. Financ. Res. Lett. 46, 102057. doi: 10.1016/j.frl.2021.102057.

Sohag, K., Husain, S., Hammoudeh, S., Omar, N., 2021. Innovation, militarization, and renewable energy and green growth in OECD countries. Environ. Sci. Pollut. R. 28, 36004-36017. doi: 10.1007/s11356-021-13326-6.

Sohag, K., Taşkın, F. D., Malik, M. N., 2019. Green economic growth, cleaner energy and militarization: Evidence from Turkey. Resour. Policy 63, 101407. doi: 10.1016/j.resourpol.2019.101407.

Sun, Y., Chen, L., Sun, H., Taghizadeh-Hesary, F., 2020. Low-carbon financial risk factor correlation in the belt and road PPP project. Financ. Res. Lett. 35, 101491. doi: 10.1016/j.frl.2020.101491.

Tu, X., Du, Y., Lu, Y., Lou, C., 2020. US-China trade war: Is winter coming for global trade?. J. Chin. Polit. Sci. 25, 199-240. doi: 10.1007/s11366-020-09659-7.

Ullah, S., Akhtar, P., Zaefarian, G., 2018. Dealing with endogeneity bias: The generalized method of moments (GMM) for panel data. Ind. Market Manag. 71, 69-78. doi: 10.1016/j.indmarman.2017.11.010.

Ulucak, R., 2020. How do environmental technologies affect green growth? Evidence from BRICS economies. Sci. Total Environ. 712, 136504. doi: 10.1016/j.scitotenv.2020.136504.

Umar, M., Ji, X., Mirza, N., Naqvi, B., 2021. Carbon neutrality, bank lending, and credit risk: evidence from the Eurozone. J. Environ. Manage. 296, 113156. doi: 10.1016/j.jenvman.2021.113156.

UNESCAP, 2012. Green Growth, Resources and Resilience: Environmental Sustainability in Asia and the Pacific (Bangkok).

Urata, S., 2020. US–Japan trade frictions: The past, the present, and implications for the US–China trade war. Asian Econ. Policy R. 15, 141-159. doi: 10.1111/aepr.12279.

Valickova, P., Havranek, T., Horvath, R., 2015. Financial development and economic growth: A meta‐analysis. J. Econ. Surv. 29, 506-526. doi: 10.1111/joes.12068.

Wang, R., Mirza, N., Vasbieva, D. G., Abbas, Q., Xiong, D., 2020. The nexus of carbon emissions, financial development, renewable energy consumption, and technological innovation: what should be the priorities in light of COP 21 Agreements?. J. Environ. Manage. 271, 111027. doi: 10.1016/j.jenvman.2020.111027.

Wang, K. H., Umar, M., Akram, R., Caglar, E., 2021. Is technological innovation making world "Greener"? An evidence from changing growth story of China. Technol. Forecast. Soc. 165, 120516. doi: 10.1016/j.techfore.2020.120516.

Wang, X., Shao, Q., 2019. Non-linear effects of heterogeneous environmental regulations on green growth in G20 countries: evidence from panel threshold regression. Sci. Total Environ. 660, 1346-1354. doi: 10.1016/j.scitotenv.2019.01.094.

Wang, Y., Sun, X., Guo, X., 2019. Environmental regulation and green productivity growth: Empirical evidence on the Porter Hypothesis from OECD industrial sectors. Energ. Policy 132, 611-619. doi: 10.1016/j.enpol.2019.06.016.

Wintoki, M. B., Linck, J. S., Netter, J. M., 2012. Endogeneity and the dynamics of internal corporate governance. J. Financ. Econ. 105, 581-606. doi: 10.1016/j.jfineco.2012.03.005.

Wooldridge, J., 2010. Econometric analysis of cross section and panel data, 2nd edition, Cambridge, MA: MIT Press.

World Bank, 2021. World Development Indicators. https://databank.worldbank.org/source/world-development-indicators/preview/on.

Zhang, W., Chiu, Y. B., 2020. Do country risks influence carbon dioxide emissions? A non-linear perspective. Energy 206, 118048. doi: 10.1016/j.energy.2020.118048.

Zhang, Y. J., 2011. The impact of financial development on carbon emissions: An empirical analysis in China. Energ. policy 39, 2197-2203. doi: 10.1016/j.enpol.2011.02.026.

Zhao, J., Jiang, Q., Dong, X., Dong, K., 2020. Would environmental regulation improve the greenhouse gas benefits of natural gas use? A Chinese case study. Energ. Econ. 87, 104712. doi: 10.1016/j.eneco.2020.104712.

Zhao, J., Shahbaz, M., Dong, K., 2022. How does energy poverty eradication promote green growth in China? The role of technological innovation. Technol. Forecast. Soc. 175, 121384. doi: 10.1016/j.techfore.2021.121384.

Zhao, J., Shahbaz, M., Dong, X., Dong, K., 2021. How does financial risk affect global CO_2 emissions? The role of technological innovation. Technol. Forecast. Soc. 168, 120751. doi: 10.1016/j.techfore.2021.120751.

Zhu, S., Ye, A., 2018. Does foreign direct investment improve inclusive green growth? Empirical evidence from China. Economies 6, 44. doi: 10.3390/economies6030044.

Tables

Table 1. Definitions and descriptive statistics of the variables used.

Table 2. Results of the cross-sectional dependence checks.

Table 3. Empirical results of the financial risk-green growth nexus.

Table 4. Estimation results of regional heterogeneous analysis.

Table 5. Results of the panel quantile regression.

Table 1. Definitions and descriptive statistics of the variables used.

Variable	Definitions	Obs.	Mean	Std. Dev.	Minimum	Maximum
lnGG	Global green growth composite index calculated in Section 3.2.1	1081	-1.052855	0.3072106	-2.172906	-0.2697069
lnFR	Global financial risk composite index calculated in Section 3.2.2	1081	-0.599678	0.3445798	-2.480657	-0.004902
lnPgdp	Economic growth gauged by per capita GDP (2010 dollars at constant prices)	1081	9.791329	1.174266	6.567978	11.62597
lnTra	Trade openness measured by the ratio of total import and export trade to total output value	1081	4.031149	0.5624842	2.510799	5.839132
lnCap	Capital gauged by the share of total capital formation on GDP	1081	3.153204	0.2449152	0.1460978	3.84289
lnPop	Population assessed by the total population of each country	1081	17.03689	1.642474	12.93416	21.05453

Notes: Std. Dev. refers to standard deviation.

Table 2. Results of the cross-sectional dependence checks.

Tests	**Statistics**	**Prob.**
Breusch-Pagan LM test	6200.63***	0.0000
Pesaran CD test	40.887***	0.0000

Note: *** represents significance at the 1% level.

Table 3. Empirical results of the financial risk-green growth nexus.

Explained variable: *LnGG*						
Variable	**OLS estimation**		**FE estimation**		**SYS-GMM estimation**	
	No	**Yes**	**No**	**Yes**	**No**	**Yes**
$lnGG_{i,t-1}$					0.755^{***}	0.538^{***}
					(139.69)	(88.85)
lnFR	0.020	-0.0001	0.061^{***}	0.055^{***}	-0.047^{***}	-0.008^{***}
	(0.74)	(-0.00)	(4.59)	(4.34)	(-14.27)	(-1.89)
lnPgdp		0.164^{***}		0.010		0.064^{***}
		(25.15)		(0.60)		(16.56)
lnTra		0.155^{***}		0.119^{***}		-0.023^{***}
		(10.99)		(7.07)		(-3.20)
lnCap		0.020		0.052^{***}		0.132^{***}
		(0.50)		(2.90)		(16.80)
lnPop		0.004		-0.399^{***}		-0.070^{***}
		(0.74)		(-15.48)		(-11.47)
_Cons	-1.041^{***}	-3.416^{***}	-1.016^{***}	5.034^{***}	-0.289^{***}	-0.251^{***}
	(-51.92)	(-18.05)	(-119.31)	(11.79)	(-53.27)	(-3.09)
K-P rk LM	55.459 [0.0000]					
K-P rk Wald F	58.134 {16.38}					
DWH test	13.818 [0.0002]					
AR (1)					0.0000	0.0000
AR (2)					0.2623	0.4812
Sargan test					0.9989	0.9243
Obs.	1081	1081	1081	1081	1034	1034

Notes: ***, **, and * refer to statistical significance at the 1%, 5%, and 10% levels, respectively; the values in parentheses represent the z-statistics. Furthermore, the value in square brackets indicates the p-value of the overidentification test, while the values in braces represents the threshold at the 10% level of the Stock-Yogo test. K-P in the table refers to Kleibergen-Paap.

Table 4. Estimation results of regional heterogeneous analysis.

Explained variable: *LnGG*						
Variable	**Regional heterogeneous analysis**				**Financial crisis shock**	
	High green growth region	**Low green growth region**	**High financial risk region**	**Low financial risk region**	**Before 2008**	**After 2008**
$lnGG_{i,t-1}$	0.518***	0.499***	0.568***	0.443***	0.540***	0.186***
	(25.39)	(30.09)	(9.10)	(80.25)	(41.46)	(46.63)
$lnGG_{i,t-2}$					0.197***	-0.030***
					(15.80)	(-7.81)
lnFR	0.027***	-0.053**	-0.198***	0.034***	0.033***	-0.013**
	(3.71)	(-2.53)	(-4.23)	(5.64)	(3.03)	(-2.27)
lnPgdp	0.034	0.028**	0.197	0.059***	0.073***	0.266***
	(0.60)	(2.42)	(0.82)	(4.83)	(10.07)	(51.77)
lnTra	0.049**	0.004	0.044	0.012	-0.071***	0.398***
	(2.09)	(0.16)	(0.90)	(1.75)	(-12.91)	(74.40)
lnCap	0.107***	0.096***	-0.090***	0.291***	0.120***	0.029***
	(3.92)	(4.02)	(-3.06)	(25.60)	(12.84)	(4.06)
lnPop	0.087	-0.077***	-0.114	-0.096***	0.024***	0.093***
	(0.37)	(-4.85)	(-0.28)	(-8.42)	(5.56)	(17.97)
_Cons	-2.705	0.117	-0.376	-0.438*	-1.469***	-6.873***
	(-0.78)	(0.48)	(-0.08)	(-1.65)	(-11.69)	(-53.45)
AR (1)	0.0014	0.0009	0.0052	0.0006	0.0001	0.0018
AR (2)	0.1087	0.8348	0.6007	0.2820	0.5112	0.5277
Sargan	0.9999	0.9822	0.9999	0.9410	0.7503	0.2509
Obs.	484	550	396	638	517	423

Note: ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively; the values in parentheses indicate z-statistics.

Table 5. Results of the panel quantile regression.

Dependent variable: *LnGG*					
Variables	**Quantiles**				
	10th	**25th**	**50th**	**75th**	**90th**
lnFR	-0.078**	-0.072***	-0.013	0.080***	0.152***
	(-2.33)	(-3.82)	(-0.52)	(2.74)	(4.29)
lnPgdp	0.189***	0.160***	0.138***	0.139***	0.144***
	(15.15)	(22.20)	(21.19)	(14.11)	(11.97)
lnTra	0.138***	0.197***	0.190***	0.141***	0.045**
	(6.07)	(7.36)	(11.84)	(8.73)	(2.15)
lnCap	0.031	0.057	0.147***	0.065	-0.022
	(0.65)	(1.37)	(3.10)	(1.03)	(-0.32)
lnPop	0.008	0.005	-0.003	-0.020***	-0.036***
	(0.62)	(0.60)	(-0.42)	(-2.73)	(-3.37)
_Cons	-3.987***	-3.849***	-3.590***	-2.657***	-1.603***
	(-10.57)	(-19.15)	(-17.09)	(-8.12)	(-5.27)
Obs.	1081	1081	1081	1081	1081

Note: ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively; the values in parentheses indicate t-statistics.

Figures

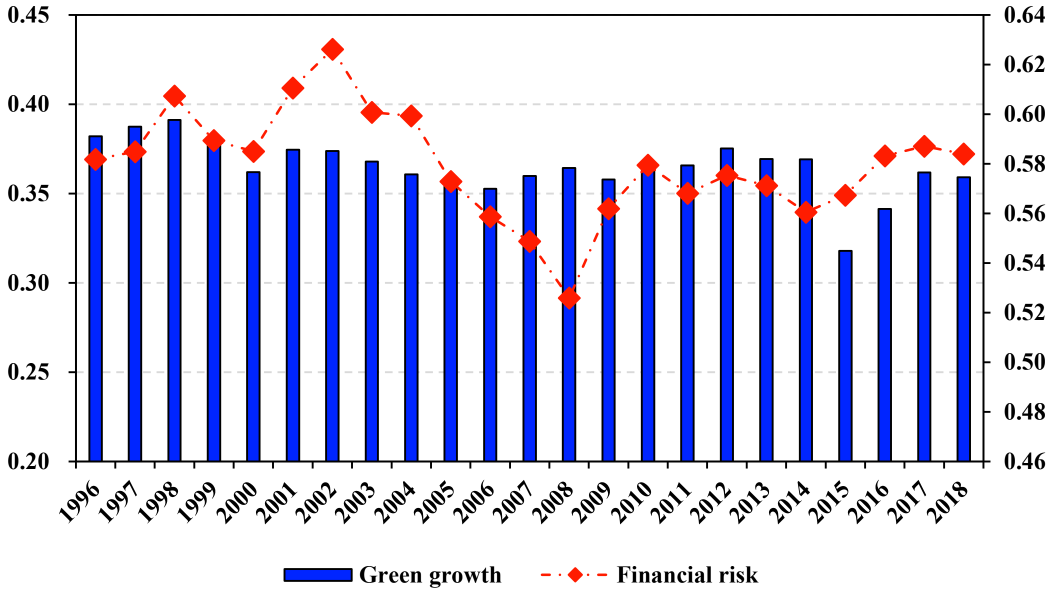

Fig. 1. Time trend chart of the average values of financial risks and green growth. ***Notes***: the left axis refers to the green growth composite index, and the right axis denotes the financial risks; the data are from the calculation from Section 3.2.

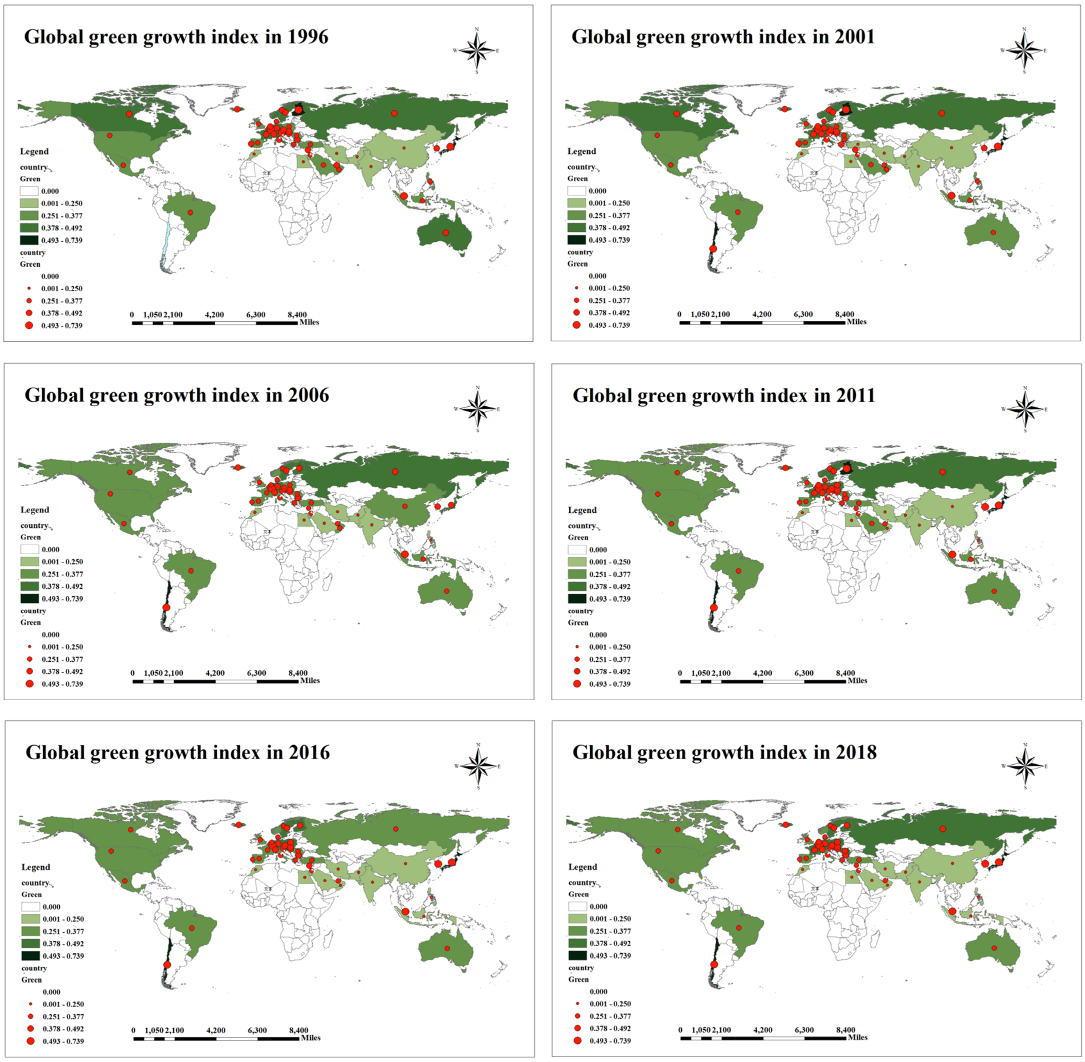

Fig. 2. The spatial distribution of the global green growth index in selected years. ***Notes***: the data of are collected from the calculation in Section 3.2.1.

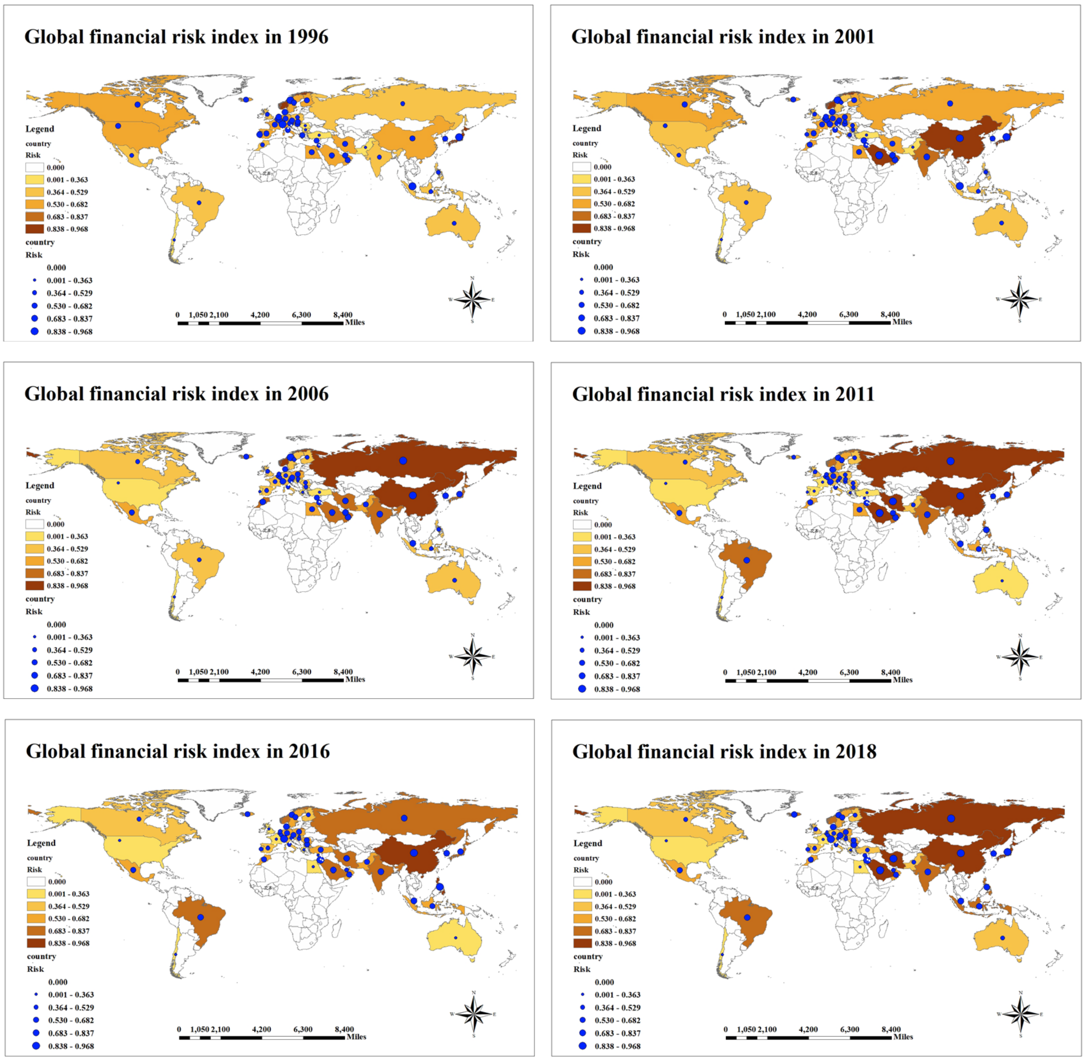

Fig. 3. The spatial distribution of global financial risks in selected years. ***Notes***: the data of are collected from the calculation in Section 3.2.2.

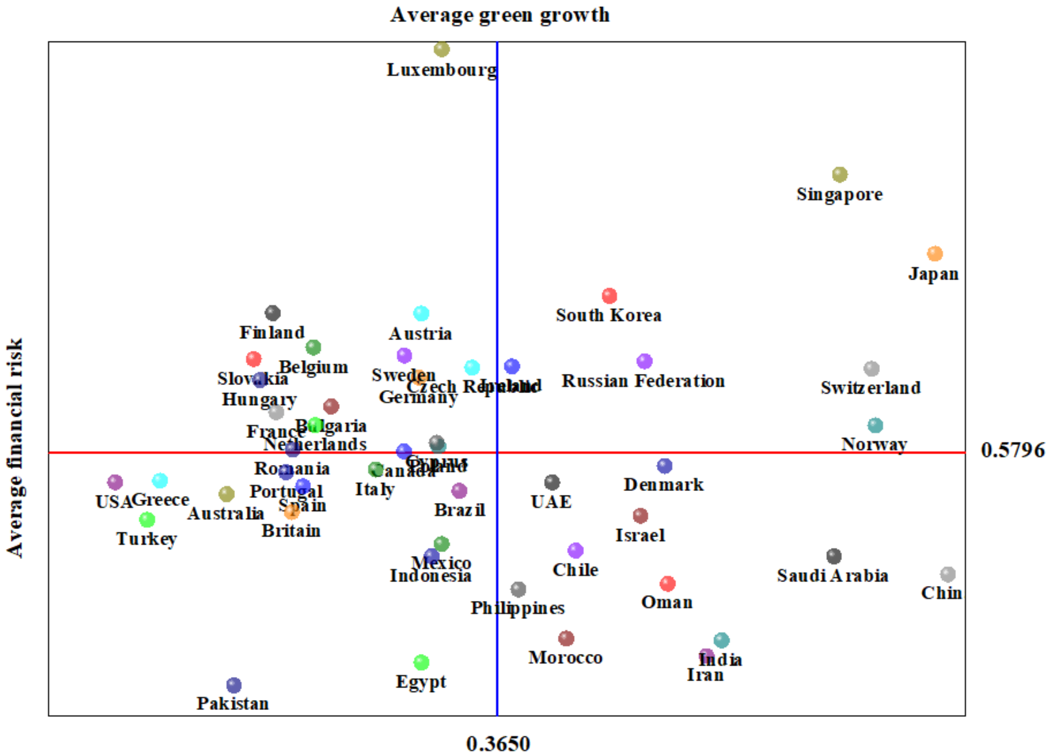

Fig. 4. The regional division of global countries based on the average values of financial risks and green growth.

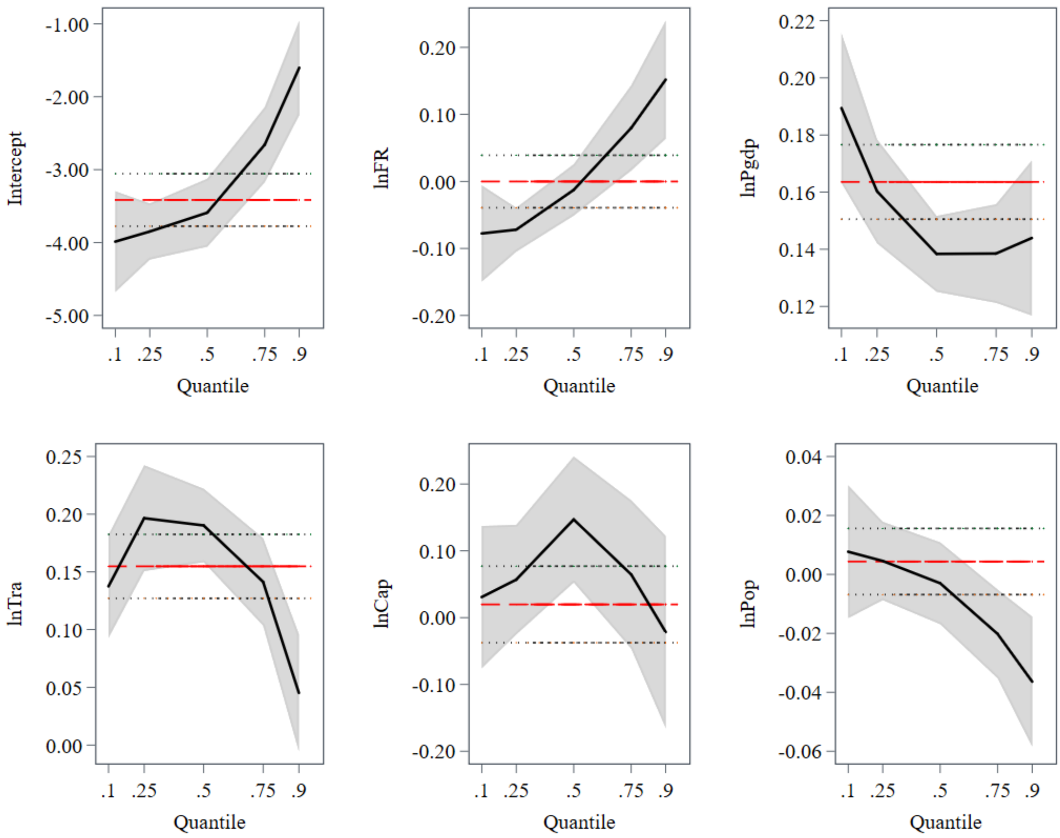

Fig. 5. Change trend chart of panel quantile regression coefficients. ***Notes***: the x-axis refers to the conditional quantiles of green growth and y-axis represents the coefficients of various variables. The red line denotes the coefficient values of panel data model with fixed effect.