

ENHANCING GREEN GROWTH: EXPLORING THE INFLUENCE OF FISCAL SPENDING AND GREEN FINANCE

Le Quoc Dinh

Lac Hong University, Dong Nai Province, Vietnam
Email: dinhle2807@gmail.com; dinhlq@lhu.edu.vn

Tran Thi Kim Oanh*

University of Finance – Marketing – Ho Chi Minh City, Vietnam
E-mail: kimoanh@ufm.edu.vn

Nguyen Thi Hong Ha

Ho Chi Minh City Industry and Trade College, Ho Chi Minh City, Vietnam
Email: ngthongha@hitu.edu.vn

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Abstract: The present study delves into the intricate correlation between fiscal spending and green growth, specifically focusing on the catalyzing effect of green finance. Spanning the timeframe from 2005 to 2021, our investigation encompasses 18 developing and 14 developed countries. Leveraging Bayesian regression analysis, our findings uncover a nuanced juxtaposition in the effect of R&D expenditure on green growth across these divergent contexts. In developing nations, R&D spending demonstrates a discouraging negative effect on green growth, supported by a robust probability of 76.74%. Conversely, in developed countries, R&D expenditure manifests a promising positive influence, with a likelihood of 71.33%. However, upon integrating the pivotal role of green finance, a synergistic relationship emerges, underscoring its potential as a catalyst for bolstering green growth in both categories of nations. Grounded in these discerning insights, we delineate tailored implications aimed at fortifying green finance initiatives within each cohort of countries.

Keywords: Fiscal Spending; Green Growth; Green Finance; Developed Countries; Developing Countries; Bayesian.

JEL Codes: E62, Q01, C11, Q49.

* Corresponding author: Tran Thi Kim Oanh. *E-mail: kimoanh@ufm.edu.vn*

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1. Introduction

In 1934, Simon Kuznets proposed the gross domestic product (GDP) measure, which subsequently became widely utilized by governments for tracking economic growth, making policy decisions, and allocating resources. However, by the early 1970s, criticism arose regarding the sole reliance on GDP as a dimension of a country's economic performance and comparisons between countries (Oanh and Dinh, 2024; Dinh et al., 2024). Variations in population, education, infrastructure, mineral resources, and currency among countries significantly influence worker productivity (Djellal and Gallouj, 2012). Consequently, alternative indicators emerged to supplement or replace GDP, such as the Human Development Index (HDI) introduced by UNDP (1990) and the World Happiness Report (WHR) proposed by Helliwell et al. (2012). Despite these criticisms, GDP remains prevalent, albeit improved to GDP per capita to gauge the productivity contribution of a nation's populace (Sloman et al., 2006). Since 1990, identifying econometric models to evaluate how economic development affects the environment has become a global objective (Cosma et al., 2020). The relentless pursuit of GDP growth by nations has heightened environmental pollution levels (Dinh et al., 2024). Recent studies have highlighted the adverse influences of GDP on environmental quality (Ozturk et al., 2021). Numerous studies have shown both linear negative impacts of economic growth on the environment and overwhelmingly positive, nonlinear effects. Therefore, there is a pressing need to develop a measure that incorporates natural resources and environmental expenditures into the national economy's manufacturing process to address the limitations of traditional GDP. With the issuance of new sustainable development goals by the Department of Economic and Social Affairs Sustainable Development in March 2016, several nations started putting new development plans with an emphasis on green growth (GG) into practice. (Dmuchowski et al., 2021, Oanh 2023). In China and the US, research on GG is moving quickly forward to achieve green GDP growth as opposed to traditional GDP growth. The pursuit of green GDP growth is closely intertwined with environmental quality (Stjepanovic et al., 2022; Oanh, 2024). However, to attain environmental sustainability goals, such as minimizing pollution, lowering greenhouse gas (GHG) emissions, and preserving natural resources, the government's regulatory role through fiscal spending (FS) assumes paramount importance (Huang et al., 2022, Oanh 2023).

Within the components comprising GDP, FS can vary considerably, constituting 20–40% of a nation's total GDP (López et al., 2011). Structural shifts in fiscal expenditure profoundly influence both economic growth and environmental pollution levels (Ullah et al., 2021). Extensive research has examined the nexus between FS and the environment. López et al. (2011) scrutinized how FS affects environmental quality, measured by SO₂ emissions. Halkos and Paizanos (2016)

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explored the interrelation among economic growth, FS, and environmental quality. Hua et al. (2018) investigated the effects of FS on the Chinese environment. Moreover, Wei et al. (2023) delved into the repercussions of R&D and education spending on technological innovation in China. Additionally, several studies have assessed the influence of FS on economic growth, including works by Carrère and De Melo (2012), Chugunov and Makohon (2019), and Chugunov et al. (2021). However, investigations into the impact of FS on GG have not yielded conclusive findings due to the lack of standardized measurement for GG. A primary impediment lies in the challenge of constructing an effective metric and accessing pertinent data, hindering comparative analyses of GG across countries and regions.

In terms of measurement, Mo et al. (2022) and Huang et al. (2022) adopt a framework based on environmentally adjusted multifactor productivity to assess GG variables. Conversely, Liu et al. (2020) utilize a comprehensive approach involving five criteria: economic development driving force, social development driving force, environmental pressure, environmental state, and technological responsiveness, to gauge GG. Nahman et al. (2016) constructed their GG variable based on sixteen criteria, encompassing carbon dioxide emission rates and energy impact. The significance of FS in fostering GG cannot be overstated, particularly considering its role in facilitating transmission through the green finance channel (Zhang et al., 2021). Green finance (GF) encompasses a spectrum of financial instruments and activities aimed at advancing environmental sustainability and mitigating the adverse effects of economic activities on the quality of the environment (Desalegn and Tangl, 2022). These activities encompass investing in renewable energy, enhancing energy efficiency, promoting environmentally friendly initiatives, and developing sustainable financial products and services (Ozili, 2022). However, given the variation in GF systems among countries and their relatively nascent stage of development, the efficacy of GF in driving GG varies based on factors such as living standards, spillover effects on regional industries, and the predominant focus on GDP growth. This singular pursuit often leads to significant natural resource depletion, environmental degradation, and ecological imbalances. Consequently, the impact of FS on GG differs notably between developed and developing nations, particularly concerning the role of GF. Nevertheless, recent research by Huang et al. (2022) and Mo et al. (2022) failed to incorporate the role of green financing, solely examining the impact of fiscal investment on GG. The study by Zhang et al. (2021) delved into the effect of fiscal investment on GG within the context of the importance of clean energy. Furthermore, prior studies have predominantly focused on single-country or regional analyses, overlooking the varying nature of GF systems across different country groups. Therefore, this study aims to assess two distinct groups—developed and developing countries—in evaluating the impact of FS on GG.

However, this form of hypothesis testing depends on several assumptions that might

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not entirely reflect actual conditions, which could result in inaccurate predictions. Furthermore, parameters are treated as fixed but unknown values by the frequency statistical approach, and these values may change when sample sizes are changed. The Bayesian approach, in contrast, treats parameters as random variables and gives them distributions to show how reliable they are. Notably, the Bayesian approach is advantageous due to its independence from sample size, ensuring model accuracy. Moreover, it addresses model flaws such as autocorrelation, heteroskedasticity, and endogeneity (Oanh, 2023). Thus, this article employs the Bayesian approach to evaluate the impact of FS on GG within the context of GF, focusing on two distinct groups: developed and developing countries. Furthermore, the research provides relevant policy implications tailored to each group.

This study significantly enhances the literature on the relationship between FS, GG, and GF by employing the Bayesian method, which overcomes the limitations of traditional frequency methods. Investigating the impact of FS on GG within the context of GF across developed and developing countries, the research provides many valuable understandings of the efficacy of fiscal policy in fostering environmentally sustainable economic development. Tailored policy implications for developed and developing nations offer practical guidance for policymakers seeking to promote GG while addressing environmental degradation. Moreover, by highlighting the Bayesian method's advantages in addressing model flaws, such as autocorrelation and heteroskedasticity, the study contributes methodologically, demonstrating the utility of Bayesian analysis in environmental economics research. Overall, it enriches the literature on GF and sustainable development, offering both theoretical insights and practical implications for policymakers and researchers.

2. Literature review

2.1. The relationship between FS, GF and GG

FS holds significant sway over GG by allocating government funds toward initiatives that foster sustainability. Such spending can bolster green industries, catalyze innovation, and facilitate the shift toward a low-carbon economy (Zhang et al., 2021). However, achieving GG objectives, including reducing GHG emissions, curbing environmental pollution, and safeguarding natural resources, hinges on the framework of GF (Tang et al., 2022). GF represents the convergence of financial mechanisms and environmentally conscious behavior (Scholtens, 2009). Essentially, it examines the financial sector's role in advancing the transition to a low-carbon, sustainable economy by mobilizing capital for initiatives and investments in environmentally beneficial endeavors such as renewable energy, energy efficiency, sustainable agriculture, and R&D in eco-friendly technologies (Liu et al., 2020; Wang, 2021). Given the variations in GF systems and GG trajectories across countries, the impact of FS (inclusive of government education and R&D

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allocations) on GG, under the auspices of GF, diverges between developed and developing nations (Stjepanović et al., 2019).

In developed countries, government education spending typically targets well-established education systems with a strong emphasis on research and innovation. Through fiscal channels, investments are directed toward universities, research institutions, and specialized training programs, fostering expertise in green technology, sustainable practices, and environmental science (Clugston and Calder, 1999). This strategic allocation can stimulate the expansion of green industries by fostering creativity and nurturing a skilled workforce. Conversely, in developing countries, government education spending primarily concentrates on enhancing access to basic education for all (Fomba et al., 2023). Nonetheless, integrating environmental education into the curriculum can cultivate awareness regarding sustainable practices, environmental conservation, and climate change mitigation. Educating environmentally conscious citizens lays the groundwork for future GG. Moreover, developing countries often grapple with skills gaps and a dearth of technical expertise in green sectors. Hence, within the framework of GF, prioritizing technical and vocational training programs in education spending equips individuals with the requisite skills for sustainable agriculture, waste management, and other green industries (Carlisle et al., 2019). This not only enhances employability but also creates job opportunities, bolstering GG efforts.

In developed countries, government R&D spending can synergize with GF mechanisms to expedite the commercialization of green technologies arising from research endeavors. GF instruments, including venture capital, green bonds, and grants, play a pivotal role in providing capital to scale up and launch innovative green technologies into the market (Riaz et al., 2024). This facilitates the transition from research to commercialization, expedites the adoption of sustainable solutions, and fosters GG (Zhang et al., 2021). Moreover, GF mechanisms contribute to establishing markets for green products and technologies. Governments can incentivize consumers and businesses to embrace sustainable technologies by offering tax incentives, subsidies, or preferential loans. Additionally, through channels of GF, government spending is channeled towards initiatives supporting the renewable energy sector and sustainable agriculture, thereby mitigating pollution in the environment (Tang et al., 2022; Lv et al., 2022; Mo et al., 2023).

Furthermore, the integration of GF with government R&D spending can foster public-private partnerships aimed at developing and commercializing green technologies (Akinsola et al., 2022). Collaborations between governments, financial institutions, industry players, and research entities enable resource and expertise pooling. Through GF mechanisms, joint investments, risk-sharing arrangements, and knowledge exchange between public and private entities are facilitated, catalyzing the advancement and deployment of green innovations (David and Venkatachalam,

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2018). In developing nations, GF facilitates the transfer of green technology from developed countries to developing ones. Governments can utilize GF instruments to access international technology transfer and capacity-building funds, enabling the adoption and adaptation of sustainable technologies developed through R&D in developed countries. This fosters GG and sustainable development (Guo et al., 2020). Additionally, governments can utilize GF tools to provide financial support, mentorship, and capacity-building programs to stimulate the growth of small businesses and green startups. This promotes innovation, job creation, and economic development while encouraging environmentally sustainable practices.

2.2. Review of previous research

Studies on the effect of FS on GG under the role of GF are currently very few and still have many limitations:

Firstly, in terms of measuring variables, methods for calculating GF and GG are varied and not yet standardized, mainly because of the difficulty in accessing data. This makes it difficult to compare and analyze the impact of GF on GG across countries and regions. Liu et al. (2020) conducted research in 30 provinces in China during the period 2007 - 2016 with a combination of 4 criteria representing GF: green investment, green credit, green insurance, and green securities. The five criteria representing GG are economic development motivation, social development motivation, environmental pressure, environmental status, and technological responsiveness. Data on these criteria are taken within China. Meanwhile, GF was studied in China, but Lv et al. (2022) measured it using a combination of four indicators, including green investment, green credit, government support, and green insurance. Jiang et al. (2020) devised a composite of economic, financial, and environmental metrics to gauge green finance (GS). In a study conducted in Bangladesh, Rahman et al. (2022) utilized the Content Analysis Method to compute GS, encompassing nine distinct criteria such as waste management, energy conservation, renewable energy adoption, and sustainable policy implementation. Due to data access constraints, most research is confined to individual countries, notably China, employing various measurement approaches. Drawing from Lv et al. (2022), Mo et al. (2023), Oanh et al. (2022), Oanh and Dinh (2024), and Dinh et al. (2024), this study assesses GS by amalgamating three key indicators: green investment, green credit, and government support. Green credit is assessed through expenditures in the agricultural and renewable energy sectors, while government support and green investment are gauged by public R&D allocations for renewable energy and environmental initiatives.

Second, evaluating GG frequently involves examining intermediary environmental elements contributing to the complexity of the correlation between fiscal investment and GG. López et al. (2011) specifically looked at how FS affected SO₂ emissions, a measure of environmental quality. Halkos and Paizanos (2016) investigated fiscal

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expenditure, environmental quality, and economic growth. As a catalyst for GG, Hua et al. (2018) explored the effect of fiscal investment on the environment in China. Wei et al. (2023) looked at how technological innovation, which boosts GG, is affected by education and R&D spending in China. Furthermore, several researchers, including Carrère and De Melo (2012), Chugunov and Makohon (2019), and Chugunov et al. (2021), have examined the linkage between FS and economic growth. Researchers have recently focused their emphasis on how FS affects GG. Lin and Zhu (2019) examined FS to boost GG in China from 2005 to 2016 using the GMM approach. Zhang et al. (2021) studied public spending on GG in BRI region nations between 2008 and 2018, utilizing the GMM model. The ARDL model was utilized by Sohail et al. (2022) to examine GG initiatives in highly polluted nations from 1994 to 2020. Huang et al. (2022) applied FMOLS and DOLS methods to investigate the impact of FS on GG in heavily polluted Asian countries in the period 1991-2019. However, these studies only focused on studying individual relationships without considering the transmission role of GF. Meanwhile, as stated above, to achieve the goal of GG through FS, minimizing environmental pollution, lowering GHG emissions, and preserving natural resources, the role of GF cannot be ignored. This study will attempt to fill that gap.

Third, most previous studies mainly focused on research within the province or country. To our best knowledge, hardly any studies have considered the role of GF when assessing the impact of FS on GG in developed and developing countries, and then compared the differences between these two country groups. Our study will clarify this issue and propose some policy recommendations for the two groups of countries.

Previous studies investigating the impact of FS on GG have predominantly relied on models employing the traditional frequency method. Lin and Zhu (2019) and Zhang et al. (2021) utilized the GMM approach, while Sohail et al. (2022) applied the ARDL model, and Huang et al. (2022) employed FMOLS and DOLS. However, this approach necessitates numerous assumptions that may not match with real-world scenarios, leading to inaccuracies in inference and prediction. Furthermore, parameters are treated as fixed values by the frequency statistical approach, which is subject to change over time as sample sizes are updated. The Bayesian approach, on the other hand, views parameters as random variables and gives them distributions that represent their reliability. Numerous articles have addressed the benefits and drawbacks of the Bayesian approach (Binh et al., 2024). Its most notable advantage is its independence from sample size, thereby ensuring model accuracy. Moreover, the Bayesian method addresses model flaws such as autocorrelation, heteroskedasticity, and endogeneity (Binh et al, 2024, Dinh, 2024). Given these considerations, this paper employs the Bayesian method to assess the impact of FS on GG in both developed and developing countries.

3. Methodology

3.1. Research variables and models

Public spending variable: Based on Huang et al. (2022), the public spending variable includes education spending and R&D spending.

GF variables, as outlined by Mo et al. (2023) and Oanh (2023), encompass indicators such as green investment, green credit, and government green support. Green credit is gauged by the extent of credit extended to the agricultural and renewable energy sectors. Agricultural credit plays a pivotal role in fostering GG within the agricultural domain by granting farmers access to financial resources for the adoption of environmentally friendly production methods. As noted by the Food and Agriculture Organization (FAO), access to agricultural credit facilitates the transition to more sustainable practices, including the utilization of organic fertilizers, conservation farming, and water-saving irrigation systems. These initiatives contribute to reducing GHG emissions, enhancing soil health, and preserving biodiversity (Abdallah, 2016).

By encouraging renewable energy sources, renewable energy credits – also called Renewable Energy Certificates (RECs) – play a critical role in furthering GG. Measured in megawatt hours of electricity generated from renewable sources, RECs can be bought, sold, and traded independently of the energy produced. According to research by the International Energy Agency, increased investment in renewable energy, facilitated by RECs, fosters the development of new renewable energy projects, thereby reducing GHG emissions and enhancing energy security. Given these benefits, the author employs credits for renewable energy and the agricultural sector as indicators to gauge green credit. The green investment variable is assessed through the public R&D budget allocated to the renewable energy sector. Notably, investments in R&D for renewable energy have spurred significant advancements in renewable energy technologies like wind power, solar photovoltaics, and biofuels, thereby enhancing their competitiveness as energy sources. Finally, green support from the government is represented by the variable of the public R&D budget allocated to environmental research. This signifies government support in researching and addressing the environmental damage and its consequences. Table 1 presents how to measure green finance (GF).

Green GDP serves as a proxy for GG as it offers a holistic assessment of economic development intertwined with environmental conservation. Unlike traditional GDP measures, green GDP incorporates the costs associated with environmental degradation resulting from economic activities, encompassing factors like natural resource depletion and pollutant emissions. Therefore, we use adjusted net savings as a proxy for green GDP. This variable was used in the previous study by Oanh (2023).

Table 1 Indicators measuring GF

Variable	Sign	Measurement	Unit	Data sources
GREEN FINANCE (GF)				
Green credit	TNN	Credit growth provided to the agricultural sector	%	OECD FAO
	TND	Credit growth provided for the renewable energy sector	%	OECD
Green investment	NS1	Public R&D budget for renewable energy per total public R&D energy	%	OECD
Support from the government	NS2	Environment-related public R&D budget over total public R&D	%	OECD

Source: Compiled by the authors

In addition, control variables such as economic growth (TGDP), Inflation rate (INF), Urban population ratio (UR), Trade openness (OPE), International integration (FDG) and Internet user ratio (IU) are added to the research model.

The model to study the linkage between FS and GG is as follows:

$$GGDP_{i,t} = \beta_0 + \beta_1 EE_{i,t} + \beta_2 RD_{i,t} + \beta_x X_{i,t} + \varepsilon_{i,t} (1)$$

$$GGDP_{i,t} = \beta_0 + \beta_1 EE * GF_{i,t} + \beta_2 RD * GF_{i,t} + \beta_x X_{i,t} + \varepsilon_{i,t} (2)$$

where $i = 1, 2, \dots, N$ is the countries and $t = 1, 2, \dots, T$ is the time; GGDP is GG; GF is Green Finance; EE is government spending on education; RD is government spending on R&D; $X_{i,t}$ is a vector of control variables including GDP, UR, OPE, INF, FDG, and IU. Details of variable measurement and data sources are presented in Table 2.

Table 2 Variables description

Dependent variable	Sign	Measurement	Research	Data source
Green growth	GGDP	GGDP is proxied with adjusted net savings which is the sum of net national savings	Oanh (2023)	WB

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		and education expenditure minus energy depletion, mineral depletion, net forest depletion, and carbon dioxide. (%)		
Government spending on education	EE	Government expenditure on education, total (% of GDP)	Huang et al. (2022)	WDI
Government spending on R&D	RD	Research and development expenditure (% of GDP)	Huang et al. (2022)	WB, OECD, Ourworldindata, Tradingeconomics.
Green finance	GF	Calculated using the PCA method with the criteria in Table 1 (%)	Lv et al. (2022), Tang et al. (2022), Mo et al. (2023), Oanh (2023)	Author's calculation
Economic growth rate	TGDP	Annual GDP growth rate (%)	Lin and Zhu (2019), Zhang et al. (2021), Dinh (2024), Dinh et al (2024);	WB
Urban population	UR	Urban population/Total population (%)	Zhang et al. (2021)	WB
Trade openness	OPE	Total exports and imports per GDP (%)	Guo et al. (2022), Jiang et al. (2020)	WB
Inflation rate	INF	Annual CPI growth rate (%)	Dumiter et al. (2015); Saydaliev and Chin (2022); Oanh et al. (2023); Oanh và Dinh (2023).	WB
International integration	FDG	Foreign direct investment to GDP (%)	Fu and Irfan (2022)	WB

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Internet user ratio	IU	Individuals using the Internet (% of the population)	Huang et al. (2022), Mo et al. (2022)	WB
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Source: Compiled by the authors

3.2. Data and methodology

The paper employs principal component analysis (PCA), a statistical technique, to assess GF. PCA transforms a dataset from a high-dimensional space into a new, lower-dimensional space via orthogonal transformation, aiming to maximize the representation of data variability. By doing so, PCA helps extract the most significant patterns or features within the data, facilitating a more concise and interpretable representation. This study utilizes PCA to quantify and evaluate various aspects of GF, providing valuable insights into its underlying structure and dynamics (Binh et al., 2024).

We use the following type of probability distribution to build a Bayesian linear regression:

$$y \sim N(\beta^T X, \sigma^2 I) \quad (3)$$

where the mean and variance of a normal distribution are used to get the value y . The displacement of the weight matrix times the prediction matrix is the linear regression mean. The variance is calculated by multiplying the identity matrix by the square of the standard deviation (σ).

The model parameters are presumed to originate from the probability distribution, in addition to the output (y) being generated from it. Based on the inputs and outputs, the posterior probability of the conditional model parameters has the following form:

$$P(\beta|y, X) = \frac{P(y|\beta, X)P(\beta|X)}{P(y|X)} \quad (4)$$

Where: $P(\beta | y, X)$ is the posterior probability distribution of the model parameters for the inputs and outputs; $P(y|\beta, X)$ is the likelihood of the data; $P(\beta|, X)$ is a prior probability distribution and $P(y|X)$ is a standard constant and can be eliminated. Therefore, equation (5) is often simplified to:

$$P(\beta|y, X) = P(y|\beta, X)P(\beta|X) \quad (5)$$

Firstly, we assume that the coefficients follow a priori normal distribution, with a mean of zero for each coefficient. This specification in Bayesian analysis tends to

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produce coefficients closer to zero rather than non-zero values, thereby averting bias in research hypotheses conclusions. Secondly, we adopt normal distributions for the likelihood functions of coefficients, with parameters derived from equations (1) and (2). Lastly, we employ the Gibbs Sampler and Markov Chain Monte Carlo (MCMC) methods for estimation and simulation, respectively, conducting 12,500 iterations. The first 2,500 draws are discarded, following standard practice. The MCMC technique is widely utilized across various domains to fine-tune complex models (Levy, 2020).

The variables were collected based on data availability. In addition to the green financial variable calculated by the authors, data for the remaining variables, including GGDP, EE, TGDP, UR, OPE, INF, FDG, and IU, were sourced from the World Bank (WB). The RD variable was obtained from WB, OECD, Our World in Data, and Trading Economics. The study covered the period from 2005 to 2021 and included 18 developing countries and 14 developed countries. Given the potential challenges associated with small sample sizes, the Bayesian method was considered suitable for the analysis. Additionally, Bayesian analysis addresses common model issues such as autocorrelation, heteroscedasticity, and endogeneity, ensuring robust and reliable results.

4. Research results and discussion

4.1. Principal Components Analysis results

According to PCA results presented in Table 3, GF is calculated by the equation below:

$$GF = 0.4166 * TDN - 0.0164 * TDL - 0.6544 * NS1 + 0.894 * NS2$$

Table 3 PCA results

GF	TDN	TDL	NS1	NS2
Coefficient	0.4166	-0.0164	-0.6544	0.894

Source: Results from Stata 17.0 software

We continue to perform Bayesian regression to examine the impact of FS on GG under the role of GF in developing and developed countries.

4.2. Bayesian regression results

4.2.1. Descriptive statistics

Table 4 Descriptive statistic of variables

Variable	Developing countries				Developed countries			
	Mean	Std. Dev.	Minimum	Maximum	Mean	Std. Dev.	Minimum	Maximum
GGDP	15.6764	2.7233	8.0861	25.1644	18.6444	4.0464	12.1644	32.1644
EE	4.7936	1.4570	1.9655	11.7809	5.0413	0.9650	3.0215	8.0306
RD	0.9717	1.2470	0.0350	4.4435	1.6390	0.9057	0.3055	4.0655
GF	16.5177	22.6910	-10.8987	200.4865	18.7514	19.7982	-5.9293	200.4865
TGDP	3.5760	5.2120	-15.1365	34.5000	1.7001	3.0796	-8.5803	8.5000
UR	65.6442	16.4044	35.2840	95.5150	73.6451	10.8604	54.3150	92.2360
OPE	71.0953	27.0628	22.1060	146.1061	90.9646	35.8331	39.1826	168.3946
INF	6.0882	5.0813	-1.5448	48.6999	2.5581	2.4996	-1.4182	15.5344
FDG	4.5047	5.4494	-37.1727	43.9121	3.4426	11.1450	-40.0866	109.0253
IU	42.4188	22.4201	3.7498	90.1273	70.5386	18.3235	15.2267	9.0000

Source: Results from Stata 17.0 software

The descriptive statistics results are presented in Table 4. The results indicate that EE, RD, GF, and GGDP are significantly higher in developed countries compared to developing countries.

4.2.2. Bayesian regression results

Table 5 displays the Bayesian regression findings for both developing and developed countries. The variable EE, representing public expenditure on education, exhibits a positive influence on GDP in both groups. Specifically, the coefficients are 0.1904 for developing countries and 0.2944 for developed countries. The probability of the EE variable positively impacting GDP is 70.30% for developing countries and notably higher at 84.90% for developed countries (refer to Table 6). This suggests that increased public spending on education, facilitating broader access to primary education, serves as a cornerstone for raising awareness about environmental issues in contemporary society. Furthermore, it lays the groundwork for fostering GG in recent times. Moreover, individuals with higher levels of education can significantly contribute to shaping policy decisions and championing sustainable practices. Education empowers individuals with a deep understanding of environmental policies, strategies for mitigating climate change, and the economic advantages of GG. This knowledge enables them to actively participate in informed dialogues, advocate for policy formulation, and drive the adoption of eco-friendly policies and

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initiatives. The findings of this study align closely with those of Zhang et al. (2021), Mo et al. (2022), and Huang et al. (2022), reinforcing the importance of education in promoting sustainable development and GG.

Under the influence of GF, the combined interaction of GF and education spending continues to positively affect GG in both country groups. Notably, the probability of this interaction fostering GG is significantly higher, standing at 90.10% for developing countries and 95.75% for developed countries. This indicates that, under the umbrella of GF, investments in education facilitate entrepreneurship programs geared toward green and sustainable enterprises. Through fiscal avenues, government spending on education targets universities, research institutions, and specialized training initiatives, fostering expertise in green technology, sustainable practices, and environmental sciences (Clugston and Calder, 1999). Furthermore, developed countries typically boast well-established education systems with a pronounced emphasis on research and innovation compared to developing nations, as evidenced by the higher probability of education spending in developed countries surpassing that in developing ones. Notably, nations like Germany are renowned for their robust investment in higher education institutions, particularly universities, focusing on areas such as renewable energy, environmental science, and sustainable engineering. Similarly, Japan places significant value on education and research, directing investments toward green technology, energy efficiency, and environmental conservation initiatives. Kyoto University stands out as a leader in sustainability-related research and innovation. Sweden's government prioritizes education spending on universities and research institutions to advance research and development in green technology and sustainable practices, with renowned institutions like Lund University and Chalmers University of Technology leading the charge in sustainable development research and education.

Table 5 also reveals that the variable RD exhibits a negative impact on GG in developing countries, with probabilities of 76.74% and 75.36% in Equation (1) and Equation (2), respectively. Conversely, in developed countries, the RD variable positively influences GG, with probabilities reaching 81.33% and 79.40% in Equation (1) and Equation (2), respectively. This disparity underscores the contrasting nature of R&D spending between these country groups. Figure 2 depicts that R&D expenditure during the study period remains relatively low, especially when compared to developed countries, indicating that R&D investment alone may not suffice to drive GG in these countries. Moreover, in developing nations, the lack of research and development infrastructure hampers the execution of research projects, impeding technology transfer and the practical application of research findings. Additionally, developing countries often struggle to allocate adequate financial and human resources for large-scale research endeavors, diminishing their capacity to innovate and access new green technologies. Furthermore, effective

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research project development and management necessitate experience and specialized managerial skills, posing further challenges for these countries.

In certain instances, developing countries may struggle with establishing robust research management systems and fostering effective coordination among ministries, agencies, and research institutions. However, under the auspices of GF, the interaction between GF and R&D expenditure yields a positive impact on GG in both country groups. This effect is observed with a probability of 80% in developing countries and 100% in developed countries. Such findings suggest that green financial instruments, including agricultural and renewable energy credits, as well as green investments, mitigate barriers for businesses and research entities to undertake R&D endeavors focused on sustainable solutions. By sharing risks and offering financial assistance, GF channels incentivize governments to allocate more resources to R&D initiatives in the green sector within developing countries. In developed countries, where GF mechanisms are prevalent, R&D spending is catalyzed, driving innovation and the continual enhancement of technologies aimed at mitigating environmental pollution.

Germany is renowned for its Energiewende (energy transition) strategy, which leverages both R&D spending and GF to propel GG. The government champions R&D endeavors in renewable energy, energy storage, and smart grids through institutions like the Fraunhofer Association. GF mechanisms such as feed-in tariffs and subsidies have expedited the deployment of renewable energy systems and the cultivation of sustainable industries, fostering job creation and economic progress. Similarly, Japan has prioritized government R&D investments in hydrogen fuel cells, energy-efficient technologies, and clean transportation, resulting in technological breakthroughs. GF initiatives, including low-interest loans and green bond issuance, have facilitated the uptake of renewable energy and energy-saving measures, bolstering Japan's GG agenda. Meanwhile, the UK exhibits a steadfast commitment to GG by intertwining R&D spending with GF. Government backing for research entities like the Energy Systems Catapult and the Faraday Institute has catalyzed innovations in battery technology and renewable energy. Furthermore, GF initiatives such as the Green Investment Group and the GF Task Force bolster sustainable infrastructure projects, encompassing renewable energy installations and energy-efficient retrofits.

Table 5 Bayesian regression results

Variable	The developing countries				Developed countries			
	Equation 1		Equation 2		Equation 1		Equation 2	
	Mean	MCSE	Mean	MCSE	Mean	MCSE	Mean	MCSE
C	-7.0084 (3.1567)	0.0316	-5.7126 (3.1548)	0.0315	0.9416 (1.6785)	0.0168	0.9751 (1.7020)	0.0170
TGDP	-0.0765 (0.1044)	0.0010	-0.0947 (0.1054)	0.0011	-0.1049 (0.0620)	0.0006	-0.1033 (0.0625)	0.0006

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UR	-0.0164 (0.0357)	0.0004	-0.0375 (0.0373)	0.0004	-0.1229 (0.0184)	0.0002	-0.1239 (0.0187)	0.0002
OPE	0.0095 (0.0237)	0.0002	0.0024 (0.0250)	0.0003	0.0329 (0.0055)	0.0001	0.0352 (0.0059)	0.0001
INF	0.0017 (0.1011)	0.0010	0.0168 (0.1013)	0.0010	-0.4048 (0.0833)	0.0008	-0.3950 (0.0841)	0.0008
FDG	-0.3167 (0.0996)	0.0010	-0.2921 (0.1008)	0.0010	0.0009 (0.0173)	0.0002	0.0026 (0.0177)	0.0002
IU	0.0345 (0.0248)	0.0002	0.0364 (0.0246)	0.0002	-0.0098 (0.0158)	0.0002	-0.0089 (0.0156)	0.0002
EE	0.1904 (0.3637)	0.0036	0.3061 (0.4213)	0.0042	0.2944 (0.2626)	0.0026	0.2825 (0.2731)	0.0028
RD	-0.8755 (0.3843)	0.0038	-1.9008 (0.6615)	0.0066	1.5454 (0.2593)	0.0026	1.5671 (0.4421)	0.0044
EE*GF			0.0023 (0.0052)	0.0000			0.0026 (0.0076)	0.0000
RD*GF			0.0522 (0.0268)	0.0000			0.0010 (0.0252)	0.0000
Avg acceptance rate	0.9270		0.9370		0.9254		0.9271	
Avg efficiency min	0.1966		0.2409		0.1797		0.2698	
Rc	1.0000		1.0000		1.0000		1.0000	

Source: Results from Stata 17.0 software

Furthermore, Table 5 indicates that TGDP and UR exert a negative influence on GG, whereas OPE positively impacts GG in both country groups. These findings align with the conclusions drawn by Zhang et al. (2021). Moreover, INF and IU exhibit a positive association with GG in developing countries, while FDG positively affects GG in developed countries. These outcomes are consistent with the findings of previous studies by Zhang et al. (2021), Mo et al. (2022), and Saydaliev and Chin (2022).

Table 6 Probability of impacts

Variable	Developing countries				Developed countries			
	(1)		(2)		(1)		(2)	
	Mean (Std. Dev)	MCSE	Mean (Std. Dev)	MCSE	Mean (Std. Dev)	MCSE	Mean (Std. Dev)	MCSE
Prob(GGDP: TGDP)<0	0.7685 (0.421)	0.004	0.8185 (0.381)	0.004	0.9559 (0.205)	0.002	0.9996 (0.030)	0.000
Prob(GGDP: UR)<0	0.6778 (0.4673)	0.0046	0.8408 (0.366)	0.004	1.0000 (0.000)	0.000	1.0000 (0.000)	0.000
Prob(GGDP: OPE)>0	0.6530 (0.476)	0.005	0.7353 (0.491)	0.005	1.0000 (0.000)	0.000	1.0000 (0.000)	0.000
Prob(GGDP: INF)>0	0.7334 (0.499)	0.005	0.666 (0.491)	0.005				

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Prob(GGDP: INF)<0					1.0000 (0.000)	0.000	1.0000 (0.000)	0.000
Prob(GGDP: FDG)<0	1.0000 (0.000)	0.000	1.0000 (0.000)	0.000				
Prob(GGDP: FDG)>0					0.666 (0.499)	0.005	0.5596 (0.495)	0.005
Prob(GGDP:) IU<0	0.999 (0.043)	0.000	0.991 (0.063)	0.000	0.8531 (0.351)	0.002	0.7446 (0.431)	0.004
Prob(GGDP: IU)>0	0.9973 (0.050)	0.000	0.9978 (0.046)	0.000	0.7661 (0.431)	0.000	0.9906 (0.369)	0.001
Prob(GGDP: EE)>0	0.7030 (0.457)	0.004	0.7674 (0.433)	0.004	0.8707 (0.333)	0.003	0.849 (0.358)	0.004
Prob(GGDP: RD)<0	0.7674 (0.434)	0.004	0.7536 (0.393)	0.004				
Prob(GGDP: RD)>0					0.8133 (0.303)	0.003	0.794 (0.311)	0.003
Prob(GGDP: EE GF)>0			0.901 (0.393)	0.004			0.9575 (0.493)	0.005
Prob(GGDP: RD GF)>0			0.8003 (0.397)	0.004			1.0000 (0.000)	0.000

Source: Results from Stata 17.0 software

The Bayesian approach employs the Metropolis-Hastings (MH) algorithm to simulate the regression model 10,000 times, generating regression coefficients in each iteration. Unlike the frequency method, which presents regression coefficients directly, the Bayesian approach provides the average value (Mean) of the coefficients in the regression results table. Additionally, it includes the standard error of the regression coefficient (Std. Dev) and the Monte Carlo standard error. Table 5 indicates that the model's minor efficiency (Avg efficiency: min) is 0.1966, surpassing the permissible level of greater than 0.01, while the average acceptance rate (Avg acceptance rate) is 0.9254, meeting the required level of 0.1. Thus, the model meets all criteria. The Monte Carlo Standard Error (MCSE) for each parameter is minimal, suggesting reliable MCMC chain performance. According to Flegal et al. (2008), the closer the MCSE is to 0, the more dependable the MCMC chain. An MCSE value below 6.5% of the standard deviation value is acceptable, with a value below 5% preferred. Given that Table 5's analysis shows all coefficients' maximum Rc values are 1, it can be concluded that the Bayesian simulation outcomes are stable.

5. Conclusions and policy implications

5.1 Conclusions

The study investigates the influence of FS on GG under the auspices of GF spanning from 2005 to 2021 across 18 developing nations and 14 developed countries. Employing Bayesian regression, the results indicate a positive impact of education expenditure (EE) on GG with a probability exceeding 70% across both country

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groups. However, research and development (RD) spending negatively affects GG in developing countries with a probability of 76.74%, whereas it positively impacts GG in developed countries with a probability of 71.33%. Furthermore, when considering the role of GF, the interaction between GF and fiscal spending (EE and RD) demonstrates a positive influence on GG in both sets of countries, with probabilities of 80.03% and 100% in developing and developed nations, respectively.

5.2. Policy implications

For developed countries:

For developed countries, enhancing the integration of green education into the curriculum is paramount. This involves incorporating environmental and sustainability education across all educational levels to heighten students' understanding of GG and environmental stewardship. Topics such as climate change, renewable energy, and sustainable development should be emphasized to instill a sense of environmental responsibility from an early age. Furthermore, developed countries should bolster support for research and development (R&D) initiatives in green technology and sustainable solutions. This entails increasing investments in academic institutions, research centers, and innovation hubs dedicated to green innovation. By fostering R&D endeavors, nations can drive technological advancements and facilitate the growth of green industries.

For developing countries:

To reinforce environmental education, developing countries should prioritize initiatives aimed at raising awareness about GG and sustainability. This encompasses conducting awareness campaigns, organizing community workshops, and implementing educational programs tailored to various segments of society. Highlighting the correlation between environmental preservation and economic advancement can garner public support for green initiatives. Moreover, developing countries should enhance technical and vocational training programs focused on cultivating green skills. These programs may center on areas such as ecotourism, waste management, sustainable agriculture, and renewable energy. By providing individuals with pertinent skills, nations can cultivate a workforce capable of propelling GG and catering to the needs of burgeoning green industries.

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Author Contributions

Le Quoc Dinh: Performed the experiments; Contributed reagents, materials, analysis tools, or data. Tran Thi Kim Oanh: Conceived and designed the experiments; Wrote the paper. Nguyen Thi Hong Ha: Analyzed and interpreted the data and wrote the paper.

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