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Article

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Foreign direct investment and green GDP: the thresholds of financial development for economic policies

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ABSTRACT

This study aims to examine the impact of foreign direct investment (FDI) on green GDP while analyzing the role of financial development thresholds in moderating the relationship in the ASEAN-6 countries. These are six leading countries in the ASEAN region. The study employs the Generalized Method of Moments (GMM) regression to estimate the models, in combination with Bayesian regression to check the results' robustness. The findings indicate that FDI plays an important role in fostering green GDP in the countries. Furthermore, the financial development thresholds can moderate this impact. Specifically, the estimation results used threshold effects reveal that the threshold value for the financial market index is 0.38, and for the financial institution index, it is 0.68, which both represent financial development. The GMM and Bayesian regression results consistently show that the positive impact of FDI on green GDP becomes evident only when financial development surpasses these threshold values. Notably, financial institutions have shown themselves to be more effective than financial markets in amplifying this impact. These findings provide a reliable foundation for the ASEAN-6 countries to develop appropriate economic policies to promote green GDP.

IMPACT STATEMENT

FDI is a critical source of capital for many countries globally, particularly for those lacking sufficient funds to foster economic growth while safeguarding the environment. However, most FDI-receiving countries are still struggling to enhance their ability to attract and absorb this capital. To address this issue, this study aims to analyze the impact of FDI on green GDP in the ASEAN-6 countries and also to clarify the moderating role of financial development thresholds in this impact. The first key finding reveals that FDI has a positive impact on green GDP in the ASEAN-6 countries, affirming the importance of FDI in promoting green GDP there. Second, the results reveal the existence of threshold values for both the financial market development and financial institution development indices. The positive effect of FDI on green GDP only becomes evident when financial development exceeds these values. Notably, financial institutions show a more effective role than financial markets in amplifying the impact of FDI on green GDP. These findings suggest that the ASEAN-6 countries should make more efforts to attract FDI while simultaneously improving their domestic financial systems to enhance their capacity to absorb this capital. The findings also provide valuable empirical evidence for researchers in this field. Additionally, the study offers meaningful insights for policymakers in the ASEAN-6 countries to identify suitable economic policies aimed at improving FDI absorption capacity, thereby boosting green GDP growth.

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1. Introduction

Green GDP can be calculated by subtracting natural resource loss and environmental pollution loss from traditional GDP. This approach ensures a balance between economic growth and environmental

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protection (Ahmed et al., 2022; Song et al., 2019; Stjepanovic et al., 2022). More specifically, green GDP is determined by subtracting three main components from traditional GDP: energy depletion (including coal, crude oil, natural gas, and other depleting minerals), net forest depletion (the value of timber harvested exceeding natural growth), and carbon dioxide damage (the cost of damages from carbon dioxide emissions resulting from fossil fuel use) (Sohag et al., 2019). With this approach, many countries are increasingly focusing on green GDP rather than merely on traditional GDP as they have done in the past (Anwar et al., 2024). This shift is understandable, as blindly pursuing traditional GDP growth can harm the environment and even hinder sustainable development (Lee & Lee, 2022). These factors have driven countries around the world to strive to identify appropriate policies to promote green GDP, which has also become an important motivation for researchers to take a greater interest in this topic. In fact, to achieve green GDP growth, countries need substantial capital and technological resources. Therefore, foreign direct investment (FDI) plays a crucial role in this process. Indeed, according to He (2006), FDI can influence green GDP in the host country in several ways: (i) FDI provides financial resources to promote green GDP; (ii) FDI contributes to technological innovation and enhances the quality of human capital, thereby encouraging green GDP growth. As a result, nations are working harder to draw in FDI to support their green GDP growth objectives.

However, FDI does not always exert positive effects on green GDP. In fact, FDI can hinder economic growth if it is not utilized effectively (Ofori & Asongu, 2024). Moreover, FDI can also be detrimental to host countries due to the competition and crowding-out effect between FDI and domestic capital (Hayat, 2019; Ofori & Asongu, 2024). Additionally, FDI can increase the scale of production, which can lead to higher levels of environmental pollution (Huynh & Hoang, 2019; Koçak & Şarkgüneşi, 2018). Therefore, improving the efficiency of FDI utilization becomes essential for host countries. One of the key conditions for enhancing the ability to attract and effectively utilize FDI is improving the development level of the domestic financial system, also known as advancing the level of domestic financial development. Indeed, financial development allows foreign investors to save time and reduce costs in accessing and using financial services (Pradhan et al., 2014). Furthermore, the financial systems in host countries can help FDI companies get closer to the additional capital needed to expand their business operations (Desbordes & Wei, 2017), improve investment efficiency, monitor investments, and enhance risk management capabilities (Bertocco, 2008).

Given its crucial role, the impact of FDI on green GDP has received great attention from researchers worldwide. However, empirical studies on this issue mainly focus on examining the effect of FDI on traditional GDP growth (e.g. Aizenman et al., 2013; Asongu & Odhiambo, 2020; Doku et al., 2017; Gui-Diby, 2014; Hayat, 2019; Mehic et al., 2013; Okada & Samreth, 2014; Okwu et al., 2020; Otieno, 2024) or on the impact of FDI on environmental quality (e.g. Hayat, 2019; Hu et al., 2018; Saqib & Dincă, 2024; Yi et al., 2023). There are only few empirical studies, such as those of Yue et al. (2016), Phung et al. (2023), Xiao et al. (2023), and Wani et al. (2024), analyzing its effect on green GDP. This highlights a big limitation in the existing literature, which primarily focuses on the impact of FDI on traditional GDP growth or environmental quality, with very few studies explicitly addressing the impact of FDI on green GDP. This limitation has resulted in an inadequate assessment of the impact of FDI on green GDP, leading to certain difficulties in identifying appropriate policies to encourage green GDP. Therefore, 'how does FDI affect green GDP?' remains a question that has not been adequately explored and addressed in the current literature.

On the other hand, a significant gap remains in the empirical research as the moderating role of financial development in the impact of FDI on green GDP has not been fully considered. The fact is that the level of financial development in host countries can amplify the effects of FDI on green GDP (Desbordes & Wei, 2017; Giovanni, 2005; Ozturk & Acaravci, 2013; Pradhan et al., 2014; Sadorsky, 2011). It is evident that this assertion has been suggested in some existing literature but has not been examined thoroughly and appropriately. Moreover, while some have measured financial development through financial markets and institutions, the approach often focuses on limited aspects. Specifically, financial market development is commonly measured by stock market capitalization to GDP (Agbloyor et al., 2014; Ibrahim & Sare, 2018; Nguyen, 2022; Sadorsky, 2011), while financial institution development is typically determined by the ratio of credit to GDP (Azman-Saini et al., 2010; Ibhagui, 2020; Ntow-Gyamfi et al., 2020; Osei & Kim, 2020; Ozturk & Acaravci, 2013; Yeboua, 2019). These measures primarily capture

the size of the financial sector relative to GDP, demonstrating financial depth, but they do not fully capture the multidimensional essence of financial development. To address this limitation, the International Monetary Fund (IMF) has developed and published composite indices representing the development of financial markets and institutions based on three criteria: depth, access, and efficiency (Pradhan et al., 2014; Svirydzhenka, 2016). This approach is superior by offering a more comprehensive reflection of financial development, encompassing its multidimensional nature, in contrast to the single-dimensional indices typically used in empirical research. However, there is still a lack of empirical studies utilizing the IMF's composite index to explore the moderating role of financial development in the impact of FDI on green GDP. In other words, 'what is the role of financial development in moderating the impact of FDI on green GDP?' has not been adequately answered in the existing literature, particularly in cases where composite indices representing the level of development of financial markets and institutions are used. This represents a significant research gap that needs to be addressed. This gap has created certain challenges for the countries in developing appropriate policies to stimulate green GDP.

This study was conducted to further clarify the impact of FDI on green GDP in the ASEAN-6 countries, while also exploring the role of financial development thresholds in moderating this relationship. In specific, green GDP is defined by subtracting natural resource loss and environmental pollution loss from traditional GDP, ensuring a balance between economic growth and environmental protection (Ahmed et al., 2022; Song et al., 2019; Stjepanovic et al., 2022). For financial development, this study employs the financial market index and the financial institution index published by the IMF to measure the level of financial development in each country. The threshold effects proposed by Hansen (1999) and Wang (2015) are used to estimate the threshold values for indices of financial market development and financial institution development. Next, the GMM regression is applied to evaluate the influence of FDI on green GDP before and after reaching the threshold values of financial development, allowing to address violations of regression assumptions and control for potential endogeneity in the models (Bui, 2023; Doytch & Uctum, 2011). Additionally, Bayesian regression is employed to re-estimate the models, further clarifying the findings and ensuring their robustness. This relatively new estimation method is superior in reflecting the probability of the impact of variables in the model (Permai & Tanty, 2018). By using this strategy, the authors expect to provide reliable empirical evidence. In addition, this study also aims to suggest policies, contribute meaningful findings to the existing literature, and offer a solid basis for the ASEAN-6 countries to determine appropriate economic policies to enhance their FDI absorption and advance green GDP.

This study makes some contributions to the existing literature. First, it analyzes the impact of FDI on green GDP in the ASEAN-6 countries as well as clarifies the moderating role of the financial development thresholds in this relationship. Unlike most previous studies on this topic, this study attempts to identify the threshold values of financial development, where financial development is measured through a composite index representing both financial market and financial institution development, rather than relying solely on component indices indicating financial depth as in the previous research. Second, this study employs a combination of GMM and Bayesian regression techniques to provide deeper insights into the findings, which also confirms the models' robustness, thereby enhancing the validity and reliability of the results. Third, it uses a sample of the top six ASEAN countries instead of focusing on a single country. This approach distinguishes this study from others by ensuring similarities among the countries and contributes to improving the effectiveness of economic policies aimed at promoting green GDP across multiple countries. In short, according to the authors' understanding, this study offers novel contributions as mentioned above. The findings are expected to provide significant empirical evidence to the existing literature and suggest policies, as well as create a reliable basis for countries to identify appropriate economic policies to enhance their capacity to attract FDI while promoting green GDP.

The next section of the paper presents the theoretical framework and relevant empirical studies. Section 3 introduces the data sample, constructs the research models, and identifies the methods used to estimate these models. Section 4 presents and discusses the estimation results. Finally, conclusions and policy implications are addressed in Section 5.

2. Literature review and hypothesis development

This section focuses on providing an overview of the theoretical framework and empirical evidence related to the topic. Based on this foundation, the authors develop the hypotheses. Three key aspects are discussed in this section: (i) First, the authors clarify the theoretical framework; (ii) Next, the authors explore the literature on the impact of FDI on green GDP; (iii) Finally, the authors provide a review of the literature on the role of financial development in the relationship between FDI and green GDP.

2.1. Theoretical framework

FDI plays a key role in promoting green GDP in host countries, particularly in those facing capital and technology shortages. This role can be explained through classical economic growth theories, namely the neoclassical growth theory (Solow, 1956) and endogenous growth theory (Romer, 1990). According to the neoclassical growth theory, the role of capital is emphasized in meeting the demand for technological innovation, thereby driving economic growth. Meanwhile, the endogenous growth theory posits that endogenous factors, such as physical capital and human capital, are the primary drivers of economic growth. Furthermore, it also highlights other factors related to each country's characteristics, particularly government policies, which can significantly influence economic growth. Besides, the theories of scale effect and technique effect (Bakhsh et al., 2017; Copeland & Taylor, 1994; Grossman & Krueger, 1991; He, 2008) also contribute significantly to explaining the impact of FDI on green GDP. Indeed, the scale effect implies that FDI can promote production scale, which can significantly impact environmental quality. Meanwhile, the technique effect refers to the adoption of cleaner and more environmentally friendly technologies that benefit the environment. This indicates that the economic growth theories focus on explaining the impact of FDI on traditional GDP, while the scale effect and technique effect concentrate on elucidating the impact of FDI on environmental quality. Therefore, we can combine them to provide a comprehensive explanation of the impact of FDI on green GDP. In fact, FDI can affect green GDP in host countries through the following mechanisms: (i) FDI provides financial resources to boost green GDP; (ii) FDI contributes to technological innovation and improves human resources, thereby promoting green GDP (He, 2006).

The level of financial development in each country can enhance GDP growth by providing funding for investment and production (Schumpeter, 1911). Moreover, financial development in host countries plays a crucial role in moderating the impact of FDI on green GDP. From a theoretical perspective, the theory of financial intermediation posits that the establishment of financial institutions can help mitigate transaction costs and information asymmetry in the market (Allen & Santomero, 1997; Diamond, 1984; Gurley & Shaw, 1960). Moreover, this formation contributes to a more perfect market by reducing transaction costs and information asymmetry. Indeed, Gurley and Shaw (1960) were among the first to assert that financial institutions play a role in lowering transaction costs, which is reflected in reduced monetary transaction costs and even lowered costs associated with searching for and monitoring capital sources. For information asymmetry, Diamond (1984) argued that financial institutions act as intermediaries between those in need of capital and capital providers, thereby enhancing the efficiency of capital use in the economy and mitigating information asymmetry issues. Besides, Claessens and Perotti (2007) emphasized that a developed financial system helps minimize systemic risks. As countries deepen their integration into the global economy, despite the benefits of international economic integration, they may also face greater challenges and vulnerabilities to fluctuations in foreign capital flows. Through financial institutions, these countries can effectively manage capital inflows and outflows, thus minimizing risks and safeguarding the economy from external shocks. In fact, improvements in the financial system in host countries demonstrate that these countries are enhancing their ability to offer high-quality financial services at lower costs, which helps foreign investors save time and reduce costs when accessing and utilizing financial services (Pradhan et al., 2014). Thanks to developments in the financial system in host countries, FDI enterprises can access the necessary capital to expand their business operations (Desbordes & Wei, 2017), which helps sustain and develop projects that they might have to abandon due to lack of funds (Giovanni, 2005). Additionally, a well-performing financial system enables FDI companies to optimize investment efficiency, monitor investments, and enhance risk management

capabilities (Bertocco, 2008). Therefore, the impact of FDI on GDP growth may greatly depend on the regulation of the financial system (Osei & Kim, 2020).

Overall, FDI can significantly influence green GDP, a relationship supported by various theoretical frameworks, such as neoclassical growth theory (Solow, 1956), endogenous growth theory (Romer, 1990), and the scale and technique effects (Bakhsh et al., 2017; Copeland & Taylor, 1994; Grossman & Krueger, 1991; He, 2008). Additionally, the theory of financial intermediation (see Allen & Santomero, 1997; Diamond, 1984; Gurley & Shaw, 1960) suggests that financial development plays a moderating role in the effect of FDI on green GDP. More than that, green GDP is also significantly affected by control variables that represent country characteristics. For instance, endogenous growth theory posits that country-specific factors, which commonly include government expenditure and inflation, are critical in fostering economic growth (Romer, 1990). Moreover, neoclassical growth theory highlights the importance of technology in economic growth (Solow, 1956), while the technique effect underscores its role in improving environmental quality (Bakhsh et al., 2017; Copeland & Taylor, 1994; Grossman & Krueger, 1991; He, 2008).

2.2. The impact of FDI on green GDP

Several empirical studies have demonstrated that FDI can reduce carbon emissions and foster the economy of host countries (Salehnia et al., 2020; Tamazian & Rao, 2010; Tang & Tan, 2015). Accordingly, FDI enables developing countries to access investments in research and development, contributing to the improvement of cleaner and more environmentally friendly technologies (Jalil & Feridun, 2011). Additionally, some empirical studies have found the positive effects of FDI on green GDP. For instance, Yue et al. (2016) identified the positive impact of FDI on green growth in 104 cities in China. Similarly, Xiao et al. (2023) confirmed that FDI can promote green growth, being a key driver for China's sustainable development. In another study, Phung et al. (2023) found the positive effects of FDI on green growth in Southeast Asian economies. More recently, Wani et al. (2024) confirmed that FDI contributes positively to green growth in the G7 countries. Moreover, this study suggests that these nations should combine technological improvements with FDI attraction to maintain sustainable development.

The reality shows that FDI can foster green GDP, which has been confirmed in several empirical studies. However, most of them typically examine the impact of FDI on either traditional GDP growth or environmental quality. Regarding traditional GDP growth, a significant number of empirical studies have revealed a positive effect of FDI on economic growth. Typical studies include those of Aizenman et al. (2013), conducted on a sample of 100 countries in the pre-financial crisis context; Mehic et al. (2013), based on data from seven Southeast European countries; Gui-Diby (2014), using a sample of 50 African countries; and Okada and Samreth (2014), focused on low- and middle-income countries. Other important research include Doku et al. (2017), conducted on 20 African nations; Hayat (2019), examining low- and middle-income countries; Okwu et al. (2020), using data from 30 leading global economies; Triatmanto et al. (2023), analyzing data from four ASEAN countries (Indonesia, Thailand, Vietnam, and the Philippines); and Otieno (2024), focusing on countries in East Africa. Nonetheless, some argue that FDI may impede economic growth. Specifically, FDI can work against host countries due to the competition and substitution effect between FDI and domestic capital. Initially, FDI boosts investment capital in host countries, but as FDI continues to rise, it may cause difficulties for local businesses and put more pressure on host countries to successfully manage FDI. Moreover, the ability to adopt and absorb advanced technology and managerial expertise poses significant challenges for their manpower (Hayat, 2019; Ofori & Asongu, 2024). The negative impact of FDI on economic growth has been revealed in studies by Okada and Samreth (2014) and Hayat (2019) when analyzing data from high-income countries. More specifically, Ofori and Asongu (2024) suggested that FDI may hinder economic growth in 42 Sub-Saharan African (SSA) countries, which need to improve their FDI management efficiency and domestic investment environment to stimulate economic growth effectively. As for environmental quality, FDI can influence environmental quality through the scale effect and technique effect (Bakhsh et al., 2017; Copeland & Taylor, 1994; Grossman & Krueger, 1991; He, 2008). In specific, the scale effect implies that FDI can increase production scale, which in turn can lead to higher levels of environmental pollution (Huynh & Hoang, 2019; Koçak & Şarkgüneşi, 2018). Indeed, many researchers believe that FDI can

increase environmental pollution in host countries. Specifically, developing countries often tend to attract FDI to address their capital and technology shortages, and may even lower environmental management standards to attract FDI, resulting in over-exploitation of domestic resources (Hu et al., 2018). In addition, these countries frequently struggle to guide the growth of green sectors, which can further increase environmental pollution (Hayat, 2019). Recently, Hoa et al. (2023) also found a positive influence of FDI on carbon emissions in Vietnam. Conversely, the technique effect is associated with the application of greener and more ecologically friendly technology, which can benefit the environment (Pazienza, 2019). However, the impact of the scale effect and technique effect can vary between countries. Indeed, Pao and Tsai (2011) suggested that the scale effect is more applicable to emerging economies, while the technique effect shows its inappropriateness to these economies. In another study, Bin and Yue (2012) argued that the technique effect reduces environmental pollution, while the scale effect increases it; however, the former may be stronger than the latter in China. Recently, Yi et al. (2023) demonstrated that FDI can reduce carbon emissions in China's manufacturing sectors. Similarly, Saqib and Dincă (2024) also affirmed that FDI could decrease carbon emissions in leading countries for clean energy investments.

It can be seen that the relationship between FDI and green GDP is a topic addressed in various empirical studies. However, these studies have certain limitations. Particularly, regarding the measurement of green GDP, this indicator can be defined as a combination of traditional GDP with environmental protection (Bagheri et al., 2018; Dai et al., 2016; Jacobs, 2012; Jouvét & de Perthuis, 2013). Nevertheless, most empirical research often examines the impact of FDI on traditional GDP (e.g. Aizenman et al., 2013; Asongu & Odhiambo, 2020; Doku et al., 2017; Gui-Diby, 2014; Hayat, 2019; Mehic et al., 2013; Okada & Samreth, 2014; Okwu et al., 2020; Otieno, 2024) or environmental quality (e.g. Hayat, 2019; Hu et al., 2018; Saqib & Dincă, 2024; Yi et al., 2023), with fewer empirical studies considering the impact of FDI on green GDP (e.g. Phung et al., 2023; Wani et al., 2024; Xiao et al., 2023; Yue et al., 2016). This indicates that this topic has received great attention in empirical research. However, there still exist some limitations, particularly concerning how green GDP is measured. These limitations have made it challenging to fully assess the impact of FDI on green GDP, especially in capturing all aspects of green GDP. With these limitations, further investigation into the impact of FDI on green GDP is essential to supplement the existing literature. Indeed, empirical studies can contribute to the existing literature on this issue by building on the most relevant research (e.g. Phung et al., 2023; Wani et al., 2024; Xiao et al., 2023; Yue et al., 2016) to further clarify the impact of FDI on green GDP, and even analyze this issue in different regions to diversify the existing literature.

It is evident that while there are different views on the impact of FDI on green GDP, the positive impact is predominant. Indeed, FDI is important in promoting green GDP, as highlighted in several empirical studies, including those of Yue et al. (2016), Phung et al. (2023), Xiao et al. (2023), and Wani et al. (2024). Specifically, FDI provides financial resources for the advancement of green GDP (He, 2006) and enables countries to access funding for research and development, which advances the creation of cleaner and more ecologically friendly technology (Jalil & Feridun, 2011). This view is also supported by additional empirical researchers, such as Bin and Yue (2012), Aizenman et al. (2013), Mehic et al. (2013), Gui-Diby (2014), Okada and Samreth (2014), Doku et al. (2017), Hayat (2019), Okwu et al. (2020), Yi et al. (2023), Otieno (2024), and Saqib and Dincă (2024). In the context of the ASEAN-6 countries, primarily developing nations, FDI can play a crucial role in driving economic development, especially during periods of domestic capital scarcity. This perspective is supported by empirical studies conducted in developing countries, such as those of Okada and Samreth (2014), Hayat (2019), and Triatmanto et al. (2023). Also, these countries are directing FDI towards the adoption of environmentally friendly technologies. Although this objective still faces significant challenges, particularly in the short term, most of the nations are striving to promote traditional GDP growth coupled with environmental quality enhancement. More importantly, this includes efforts to attract FDI into projects that improve environmental quality and support the adoption and innovation of advanced, environmentally friendly technologies. With these foundations, FDI can potentially exert positive impacts on green GDP in the ASEAN-6 countries. Based on this foundation, the authors propose the research hypothesis as follows:

Hypothesis H₁: FDI positively affects green GDP in the ASEAN-6 countries.

2.3. *The role of financial development in the impact of FDI on green growth*

Evidence from several empirical research has demonstrated that the moderating role of the financial system is a prerequisite for promoting the positive impact of FDI on GDP growth (Alfaro et al., 2004; Azman-Saini et al., 2010; Xu, 2000). However, some argue that the impact of FDI on GDP growth is insignificant if the financial sector expands in scale but operates inefficiently (Ibhagui, 2020; Osei & Kim, 2020). Thus, if this development is only considered in terms of scale, it may not completely perform its moderating function in the impact of FDI on GDP growth. Furthermore, some empirical studies have examined the role of financial development in the impact of FDI on environmental quality. Indeed, the development of the financial system can help companies expand their operations and access cleaner, more eco-friendly technologies, thereby reducing environmental pollution (Tamazian & Rao, 2010). However, expansion in production without caring for environmental protection can lead to increased environmental pollution (Ozturk & Acaravci, 2013; Sadorsky, 2011). Therefore, financial development in host countries can play a key role in moderating the impact of FDI on green GDP.

The characteristics of the financial system in each country are reflected in the level of development of financial markets and institutions (Choi & Park, 2018; Fisman & Love, 2003; Lim, 2018; Osei & Kim, 2020). From the perspective of the financial market, Agbloyor et al. (2014) reported that countries with more advanced financial markets may benefit through an increased capacity to absorb FDI capital. Using a sample of ASEAN-6 countries, Nguyen (2022) found that the threshold value of stock market capitalization relative to GDP is 21.95%, with the positive influence of FDI on economic growth rocketing significantly beyond this threshold. From the perspective of the development level of financial institutions, Azman-Saini et al. (2010) argued that the positive impact of FDI on economic growth becomes evident only when the ratio of credit to GDP exceeds the threshold of 49.7%. Yeboua (2019) identified a threshold value for the ratio of credit to GDP at 15.6%, where the impact of FDI on economic growth is negative below the threshold but turns positive after surpassing it. From a different perspective, Ibhagui (2020) revealed that the threshold value for the ratio of credit to GDP is 14.58%, with the positive impact of FDI on economic growth observed below this threshold, while the effect becomes insignificant once surpassed. Similarly, Osei and Kim (2020) confirmed that the impact of FDI on economic growth becomes insignificant when domestic credit to GDP exceeds the threshold of 95.6%. This result can be explained by the fact that uncontrolled credit expansion may lead to instability or even financial crises, thereby reducing the efficiency of FDI utilization in the economy.

It is obvious that the impact of FDI on green GDP may considerably depend on the moderation of the financial system, specifically the development level of the financial market and financial institutions in host countries. With divergent opinions regarding the impact of FDI on green GDP both before and after these threshold values, there is, nevertheless, no agreement on the threshold values for the development of financial markets and institutions. Moreover, empirical studies face limitations in measuring financial development. Indeed, in empirical research, financial market development is often calculated by stock market capitalization relative to GDP (Agbloyor et al., 2014; Ibrahim & Sare, 2018; Nguyen, 2022; Sadorsky, 2011), while financial institution development is typically measured by the ratio of credit to GDP (Azman-Saini et al., 2010; Ibhagui, 2020; Ntow-Gyamfi et al., 2020; Osei & Kim, 2020; Ozturk & Acaravci, 2013; Yeboua, 2019). Thus, most empirical studies are limited in their scope when only measuring financial development through the size of financial markets and institutions, which reflects only financial depth. Meanwhile, financial development can also be evaluated through the accessibility and efficiency of the financial sector (Pradhan et al., 2014; Svirydzienka, 2016). This suggests that there is a significant gap in empirical research because the multidimensional nature of financial development is not well captured when measuring it just based on financial depth. This gap leads to an incomplete assessment of the role of financial development in moderating the impact of FDI on green GDP, making it difficult to identify appropriate economic policies to boost green GDP. Therefore, empirical studies can bridge this gap by building on the most relevant prior research to further clarify this issue. For instance, the findings of Xu (2000), Alfaro et al. (2004), and Azman-Saini et al. (2010) highlighted the moderating role of financial development in the impact of FDI on green GDP. Meanwhile, Fisman and Love (2003), Pradhan et al. (2014), Choi and Park (2018), Lim (2018), and Osei and Kim (2020) emphasized the

necessity of specifically measuring the level of financial development through the growth of financial markets and institutions.

In general, the level of financial development in each nation is indicated by development of financial markets and institutions (Choi & Park, 2018; Fisman & Love, 2003; Lim, 2018; Osei & Kim, 2020; Pradhan et al., 2014). The financial market makes it easier to buy and sell financial instruments, while financial institutions consist of entities primarily providing financial services. Consequently, the impact of FDI on green GDP may depend on the regulation of financial development, specifically the development indices of the financial market and financial institutions.

The financial market facilitates the exchange and trading of financial instruments, enabling capital suppliers to directly provide funds to those in need of capital. This ease of access to capital allows companies to expand their business operations (Sadorsky, 2011), thereby promoting green GDP. Financial market development can even potentially reduce carbon emissions by encouraging companies to improve technology in the long term (Tamazian & Rao, 2010). This perspective is in line with the findings of Agbloyor et al. (2014) and Nguyen (2022). The ASEAN-6 countries, primarily developing economies, have relatively underdeveloped financial markets, especially in the green capital sector. Boosting the development of these markets is essential to optimize the contribution of FDI to green GDP growth. Based on this, the next research hypothesis is proposed as follows:

Hypothesis H_{2a}: There is a threshold value for the financial market index, where the positive impact of FDI on green GDP in the ASEAN-6 countries becomes evident beyond this threshold.

Financial institutions play an intermediary role by supplying financial services as they act as a bridge between capital suppliers and those in need of capital. With their functions, they enhance liquidity and ensure the continuity of physical capital investment activities. In addition, they can transform short-term surplus funds into long-term investments. By improving financial services, they can stimulate investment (Botev et al., 2019) and promote the efficient allocation of investment capital (Bencivenga & Smith, 1991; Diamond, 1984), thereby driving green GDP growth. This aligns with what has been found previously by Azman-Saini et al. (2010) and Yeboua (2019). Furthermore, this perspective aligns well with the ASEAN-6 context, where most countries are developing economies and heavily dependent on financial institutions for capital supply. Although green credit sources have yet to receive adequate attention, financial institutions are increasingly recognized for their role in balancing economic growth and environmental protection in the ASEAN-6. Therefore, as financial institutions reach a certain level of development, the effectiveness of FDI in enhancing green GDP becomes attainable in these nations. Therefore, the final hypothesis is proposed as follows:

Hypothesis H_{2b}: There is a threshold value for the financial institution index, where the positive impact of FDI on green GDP in the ASEAN-6 countries becomes evident beyond this threshold.

3. Estimation method and data

3.1. Estimation method

Based on the current literature, FDI can significantly impact green GDP. Following that, the authors propose the first research model as follows:

$$\text{Green_GDP}_{it} = \alpha_1 + \beta_1 \text{FDI}_{it} + \mu_1 \text{Control}_{it} + \varepsilon_{it} \quad (1)$$

Model 1 examines the impact of FDI on green GDP. In specific, green GDP (Green_GDP) is measured using the logarithm of green GDP per capita, which is calculated by deducting natural resource loss and environmental pollution loss from traditional GDP. More specifically, green GDP is defined by subtracting the following components from traditional GDP: energy depletion (which includes coal, crude oil, natural gas, and other depleting minerals), net forest depletion (specifically, the value of harvested timber exceeding natural growth), and carbon dioxide damage (the cost of damage from carbon dioxide emissions resulting from fossil fuel use) (Ahmed et al., 2022; Sohag et al., 2019; Song et al., 2019).

FDI is measured as net foreign direct investment relative to GDP (Asongu & Odhiambo, 2020; Jalil & Feridun, 2011; Phung et al., 2023; Salehnia et al., 2020; Tamazian & Rao, 2010; Tang & Tan, 2015).

Moreover, examining the impact of FDI on green GDP is entirely consistent with foundational theories such as neoclassical growth theory (Solow, 1956), endogenous growth theory (Romer, 1990), and the scale and technique effects (Bakhsh et al., 2017; Copeland & Taylor, 1994; Grossman & Krueger, 1991; He, 2008).

Additionally, the authors also incorporate control variables into the research model. The control variables include government expenditure (GOV), which is government final consumption expenditure relative to GDP (Asongu & Odhiambo, 2020); inflation (INF), which is the annual growth rate of the consumer price index (Asongu & Odhiambo, 2020; Phung et al., 2023; Tamazian & Rao, 2010); technology (TEC), which is the average value of three indicators representing each country's technology infrastructure, specifically: fixed telephone subscriptions (% of population), mobile cellular subscriptions (% of population), and individuals using the Internet (% of population) (Asongu & Odhiambo, 2020). In specific, endogenous growth theory highlights the importance of country-specific factors in enhancing economic growth (Romer, 1990). Based on this foundation, the authors identify the control variables of government expenditure (GOV) and inflation (INF) within the research model. Furthermore, neoclassical growth theory emphasizes the role of technology in economic growth (Solow, 1956), while the technique effect underscores the significance of technology in environmental quality (Bakhsh et al., 2017; Copeland & Taylor, 1994; Grossman & Krueger, 1991; He, 2008). Consequently, the authors include the variable of technology (TEC) as a control variable in the research model. Finally, ε represents the error term of the model.

For estimation, the authors employ the GMM regression method proposed by Arellano and Bond (1991) to estimate Model 1. This method is advantageous as it resolves regression assumption violations and controls potential endogeneity within the model (Bui, 2023; Doytch & Uctum, 2011). In other words, the GMM regression can address violations of regression assumptions, ensuring reliable and valid estimation results. Additionally, the authors use Bayesian regression to test the robustness of Model 1. This approach not only confirms the robustness of the estimation results but also determines the probability of the effects of the variables in the model, which traditional estimation methods like GMM cannot address. Specifically, according to the Bayesian perspective, all parameters in the model are not single estimated values but are drawn from a probability distribution (Permai & Tanty, 2018). Moreover, Bayesian regression has the advantage of being applicable to small sample sizes and increasing the robustness of estimation results (McNeish, 2016).

According to Azman-Saini et al. (2010), Agbloyor et al. (2014), Yeboua (2019), Ibhagui (2020), Osei and Kim (2020), and Nguyen (2022), financial development may moderate the impact of FDI on green GDP. This issue is also entirely consistent with the theory of financial intermediation (Allen & Santomero, 1997; Diamond, 1984; Gurley & Shaw, 1960). Furthermore, it is plausible that a threshold value of financial development exists, and the influence of FDI on green GDP might vary below and beyond it. Thus, the model examining the impact of FDI on green GDP, moderated by the thresholds of financial development, can be generally formulated as follows:

$$\text{Green_GDP}_{it} = \alpha_2 + \begin{cases} \beta_{21}\text{FDI1}_{it}, & \text{FSD} \leq \lambda \\ \beta_{22}\text{FDI2}_{it}, & \text{FSD} > \lambda \end{cases} + \mu_2\text{Control}_{it} + \varepsilon_{it} \quad (2)$$

Model 2 focuses on examining the impact of FDI on green GDP under the moderation of financial development thresholds. Specifically, it aims to determine the threshold value of financial development and subsequently analyze the effect of FDI on green GDP in the regions before and after this threshold value. In Model 2, financial development (FSD) represents the level of financial system development in each country (Ahmed et al., 2022; Tamazian & Rao, 2010; Wen et al., 2022). λ is the threshold value for financial development, where $\text{FSD} \leq \lambda$ represents the pre-threshold area and $\text{FSD} > \lambda$ represents the post-threshold area. FDI1 denotes the values of FDI in the pre-threshold area, i.e. $\text{FSD} \leq \lambda$. FDI2 denotes the values of FDI in the post-threshold area, i.e. when $\text{FSD} > \lambda$. The other variables are similar to those in Model 1. In particular, financial development can be determined through the development level of financial markets and institutions (Choi & Park, 2018; Fisman & Love, 2003; Lim, 2018; Osei & Kim, 2020; Pradhan et al., 2014). Therefore, the authors measure financial development using the financial market index (FMI) and the financial institution index (FII), which were published by the IMF. This approach allows for a comprehensive assessment of financial development through composite indices, evaluating

both financial market and financial institution development aspects. Therefore, Model 2 is developed into two specific models, Model 2a and Model 2b, as follows:

$$\text{Green_GDP}_{it} = \alpha_{2a} + \begin{cases} \beta_{21a} \text{FDI1a}_{it}, & \text{FMI} \leq \lambda_a \\ \beta_{22a} \text{FDI2a}_{it}, & \text{FMI} > \lambda_a \end{cases} + \mu_{2a} \text{Control}_{it} + \varepsilon_{it} \quad (2a)$$

$$\text{Green_GDP}_{it} = \alpha_{2b} + \begin{cases} \beta_{21b} \text{FDI1b}_{it}, & \text{FII} \leq \lambda_b \\ \beta_{22b} \text{FDI2b}_{it}, & \text{FII} > \lambda_b \end{cases} + \mu_{2b} \text{Control}_{it} + \varepsilon_{it} \quad (2b)$$

Specifically, Model 2a identifies the threshold value λ_a of the financial market index, while Model 2b focuses on determining the threshold value λ_b of the financial institution index. In addition, Model 2a investigates the effect of FDI on green GDP in the regions before and after the threshold value of the financial market development index, while Model 2b analyzes the impact of FDI on green GDP in the regions before and after the threshold value of the financial institution development index. The remaining variables are similar to those in Model 2.

For estimation, the authors employ the threshold effects to estimate the threshold values λ_a and λ_b in Models 2a and 2b. This approach, proposed by Hansen (1999) and later developed into the fixed-effect panel threshold method by Wang (2015), is based on fixed-effect threshold regression for balanced panel data. However, this method has limitations, particularly in controlling potential endogeneity in the research model. To address this limitation, the authors use the GMM regression method proposed by Arellano and Bond (1991) to estimate the impact of FDI on green GDP in both the pre-threshold and post-threshold areas of financial development. Like Model 1, Bayesian regression is also employed to test the robustness of the estimation results, providing a broader understanding of the results for Models 2a and 2b.

3.2. Data

The data sample in this study includes the ASEAN-6 countries, which are Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Vietnam. These six countries are the leading economies in the ASEAN region, collectively accounting for approximately 95% of the region's GDP (Ha et al., 2020). Furthermore, they share many similarities, particularly in their recent efforts to promote green GDP. The dataset covers the period from 2000 to 2021, ensuring that all countries in the sample have a complete dataset, thereby maintaining a balanced one. Financial development indices (FMI and FII) are obtained from the IMF database. The data for the components that constitute green GDP (including energy depletion, net forest depletion, and carbon dioxide damage) are collected from the World Development Indicators (WDI) database of the World Bank. Similarly, the other variables in the research model (including FDI, GOV, INF, and TEC) are also obtained from that database.

4. Empirical results

4.1. Basic statistics

The dataset is collected from the ASEAN-6 countries during the period from 2000 to 2021, including Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Vietnam. Descriptive statistics for this dataset are presented in Table 1.

It can be observed from Table 1 that Green_GDP has an average value of 8.38 (corresponding to \$1,073.73), with the lowest value being 5.89 (corresponding to \$359.63) observed in Vietnam in 2002, and the highest value being 11.26 (corresponding to \$77,325.57) observed in Singapore in 2018. For FDI, the average value is 5.67%, with the lowest value being -2.76% recorded in Indonesia in 2000, and the highest value being 32.69% recorded in Singapore in 2021.

To elucidate the relationships between the variables in the models, the authors perform a correlation analysis, with the results shown in Table 2.

The correlation coefficients between the variables are shown in Table 2. More specifically, Green_GDP is positively correlated to FDI. Regarding the control variables, Green_GDP has a negative association with inflation (INF) and a positive link with government expenditure (GOV) and technology (TEC).

Table 1. Descriptive statistics.

Variable	Mean	Std. Dev	Min	Max
Green_GDP	8.38	1.28	5.89	11.26
FDI	5.67	7.27	−2.76	32.69
GOV	10.96	2.81	5.47	18.26
INF	3.56	3.56	−1.71	23.12
TEC	50.53	27.03	1.49	97.48

Source: Authors' work.

Table 2. Correlation matrix.

Variable	Green_GDP	FDI	GOV	INF	TEC
Green_GDP	1.00				
FDI	0.76*** (0.00)	1.00			
GOV	0.32*** (0.00)	−0.13 (0.13)	1.00		
INF	−0.44*** (0.000)	−0.21** (0.02)	−0.46*** (0.00)	1.00	
TEC	0.82*** (0.00)	0.52*** (0.00)	0.37*** (0.00)	−0.34*** (0.00)	1.00

Note.

*** $p \leq 0.01$.

** $p \leq 0.05$.

Source: Authors' estimation.

4.2. Results of estimating the impact of FDI on green GDP

In this section, the authors analyze the impact of FDI on green GDP through Model 1. To perform that, the authors first test the regression hypotheses for Model 1, with the results illustrated in Table 3.

Table 3 shows that the average variance inflation factor (VIF) is relatively low, indicating that multicollinearity in this model is not considered severe. However, Model 1 violates other regression assumptions, specifically exhibiting issues of heteroscedasticity, autocorrelation, and endogeneity. Therefore, to address these issues, the authors estimate Model 1 using the GMM regression.

Table 4 shows that the estimation results of Model 1 using the GMM regression are significant, with all appropriate tests. Accordingly, they indicate that FDI has a positive impact on green GDP. Regarding the control variables, they reveal that government expenditure (GOV) and technology (TEC) positively influence green GDP, while inflation (INF) has a negative impact on green GDP.

To assess the robustness of these results, the authors apply Bayesian regression. This approach addresses a gap in traditional methods like GMM by identifying the probability of the influence of FDI on green GDP in addition to confirming the robustness of the results. The estimation results of this impact using Bayesian regression are presented in Table 5.

Table 5 indicates that the estimation results of Model 1 using Bayesian regression are appropriate, with the indicators of avg acceptance rate, avg efficiency (min), and Gelman-Rubin R_c (max) all meeting the criteria. Specifically, FDI exerts a positive effect on green GDP, with the probability of occurrence, i.e. a 100% probability. For the control variables, the results demonstrate that government expenditure (GOV) and technology (TEC) have a positive impact on green GDP, while inflation (INF) is negatively related to it. Thus, the estimation results of Model 1 using the Bayesian regression (Table 5) are completely consistent with those observed from the GMM regression (Table 4). This reinforces the robustness of Model 1.

4.3. Results of estimating the impact of FDI on green GDP under the moderating influence of financial development thresholds

In this section, the authors consider the impact of FDI on green GDP under the moderation of financial development thresholds. To achieve this, the authors employ the threshold effects, as proposed by Hansen (1999) and further developed by Wang (2015), to estimate the threshold values for the financial market index (λ_a) and financial institution index (λ_b) in Models 2a and 2b, respectively.

First, the authors test for the existence of multiple thresholds in Models 2a and 2b. The estimation results in Table 6 indicate that there is only one threshold for the financial market index (λ_a) and financial institution index (λ_b). Specifically, Table 6 shows that the threshold value for the financial market index is $\lambda_a = 0.38$ and that for the financial institution index is $\lambda_b = 0.68$. Thus, the impact of FDI on

Table 3. Results of testing the hypotheses for the impact of FDI on green GDP.

Model	Test for heteroscedasticity	Test for autocorrelation	Mean VIF	Test for endogeneity
Model 1	70.46*** (0.00)	336.44*** (0.00)	1.68	15.45*** (0.00)

Note.

*** $p \leq 0.01$.

Source: Authors' estimation.

Table 4. Results of estimating the impact of FDI on GDP using GMM regression.

Green_GDP	Model 1
FDI	0.07*** (0.00)
GOV	0.02* (0.09)
INF	-0.07*** (0.00)
TEC	0.02*** (0.00)
_cons	6.80*** (0.00)
Wald chi2	1,771.05*** (0.00)
Arellano-Bond test	AR(1) AR(2)
	-3.09*** (0.00) -1.54 (0.12)
Sargan test	4.70 (0.20)

Note.

*** $p \leq 0.01$.* $p \leq 0.1$.

Source: Authors' estimation.

Table 5. Results of estimating the impact of FDI on GDP using Bayesian regression.

Green_GDP	Model 1	
	Mean	Probability
FDI	0.10 [0.08; 0.11]	1
GOV	0.11 [0.07; 0.14]	1
INF	-0.02 [-0.05; 0.01]	0.93
TEC	0.02 [0.02; 0.03]	1
_cons	5.67 [5.21; 6.11]	
Avg acceptance rate	1	
Avg efficiency (min)	0.87	
Gelman-Rubin Rc (max)	1	

Source: Authors' estimation.

Table 6. Results of estimating the financial development threshold values.

Threshold effect test	Threshold value for the financial market index (λ_a)			Threshold value for the financial institution index (λ_b)		
Single	30.99*** (0.00)			18.11* (0.09)		
Double	4.25 (0.57)			13.48 (0.13)		
Threshold estimator	Threshold	Lower	Upper	Threshold	Lower	Upper
λ	0.38	0.37	0.40	0.68	0.58	0.69

Note.

*** $p \leq 0.01$.* $p \leq 0.1$.

Source: Authors' estimation.

green GDP may differ in the areas below and above these threshold values, which aligns with Models 2a and 2b. Consequently, the authors estimate the impact of FDI on green GDP in the regions before and after these threshold values. Specifically, FDI1a and FDI2a represent FDI in the areas before and after the threshold λ_a , while FDI1b and FDI2b indicate FDI in the areas below and above the threshold λ_b .

Like Model 1, the authors perform hypothesis tests for Models 2a and 2b, with results demonstrated in Table 7. To be specific, the findings report that multicollinearity in Models 2a and 2b is not serious; however, these models violate other regression assumptions, specifically, issues of heteroscedasticity, autocorrelation, and endogeneity. Therefore, the GMM regression is employed to estimate Models 2a and 2b.

Table 8 indicates that the results of estimating Models 2a and 2b using the GMM regression are appropriate and valid. Specifically, the results for Model 2a indicate that FDI1a has a negative impact (-0.04) on green GDP when FMI is below the threshold value of 0.38. This effect becomes positive and stronger (0.07) once the threshold is exceeded. For the control variables, government expenditure (GOV)

Table 7. Results of testing the hypotheses for the model of FDI's impact on green GDP under the moderation of financial development thresholds.

Model	Test for heteroscedasticity	Test for autocorrelation	Mean VIF	Test for endogeneity
Model 2a	49.99*** (0.00)	335.32*** (0.00)	1.85	9.16*** (0.00)
Model 2b	69.62*** (0.00)	626.66*** (0.00)	1.72	12.91*** (0.00)

Note.

*** $p \leq 0.01$.

Source: Authors' estimation.

Table 8. Results of estimating the impact of FDI on green GDP under the moderation of financial development thresholds using GMM regression.

Green_GDP	Model 2a	Model 2b
FDI1a (FMI ≤ 0.38)	-0.04** (0.02)	
FDI2a (FMI > 0.38)	0.07*** (0.00)	
FDI1b (FII ≤ 0.68)		-0.04** (0.04)
FDI2b (FII > 0.68)		0.08*** (0.00)
GOV	0.06*** (0.00)	0.02* (0.08)
INF	-0.01** (0.05)	-0.05*** (0.00)
TEC	0.03*** (0.00)	0.02*** (0.00)
_cons	6.19*** (0.00)	7.24*** (0.00)
Wald chi2	3,712.11*** (0.00)	2,192.89*** (0.00)
Arellano-Bond test	AR(1) AR(2)	-2.77*** (0.01) 0.99 (0.32)
Sargan test	0.41 (0.52)	5.09 (0.17)

Note.

*** $p \leq 0.01$.

** $p \leq 0.05$.

* $p \leq 0.1$.

Source: Authors' estimation.

and technology (TEC) are positively associated with Green_GDP, whereas inflation (INF) has a negative impact on Green_GDP. For Model 2b, the results are quite similar to those found in Model 2a. Specifically, FDI1b negatively affects (-0.04) green GDP when FII is below the threshold value of 0.68. This effect turns out to be positive and much stronger (0.08) once the threshold is exceeded. The results for the control variables are also consistent with those shown in Model 2a. An interesting finding of this study is that the level of financial institution development appears to be more effective than financial market development in moderating the impact of FDI on green GDP. Indeed, the threshold λ_b of the financial institution index has reinforced the impact of FDI on green GDP from -0.04 (below the threshold) to 0.08 (above the threshold), with this amplification being stronger compared to the threshold value λ_a of the financial market index (where the effect increases from -0.04 below the threshold to 0.07 above the threshold). This affirms that the positive impact of FDI on green GDP becomes evident only when the financial market and financial institution development indicators reach certain levels, specifically exceeding their respective threshold values of $\lambda_a = 0.38$ and $\lambda_b = 0.68$. Notably, the amplification of the financial institution development threshold is stronger than that of the financial market development threshold in enhancing the impact of FDI on green GDP.

Table 9 presents the results of estimating the impact of FDI on green GDP under the influence of the financial development thresholds, using Bayesian regression. The results for both Models 2a and 2b are appropriate and valid. As expected, the Bayesian estimates (Table 9) align perfectly with the GMM estimates (Table 8), confirming the robustness of Models 2a and 2b. Furthermore, the results reveal that in both Models 2a and 2b, the probability of a positive effect of FDI on green GDP above the threshold is 100%, which is higher than the probability of a negative effect (95%) below the threshold. This is an intriguing finding of the study.

4.4. Discussion

The estimation results from Model 1 indicate that FDI plays a significant role in promoting green GDP in the ASEAN-6 countries. Moreover, the findings from Models 2a and 2b reveal that financial development plays a key role in amplifying the impact of FDI on green GDP. This is evident in both cases where

Table 9. Results of estimating the impact of FDI on green GDP under the moderation of financial development thresholds using Bayesian regression.

Green_GDP	Model 2a		Model 2b	
	Mean	Probability	Mean	Probability
FDI1 _a (FMI ≤ 0.38)	−0.05 [−0.12; 0.01]	0.95		
FDI2 _a (FMI > 0.38)	0.08 [0.07; 0.10]	1		
FDI1 _b (FII ≤ 0.68)			−0.04 [−0.08; 0.01]	0.95
FDI2 _b (FII > 0.68)			0.09 [0.08; 0.10]	1
GOV	0.07 [0.04; 0.11]	1	0.09 [0.06; 0.13]	1
INF	−0.02 [−0.05; 0.41 × 10 ^{−2}]	0.95	−0.34 × 10 ^{−2} [−0.03; 0.02]	0.61
TEC	0.02 [0.02; 0.03]	1	0.02 [0.02; 0.03]	1
_cons	6.06 [5.62; 6.49]		6.05 [5.65; 6.44]	
Avg acceptance rate	1		1	
Avg efficiency (min)	0.87		0.88	
Gelman-Rubin Rc (max)	1		1	

Source: Authors' estimation.

financial development is measured through the financial market index and the financial institution index. Specifically, the positive effect of FDI on green GDP becomes apparent only when the financial market development and financial institution development indices surpass the respective threshold values of $\lambda_a = 0.38$ and $\lambda_b = 0.68$. More importantly, financial institutions prove to be more effective than financial markets in highlighting the impact of FDI on green GDP, which is a novelty of this study.

4.4.1. Discussion on the impact of FDI on green GDP

The estimation results from Model 1 reveal that FDI exerts a positive effect on green GDP, with a 100% probability of occurrence. Therefore, hypothesis H_1 is accepted. This suggests that FDI provides vital financial resources for the ASEAN-6 countries to support green GDP. More than that, FDI stimulates green GDP growth by fostering technological innovation and improving the quality of the labor force in these countries. These findings are in line with the theories of economic growth and the technical effects related to environmental protection. The study's results also confirm previous conclusions by Yue et al. (2016), Phung et al. (2023), Xiao et al. (2023), and Wani et al. (2024). Although the positive impact of FDI on green GDP has been revealed in prior research, this study contributes to the existing literature by providing new insights. First, this research employs a combination of GMM and Bayesian regressions to clarify and enhance the robustness of the findings, distinguishing it from previous studies. Specifically, the estimation results from the Bayesian regression model indicate a 100% probability of a positive impact of FDI on green GDP, which is in line with the results obtained from the GMM regression model. Furthermore, this study utilizes a sample consisting of the six leading countries in the ASEAN region. This provides significant empirical evidence that supplements the existing literature and offers a reliable foundation for the ASEAN-6 countries to develop appropriate economic policies to further promote green GDP growth. These findings are in line with the ASEAN-6 countries' actual circumstances. Specifically, Figure 1 demonstrates that FDI positively impacts green GDP in most of the countries, particularly in those with high levels of FDI and green GDP, such as Singapore, which is actively working to become a green financial hub in Asia. However, some countries in the sample like Indonesia, the Philippines, and Vietnam, have relatively low levels of both FDI and green GDP. In recent years, the ASEAN-6 countries have implemented numerous policies aimed at attracting FDI and stimulating green GDP growth. Nevertheless, the execution of these policies has faced certain challenges, including optimizing the economic benefits of FDI and ensuring environmental quality during FDI attraction. Therefore, these countries need to make further efforts to refine policies to maximize FDI's impact, especially those that link FDI attraction with environmental improvements, which is crucial for long-term green GDP growth.

4.4.2. Discussion on the impact of FDI on green GDP under the moderation of the financial market development threshold

The estimation results for Model 2a indicate the existence of a threshold value for the financial market index at $\lambda_a = 0.38$. Specifically, the positive effect of FDI on green GDP becomes obvious when the financial market index exceeds this threshold, thereby confirming hypothesis H_{2a} . This means that

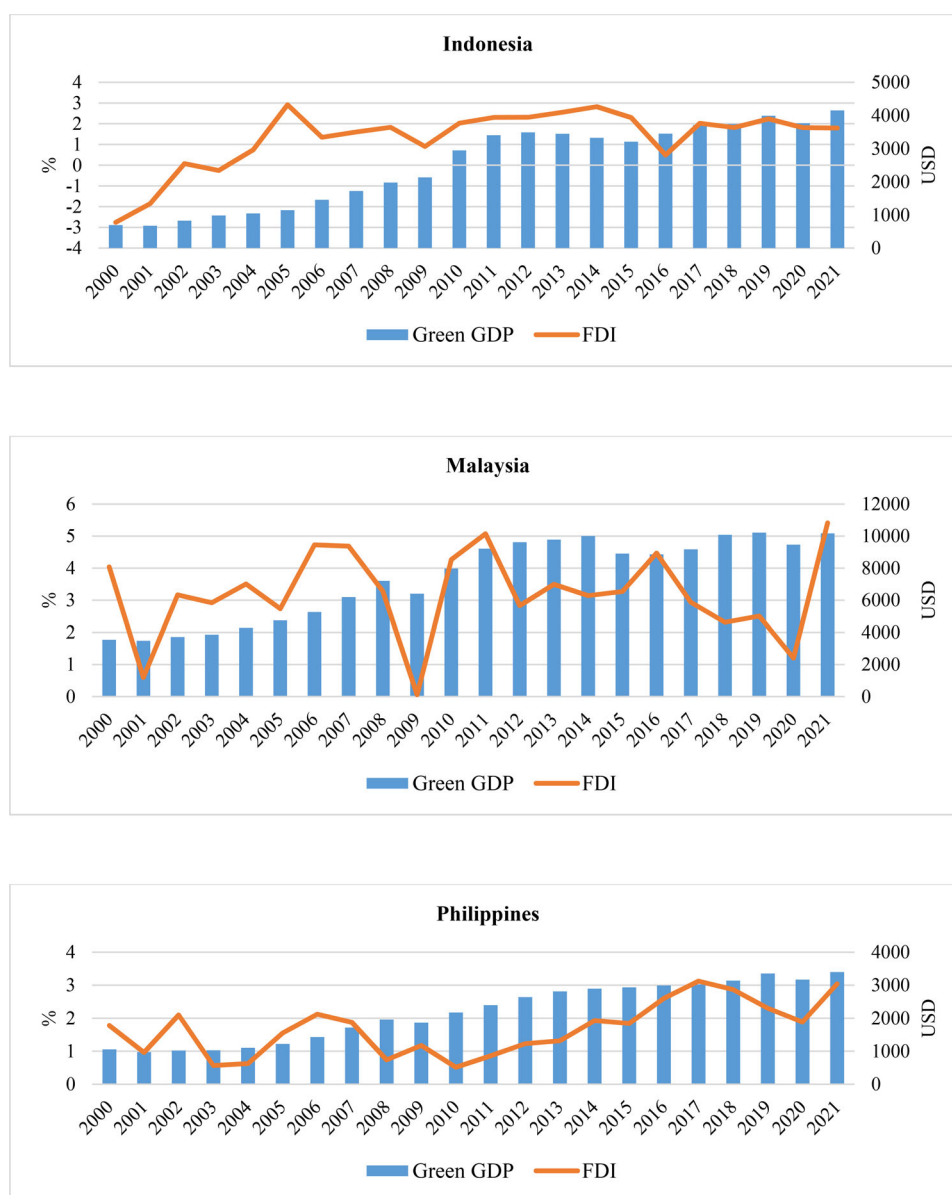


Figure 1. FDI and green GDP in the ASEAN-6 countries.

financial markets can moderate the extent of FDI's impact on green GDP, with this moderating role only proving effective when financial markets have developed to a certain level, particularly when they go beyond the threshold value. If the financial market is underdeveloped, FDI capital may not be effective for the economy and could even harm environmental quality (Ozturk & Acaravci, 2013; Sadorsky, 2011). A well-developed financial market, on the other hand, supports companies by offering favorable conditions for effectively utilizing FDI, facilitating access to both FDI and domestic capital, improving risk management capabilities, and even motivating companies to enhance technology in the long term. This is a critical foundation for the ASEAN-6 countries to promote green GDP. These findings are consistent with previous observations by Agbloyor et al. (2014) and Nguyen (2022). A key distinction of this study is the measurement of financial market development through a composite index, rather than relying solely on the financial market size relative to GDP, as in previous studies. In practice, the ASEAN-6 countries have made significant efforts to formulate policies aimed at developing financial markets recently. These policies have achieved certain successes in expanding market size, enhancing efficiency, improving accessibility, and increasing market stability. However, these efforts are limited, as they lack sufficient focus on developing green capital markets, including green equity and bond markets. This limitation has caused certain challenges in promoting green GDP across the countries.

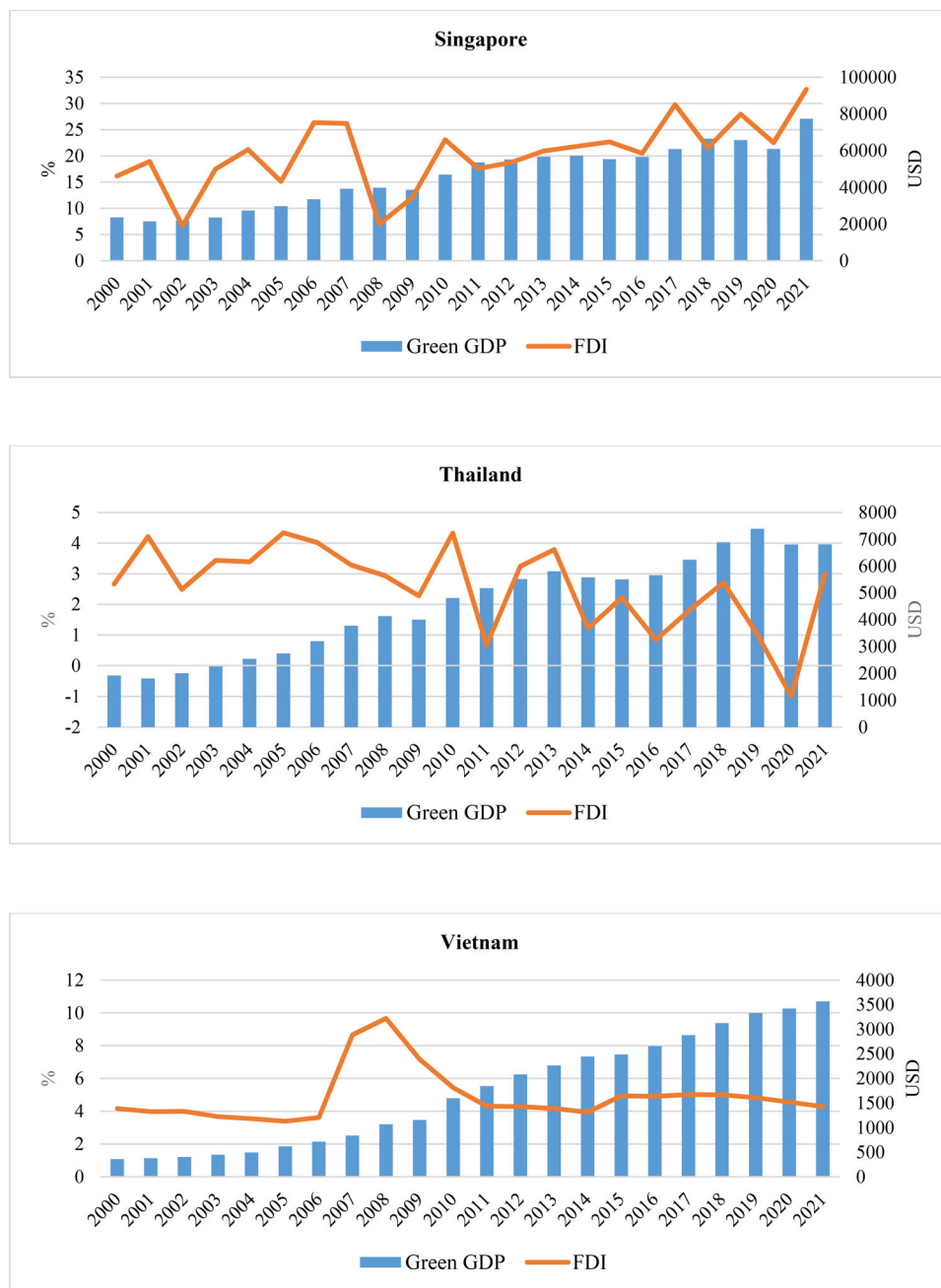


Figure 1. Continued.

In practice, some countries in the sample, such as Indonesia, the Philippines, and Vietnam, currently have financial market development levels below the threshold value (Table 10). Thus, in order to maximize FDI's contribution to green GDP, these nations must prioritize promoting the development of their financial markets in order to exceed the threshold value. For instance, in the case of Vietnam, the financial market index (FMI) exceeded the threshold value in most years prior to 2010 but fell below this threshold in most years afterward. Within the study sample, Vietnam's FMI fluctuates the most across the threshold boundary, which prompted the authors to select it for further discussion. Specifically, between 2005 and 2008, Figure 1 indicates that Vietnam experienced significant increases in both FDI and green GDP while the FMI was above the threshold. However, from 2011 onward, the positive impact of FDI on green GDP is less evident, as this period corresponds to Vietnam's FMI falling below the threshold, with limited improvement in FDI levels.

Table 10. Comparison of the financial market index with the threshold value ($\lambda_a = 0.38$) across the countries.

Year	Indonesia	Malaysia	Philippines	Singapore	Thailand	Vietnam
2000	B	A	A	A	A	A
2001	B	A	B	A	A	B
2002	B	A	B	A	A	A
2003	B	A	B	A	A	A
2004	B	A	B	A	A	B
2005	B	A	B	A	A	A
2006	B	A	B	A	A	A
2007	B	A	B	A	A	A
2008	A	A	B	A	A	A
2009	B	A	B	A	A	A
2010	B	A	B	A	A	A
2011	B	A	B	A	A	B
2012	B	A	B	A	A	B
2013	B	A	B	A	A	B
2014	B	A	B	A	A	A
2015	B	A	B	A	A	B
2016	B	A	B	A	A	B
2017	B	A	B	A	A	B
2018	B	A	B	A	A	B
2019	B	A	B	A	A	B
2020	B	A	B	A	A	B
2021	B	A	B	A	A	B

Note. A: FMI > 0.38, B: FMI ≤ 0.38.

Source: Authors' work.

4.4.3. Discussion on the impact of FDI on green GDP under the moderation of the financial institution development threshold

The estimation results for Model 2b reveal a threshold value for the financial institution index at $\lambda_b = 0.68$. The positive impact of FDI on green GDP becomes evident when the level of financial institution development exceeds this threshold, thereby accepting Hypothesis H_{2b} . This implies that underdeveloped financial institutions can reduce the effectiveness of FDI on green GDP, which is in line with previous findings by Yeboua (2019). Nevertheless, once financial institutions reach a certain level of development, specifically beyond the threshold value, FDI can have a significant positive impact on green GDP. This is comprehensible as well-developed financial institutions help foreign investors save time and costs when accessing and using financial services Pradhan et al. (2014) and can even boost the efficiency of investment supervision and enhance risk management capabilities (Bertocco, 2008). The impact of FDI on green GDP can therefore be moderated by the level of financial institution development, with FDI only showing significant effects when financial institutions develop above the threshold value. This aligns with previous findings of Azman-Saini et al. (2010) and Yeboua (2019). The research is new, though, because it employs a composite index to measure financial institution development instead of just the credit-to-GDP ratio, as in earlier studies. Notably, financial institutions prove to be more effective than financial markets in amplifying the impact of FDI on green GDP, which is a new finding of this study. This finding is fully suitable with the reality in the ASEAN-6 countries, where financial markets are still relatively nascent and face limited. Their financial institutions, particularly commercial banks, still play a dominant role in providing medium- and long-term capital to the economy. Therefore, the fact that financial institutions are more effective than financial markets in amplifying the impact of FDI on green GDP is highly appropriate. It is evident that financial institutions continue to play a dominant role in providing capital to the ASEAN-6 economies. To reinforce this role, these countries have implemented various policies aimed at developing financial institutions, particularly in increasing capital provision capacity and managing risks amidst global economic fluctuations. However, the lack of emphasis on green credit policies in these countries presents a major obstacle to advancing green GDP growth and enhancing environmental quality.

Several countries in the sample, including Indonesia, the Philippines, and Vietnam, have financial institution development levels below the threshold (Table 11). As a result, promoting financial institution development beyond the threshold value is crucial for these countries to enhance the effectiveness of FDI on green GDP. Meanwhile, Singapore is the only country in the sample to exhibit both FMI and FII consistently above the threshold throughout the study period (Tables 10 and 11). Interestingly, Figure 1

Table 11. Comparison of the financial institution index with the threshold value ($\lambda_b = 0.68$) across the countries.

Year	Indonesia	Malaysia	Philippines	Singapore	Thailand	Vietnam
2000	B	B	B	A	B	B
2001	B	B	B	A	B	B
2002	B	B	B	A	B	B
2003	B	B	B	A	B	B
2004	B	B	B	A	B	B
2005	B	B	B	A	B	B
2006	B	B	B	A	B	B
2007	B	B	B	A	B	B
2008	B	B	B	A	B	B
2009	B	B	B	A	B	B
2010	B	B	B	A	B	B
2011	B	A	B	A	B	B
2012	B	A	B	A	B	B
2013	B	A	B	A	B	B
2014	B	A	B	A	A	B
2015	B	A	B	A	A	B
2016	B	A	B	A	A	B
2017	B	A	B	A	A	B
2018	B	B	B	A	A	B
2019	B	A	B	A	A	B
2020	B	A	B	A	A	B
2021	B	A	B	A	A	B

Note. A: FII > 0.68, B: FII ≤ 0.68.

Source: Authors' work.

clearly illustrates a positive relationship between FDI and green GDP in Singapore over the entire period. This finding supports the validity of the research results and underscores the importance of exceeding the FMI and FII thresholds for the other countries.

4.4.4. Discussion on the impact of the control variables on green GDP

The estimation results of Models 1, 2a, and 2b consistently show that green GDP is positively influenced by government spending (GOV) and technology (TEC), while it is negatively affected by inflation (INF). Thus, in line with the economic development theories, the promotion of green GDP in the ASEAN-6 countries is mostly dependent on government investment and technological advancement. On the other hand, increased inflation can lead to significant challenges for the economy, hindering efforts to boost green GDP in these countries. These findings are consistent with previous studies by Tamazian and Rao (2010), Asongu and Odhiambo (2020), and Phung et al. (2023). This highlights that, in addition to FDI, these countries should pay more attention to government spending, technological infrastructure, and macroeconomic stability. Acknowledging this, the ASEAN-6 countries have implemented various policies to improve the investment environment and facilitate the promotion of green GDP. These efforts include policies focused on increasing government spending, maintaining macroeconomic stability, and enhancing technological infrastructure innovation. However, these policies encounter certain challenges, particularly in improving the efficiency of government spending, ensuring macroeconomic stability amid significant global economic fluctuations, and advancing technology infrastructure to keep pace with global developments.

5. Conclusion and policy implications

5.1. Conclusion

The objectives of this study are to analyze the impact of FDI on green GDP in the ASEAN-6 countries and to examine the moderating role of the financial development threshold in this impact, which is a novel aspect compared to previous research.

This study has achieved its research objectives by analyzing the impact of FDI on green GDP in the ASEAN-6 countries and clarifying the moderating role of financial development thresholds in this impact. First, the authors employ GMM regression to estimate the impact of FDI on green GDP, combined with Bayesian regression to test the robustness of the results. The estimation results indicate that FDI positively impacts green GDP in the ASEAN-6 countries. This finding supports the conclusions of most prior studies while affirming the relevance of related theories, such as the neoclassical growth theory (Solow, 1956), endogenous growth theory (Romer, 1990), and the concepts of scale effect and technique effect (Bakhsh

et al., 2017; Copeland & Taylor, 1994; Grossman & Krueger, 1991; He, 2008). However, a notable contribution of this study is demonstrating that the probability of FDI affecting green GDP is certain, which means that this impact occurs with a probability of 100%. To identify the moderating role of financial development in the impact of FDI on green GDP, the authors use the threshold effects proposed by Hansen (1999) and Wang (2015) to estimate the threshold values for the financial market index and the financial institution index, respectively. According to the estimation results, there exist threshold values for the financial market index ($\lambda_a = 0.38$) and the financial institution index ($\lambda_b = 0.68$), respectively. This supports previous findings by Azman-Saini et al. (2010), Agbloyor et al. (2014), Yeboua (2019), Ibhagui (2020), Osei and Kim (2020), and Nguyen (2022), while affirming the relevance of the theory of financial intermediation (Allen & Santomero, 1997; Diamond, 1984; Gurley & Shaw, 1960). However, a noteworthy distinction in this study is the identification of a threshold value for financial development, which is measured through a composite index representing the overall development level of financial markets and institutions. This approach differs from most prior studies, which primarily focus on financial depth as a key indicator. Furthermore, the results from both GMM and Bayesian regressions show that the positive impact of FDI on green GDP is only significant when the levels of financial market development and financial institution development exceed these threshold values. Financial institutions are especially to be more effective than financial markets in amplifying this impact, which is a new finding of this study. In addition, the results indicate that green GDP is positively influenced by government spending and technology, while it is negatively impacted by inflation. Overall, this study contributes to knowledge and academia in several areas, including generalizing the impact of FDI on green GDP and clarifying the moderating role of financial development thresholds in this impact. The findings are meaningful in providing empirical evidence to the existing literature, refining the theoretical framework, and affirming the relevance of related theories. In addition, they offer a solid foundation for these countries to develop effective economic policies aimed at attracting more FDI while simultaneously promoting green GDP.

5.2. Policy implications

The findings reveal that FDI can positively influence green GDP in the ASEAN-6 countries. However, this positive effect becomes more pronounced when financial development reaches certain threshold values. Specifically, the financial market index and the financial institution index must exceed the respective threshold values of $\lambda_a = 0.38$ and $\lambda_b = 0.68$. Based on these findings, the authors suggest the economic policies related to FDI in the moderation of the financial development thresholds to enhance green GDP in ASEAN-6 countries as follows:

5.2.1. Implications related to financial development for amplifying the positive impact of FDI on green GDP in the ASEAN-6 countries

The results confirm that the development level of financial markets and institutions plays a key role in regulating the impact of FDI on green GDP in the ASEAN-6 countries. More specifically, when financial markets and institutions reach higher development levels than the threshold values, the positive impact of FDI on green GDP is amplified. Therefore, they must promote their financial markets and institutions to facilitate the effective use of FDI for enhancing green GDP. This issue is particularly important for countries with financial market and institutional development levels below the thresholds, such as Indonesia, the Philippines, and Vietnam. To obtain this, financial development - which includes financial markets and institutions - must be thoroughly enhanced. Financial markets should further enhance the role of these markets, particularly by focusing on the development of green capital markets, including green stock and green bond markets. This foundation will facilitate green investment activities by providing easier access to capital at lower costs. To achieve this, these countries need to gradually build and refine standards and regulatory systems related to green bonds and green stock markets. For financial institutions, especially commercial banks, their role is crucial in channeling and connecting capital between investors and those in need. Therefore, these countries should keep utilizing the financial institutions' essential role in advancing green GDP. Their financial institutions need to work much harder to increase the amount of capital they can supply to the economy, especially green credit. To be specific, financial institutions should focus on projects related to environmental protection, energy efficiency, and

the use of advanced and environmentally friendly technologies. Furthermore, they must give top priority to improving green credit standards, which will guide the selection, evaluation, and monitoring of green credit. Additionally, domestic credit institutions should enhance international cooperation in financing green projects. Long-term credit policies should be created and upheld with an emphasis on risk prevention in capital provision, especially through the integration of environmental, social, and governance (ESG) factors. Some detailed implications for the countries are suggested as follows:

5.2.1.1. For Indonesia, the Philippines, and Vietnam. Their financial market and financial institution development levels are currently below the thresholds (as shown in Table 10 and Table 11), so it is crucial to develop their financial markets and institutions, especially to surpass the identified threshold value. This is essential for enhancing the effectiveness of FDI on green GDP in these countries. To achieve this, in addition to the general implications mentioned earlier, these countries should focus on strengthening the primary role of financial institutions in supplying capital to the economy, particularly by promoting green credit. Besides, these countries should place greater emphasis on the comprehensive development of financial institutions, ensuring balanced growth between banks and other financial institutes. They also need to establish and diversify financial products, especially those tailored to the renewable energy sector and environmental protection objectives. For the financial market, these countries need to undertake a comprehensive restructuring, with a particular focus on developing the green capital market, advancing market classification, and enhancing global integration. They also should concentrate on diversifying financial instruments, thereby creating favorable conditions for attracting foreign investors and improving investment efficiency and risk management in the market.

5.2.1.2. For Malaysia and Thailand. These countries have maintained a financial market development level above the thresholds throughout the study period (as shown in Table 10). Furthermore, the development level of financial institutions has improved, transitioning from below to above the threshold since 2011 for Malaysia and since 2014 for Thailand (as shown in Table 11). It can be observed that these two countries have gained significant achievements in financial development, particularly in improving the level of financial institution development beyond the thresholds in recent years. In the future, these countries should continue to sustain and enhance their financial development in both financial markets and institutions. In specific, these countries should aim to promote green credit capital, including increasing funding for renewable energy sectors and environmental protection goals. Additionally, they need to continue improving financial tools that encourage international investment to generate resources for environmental protection solutions and sustainable development.

5.2.1.3. For Singapore. This is the only country in the study sample with financial market and institution development levels consistently above the threshold throughout the period (as shown in Table 10 and Table 11). In practice, Singapore is positioning itself to become a green financial hub in Asia. To achieve this goal, Singapore needs to continue developing green financial instruments and attracting international investors to support green projects. Moreover, Singapore's financial institutions and companies should strictly adhere to ESG standards. This commitment is a crucial foundation for building trust among international investors and attracting FDI to support Singapore's green GDP growth.

5.2.2. Implications related to FDI for promoting green GDP in the ASEAN-6 countries

The ASEAN-6 countries should enhance their capacity to attract and effectively utilize FDI, as it is an essential financial resource for promoting green GDP, particularly for capital-constrained countries. Moreover, FDI helps them easily access advanced and environmentally friendly technologies as well as management practices. FDI attraction should be focused more on sectors where the ASEAN-6 countries have competitive advantages, especially those requiring high technology and projects aimed at fostering economic growth coupled with protecting the environment. In order to guarantee a long-term, coordinated, and consistent strategy across all levels of government, from upper to lower, their FDI attraction policies need to be refined. Together with increasing FDI, they should also improve domestic resource utilization to create a favorable environment for enhancing FDI efficiency and avoiding over-dependence on foreign capital. Achieving this will enable them to enhance economic stability and become more proactive in allocating resources in order to support green

GDP. Furthermore, they need to ensure the protection of foreign investors' interests and build their trust, particularly by maintaining equality between domestic and foreign investors. These measures are essential for enhancing the capacity to attract FDI. Some specific implications for the countries are suggested as follows:

5.2.2.1. For Indonesia, the Philippines, and Vietnam. These countries currently have the lowest levels of FDI and green GDP in the sample (Figure 1). Therefore, attracting FDI to stimulate green GDP growth is crucial for these nations. To obtain this, they need to make greater efforts to attract FDI, particularly in sectors related to renewable energy development and environmental protection. Furthermore, these countries should place additional emphasis on improving their domestic investment environments, especially regarding administrative procedures and legal regulations for foreign investors. Besides, it is vital to develop infrastructure and technology as it creates favorable conditions to enhance FDI attraction and its investment efficiency.

5.2.2.2. For Malaysia and Thailand. With their moderate levels of FDI and green GDP (Figure 1), they need to continue enhancing their capacity to attract FDI linked to green GDP. Moreover, these countries could aim to establish green industrial zones, which would offer good conditions for foreign investors in green projects, especially those that significantly benefit environmental quality.

5.2.2.3. For Singapore. This country has reached the highest levels of FDI and green GDP in the sample (Figure 1). Singapore should actively encourage the development of green financial products in order to become Asia's green financial hub in the future. Furthermore, Singapore needs to impose stricter regulations on ESG compliance among companies, particularly FDI enterprises. This approach will improve the effectiveness of FDI in contributing to green GDP while also accelerating Singapore's transition toward a leading green financial center.

5.2.3. Implications for promoting green GDP in the ASEAN-6 countries

The findings indicate that green GDP is positively influenced by government spending and technology, but negatively affected by inflation. To promote green GDP, the ASEAN-6 countries need to implement a comprehensive set of economic policies, particularly those addressing the control variables identified in the research models. For government spending, these countries should keep increasing their government expenditures, putting a focus on distributing resources to essential industries, cutting waste, and fostering environments that promote economic growth while protecting the environment. For technology, the results prove the importance of technological infrastructure for the countries to advance green GDP. They, consequently, need to intensify technological investments and management, improve access to modern technologies, and mitigate risks associated with technology adoption for individuals and companies. They might also seek more privatization of technology development, draw in foreign capital, and promote fair competition in the field. For inflation, they should focus on keeping it under control to create a favorable atmosphere for attracting and making good use of FDI, thereby promoting green GDP. Additionally, they should place greater emphasis on forecasting macroeconomic trends to be more proactive in developing and implementing policies that promote green GDP. They will be able to adjust policies effectively in response to economic fluctuations with the help of accurate and timely macroeconomic forecasting, guaranteeing that green growth objectives are consistently prioritized.

Overall, to establish a favorable investment environment, the ASEAN-6 countries must undertake a complete set of policies in addition to improving their capacity to attract and efficiently utilize FDI. This should include focusing on improving domestic financial systems, controlling inflation, increasing government spending, and modernizing technological infrastructure. These are the key foundations for promoting green GDP in these countries.

5.3. Further research suggestions

There are several limitations to the research, even though it successfully achieved its objectives by examining how FDI affects green GDP in the ASEAN-6 nations and elucidating the moderating effect of financial development thresholds in this relationship. The study was unable to conduct a country-specific data

analysis or compare estimation results across different groups of countries globally. In fact, these are prominent nations within the ASEAN region, sharing certain similarities; however, they are not entirely alike. Consequently, analyzing a pooled dataset for the ASEAN-6 countries may have certain limitations. If the country data could be individually analyzed, it might reveal more nuanced findings. Additionally, the control variables used in this research are commonly employed in prior studies, but there may be other control variables that affect green GDP that were not considered. Indeed, beyond the factors included in this paper, the relationship between FDI and green GDP may be influenced by non-economic factors, such as political stability, governance quality, or environmental regulations. There may even exist unobservable factors or insufficient data for certain variables that could impact green GDP or change the financial development threshold. Another limitation is that this paper focuses on using both GMM and Bayesian regression to assess the robustness of the findings. In addition to this approach, future research could incorporate methods such as sensitivity analysis or explore alternative models to further support the findings and validate their robustness. Furthermore, future research could explore country-specific data analysis or even compare estimation results between country groups globally to highlight differences. Moreover, future studies could incorporate additional control variables to better align with the characteristics of each country and dataset. More than that, future research could explore the role of FDI in other regions or examine additional moderating factors (such as technological development, political stability, governance quality, or environmental regulations) in the relationship between FDI and green GDP.

Authors' contribution

Substantial contributions to the conception or design of the work: Ngoc Toan Bui. The acquisition, analysis, or interpretation of data for the work and drafting of the work: Thu-Trang Thi Doan. Reviewing it critically for important intellectual content: Ngoc Toan Bui. Final approval of the version to be published: Ngoc Toan Bui. All authors have read and agreed to the published version of the manuscript.

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Data availability statement

Data were obtained from the World Bank (<https://data.worldbank.org/>) and International Monetary Fund (<https://data.imf.org/?sk=f8032e80-b36c-43b1-ac26-493c5b1cd33b>) databases.

Data will be made available on request from the corresponding author (Thu-Trang Thi Doan, doanthithutrang@iuh.edu.vn).

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