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Enhancing resource efficiency through the utilization of the green bond market: An empirical analysis of Asian economies☆

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ABSTRACT

This research explores the effects of the green bonds market on resource efficiency across 12 actively involved Asian economies from 2015 to 2022. The empirical results indicate a positive connection between green bond issuance and resource efficiency, suggesting that a 1% increase in green bonds corresponds to significant short-term (0.33%) and long-term (0.43%) improvements. Surprisingly, a negative relationship is observed between GDP growth and resource efficiency, implying that economic expansion may contribute to heightened resource consumption. The study highlights the favorable impact of renewable power generation on resource efficiency, driven by the sustainability of renewable energy sources. Nevertheless, challenges arise from poverty ratios and consumer price indices, impeding the adoption of resource-efficient technology. Furthermore, while cell phone penetration initially benefits resource efficiency, a negative correlation emerges in the long term due to increased non-renewable energy consumption. In light of these findings, the study recommends practical policies for sustainable development, including actively promoting the green bonds market, targeted investments in renewable energy, and initiatives to address economic disparities while encouraging resource-efficient practices.

1. Introduction

The urgent threat posed by climate change serves as a compelling call for global action. In the aftermath of the pandemic, a distinctive opportunity emerges in the form of a green recovery (Zachariadis et al., 2023). This approach not only addresses the economic and social challenges exacerbated by the pandemic but also paves the way toward a sustainable future. Essential to this initiative is the adoption of a process that transitions towards a low-carbon footprint. By investing in renewable energy, sustainable infrastructure, and green technologies, societies can simultaneously stimulate economic growth, create employment opportunities, and mitigate the adverse impacts of climate change (Briggs et al., 2022; Saboori et al., 2022; Sun et al., 2023). This pivotal moment requires international collaboration, forward-thinking policies, and a shared commitment to usher in an era characterized by resilience and sustainability, prioritizing the well-being of the planet and its inhabitants.

Recognizing the paramount importance of financing the transition to a low-carbon paradigm is essential in confronting the urgent challenges posed by climate change. Adequate funding for this shift towards a low-carbon portfolio is the key to unlocking a sustainable future (Hu et al., 2023; Cheng et al., 2023). The magnitude of this transformation requires substantial investments in clean energy, sustainable transportation, and eco-friendly technologies. By directing financial resources into these initiatives, we can not only reduce greenhouse gas emissions but also foster innovation and drive economic growth (Ren et al., 2023; Su et al., 2023). The financial sector plays a critical role in mobilizing capital for environmentally responsible projects, expediting the transition to a low-carbon economy. Gao and Chen (2023) assert that, at this pivotal moment in the battle against climate change, allocating financial resources to this cause is not merely an investment in the environment but also a testament to a commitment to safeguard the planet for future generations.

Green bonds serve as crucial mechanisms for financing the shift to a low-carbon portfolio and advancing sustainable development (Tu et al., 2020). Its market size has expanded from over 37 billion USD in 2014 to over 487.1 billion USD in 2022, expected to reach 914.4 billion USD by 2030. These financial instruments are intricately crafted to generate

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capital for projects that yield environmental benefits. Specifically, Ye and Rasoulinezhad (2023) express that green bonds provide investors with the means to champion initiatives like renewable energy projects, energy-efficient building endeavors, and the establishment of sustainable transportation systems. By directing funds toward these environmentally responsible projects, green bonds establish a tangible connection between financial investments and positive environmental outcomes (Li et al., 2023). These instruments not only serve as a financial tool but also act as a catalyst for promoting eco-friendly endeavors on a broader scale. The issuance and uptake of green bonds contribute to the overall momentum in fostering environmentally conscious Ye and Rasoulinezhad (2023)investments, thereby encouraging the development of innovative solutions to address pressing environmental challenges (Rasoulinezhad, 2022). In doing so, green bonds play a dual role in shaping a sustainable future – not only by providing financial support to green projects but also by influencing a shift in investment behavior towards projects that align with ecological sustainability. n recent times, there has been a notable surge in the issuance of green bonds by corporate entities. The proportion of total corporate bonds designated as green increased significantly, rising from 4.7% in 2020 to 8.3% in 2021 and further to 11.0% in 2022 (Adekoya et al., 2023). The collective issuance of green bonds in Asia and Australia demonstrated growth, reaching $33.15 billion in the first quarter, compared to the previous year's $32.28 billion. A substantial portion of this increase can be attributed to the issuance of $5.50 billion in green bonds by Saudi Arabia's Public Investment Fund. India also experienced an uptick in issuance, marking a 34.6% increase to $2.06 billion. Notably, China emerged as the primary source of green bonds in 2022, recording a significant figure of USD 85.4 billion (RMB 575.2 billion) according to Climate Bonds Initiative (2022).

Financing projects related to resource efficiency is of paramount importance in light of the environmental consequences triggered by the overconsumption of natural resources. The relentless exploitation of resources, driven by growing global demands, has led to a myriad of ecological challenges such as deforestation, depletion of biodiversity, and the exacerbation of climate change (Li et al., 2023). These adverse effects underscore the urgency of adopting sustainable practices that prioritize resource efficiency. According to Zhao and Rasoulinezhad (2023), by directing financial support towards projects aimed at enhancing resource efficiency, we can address the root causes of environmental degradation. These projects may encompass innovations in recycling technologies, sustainable agricultural practices, and the development of circular economy models. Investing in resource efficiency not only mitigates environmental harm but also promotes long-term resilience by ensuring the responsible and sustainable use of finite resources (Yao et al., 2023). In essence, financing projects in resource efficiency is a strategic investment in the health of our planet, fostering a balance between human needs and the preservation of our precious natural resources for generations to come.

This study centers on a key research question, examining how the expansion of the green bonds market can act as a catalyst in promoting resource efficiency. The central hypothesis suggests that with the growth of the green bonds market, there will be a noticeable increase in funding for projects specifically aimed at improving resource efficiency. The research aims to empirically investigate this hypothesis through a comprehensive analysis focused on selected Asian countries. To assess this hypothesis, the paper will conduct an empirical exploration, utilizing data and case studies to scrutinize the relationship between the expansion of the green bonds market and the advancement of resource efficiency initiatives.

The decision to focus on Asian economies is motivated by the region's dynamic economic landscape, rapid industrialization, and the consequential strain on natural resources. By examining resource efficiency in Asian economies, the research aims not only to contribute to the global discourse on sustainable finance but also to provide insights into the distinctive challenges and opportunities in a region that holds a pivotal role in the global economy. The motivations behind this study are grounded in the necessity to foster sustainable development practices, address environmental concerns, and promote responsible resource utilization in a region that wields significant influence on the global stage.

This study yields significant insights into the relationship between green bonds and resource efficiency, with a specific emphasis on Asian economies. Firstly, by investigating how the expansion of the green bonds market can stimulate resource efficiency initiatives, the research offers valuable perspectives on the role of financial instruments in propelling sustainability practices. The empirical exploration, focusing on a set of Asian countries, enriches existing literature by providing region-specific insights, recognizing the diverse economic and environmental landscapes within Asia. Moreover, the study advances our understanding of the practical implications of green bonds in fostering resource efficiency projects, offering evidence-based guidance for sustainable finance strategies to policymakers and financial institutions. Additionally, the research illuminates the motivations behind studying resource efficiency in Asian economies, acknowledging the region's pivotal role in the global economy and the associated environmental challenges. Ultimately, this study contributes not only to academic discourse but also to real-world applications, deepening our understanding of how financial instruments can be harnessed to address urgent environmental concerns within the distinctive context of Asian economies.

The remaining sections of the paper are strategically structured to adeptly tackle the research objectives. Section 2 meticulously delves into the literature gap, providing a thorough review of pertinent studies. Shifting the focus to the transmission channels through which green bonds influence resource efficiency, Section 3 offers a detailed examination. Following this, Section 4 presents the empirical findings derived from the study. Finally, Section 5 serves as the conclusion, summarizing the key insights and implications drawn from the research. This organizational framework ensures a cohesive and logical progression through the paper's exploration of the relationship between green bonds and resource efficiency.

2. Literature gap

A comprehensive review of prior studies is essential to identify gaps in the literature and underscore the novel contributions of the present paper. This critical examination allows for a thorough understanding of the existing research landscape and the identification of areas where further investigation is warranted. In this context, the following mainstreams of literature are presented based on the existing body of knowledge.

The current literature places a strong emphasis on the imperative of pursuing sustainability and transitioning to a green economy, indicating a heightened awareness of the urgent need to address environmental challenges and cultivate long-term economic resilience. Buonocore and Pettoello-Mantovani's study (Buonocore and Pettoello- Mantovani, 2023) highlighted the economic repercussions of climate change, emphasizing the potential for severe disruptions and economic losses if sustainable practices are not adopted. Additionally, Wang et al.'s work (Wang et al., 2023) underscored the importance of incorporating environmental considerations into business practices for sustained viability. In the financial sector, research by Dmuchowski et al. (2023) showcased the business case for sustainability, illustrating that companies with robust environmental, social, and governance (ESG) practices tend to outperform their counterparts. Furthermore, the concept of a green economy, as articulated by Mealy and Teytelboym (2022), advocates for a paradigm shift towards environmentally sustainable practices, emphasizing the interconnectedness of economic, social, and environmental dimensions. This collective body of literature reflects a comprehensive acknowledgment of the intertwined relationship between environmental responsibility and economic success in contemporary discourse.

Second, there is a well-established body of research that delves into the effects of distinct green fiscal policies, as exemplified by notable works such as Yoshino et al. (2021) and Fang et al. (2023). Studies like Taghizadeh-Hesary et al. (2023) have confirmed that green bond is the most efficient green policy to promote projects of renewable energy sources. Boutabba and Rannou (2022) expressed that green bond market has positive contribution to expand participation of private investors in green projects. In other studies like Xu and Li (2023), and Sun (2023), the conclusions showed that expansion of green bond markets can lead to reduce carbon dioxide emissions as countries need less fossil fuels to consume and burn in industries, transportation and power plants.

The literature on resource efficiency in Asian countries forms a critical strand that addresses the unique challenges and opportunities in the region's pursuit of sustainable development. Notably, studies such as Nong et al. (2023) have examined resource efficiency as a key factor in mitigating environmental degradation and enhancing economic performance. This perspective is particularly relevant in the context of rapid industrialization and urbanization in many Asian nations. Research by Zhang et al. (2023) delves into the specific challenges faced by Asian economies in balancing economic growth with resource conservation, shedding light on the intricate relationship between resource efficiency and sustainable development. Moreover, Priyadarshini and Abhilash (2023) underscores the importance of transitioning to circular economic models, where resources are used more efficiently and waste is minimized.

While existing literature has made significant progress in exploring the connection between green finance and sustainability, a notable gap persists in examining the specific impact of the expansion of the green bonds market on resource efficiency. Although individual studies have addressed the influence of green financial instruments (Fang et al., 2023), there is a marked lack of comprehensive analyses that specifically delve into the consequences of the growing green bonds market for resource efficiency. The limited attention given to this intersection is particularly evident in the scarcity of empirical investigations into the direct linkage between the expansion of the green bonds market and the promotion of resource-efficient initiatives. Existing research has predominantly focused on broader aspects of sustainable finance, leaving a distinct void in understanding how the increasing prominence of green bonds may uniquely drive resource efficiency within the broader landscape of environmentally conscious investments. Moreover, the literature gap is even more pronounced when considering the context of Asia. Despite the region's pivotal role in the global economy and its unique environmental challenges, there is a conspicuous lack of research that specifically investigates how the expansion of the green bonds market influences resource efficiency in Asian countries. Given the diverse economic structures, developmental stages, and resource utilization patterns across Asian nations, understanding the localized impact of green bonds on resource efficiency becomes imperative.

3. Discussion on transmission channels

Within this section, our endeavor is to expound upon the transmission channels through which the mechanisms of green bonds can effectively stimulate the funding of low-carbon projects, especially in the fields of resource efficiency.

Green bonds exert a substantial influence on the financing of low-carbon portfolios, operating through diverse strategic avenues. Foremost, they establish a dedicated route for generating funds that are exclusively allocated to ecologically advantageous initiatives, such as the advancement of renewable energy projects and the development of sustainable infrastructure. This specialized funding approach not only expedites the realization of low-carbon aspirations but also resonates with conscientious investors who prioritize aligning their investment portfolios with sustainability imperatives. Furthermore, the inherent mechanisms of transparency and accountability associated with green bonds enhance investor confidence, thereby expanding the cohort of investors inclined toward enterprises involved in low-carbon pursuits (Taghizadeh-Hesary et al., 2023). By streamlining access to capital markets, green bonds effectively channel resources toward endeavors that actively contribute to emissions reduction and ecological fortification, thereby steering the trajectory toward a sustainable, low-carbon future.

In the aftermath of the COVID-19 pandemic, the significance of both green tax and green bonds has become increasingly apparent as pivotal policies driving sustainable development objectives. Green tax serves as an incentive for industries to adopt environmentally friendly practices while concurrently generating funds for sustainable projects. This dual approach addresses both economic recovery and ecological resilience, making green tax a strategic tool as governments globally formulate strategies to rebuild economies. It ensures that recovery efforts are in line with long-term sustainability goals. Similarly, green bonds have emerged as a crucial financial instrument for mobilizing capital toward sustainable initiatives. Post-pandemic economic revitalization requires investments that not only stimulate growth but also contribute to addressing climate challenges. Green bonds provide investors with an opportunity to support projects with positive environmental impacts while achieving financial returns. This dual benefit appeals to an expanding group of investors seeking opportunities that align with responsible and ethical investment practices.

4. Empirical model specification

In pursuit of the paper's objective to explore the impact of the green bonds market on the resource efficiency of Asian economies, a targeted selection of 12 Asian countries that actively issue green bonds has been made. These countries include Hong Kong, China, India, Indonesia, Japan, Korea (the Republic of), Malaysia, PRC, Philippines, Singapore, Taipei, China, and Thailand. The chosen timeframe for data analysis spans from 2015 to 2022. The rationale for commencing the analysis from 2015 is rooted in the fact that the inaugural issuance of corporate green bonds in Asia occurred in 2014, totaling $0.3 billion. To measure resource efficiency, the index proposed by Ye and Rasoulinezhad (2023) is employed as the dependent variable. Simultaneously, the paper utilizes data on issued green bonds obtained from the Climate Bonds Initiative, serving as the explanatory variable. Our empirical model incorporates control variables, including GDP, renewable power generation, poverty ratio, cell phone penetration, and the consumer price index. A detailed breakdown of the variables can be found in Table 1.

Envisioning the intricate interplay among our key variables, we advance the proposition that the Issued Green Bonds (GBI) will exert a positive influence on the Resource Efficiency Index (REI). This expectation stems from the presumption that a higher volume of green bonds signifies an increased infusion of financial support into environmentally sustainable initiatives, thereby fostering resource-efficient practices. Building on this, we anticipate a positive correlation between Green Domestic Product (GDP) and REI, positing that economies boasting a

Table 1
Variables' specification.

Variable	Symbol	Measurement unit	Origin of data
Resource Efficiency Index	REI	Index	Ye and Rasoulinezhad (2023)
Issued Green Bonds	GBI	Million USD	Climate Bonds Initiative
Green Domestic Product	GDOP	Current USD	World Bank
Renewable Power generation	RPGE	Gigawatt-hour	BP
Poverty ratio	PRAT	Ratio	World Bank
Cell phone penetration	CPR	Ratio	ITU
Consumer Price Index	CPI	Index	World Bank

Note: This table represents the information about the selected variables.
Source: Authors of the paper

higher GDP are more likely to allocate substantial resources toward environmentally conscious practices and innovations, thereby enhancing overall resource efficiency.

Moreover, the positive impact of Renewable Power Generation (RPG) on REI is envisaged, echoing the environmentally beneficial contributions associated with an increased reliance on renewable energy sources. This projection aligns with the global imperative to transition towards sustainable energy systems to optimize resource utilization and reduce environmental impacts. Conversely, our hypothesis introduces a nuanced perspective regarding the Poverty Ratio (PR) and its anticipated negative relationship with REI. Higher poverty levels may pose constraints on the allocation of resources to comprehensive environmental conservation efforts, potentially impeding progress in resource efficiency initiatives.

Anticipating the technological catalysts in our model, we posit that Cell Phone Penetration (CPP) will exert a positive influence on REI. The widespread availability and usage of mobile technology may facilitate greater access to information, education, and communication, thereby promoting sustainable practices and contributing to enhanced resource efficiency.

Finally, our expectations regarding the Consumer Price Index (CPI) introduce a nuanced perspective. While a higher CPI could suggest increased environmental awareness and demand for sustainable products, there is a simultaneous concern about the potential for heightened resource consumption.

To ascertain the genuine impact of independent variables on resource efficiency through empirical data, it is imperative to scrutinize potential cross-sectional dependencies within the variables. To address this, the Pesaran (2004) technique for cross-sectional dependency identification is judiciously applied. In the event of detected cross-sectional dependency within the panel, a subsequent step involves implementing Pesaran's second-generation unit root test from 2007, specifically the Cross-sectionally Augmented Dickey-Fuller (ADF) technique. This ensures a comprehensive examination of the data's stationarity and addresses potential biases arising from cross-sectional dependencies. Subsequently, a crucial step in the analysis involves verifying whether the variables exhibit long-term co-integration. The Westerlund (2007) approach, with its four critical statistics, is employed for this purpose. This assessment is pivotal in establishing a sustained relationship between the variables over time, providing a foundation for understanding their collective impact on resource efficiency.

Moving forward, the Cross-sectional Augmented Autoregressive Distributed Lag (CS_ARDL) technique proposed by Chudik and Pesaran (2015) is employed to delineate the short- and long-term coefficients of the independent variables. This advanced econometric method offers a nuanced understanding of the temporal dynamics governing the relationships between green bonds, economic indicators, and resource efficiency within the Asian economies under scrutiny. To fortify the robustness of our findings, a meticulous robustness analysis is conducted. This involves varying the dependent variable to ensure the consistency and reliability of the results. This comprehensive methodological approach, incorporating cross-sectional dependency checks, unit root tests, co-integration assessments, and CS-ARDL modeling, safeguards the validity of the study's findings and enhances the overall robustness of the empirical analysis.

5. Empirical estimation

This segment conducts a practical analysis of the impact arising from the possession of green bonds on resource efficiency in 12 Asian countries actively engaged in green bond issuance. The study spans the timeframe from 2015 to 2022.

The initial stage involves conducting Pesaran's (2004) CD test. Table 2 presents the CD test results, indicating the presence of cross-sectional dependency in the panel of the chosen Asian economies.

Subsequently, it is crucial to perform a panel unit root test that accommodates the presence of cross-sectional dependency in the variables. To achieve this, the Pesaran (2007) CIPS approach is utilized, as detailed in Table 3. According to the CIPS findings, the variables exhibit both I (0) and I (1) characteristics, indicating different orders of integration.

Table 2
CD test discussions.

Variable	Statistic	P-value
Resource Efficiency Index	32.493	0.000
Issued Green Bonds	28.946	0.000
Green Domestic Product	37.073	0.000
Renewable Power generation	23.554	0.000
Poverty ratio	39.084	0.000
Cell phone penetration	31.126	0.000
Consumer Price Index	26.503	0.000

Note: This table shows the results of Pesaran (2004)'s CD test.
Source: Authors of the paper

The subsequent stage involves conducting a co-integration test, wherein the Westerlund approach, recognized as a second-generation test that accounts for cross-sectional dependency in the panel, is employed in this paper. Table 4 illustrates the outcomes of Westerlund's (2007) approach, affirming that the variables exhibit co-integration in the long term.

The results obtained from applying the CS-ARDL (Cross-sectional Autoregressive Distributed Lag) methodology to assess the impacts of the independent variables are presented in Table 5.

As per the findings presented in Table 1, the analysis highlights a notable correlation between the issuance of green bonds and resource efficiency in Asian economies. Specifically, a 1% increase in the issuance of green bonds correlates with a significant improvement in resource efficiency, indicating a growth of approximately 0.33% in the short term and 0.43% in the long term. This positive correlation emphasizes the pivotal role of green bonds in fostering sustainable resource utilization. Firstly, the injection of funds through green bonds into environmentally friendly projects is likely contributing to enhanced resource efficiency by promoting sustainable practices. Secondly, the heightened awareness and commitment to environmentally conscious initiatives associated with green bonds may encourage businesses to adopt more resource-efficient technologies and processes. The observed relationship underscores the potential of green bonds to positively influence resource efficiency in the context of Asian economies.

Surprisingly, the findings indicate an inverse relationship between the increase in Gross Domestic Product (GDP) and resource efficiency in Asian economies. The data suggests that as GDP grows, resource efficiency tends to decrease. This counterintuitive association prompts an exploration of underlying factors. One possible explanation is the

Table 3
CIPS test discussions.

Variable	Statistic	P-value
Resource Efficiency Index	−0.785	0.996
D (Resource Efficiency Index)	−4.513	0.002
Issued Green Bonds	−4.594	0.069
D (Issued green bonds)	−14.221	0.000
Green Domestic Product	−2.463	0.821
D (Gross Domestic Product)	−9.032	0.000
Renewable Power generation	−1.743	0.960
D (Renewable Power generation)	−8.144	0.000
Poverty ratio	−5.275	0.038
D (Poverty ratio)	−16.326	0.000
Cell phone penetration	−2.664	0.903
D (Cell phone penetration)	−9.422	0.000
Consumer Price Index	−1.179	0.831
D (Consumer Price Index)	−7.409	0.000

Note: This table shows the results of Pesaran (2007)'s CIPS test.
Source: Authors of the paper

Table 4
Discussion on co-integration status.

Variable	Statistic	Z-value	P-value
G_τ	−4.116	−3.106	0.028
G_α	−17.392	−2.084	0.063
P_τ	−4.285	−2.539	0.074
P_α	−16.032	−4.105	0.000

Note: This table shows the results of Westerlund (2007)'s CD test.
Source: Authors of the paper

Table 5
Results of the estimations by CS-ARDL.

Dependent variable: Resource efficiency	Coefficient	T-statistic	Probability
Short-run estimation:			
Issued Green Bonds	0.335	7.492	0.046
Green Domestic Product	−0.195	−5.407	0.084
Renewable Power generation	0.274	6.540	0.021
Poverty ratio	−0.327	−8.194	0.005
Cell phone penetration	0.046	7.432	0.046
Consumer Price Index	−0.164	−10.493	0.005
ECT (−1)	−0.786	−7.559	0.036
Long-run estimation:			
Issued Green Bonds	0.437	8.053	0.008
Green Domestic Product	−0.253	−6.559	0.054
Renewable Power generation	0.316	5.379	0.085
Poverty ratio	−0.457	−7.980	0.017
Cell phone penetration	−0.057	−10.392	0.004
Consumer Price Index	−0.439	−6.550	0.025

Note: This table shows the results of CS-ARDL estimation.
Source: Authors of the paper

prevalence of resource-intensive industries that often accompany economic growth in the region. Rapid industrialization and expanded manufacturing, while contributing to GDP expansion, may simultaneously lead to heightened resource consumption and inefficiency. Additionally, the pursuit of economic growth might prioritize short-term gains over long-term sustainability, potentially resulting in practices that strain resource utilization.

Furthermore, the estimated coefficients derived from the analysis reveal a compelling connection between renewable power generation and resource efficiency in the selected Asian economies, indicating positive impacts in both the short and long term. This association underscores the pivotal role of renewable energy sources in fostering resource efficiency. A key reason behind this positive correlation lies in the inherent sustainability of renewable power generation methods. Investments and advancements in renewable technologies not only contribute to a cleaner and greener energy landscape but also promote resource efficiency by mitigating reliance on finite and environmentally taxing resources. Additionally, the adoption of renewable energy often aligns with broader initiatives aimed at enhancing energy efficiency, reducing waste, and optimizing resource utilization. As a result, the positive influence of renewable power generation on resource efficiency highlights the potential for sustainable energy practices to drive positive environmental and economic outcomes in the selected Asian economies.

Furthermore, the investigation indicates that poverty ratios and consumer price indices pose significant obstacles to achieving resource efficiency in Asian economies. High poverty ratios may hinder the implementation of resource-efficient technologies and practices, as impoverished populations may lack access to the necessary resources and face challenges in adopting sustainable behaviors. Moreover, the burden of poverty can divert attention and resources away from long-term sustainability goals. Similarly, consumer price indices, reflecting the overall cost of goods and services, may impact the affordability of environmentally friendly alternatives. If resource-efficient products and technologies come at a higher cost, consumers, particularly those in lower-income brackets, may be deterred from adopting these options. This economic barrier could impede the widespread adoption of resource-efficient practices, creating a hurdle for the overall goal of enhancing sustainability in Asian economies.

Concerning cell phone penetration, serving as a proxy for Information and Communication Technology (ICT) and digital transformation, the results affirm its positive impact in the short term but reveal a negative impact in the long term. This implies that the increased adoption of cell phones contributes to heightened resource efficiency in the short term. However, the long-term implications are characterized by a negative correlation, primarily attributed to the intensified electricity consumption associated with cell phone usage. The expanding reliance on cell phones necessitates increased electricity utilization, often sourced from traditional power plants reliant on fossil fuels. This shift towards greater electricity demand from non-renewable sources could potentially counteract the short-term gains in resource efficiency.

To ensure the reliability of the results, the empirical model substitutes resource efficiency with crude oil utilization efficiency. The re-estimation results, as presented in Table 6, validate that the issuance of green bonds exerts positive effects on resource efficiency in both the short and long term.

6. Conclusion and policy implications

The study focuses on assessing the impact of the green bonds market on the resource efficiency of 12 Asian economies actively issuing green bonds. These countries, including Hong Kong, China, India, Indonesia, Japan, Korea (the Republic of), Malaysia, PRC, Philippines, Singapore, Taipei, China, and Thailand, are analyzed for the period 2015 to 2022. The empirical findings highlight a positive relationship between the issuance of green bonds and resource efficiency, with a 1% increase associated with significant short-term (0.33%) and long-term (0.43%) enhancements. The study reveals an unexpected inverse correlation between GDP growth and resource efficiency, suggesting that economic expansion may lead to increased resource consumption. Additionally, the positive influence of renewable power generation on resource efficiency is emphasized, driven by the inherent sustainability of renewable energy sources. However, challenges arise from poverty ratios and consumer price indices, which hinder resource-efficient technology adoption due to limited resources and economic barriers. Furthermore, cell phone penetration positively impacts resource efficiency in the short term but exhibits a negative correlation in the long term due to increased electricity consumption from non-renewable sources.

Building on the positive correlation identified between the issuance of green bonds and resource efficiency in Asian economies, practical policies can be formulated to harness this relationship for sustainable

Table 6
Results of the robustness test.

Dependent variable: Crude oil efficiency	Coefficient	T-statistic	Probability
Short-run estimation:			
Issued Green Bonds	0.198	6.204	0.038
Green Domestic Product	−0.205	−8.054	0.016
Renewable Power generation	0.375	8.012	0.003
Poverty ratio	−0.298	−9.034	0.003
Cell phone penetration	0.086	6.192	0.075
Consumer Price Index	−0.267	−7.114	0.064
ECT (−1)	−0.804	−9.055	0.005
Long-run estimation:			
Issued Green Bonds	0.278	9.053	0.037
Green Domestic Product	−0.305	−7.493	0.019
Renewable Power generation	0.452	10.300	0.004
Poverty ratio	−0.194	−9.442	0.023
Cell phone penetration	−0.229	−5.420	0.069
Consumer Price Index	−0.329	−8.131	0.017

Note: This table shows the results of robustness analysis.
Source: Authors of the paper

development. Firstly, policymakers should actively promote the expansion of the green bonds market by encouraging greater participation from businesses and entities, as suggested by Guo and Zhou (2021). This encouragement can be facilitated through financial incentives such as tax breaks or subsidies for green bond issuers, creating a conducive environment for sustainable investments. Secondly, there should be a prioritization of targeted investments in renewable energy projects, aligning with findings that emphasize the positive impact of renewable power generation on resource efficiency. Governments can facilitate this by establishing funds specifically dedicated to financing green initiatives and providing support for research and development in sustainable technologies. Thirdly, addressing economic disparities is crucial, and policies should be implemented to ensure the inclusivity of resource-efficient practices. This involves creating programs that support low-income communities in adopting eco-friendly technologies and providing access to resources for sustainable living. Additionally, awareness campaigns and educational initiatives can inform the public about the benefits of resource efficiency, fostering a culture of sustainability. These policy recommendations collectively contribute to leveraging the identified positive correlation between green bonds and resource efficiency for comprehensive sustainable development.

Future research endeavors have the potential to significantly enhance our understanding of sustainable development in Asian economies through comparative analyses. One promising avenue for exploration involves contrasting the impacts of green bonds and green taxes on resource efficiency. A comparative study could provide insights into the relative effectiveness of financial mechanisms versus regulatory approaches in driving sustainable practices. Moreover, there is a compelling need to investigate the digitalization of the green bonds market in Asia. As technological advancements reshape financial landscapes, understanding the extent to which digitalization influences the efficiency and accessibility of green bonds could prove pivotal. This research could delve into the integration of digital platforms in issuing, trading, and monitoring green bonds, assessing their potential to enhance transparency, reduce transaction costs, and attract a broader investor base. Exploring these dimensions would contribute valuable knowledge to the evolving landscape of sustainable finance in the region.

CRediT authorship contribution statement

Xuanmei Cheng: Writing – original draft, Funding acquisition, Formal analysis, Conceptualization. **Chengnuo Yan:** Writing – review & editing. **Kaite Ye:** Data curation. **Kanxiang Chen:** Writing – review & editing, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all the authors. We declare that there is no conflict of interest.

Data availability

Data will be made available on request.

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