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Policy Instruments and Green Indicators in the Diffusion of Green Innovation: A Comparative Analysis of Poland and Thailand

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Abstract: The diffusion of green innovation technologies is critically influenced by policy instruments and green indicators, with significant variations observed across different countries. This study offers a comparative analysis of the policy frameworks and green indicators implemented in Poland and Thailand to support the adoption of environmentally sustainable technologies. A narrative review was conducted, drawing on secondary sources including government reports, regional studies, and an extensive range of academic literature. The mechanisms of financial incentives, such as subsidies, tax incentives, and innovation programs, are examined to understand their role in promoting eco-friendly technologies in these two nations. Specifically, financial instruments such as the EU Cohesion Fund, the National Fund Programs, and the Bio-Circular Green Economy Program in Poland, alongside Thailand's Solar PV Rooftop Program, are explored in detail. Additionally, the regulatory frameworks influencing green innovation adoption are discussed, highlighting the distinct approaches taken by both countries to address the challenges posed by environmental sustainability. The study identifies key green indicators—such as the Green Innovation Index, technology adoption rates, and environmental impact metrics—and compares their performance in Poland and Thailand. These indicators provide insight into the effectiveness of policy instruments in achieving green innovation goals. The findings suggest that while both countries have made considerable strides in fostering green innovation, the outcomes are influenced by unique socio-economic and environmental contexts. It is recommended that policymakers adopt tailored, comprehensive frameworks, incorporating robust green indicators, to guide future efforts in green innovation diffusion. This study underscores the need for context-specific policy interventions to accelerate the transition to a green economy.

Keywords: Green innovation; Green indicators; Policy instruments; Technology innovation; Diffusion; Narrative review

1. Introduction

Green innovation encompasses the development of novel technologies, products, services, and processes aimed at reducing environmental pollution and mitigating the effects of climate change, thereby enhancing sustainability. Key eco-friendly technologies contributing to environmental solutions include electric vehicles for carbon emission reduction, solar energy for decreasing reliance on fossil fuels, and smart grids for optimising electricity usage and reducing waste. These innovations represent vital steps toward achieving a sustainable and low-carbon future. The diffusion of such technologies refers to the process by which innovations spread and become increasingly adopted. In particular, the transfer of eco-friendly technologies from developed to developing countries plays a crucial role in fostering economic growth and addressing global environmental challenges. Green technology diffusion is anticipated to be central to the efforts of various nations in combating climate change and promoting sustainability (Straka et al., 2021).

Green innovation is one of the most feasible solutions to worldwide environmental problems that involve

environmental pollution and climate change. Several international approaches to green innovation in dealing with environmental pollution and climate change have been noted, ranging from 2024 by Thirakulwanich (2024) to 2021 by Tolliver et al. (2021). Surprisingly, international agreements go a long way in increasing global climate actions, hence leading to the realization of international goals for the environment. For instance, the 2015 Paris Agreement commitments by countries from every continent toward a vision of sustainable development goals by 2030 through making development low carbon, climate resilient and sustainable were made. An example of policies that are highly contributing to green innovation globally includes subsidies, tax incentives, and regulations. Besides, environmental regulations such as greenhouse gas emissions ensure that multinational corporations are shifting toward eco-friendly innovations to be at an advantage in different markets.

1.1 Importance of Policy Instruments in Promoting Green Innovation

Policy regulations create a playing field for eco-friendly innovations and an enabling environment for technology innovation. Yi et al. (2019) posit that policy instruments are relevant in enhancing research and development toward green innovation. Through the use of financial incentives as policy instruments, governments reduce the risk of investment by private sectors toward green technologies, thereby raising sustainable innovations. Besides, policy instruments play a great role in the standardization of green innovation. Setting of standards and compliance regulations stimulates businesses in seeking new technologies aimed at reducing environmental degradation and, consequently, promoting green innovation development. On a similar note, Wang et al. (2022) postulate that tax credits and public-private partnerships are considered the most important policy instruments in stimulating research and development of green technologies. Since green technologies are high-cost-driven, government partnerships and incentives through tax credits on R&D reduce the high costs in green technologies and hence boost green innovation as identified by Tantayanubutr & Panjakajornsak (2017). Indicators of greens normally help policy-makers make their decisions on whether policies are effective in the promotion of green technologies or not. The rate of technology adoption is one of the key measurement indicators in the adoption of green technology; this implies the rate at which the population adopts green technologies. Another key green indicator is the improvement in energy efficiency, which involves assessing the amount of energy consumed in the production of each unit of output. This indicator is also useful in identifying areas where efficiency improvements are needed

1.2 Comparative Relevance of Poland and Thailand

The adoption of green innovation keeps on increasing globally, influenced by various factors: environmental compliance regulations, financial incentives, and changing green consumer prevalence, among other factors. Thailand is one of the countries in Southeast Asia tapping into green innovation. Based on the Global Green Growth Institute (GGGI), Thailand scores 64 points in the measure for green growth dimensions (Barua, 2022). Poland, on the other hand, is ranked with 59 points under the EU average of 100 points in green innovation (Domaracká et al., 2023). Thailand maintains a high development rate and is considered an upper middle-income country, making it an ideal country to determine the impact of green technology diffusion in performance. Similarly, Poland under the EU is considered a high-income country whose economy is shock resistant to economic blows (Dorjnyambuu, 2024; Weitzel et al., 2024; Avi & Hassan, 2021; Weresa, 2015). Even though both Poland and Thailand are highly developing countries, the two countries have varying ways of approaching green innovation. For instance, Thailand focuses on regulations for compliance that drive green innovation initiatives such as environmental regulations and public-private partnerships like the promotion of renewable energy that promote the adoption of green innovation. Poland prioritizes financial incentives, including subsidies, tax relief, and grants aimed at encouraging businesses to invest in green technologies.

1.3 Research Objectives

From the analysis presented, this research is geared towards achieving the following objectives.

Objective 1: To identify and review the policy instruments used in Poland and Thailand to promote green innovation diffusion.

Objective 2: To analyze the green indicators that measure the effectiveness of these policies, focusing on outcomes like environmental impact and technology adoption rates.

Objective 3: To provide a comparative analysis highlighting the strengths, weaknesses, and opportunities in both countries' policy approaches.

This research has significance as it explores the increasing global focus on sustainable development and the diffusion of green innovations. It highlights the contrasting paths these two nations have taken in promoting eco-friendly technologies. By comparing the policy frameworks of Poland and Thailand, this review offers valuable insights into how different economies with unique regulatory, political, and economic landscapes can foster green

technology diffusion. Examining the successes and limitations of each country's approach can help policymakers and stakeholders in both regions adapt and enhance their strategies. The rest of the paper is organized to elucidate the green innovation narrative in Poland and Thailand under the following headings: first is the theoretical framework and literature review that looks at the theories and studies relevant to the discourse. The methodology section follows, detailing the methodology and data collection processes for the study. Next, we present the results and outline the relevant policies, initially for Poland and then for Thailand. The discussions from the results, the policy implications of the findings, and the policy recommendations for Poland and Thailand, and by extension the EU and Southeast Asia region, are examined next. The conclusion summarizes the highlights of the study.

2. Theoretical Framework and Literature Review

2.1 Innovation Diffusion Theory

The Diffusion of Innovation Theory can be used to describe how, why, and the rate at which the social systems accept green innovations. The theory described by Everett Rogers in 1962, articulates that the adoption of new technologies is a gradual process and involves categories including the innovators, early adopters, early majority, late majority, and the laggards (Miller, 2015). The adopters of green technology are thus likely to advance through the five categories as they understand the innovations and decide whether to adopt them based on the innovation's contributions and effectiveness in adding value (Shpak et al., 2017; Xia et al., 2022). Based on the technology adopter category representation, the innovators represent the smallest group and include those who want to be the first to acquire new technology and are regarded as risk-takers. The early adopters represent a higher number than the innovators and are the opinion leaders of the new technologies. The early majority and late majority adopters represent the highest distribution of adopters, with the laggards representing the conservatives in the adoption of new technology.

2.2 Empirical Literature Review

Several studies have highlighted the green innovation policies in Thailand and Poland, emphasizing the strategies promoting eco-friendly technologies (Dzikuć et al., 2021; Tantayanubutr & Panjakajornsak, 2017; Zieliński et al., 2024). Anambutr (2010) expresses that policy support is one of the key driving forces for eco-friendly technology innovation in Thailand; this was reiterated in Naruetharadhol et al. (2024) and Youngswaing et al. (2024). The open eco-innovation policy aims to collaborate with the diverse stakeholders in Thai business to address the research gap on eco-friendly technologies. Similarly, Thailand, through the Bio-Circular-Green (BCG) model, shifted to macroeconomic policies toward a green and sustainable economy (Lin & Wei, 2023; Maolanont & Pochanart, 2023; Suksanchananun et al., 2024). The BCG model develops policies to promote green technology and environmental conservation across government operations. Thawesaengskulthai et al. (2024) observed that Thailand also utilizes tax incentives to promote green innovations and investments. For instance, in 2017, Thailand introduced the Investment Promotion Act, aimed at providing tax incentives to businesses using high technologies in manufacturing. The incentive includes exemption of import duty on material imported for research and development for green technologies. Similarly, policy frameworks play a critical role in promoting green innovation in Thailand. The study by Suzuki et al. (2024) asserts that Thailand's green growth policy framework aims to find the right policy to address environmental issues, including the pledge to achieve carbon neutrality by 2050.

Various studies highlight the strategies implemented by Poland to promote green innovation and sustainability. Sanchez-Reaza et al. (2023) articulate that Poland benefits from green innovation through being part of the EU Green Deal. The European Union's Green Deal incorporates sustainable growth through regulations like renewable energy directives, emissions trading systems, and energy efficiency directives. Poland also utilizes government green incentives to promote green technology adoption. According to Miranda & Larcombe (2012), Poland, through the GreenEvo regulation program, ensures the promotion of environmental technologies in key areas including waste management, renewable energy sources, air quality, energy savings, and biodiversity conservation. As Poland transitions from a planned economy to a free market system, it continues to utilize research and development (R&D) to achieve green innovation. Zawalińska et al. (2018) report that Poland's R&D budgets have increased over the last two decades, peaking at 6% in 2012. However, the investment fell to less than 2% in 2021. Nevertheless, scientific performance continues to rise due to the increase in research and international collaboration. Similarly, Poland leverages green awareness to foster innovative green initiatives within the manufacturing SME sector. In response to the current environmental challenges, Wysocki (2021) encourages SMEs to adopt pro-ecological green initiatives to enhance their financial performance and mitigate environmental pollution. While there is limited comparative research on green innovation strategies utilized in Thailand and Poland, both countries support SME green initiatives towards green technology diffusion and adoption. For instance, while Thailand has a certification program for green programs in SMEs, Poland uses public-private

partnerships to encourage SME green innovation.

Several gaps in the literature are discernible from the discourse; there is a limited comparative research analysis between Thailand's and Poland's green innovation strategies, especially in assessing the policy effectiveness and implementation approaches. There is also the absence of quantitative analysis on the impact of tax incentives and financial mechanisms on the adoption rates of green innovation in both countries. The study also addresses the paucity of research about the role of cultural and institutional factors when examining the diffusion of technology in the economic context of Poland and Thailand. These are adequately addressed to offer a better understanding of the narratives surrounding green innovation in both countries.

3. Methodology

In the research design, the study has adopted a narrative review approach in order to explore and analyze the role of policy instruments and green indicators in promoting green innovation diffusion in Thailand and Poland. This design was considered suitable because it allowed the analysis of diverse sources of information, including articles, policy documents, case studies, etc. The study commenced with an extensive literature search for relevant information that could answer the research questions. Peer-reviewed academic articles, government official reports of Thailand and Poland; international organization publications that included OECD, UN, and EU reports and relevant case studies. We used some keyword sets related to the subject at hand, which were relevant to green innovation diffusion, policy instruments of sustainability, green indicators, Thailand Green Policies, and Poland Sustainability Frameworks in eco-friendly technology adoption and sustainable development policies to help retrieve useful information. In this study, the inclusion criteria adopted included those studies that were focused on green innovation and technology diffusion in Poland and Thailand between 2006 and 2024. The documents of the studies the research included were those discussing policy instruments or green indicators; these include qualitative and quantitative studies. Being a narrative review, this study, in nature, focuses on addressing the policy instruments or the green indicators concerning the green innovation diffusion process. Among such analyses, the first deals with identifying and analyzing significant policy instruments adopted by Thailand and Poland in order to develop a platform that could potentially support or nurture the diffusion of green innovations. These were then subgrouped under financial incentives and regulatory frameworks, specifically environmental regulations and targets pertaining to emissions reduction. The findings then looked at each one separately for the level and magnitude of their effects as relating to the adoption and dissemination of green technology. The second set of analyses focused on green indicators adopted and used in the country for the measurement of the effectiveness of these policy instruments. Indicators such as the rate at which the technology is being adopted to environmental impact metrics around carbon emission reduction and energy efficiency improvement. Lastly, the analysis had a comparative section on Poland and Thailand. It compares the differences and similarities in the use of policy instruments, the effectiveness of green indicators in measuring policy intervention, and the key factors that have contributed to successful green innovation diffusion.

4. Results

4.1 Policy Instruments for Green Innovation Diffusion

The following section has described and analyzed the differing policy instruments that have governed green innovation diffusion in Poland and Thailand. These sets of policies represent important incentives, regulatory standards, and sustainable economic activities that have shaped the environment of green technology adoption.

4.1.1 Poland policy instruments for green innovation

As a member of the European Union, Poland, on its path to becoming a green economy, pursues a mix of the driven EU policies and nationally set incentives for promoting green innovation diffusion. The policies are grouped into: financial incentives, regulatory frameworks, and public-private partnerships.

Financial Incentives

The alignment of the Polish economy to EU green and climate initiatives has had a strong enough influence to shape Poland's incentive policy. The first initiative is the EU Cohesion and National Fund Programs. Poland has greatly benefited from this initiative aimed at promoting green innovation efforts.

The first financial incentive is the Cohesion Policy Fund. From the fund (€76.5 billion), a total of €17.9 billion is directed to the investment in green initiatives, innovations, and strategies such as renewable energy sources and reduction of greenhouse gas emissions.

The Just Transition Fund is another financial incentive that is being implemented under the EU cohesion policy. The fund saw Poland receive Euro 3.8 billion for the transition towards a green economy, termed a climate neutrality economy, between 2021 and 2027. The fund majorly targeted coal regions of Silesia, Małopolska, Wielkopolska, Lower Silesia, and Łódzkie (European Commission, 2022).

Another financial incentive is the My Electricity program, adopted and carried out as a nationwide initiative to promote solar PV in the production of electricity. The project is funded to the tune of PLN 1.1 billion (EUR 243 million) by the National Fund for Environmental Protection and Water Management (International Energy Agency, 2024).

Regulatory Frameworks

The European Green Deal is the first regulatory policy instrument that is adopted by Poland towards green innovation diffusion. It is a package of policy initiatives that are geared towards the transition of the EU towards the green transition to achieve climate neutrality by 2050. Poland is among the benefits of the program's EUR 24 billion budget, boosting Poland's green efforts and socio-economic development (Council of the European Union, 2024).

Another is the Polish Research and Innovation Policy, whose mandate is achieving a green economy. This is through building Green Innovation Hubs and supporting activities aimed at green innovations (National Centre for Research and Development, n.d.). The National Energy and Climate Plan (NECP) outlines the long-term strategy for energy transition. The policy promotes and supports green innovation initiatives and projects that align with the EU energy efficiency standards. The Polish government endorsed the New Public Management (NPM) innovation instrument to foster innovation and growth. They assert that the use of innovative management methods at the national level may enhance the establishment of a resilient innovation system that fosters economic development, competitiveness, and sustainable growth in the country (Czerny & Kowalczyk, 2023; Zieliński et al., 2024). Polcyn et al. (2022) assert that GDP per capita is the main determinant of renewable energy use in Poland, recommending that governments prioritize measures aimed at enhancing economic growth. They argue that it is essential to adopt strategies to mitigate carbon emissions in SMEs and to advance contemporary technology for renewable energy generation.

Currently, Poland ranks 13th in the EU Green Innovation Index based on data from Bower Collective (2024), with the data showing a clear north-south and east-west divide in terms of performance and investments. The data for European Green Innovation performance reveals distinct patterns in green innovation across (see Figure 1), with clear leaders and emerging players. Germany dominates with 364 green startups and 3,955 green patents, securing €7.3B in funding. Sweden shows exceptional efficiency with 201 startups and the highest funding (€7.6B). The Netherlands and France tied for third, with the Netherlands excelling in startups (336) and France in patents (1,445). Poland is its 13th (tied with Belgium) and has 43 green startups (4% of total startups), 60 green patents (9% of total patents), and €450M in funding with -€40M net investment with different funding dynamics. Poland lags significantly behind regional leaders like Sweden, Denmark, and Norway, showing high green startup percentages.

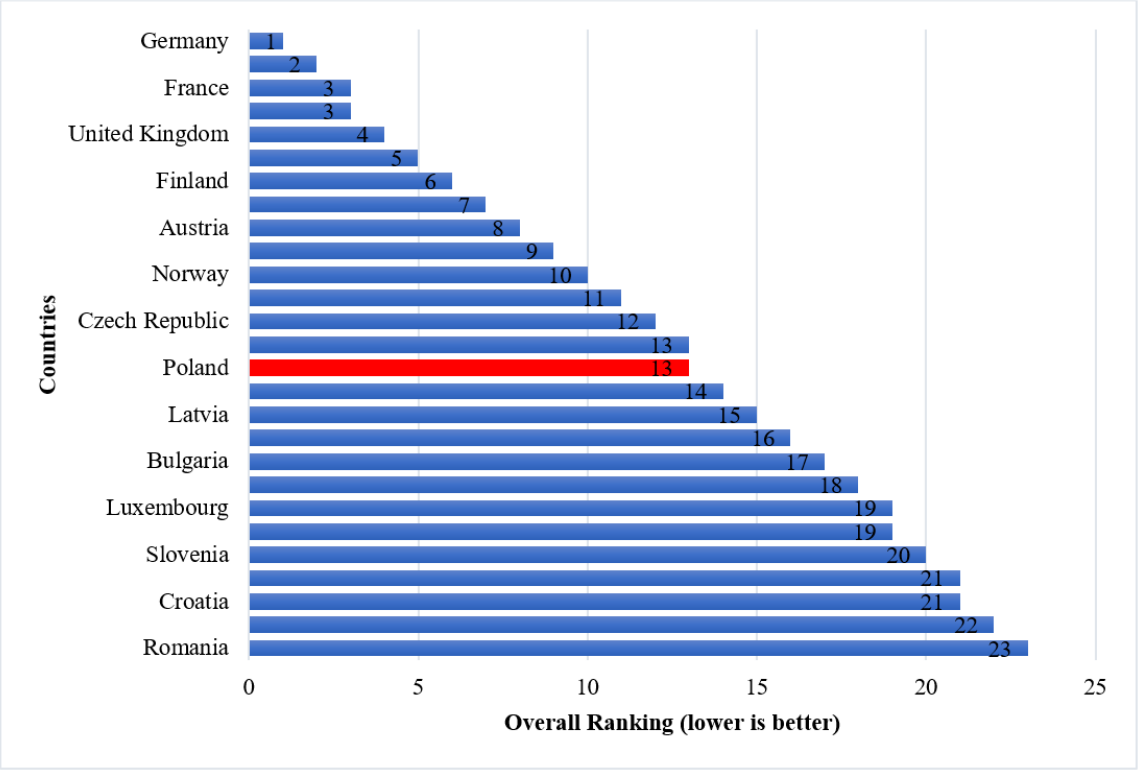

Figure 1. EU Green Innovation Index (Bower Collective, 2024)

4.1.2 Thailand policy instruments for green innovation

Thailand has pursued a mix of regulatory and market-based policy instruments to support the diffusion of green technologies, aligning with its broader sustainable development goals.

Incentives and Subsidies

Among the policy instruments in Thailand that support green innovation are financial incentives and subsidies. The Thai government is keen to advance subsidies to firms adopting renewable energy technologies such as wind and solar. Corporate tax incentives, exemptions, and import duty reductions have played a critical role in encouraging investment in the green innovation domain, particularly in the manufacturing and energy sectors. Specifically, the Board of Investment of Thailand (n.d.) provides investment incentives for renewable energy initiatives, including corporate income tax exemptions for up to eight years, limited to the total invested amount before the imposition of the standard 20% rate. Import tariff exemptions are available for equipment and raw materials, a streamlined immigration process for foreign workers is in place, and land ownership is permitted. A Feed-in Tariff (FiT) program ensures a predetermined payment rate for renewable energy providers, establishing a long-term power purchase agreement (PPA) for solar, wind, and biomass for 25 years. This motivates corporations to invest in renewable energy sources and provide creative solutions that diminish carbon emissions and promote sustainable development (NOINA PWPFF, 2024; OECD, 2024; TMF Group, 2023).

This prompted the BOI in Thailand to also introduce policy, namely, the Bio-Circular Green Economy program, with the aim to attract investors to fund and develop green innovations within the renewable energy industry. Some of these incentives include subsidies for investors in the sector, tax breaks, and various other forms of support provided to the investor. Some others include the Solar PV Rooftop program, aimed at facilitating finances for installing solar panels in households and business establishments. In this manner, the government inspires green innovation initiatives (Naruetharadhol et al., 2024; Yoomak et al., 2019). Also, green financial facility programs have also captured green innovation in the marketplaces. For instance, Thailand's Bank for Agriculture and Agricultural Cooperatives (BAAC) has adopted the green credit schemes aimed at promoting green agricultural practices. These programs provide low-interest loans to farmers who adopt green technologies.

Regulatory Frameworks

The first notable regulatory framework is the Green Certification initiative. The certification process was aimed at encouraging and ensuring that stakeholders adhere to green practices, hence encouraging green innovation (Crosio & Hayden-Gilbert, 2023; Pakurár et al., 2020; Tariq et al., 2019; The Nation, 2024). These certifications include the green building certification called Thai's Rating of Energy and Environmental Sustainability (TREES) (Sarkar et al., 2024; Shen et al., 2018). It encourages practices such as green innovation, environmental protection, and materials and resources management. Others include Green Label Products certification and Green Industry Certification. The Bio-Circular Green Economic Model (BCG) is an innovative green framework. The initiative was introduced by the research community and promoted by the Thailand government. It harnesses the country's biodiversity strength to drive the technology and green innovation agenda. The objective is to drive Thailand to a value-based and innovation-driven economy, in line with the UN Sustainable Development Goals (Royal Thai Embassy, Washington D.C., 2023). The Thai Bio circular economy model is adapted in Figure 2.

Figure 2. Green innovation model for Thailand's Bio-Circular economy (Mahanakorn Partners Group, 2023)

Politically, the government's green industry programs aim to enhance the capabilities of Thai businesses, especially the capacity of SMEs, to engage in environmentally sustainable practices per eco-efficiency trends (Naruetharadhol et al., 2024; Permatasari & Gunawan, 2023). The programs are designed to improve corporate development and competitive advantages in international commerce, so they aim to improve green GDP and the sustainability of the nation's green economy. The Green Industry Project was founded on two core principles: a regime of continuous improvement and sustainable development. It integrates total quality management and a

triple bottom line, encompassing social, environmental, and economic factors (Rame et al., 2024; Handoyo et al., 2024). The Thai government's participation is crucial, tasked with formulating legislative initiatives that effectively promote innovation and the Sustainable Development Goals (Chonsalasin et al., 2024; Sagarik et al., 2018). Current difficulties highlight that environmental concerns are among the most urgent global threats. The huge impacts on the environment caused by the rapidly growing population and consumption of natural resources are some of the issues countries like Thailand are suffering from. In innovation-based economy making, the Thai government has come up with the Thailand 4.0 policy. This strategy, integral to Thailand's 20-Year National Strategy (2018–2038), asserts that technology and innovation are essential tools for enhancing the quality of life and promoting competitive advantage (Open Development Initiative, 2018; Insee & Suttipun, 2023; Intalar et al., 2024).

4.2 Green Indicators for Green Innovation Diffusion

Indicators of the diffusion of green innovation are fundamental in measuring the pervasion of green innovation into the various strata of the economy. They are qualitative or quantitative measures of the performance of green innovations. They can consist of performance measures, policy evaluation, and public awareness, among other things (Borsatto & Amui, 2019). This section presents an analysis of the indicators used in Poland and Thailand.

4.2.1 Green Innovation Index

One such major green indicator adopted in the assessment of the diffusion of green innovations that occurs includes the Green Innovation Index. In the world, this indicates a ranking index of country preparedness and effort over green innovation initiatives and utilizing frontier green technologies (World Economic Forum, 2023). The leading countries for the 2023 ranking were the United States, Sweden, Singapore, Switzerland, and the Netherlands. Comparing Poland and Thailand, Poland ranked higher at number 27 out of 166 countries, while Thailand ranked number 49 (UNCTAD, 2023) (Figure 3). The ranking evaluates green innovation technologies, showing the abilities of the countries to produce goods and services with smaller carbon footprints.

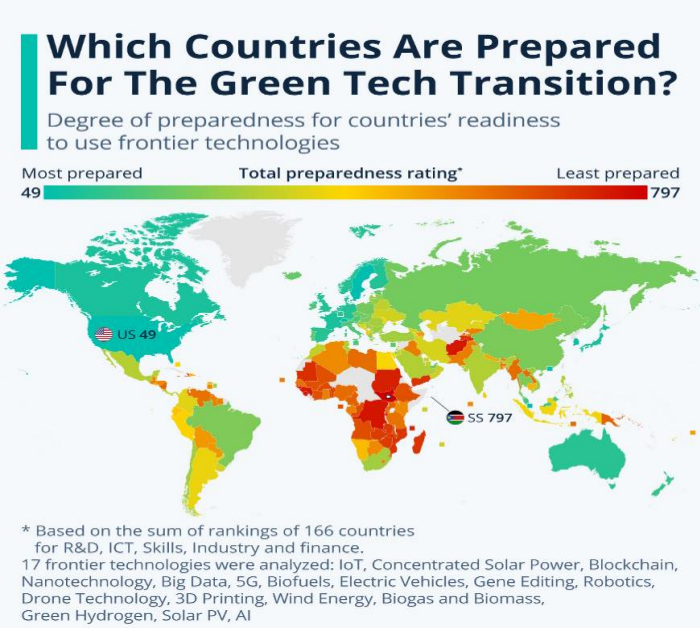

Figure 3. Green Innovation Index (UNCTAD, 2023)

4.2.2 Technology adoption rates

The other clear indicator of the diffusion of green innovation is the adoption rates of green technology. Considering Poland, the country has made significant strides in wind power technology adoption. Various policy frameworks and available incentives drive this.

The statistics reveal that wind power comprises 14% of the total power generated in 2023 (GlobalData, 2024), with the expectation that it will increase to 23% in 2024. According to the data presented in Statista, the wind power plants installed in Poland reached 9.5 gigawatts in 2024, which was an 8.1% increase as compared to the previous period (Adriana, 2024). Figure 4 shows the growth of power generation in Poland.

The adoption of green technology in Thailand is concentrated on solar PV installations (see Figure 5). This renewable and green technology has experienced a rapid increase in the country due to the policies adopted. The

statistics indicate that the cumulative installed capacity of rooftop PV systems increased from 130 megawatts in 2015 to 1893 megawatts as of the year 2022 (Energy Research Institute ERI, 2024).

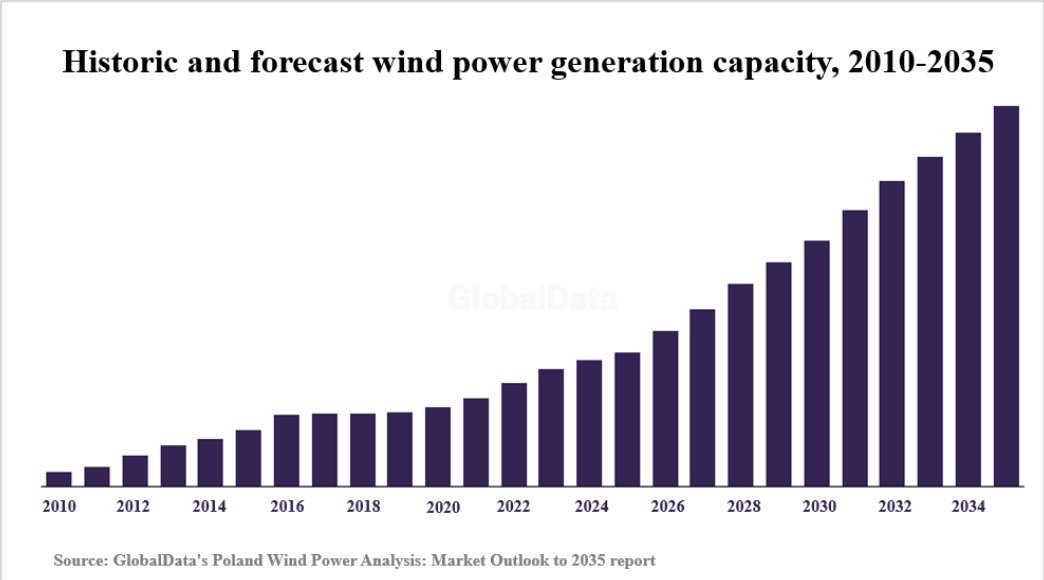

Figure 4. Wind power generation capacity in Poland (GlobalData, 2024)

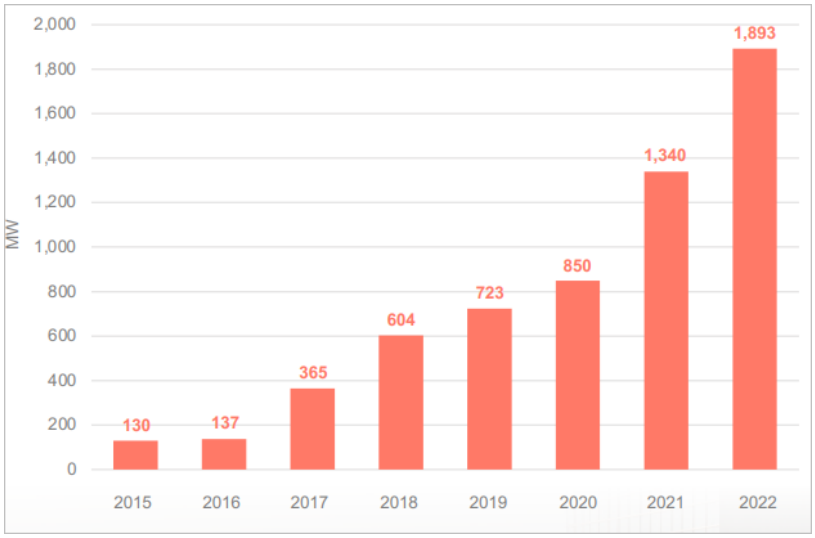

Figure 5. Solar power generation in Thailand (Energy Research Institute ERI, 2024)

4.2.3 Environmental impact metrics

Another green indicator that has been adopted as an effective measure of the green innovation diffusion is the environmental impact metrics. This measure focuses on the effort made toward carbon emission reductions and the improvements in energy efficiency across various sectors (De Verteuil et al., 2024). In Poland, the major emphasis of environmental impacts is on the overall greenhouse gas emissions reductions and energy efficiency enhancements. Poland's National Energy and Climate Plan (NECP) has set the target of a 30% reduction in greenhouse gas emissions by 2030 (Ministry of National Assets, 2019). In the case of Thailand, the environmental impact metrics focus on reducing carbon emissions and improving energy efficiency across various sectors. As indicated by Thailand's Alternative Energy Development Plan (AEDP), they aim to cut CO_2 emissions by 111 million tons by 2037 (Department of Alternative Energy Development & Efficiency (DEDE), 2024).

5. Discussions: Comparison Between Poland and Thailand

This section presents a critical discussion of the findings presented in the previous section. The comparison

focuses on the policy instruments and green indicators that impact the adoption of green practices in Poland and Thailand. Interesting findings were obtained regarding the policy instrument adopted to derive and promote green innovations in the two countries. When comparing the policy instruments of Thailand and Poland, several commonalities and differences emerge. With regard to the subsidies, both countries use subsidies and financial incentives to support green innovation. However, while Thailand focuses more on domestic programs like the Solar PV Rooftop Program, Poland relies heavily on EU-backed programs like the "Innovation Fund" and the "My Electricity" Program. Another aspect of comparison is that Poland has invested in quite a wide range of subsidy schemes, including renewable energy—wind, solar, and biomass. For instance, the My Electricity program supports residential solar installations (International Energy Agency, 2024). However, in Thailand, the subsidies primarily target solar energy, including initiatives such as solar PV rooftops. There is also a difference concerning the focus of the support from the green innovation subsidies. Poland places a greater emphasis on residents, particularly homeowners, and encourages them to participate in green innovation projects through subsidies. Thailand primarily provides sector-specific support, promoting sustainable agriculture and eco-friendly production practices.

As green innovation is increasingly important and significant, the policy tool that both Poland and Thailand are currently practicing is tax exemption. Therefore, in that sense, such exemptions and reliefs act as major incentives to green innovation. While in general, Poland does provide exemptions and reliefs, however, the forms of providing it are somewhat different from the ways in which Thailand is trying to promote green innovation. In concrete detail, Poland provides mainly an investment tax relief with a view to stimulating the investment demand for green innovation, which lies particularly in energy. However, in Thailand, these corporate exemptions target firms investing in green innovations. Regulatory frameworks bear great significance with respect to the diffusion of green innovations across Thailand and Poland. While EU directives result in the Polish regulatory regimes being very favorable to very ambitious decarbonization, Thai regulation focuses rather on the national level and promotes energy efficiency with environmental care. Even though both countries use tools such as regulatory frameworks for green innovation implementation, multi-level and differential approaches have been put forward by both, in whose dimensions differ according to unique contexts. Among those leading the front in the efforts put forward by Poland in trying to promote greener practices in energy is the Energy Efficient Act Plan, quite an ambitious policy, for that matter. In contrast, Thailand has more elaborate, sector-specific plans, such as the Alternative Energy Development Plan and the Energy Efficiency Development Plan, that aim to increase renewable energy shares and reduce energy intensity. Results of interesting analysis are shown when green indicators are analyzed. The different rankings between Poland and Thailand show that significant contrasts can be seen in their green innovation ecosystems. It is an indication that Poland is doing well in the adoption and promotion of green technologies and sustainable practices.

This high ranking well expresses large-scale regulatory frameworks alongside far-stretched subsidy programs implemented in Poland. Ranking 49, Thailand demonstrates itself to be a rather decent step towards green innovation; on the other side, it includes great opportunities for further enhancements, being much behind Poland's rank of 27. The country's recent step to engage in green took a big push from step developments concerning solar energy together with sector-specific strategies; as has been pointed out already, less diverse policy instruments place this country far behind Poland. In these green innovation endeavors between the two countries, there reflects a difference of national priorities. Poland tries to use broader approaches toward most of the renewable energy source channels, while Thailand adopts a focused interest in the realm of solar; both signal differing national priorities and strategic implementations in nurturing sustainable technologies.

5.1 Policy Implications of the Study

The analysis of the narrative on policy instruments and green indicators for the diffusion of green innovation will provide important insights for policymakers in promoting green innovation practices and their diffusion in Poland and Thailand. Targeted subsidies have been playing a crucial role in driving green innovation initiatives in both countries. With great recorded effectiveness, policymakers are called to widen the subsidy programs into wider coverages of green technologies (Abhiyan, 2017). This is so that balance in support is ensured at inter-sector levels. Successful policies such as those on subsidies for solar energies in Thailand could be successfully taken over by other countries, while the diverse subsidies provided in Poland for renewable energies would serve as a model in holistic sector support.

Another policy recommendation should be the inclusion of SMEs in green innovation initiatives. The tax incentives and subsidies should be focused on SMEs, due to their vibrant innovation capacities, as well as their significant proportion in the economy. This expansion to a wider audience would accelerate the update of green innovation technologies. This study further suggests the need for well-designed regulatory and policy frameworks that would ensure regulations are flexible yet stringent enough to drive significant environmental impact. The combination of long-term goals and immediate regulatory actions, as seen in Thailand and Poland, can provide a balanced approach to fostering green innovation. This study recommends the need for an elaborate monitoring and

evaluation mechanism. Policymakers should establish robust mechanisms to track the progress and effectiveness of their policies, ensuring continuous improvement and adaptation to emerging challenges. The use of comprehensive green indicators, as seen in this study, can guide policymakers in refining their strategies and maximizing their impact. Lastly, considering that green innovation is a global agenda, this study advocates for international collaboration. Sharing best practices and joint initiatives would play a critical role in advancing the diffusion of green innovation and also extending these policy implications to other countries in the Southeast subregion and EU.

5.2 Policy Recommendations for Poland and Thailand

The researchers looked at Poland's and Thailand's green innovation policies and came up with the following policy suggestions for areas like financial incentives, regional development, the innovation ecosystem, the regulatory framework, implementation support, and economic integration. We can break them down individually for each instrument. Examining the enhancements for financial incentives, the authors recommend creating specific funding lines to assist SMEs in transitioning to green technologies, expanding the "My Electricity" program and the Feed-in Tariff program to include renewable power sources other than solar PV, and developing green vouchers to accelerate the adoption of green technologies and support research and development of green technologies. The researchers recommended establishing special green zones for regional development, particularly in regions with coal and hydrocarbon plants; developing customized innovation hubs at regional levels for green tech; and establishing cross-border partnerships dedicated to green innovation within the EU framework.

The scholars recommend strengthening green innovation hubs through additional funding and resource allocation, forging a strong partnership between academia and industry to improve green innovation, and building and showcasing demonstration products driven by green technology to enhance support for the innovation ecosystem. The authors also recommended the enhancement of the regulatory framework by streamlining permit processes and incentives for early adopters of green innovation projects and developing clear guidelines for certification. This recommendation is in addition to the integration of policies that align green innovation with Thailand 4.0 economic strategy objectives. The proposed recommendation for implementation support would be the establishment of dedicated agencies to oversee and harmonize green innovation initiatives. This would cover monitoring and evaluating the effectiveness of green policy frameworks. For market development, the government should create green procurement requirements to guide public institutions and help develop market mechanisms for trading environmental certificates while establishing green standards that align with country and regional requirements. Finally, the need to address industrial transformation by supporting SMEs' transition to green innovation technologies using targeted programs that develop sector-specific roadmaps to incentivize industrial modernization.

6. Conclusion

This study revealed the critical role of green innovation in tackling global environmental issues such as environmental pollution and climate change. Various global efforts are aimed at addressing environmental pollution and climate change through green innovation. Green policy instruments and indicators are crucial components that showcase the progress towards green innovation. This study compared Poland’s and Thailand’s green innovation policy instruments and indicators. Among the most recognized green innovation policy instruments are financial incentives and regulatory frameworks. Both countries have adopted varied financial incentives to encourage green innovation. For instance, the EU Cohesion and National Fund Programs and Cohesion Policy Fund in Poland, the Bio-Circular Green Economy program, and the Solar PV Rooftop program in Thailand. Additionally, the efforts towards the green innovation agenda are significantly shaped by various regulatory frameworks. The green indicators identified include the Green Innovation Index, technology adoption rates, and environmental impact metrics, which show varied levels of performance between Poland and Thailand in terms of green innovation diffusion. The study recommended that policymakers should consider a strategic, well-rounded policy framework that can adapt to the unique socio-economic and environmental contexts of each country. This study proposes that a deeper understanding of tailored and broad policy instruments can create conducive environments for the diffusion of green technologies in the future.

Data Availability

Not applicable.

Conflicts of Interest

The authors declare no conflict of interest.

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