Central bank transparency and green innovation policy in Indonesia

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Abstract

A green economy is a sustainable and environmentally friendly development model. The green economy is expected to improve people's welfare without compromising the quality of the environment and natural resources. The purpose of this study is to determine the long-term and short-term relationship between monetary variables, namely interest rates, broad money, and central bank transparency, on the green economy in Indonesia. This study uses ARDL analysis with a sample period of 1999Q1 to 2019Q4. The results of short-term ARDL research show that green innovation is significantly influenced by innovation in the previous period, interest rates, and central bank transparency. Green innovation tends to increase when influenced by past performance and accommodative monetary policy, although some factors show the opposite impact in specific periods. Meanwhile, the effect of money supply on green innovation is dynamic, initially showing a significant positive impact in the short term but becoming negative in the subsequent period. Central bank transparency is also significant, with a positive direction in lag one and a negative in lag 2.

Keywords: green economy; interest rate; central bank transparency; Indonesia

JEL Classification: E40; E52; Q56

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1. Introduction

Developing countries today face significant environmental challenges, while at the same time striving to achieve economic development. Environmental degradation and ecological disasters now incur substantial costs, as they raise important issues for sustainable development (Qori'ah, 2016; Wardhono et al., 2018). Therefore, developing countries need to find ways to balance economic growth and environmental protection, and one key factor that can influence this balance is monetary policy. Monetary policy can support a green economy by stimulating innovation and investment in renewable energy and low-carbon technologies through the implementation of low and stable interest rates, which can reduce the cost of capital for environmentally friendly projects, projects that typically have high initial costs but low operational costs. Monetary policy can also create incentives for financial institutions to provide more loans to environmentally friendly sectors and businesses by offering preferential refinancing rates or collateral requirements for green loans (Bilal et al., 2022; Spyromitros, 2023; Wei et al., 2023).

There are two main climate-related financial risks: transition risks associated with the revaluation of carbon-intensive assets as a result of shocks caused by the shift toward a low-carbon economy, and physical risks related to financial losses from climate change-related disasters (Aghion et al., 2022; Sahin & Ayyildiz, 2022; Wardhono et al., 2016). On one hand, green innovation encourages economic entities to internalize the externalities of their environmental emissions, playing an important role in creating a better trade-off between economic growth and environmental protection. Green innovation also helps maintain the economic benefits generated by conventional innovations (Cai et al., 2020; Wen et al., 2023; Yu et al., 2022).

Green innovation, which encompasses an environmentally friendly economy, has a strong relationship with a country's GDP (Gross Domestic Product), CO_2 emissions, and monetary policy related to interest rates. This is because green innovation is linked to GDP through the development of environmentally friendly renewable technologies, which are expected to reduce CO_2 emissions (Khezri et al., 2022; Liang et al., 2022). Furthermore, monetary policy is one of the main variables influencing innovation in the green sector. By balancing portfolios, expansionary monetary policy increases consumption and energy use by directly supplying money or lowering interest rates (Ziaei, 2018). Consequently, product demand will increase across all markets. Industrialists tend to prefer conventional manufacturing processes if innovation-related financing is offered at higher interest rates. The increase in pollutant emissions is driven by greater consumption of less environmentally friendly technology (Mughal et al., 2021). Similarly, the supply-side argument suggests that expansionary monetary policy fosters economic growth, motivates consumers to purchase renewable goods, and pressures producers to increase output to meet rising demand. By leveraging environmentally friendly innovation, more renewable energy products can be produced at lower costs.

In describing the potential impact of expansionary monetary policy on green innovation, there are two perspectives: the demand side and the supply side. The demand side argues that expansionary monetary policy stimulates consumption and energy use, which leads to more pollution and reduced demand for environmentally friendly products. The supply side argues that expansionary monetary policy drives economic growth and innovation, leading to increased production and supply of environmentally friendly products (Campiglio, 2016). There is a conflict between these two perspectives because they produce different outcomes for the environment and the economy. The demand side suggests that expansionary monetary policy is harmful to the environment and does not promote green innovation. The supply side suggests that expansionary monetary policy is beneficial to the environment and fosters green innovation. This conflict also reflects the trade-off between the short-term and long-term effects of monetary policy. The demand side focuses on the immediate impact of monetary policy on consumption and energy use, while the supply side focuses on the long-term impact of monetary policy on innovation and production (Spyromitros, 2023; Ziaei, 2018).

In the context of long-term economic growth, there are two approaches that explain the sources and determinants of such growth: the Schumpeterian growth theory and the endogenous growth theory (Fischer & Nijkamp, 2014; Juhro & Trisnanto, 2018; Yay & Yay, 2022). The Schumpeterian growth theory, as developed by Aghion & Howitt (1997), is based on the concept of creative destruction, which means that new innovations replace old technologies and render them obsolete. This implies a trade-off between innovation and rent protection, as incumbent firms have less incentive to innovate if they fear losing their market power to new entrants. Therefore, the Schumpeterian growth theory predicts an inverse relationship between competition and growth, since too much or too little competition can reduce innovation incentives (Dafermos et al., 2018; Jiang et al., 2022; Sahin & Ayyildiz, 2022).

The endogenous growth theory, as developed by Romer (1990), Lucas (1998), and Fischer & Nijkamp (2014), is based on the concept of knowledge spillover, which means that new innovations benefit not only the innovators themselves but also other firms and sectors that can use or imitate them. This implies the existence of positive externalities from research and development, as the social benefits of innovation are greater than the private benefits. Therefore, the endogenous growth theory predicts a positive relationship between competition and growth, since more competition leads to more innovation and greater diffusion of knowledge.

The concept of green innovation is built upon Schumpeter's (1943) growth theory, focusing on the role of innovation in driving sustainable development and addressing environmental challenges (Yay, 2021; Yay & Yay, 2022). Green innovation refers to the development and adoption of new technologies, products, and processes that reduce environmental impact and improve resource efficiency (Cai et al., 2020; Zhao & Wang, 2022). The link between Schumpeter's growth theory and green innovation lies in their shared emphasis on the importance of innovation in driving economic growth and development (Hu & Wang, 2022; Wen et al., 2023). However, green innovation goes beyond traditional innovation by explicitly focusing on environmental sustainability and resource efficiency. By promoting the development and implementation of environmentally friendly technologies and practices, green innovation can help address urgent environmental challenges and foster long-term sustainable economic growth (Wan et al., 2022; Wei et al., 2023).

Research on the relationship between monetary policy and green innovation reveals both short-term and long-term effects. Expansionary monetary policy generally has a positive impact on green innovation performance in various countries (Spyromitros, 2023). Conversely, contractionary monetary policy, such as raising interest rates, tends to worsen environmental sustainability (Ahmad & Satrovic, 2023). Low central bank independence and weak property rights protection in developing countries can hinder the positive impact of monetary policy on green innovation (Yin et al., 2022). In the long term, lower interest rates and an increased money supply tend to stimulate green innovation, particularly in developing countries (Spyromitros, 2023). However, the short-term benefits of green process innovation may not be immediately visible (Ma et al., 2017). Factors such as central bank independence, property rights protection, and environmental regulation can influence the effectiveness of monetary policy on green innovation (Yin et al., 2022). Private investment and inward foreign direct investment also play an important role in promoting green finance (Desalegn et al., 2022). While monetary policy can be a powerful tool to encourage green innovation, its impact can vary depending on institutional quality, industrial concentration, and energy intensity (Spyromitros, 2023).

This study makes a significant contribution by integrating a new monetary proxy in the form of Central Bank Transparency, in addition to conventional indicators such as interest rates and broad money. This aspect has not been widely explored in previous studies. Although several studies have examined the relationship between green innovation and monetary policy, comprehensive analyses focusing on green innovation and monetary policy in Indonesia remain limited (Spyromitros, 2023; Yin et al., 2022). The focus on Central Bank Transparency in this research aims to understand the extent to which the predictability and openness of central bank policies can influence decisions and investments in green innovation. High transparency reduces uncertainty, supports economic stability, and can foster a more conducive investment climate for the development of environmentally friendly technologies and policies. Based on an extensive literature review, no comprehensive study has specifically examined the interaction between green innovation and Central Bank Transparency in the context of Indonesia. Therefore, the findings of this study are expected to enrich the body of literature on green innovation and Central Bank Transparency, as well as provide substantial policy implications for stakeholders in efforts to optimize this subsector as a national development priority.

2. Methodology

The data used in this study are secondary data obtained from the World Development Indicators, Eichengreen's online database, and OECD Statistics. The study employs quarterly time series data from 1999Q1 to 2019Q4. This period was selected based on several relevant methodological and practical considerations. First, this period aligns with the environmental and green economy issues that are the focus of this research. These issues began to attract attention among academics and policymakers following the publication of the Limits to Growth report by the Club of Rome in 1972 (UNDESA, 2012). This report warned of the negative impacts of uncontrolled economic growth on natural resources and the environment. Second, the decision to end the period at 2019Q4 was based on the limited availability of data.

For the Central Bank Transparency variable, which is one of the key variables in this study. The Central Bank Transparency data used were sourced from Eichengreen's online database, which is only available up to 2019, with the latest index based on the revised methodology published by Dincer et al. (2022). This temporal data limitation serves as a binding constraint determining the study's observation period.

Studies by Cerutti et al. (2021) and Prakash (2018) also support this report, noting that the 1997/1998 monetary crisis hurt the environment. The novelty of this research compared to Tan & Cao (2022) lies in the finding that green technological innovation and renewable energy consumption have a significant effect on CO_2 emissions, as expressed in equation 1.

$$Y_t = f(G,M) \tag{1}$$

Where Y represents CO_2 emissions and CO_2 emissions per capita; G represents green patents, renewable energy consumption, and total renewable energy; M represents GDP per capita, population, FDI, trade, urban population, total natural resource rents, and industry. The study by Yin et al. (2022) states that green innovation is positively and significantly influenced by monetary policy, as expressed in equation 2.2.

IH=f(BM,RM,GDP,IND,TK) (2)

Where IH represents green innovation, BM represents broad money, RM represents reserve money, GDP represents gross domestic product, IND represents industry, and TK represents labor. Furthermore, according to Spyromitros (2023), there is also the possibility that key monetary policy variables, such as inflation and central bank characteristics, such as central bank independence and transparency, affect green innovation.

IH=f(i,IBS,TBS,CO2,EXP,BUR) (3)

Where IH represents green innovation, i represents the real interest rate, IBS represents central bank independence, TBS represents central bank transparency, CO_2 represents CO_2 emissions, EXP represents exports, and BUR represents the bureaucracy index. This study employs the Autoregressive Distributed Lag (ARDL) method, based on several methodological considerations relevant to the characteristics of the data and the objectives of the analysis, which will be outlined. The ARDL model used in this study is as follows:

$$Y_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i \, Y_{t-i} + \sum_{j=0}^{q1} \beta_j^1 \, X_{t-j} + \epsilon_t \quad (4)$$

Where Y_t is the dependent variable at time t; X_{t-j} is the vector of independent variables at time t–j; α_0 is the constant (intercept); α_i is the coefficient of lag i for the dependent variable; β_j is the coefficient of lag j for the independent variables; ε_t is the error term that is serially uncorrelated; and p and q are the lag lengths of the dependent and independent variables, respectively. It is then transformed into the following econometric model:

$$IH_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i \, IH_{t-i} + \sum_{j=0}^{q1} \beta_j^1 \, BM_{t-j} + \sum_{j=0}^{q2} \beta_j^2 \, SB_{t-j} + \sum_{j=0}^{q3} \beta_j^3 \, TBS_{t-j} + \epsilon_{t_t} \quad (5)$$

Where: α_0 is the constant (intercept); α_i is the coefficient of lag i for the export variable; β_j^1, β_j^2, and β_j^3 are the coefficients of lag j for the interest rate, broad money, and central bank transparency variables, respectively; p is the lag length of the dependent variable (exports); q_1, q_2, and q_3 are the lag lengths of the independent variables (interest rate, broad money, and central bank transparency); and ε_t is the error term at time t.

Where: α_0 is the constant (intercept); α_i is the coefficient of lag i for the export variable; β_j^1, β_j^2, and β_j^3 are the coefficients of lag j for the interest rate, broad money, and central bank transparency variables, respectively; p is the lag length of the dependent variable (exports); q_1, q_2, and q_3 are the lag lengths of the independent variables (interest rate, broad money, and central bank transparency); and ε_t is the error term at time t. Before estimating the ARDL model, a stationarity test is first conducted using the Phillips–Perron (PP) method. This test aims to check for the presence of a unit root in the data, where the data are considered stationary if the null hypothesis is rejected (Ziaei, 2018). After confirming stationarity, the next step is to conduct a bounds test to determine whether there is a long-term relationship between the variables in the model. In addition, the optimal lag selection is carried out to ensure that the ARDL model includes the appropriate lags, allowing for more accurate and unbiased estimation. After the model is estimated, a stability test using the Cumulative Sum of Recursive Residuals (CUSUM) is applied to evaluate the stability of the model's parameters over time. The CUSUM test will indicate whether the resulting model is stable in the long run (Wang et al., 2022; Yilmaz & Sensoy, 2022).

The selection of the variables interest rate, broad money, and central bank transparency in this research model is based on several considerations. Focusing on the main instruments of monetary policy and the institutional aspect of the central bank allows for a deeper analysis of the monetary policy transmission mechanism to green innovation. The inclusion of the central bank transparency variable fills a gap in the existing literature, particularly in the context of Indonesia, providing a significant theoretical contribution. In addition, the selection of these variables takes into account the contextual relevance to Indonesia's economy, the availability of consistent data, and the potential for more actionable policy implications for monetary authorities. The variables used in this study are summarized in Table 1.

Table 1. Research Variables and Data Sources

Variable	Symbol	Data Unit	Results
Green Innovation	IH	Percentage %	OECD
Broad Money	BM	Percentage %	WDI
Real Interest Rate	SB	Percentage %	WDI
Central Bank Transparency	TBS	Index	Eichengreen's database

Source: Processed by Author

3. Results and Discussion

The Autoregressive Distributed Lag (ARDL) model allows researchers to analyze both long-term and short-term dynamic relationships between the dependent and independent variables. Based on the stationarity test results presented in Table 2 using the Phillips–Perron method, it is found that all variables become stationary at the first difference level with a 5 percent significance level. Since these variables are not stationary at the level, this indicates the potential existence of a long-term relationship. Therefore, a bounds test is conducted to examine the possibility of cointegration among the variables.

Table 2. Stationary Test

Variable	(I(0)) Prob.	(I(I)) Prob.
IH	0.022	0.000
BM	0.012	0.000
SB	0.352	0.001
TBS	0.382	0.026

Source: Processed by Author

The ARDL bounds test results in Table 3 provide strong evidence of a long-term relationship among the variables under study. With an F-statistic value of 3.654, the null hypothesis of no level relationship is rejected at the 10% significance level, as this value exceeds the upper critical bound I(1). Although the results become inconclusive at the 5% significance level, the presence of cointegration at the 10% level still offers an essential indication of a long-term association among the variables. These findings support the validity of the ARDL model used and suggest that analyzing the long-term relationships among the variables in the model is appropriate, even if the level of confidence is moderate.

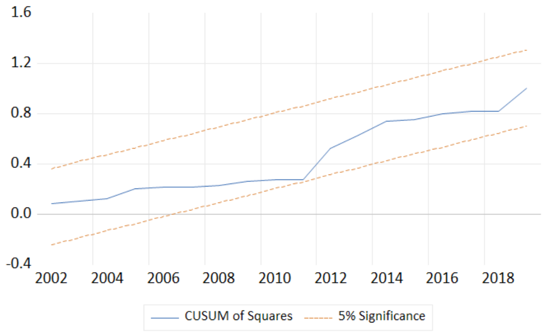
Table 3. Cointegration Test

Test Stat.	Value	Sig.	I(0)	I(1)
F-statistics	3.654	10%	2.37	3.20
		5%	2.79	3.67
		2.5%	3.15	4.08
		1%	3.65	4.66

Source: Processed by Author

The best ARDL model was selected using the optimal lag combination based on the Akaike Information Criterion (AIC). According to the AIC selection, the best ARDL model for this study is ARDL(4,2,2,2). Furthermore, the stability test results using the CUSUM graph indicate that the model demonstrates good and consistent stability throughout the study period. The CUSUM line consistently remains within the 5% significance bounds, providing strong evidence of the model's validity and reliability.

Figure 1. Stability Test



Source: Processed by Author

The partial significance test is observed based on the t-statistic value and the probability value. To determine the presence of a significant relationship, the first step is to compare the probability value with the alpha value. Based on the long-run ARDL estimation results presented in Table 4, the variable I, representing changes in interest rates, has a positive coefficient of 2.691 with a t-statistic of 2.328. This indicates that, in the long run, an increase in interest rates tends to be positively associated with green innovation, although the effect is not significant at conventional confidence levels. The variable BM has a larger positive coefficient of 3.900 but with a lower level of significance (t-statistic 2.207, Prob. 0.114). Meanwhile, the variable TBS shows the most significant positive coefficient at 6.531, but it is also statistically insignificant (t-statistic 2.094, Prob. 0.127).

Table 4. Cointegration Test

Variable	Value	Std.Error	t-stat	I(1)
I	2.691	1.155	2.328	3.20
BM	3.900	1.766	2.207	3.67
TBS	6.531	3.117	3.15	4.08
C	-103.609	53.251	3.65	4.66

Source: Processed by Author

Based on the short-run ARDL estimation results presented in Table 5, it is observed that green innovation (IH), as the dependent variable, is influenced by several economic factors, including interest rates (I), broad money (BM), and central bank transparency (TBS). The coefficient for IH at the first lag (IH(-1)) is 1.969, indicating that past green innovation levels have a positive effect on current green innovation, with a p-value of 0.063, close to significance at the 10% level. This suggests a continuation or persistence effect in green innovation implementation, where increases in green innovation in the previous period tend to drive increases in the current period. However, at the second lag (IH(-2)), the effect becomes negative, with a coefficient of -0.298 and an insignificant p-value (0.348), indicating that the impact of past green innovation begins to diminish after a specific period, suggesting the effect is not long-lasting.

The effect of interest rates (I) on green innovation shows an interesting dynamic. Without lag, interest rates have a positive and significant impact on green innovation, with a coefficient of 2.406 (p-value = 0.023), meaning that higher interest rates directly encourage green innovation in the short run. However, at the first lag (I(-1)) and the second lag (I(-2)), the effects turn negative and are significant, with coefficients of -3.763 (p-value = 0.062) and -2.728 (p-value = 0.006), respectively. This suggests that while higher interest rates may initially drive green innovation, perhaps by increasing capital costs and thereby encouraging efficiency, this effect reverses over time. Prolonged high interest rates can reduce firms' incentives to invest in green innovation due to higher borrowing costs.

The influence of broad money (BM) on green innovation also shows significant variation. Directly, BM harms green innovation, with a coefficient of -5.462 (p-value = 0.049), indicating that increased liquidity in the economy may reduce incentives for green innovation. However, at the first lag (BM(-1)), the effect turns positive and significant (coefficient 4.167; p-value = 0.028), suggesting that the positive impact of liquidity on innovation may take time to materialize. At the second lag (BM(-2)), the effect becomes negative again (coefficient -4.626; p-value = 0.052), implying that the impact may be temporary and subject to other factors such as financial instability. Central bank transparency (TBS) shows a directly significant adverse effect (-16.615; p-value = 0.028) and varied impacts at lags, reflecting that transparency policies require time to create a supportive environment for green innovation.

Table 5. Cointegration Test

Variable	Coefficient	Std.Error	t-stat	Prob.
IH(-1)	1.969	0.685	2.873	0.064**
IH(-2)	-0.298	0.269	-1.108	0.349
I	2.406	0.558	4.311	0.023*
I(-2)	-3.764	1.301	-2.892	0.063**
I(-2)	-2.729	0.813	-3.357	0.044*
BM	-5.463	1.703	-3.209	0.049*
BM(-1)	4.167	1.053	3.959	0.029*
BM(-2)	-4.626	1.481	-3.123	0.052**
TBS	-16.615	8.211	-2.024	0.136
TBS(-1)	27.475	8.671	3.168	0.051**
TBS(-2)x	-20.777	6.535	-3.179	0.050**
C	157.309	59.523	2.643	0.078**
R-squared	0.920	Adjusted R-squared	0.578	

Source: Processed by Author

Note: * Significant at 0.05 ; ** Significant at 0.10

This study reveals the dynamic influence of monetary variables on green innovation. The ARDL estimation tool was used to identify the significance of correlations among the predetermined variables. The ARDL estimation results show that several key factors significantly influence green innovation in Indonesia: past innovation performance, interest rates, broad money, and central bank transparency, although their effects vary and sometimes contradict each other over time.

Green innovation exhibits persistence in the short run, where increases in the previous period tend to trigger increases in the current period. However, this effect tends to fade after several periods. This finding aligns with endogenous growth theory, particularly the Schumpeterian framework, which emphasizes the importance of continuous knowledge flows and sustained research investment, while also recognizing the innovation life cycle from peak to decline (Romer, 1990; Aghion et al., 2016; Yin et al., 2022).

Interest rates show varied impacts, initially having a direct positive effect on green innovation, but shifting to negative implications in subsequent periods. This indicates a trade-off between short-term efficiency gains and potential long-term investment constraints caused by rising capital costs. In line with Schumpeter's theory, this finding reflects creative destruction, where increased capital costs can drive efficiency and innovation in the early stages, but if prolonged, may reduce incentives for new technology investment. From the perspective of expansionary monetary policy, lowering interest rates in Indonesia has the potential to stimulate green innovation by reducing financing costs, consistent with the supply-side argument. However, this effect must be managed carefully to prevent it from reversing into a barrier due to long-term cost pressures (Caballero & Jaffe, 1993; Aghion, Akcigit, & Deaton, 2016; Yin, Chang, & Wang, 2022).

In addition, broad money and central bank transparency show significant yet varied effects. An increase in broad money, reflecting higher liquidity in the economy, may initially reduce incentives for green innovation. Still, its positive effects tend to appear with a time lag, indicating the complexity of the relationship between monetary policy and sustainable innovation. This suggests that increased liquidity in Indonesia requires time to be translated into research and development activities that yield green innovation, as explained in the concept of knowledge spillover. However, the short-lived positive effect indicates limitations in technological absorption capacity or structural challenges within the domestic innovation ecosystem (Romer, 1990; Desalegn, Fekete-Farkas, & Tangl, 2022; Spyromitros, 2023).

Central bank transparency shows a complex yet strategic influence in promoting market stability and long-term investment. In the short term, increased transparency often triggers negative market responses due to sudden adjustments in expectations or uncertainty over the direction of new policies. This reflects adaptation challenges, particularly in sectors sensitive to changes in policy signals, such as renewable energy. However, in the long run, transparency plays a crucial role in building market trust, stabilizing economic actors' expectations, and creating the certainty needed by green investors. From the perspective of endogenous growth theory, improving the transparency of Bank Indonesia's monetary policy requires time to build credibility, reduce uncertainty, and create an investment climate conducive to green technology adoption.

The subsequent decline in effects may align with the Schumpeterian view, as the stability of rules can reduce opportunities for innovative rent-seeking by certain actors, thereby lowering innovation incentives (Mishkin, 2004; Eijffinger & Geraats, 2006; Dincer & Eichengreen, 200). The findings of this study are consistent with those reported by Spyromitros (2023), which show that a 1% increase in central bank transparency (CBT) correlates with a 0.39% increase in green innovation. Implementing transparent methods has the potential to attract more resources linked to environmental benefits, thus generating a significant positive impact. A high level of central bank transparency can increase trust and a sense of security among investors, which is a key prerequisite for participating in foreign investment with minimal concerns about asset dissipation risk (Bevan, Estrin, & Meyer, 2004). Conversely, low transparency tends to exacerbate information asymmetry due to limited disclosure and the availability of information needed to implement transparent macroeconomic policies. This condition, in turn, worsens uncertainty in financial markets, increases return volatility, and raises corporate capital costs. The accumulation of these factors negatively affects capital inflows into a country (Portes & Rey, 2005; Du, Boateng, & Newton, 2016; Kwabi et al., 2020).

In Indonesia, the implementation of central bank transparency covers both ex-ante and ex-post dimensions. Ex-ante transparency is reflected through the forward guidance mechanisms employed by Bank Indonesia, particularly regarding the direction of interest rate policy (such as the BI 7-Day Reverse Repo Rate), inflation projections, and macroeconomic outlook, which are publicly communicated through formal forums such as the Board of Governors' Meeting (Rapat Dewan Gubernur or RDG) and the *Laporan Perekonomian Indonesia* (Indonesian Economic Report). The primary goal of this approach is to shape market participants' expectations before policies are implemented, thereby reducing volatility arising from uncertainty over the direction of monetary policy. Institutional implementation of central bank transparency began to be strengthened with the enactment of Law No. 23 of 1999 concerning Bank Indonesia, which marked the restoration of Bank Indonesia's independence following the 1998 crisis. The law mandates transparency obligations through the submission of annual and quarterly reports to the government and the House of Representatives (DPR). These reports include evaluations of monetary policy achievements, policy strategies for the upcoming period, and performance in the areas of price stability, payment systems, and financial stability.

In addition to being submitted to the relevant authorities, summaries of these reports must also be published in the State Gazette and disseminated to the public through mass media. Bank Indonesia's reports cover aspects of macroeconomics, monetary policy, payment systems, and financial stability. In practice, Bank Indonesia consistently provides information to three primary stakeholder groups: the public, the government, and parliament. This information is presented in various formats, with annual and quarterly reports as the primary forms. In contrast, other publications such as working papers and evaluation reports are issued on a limited basis. Furthermore, transparency to the public is reinforced through Bank Indonesia's official website, which provides regular updates on monetary policy, financial stability, payment systems, press releases, and speeches by the Governor (Kasiyanto, 2017).

Next, the correlation between interest rates and green innovation shows a positive direction; however, this finding is not statistically significant, indicating the need for a more accommodative monetary policy approach. Lowering interest rates or implementing other expansionary monetary policies focused on green technology sectors could provide more substantial incentives for investment in those areas by increasing liquidity and reducing borrowing costs. However, to maximize the positive effects of such monetary policies, institutional reforms that strengthen central bank independence and transparency must be reinforced, as suggested by Spyromitros (2023). This step would enhance market participants' confidence in the policies implemented and ensure that they can effectively support green innovation. In addition, the finding that broad money has a positive impact on green innovation but a negative impact on renewable energy consumption indicates an imbalance in financing allocation. More coordinated fiscal and monetary policies are needed to ensure that increased liquidity is effectively directed toward the sectors most in need, such as renewable energy. Consistent with the empirical evidence from Yin et al. (2022), Bank Indonesia and the government could develop a more transparent framework to channel investments into green energy infrastructure through tax incentives, subsidies, or easier access to credit.

Finally, the importance of central bank transparency and governance in influencing green innovation and sustainable economic growth cannot be overlooked. Although most central banks worldwide do not yet have an explicit sustainability mandate, the findings of this study suggest that implicit support for the government's climate policy priorities is already a significant step, aligned with the research of Dikau & Volz (2021). Bank Indonesia could strengthen its position by clarifying its sustainability mandate within its policy framework and ensuring that monetary policy aligns with national climate goals. In doing so, more targeted policies and improved governance could enhance the effectiveness of monetary policy in promoting green innovation and supporting Indonesia's transition toward a more resilient and sustainable economy.

4. Conclusion

This study shows that various economic factors influence green innovation in the short run. Green innovation in the previous period has a positive effect that diminishes over time, indicating an initial momentum that needs to be maintained. Interest rates have an immediate positive effect but turn negative in subsequent periods, highlighting the importance of cautious monetary policy. Broad money exerts a varied influence, initially negative but later positive, indicating the critical role of liquidity in driving green innovation after an adjustment period. Central bank transparency has an immediate adverse effect that changes over time, underscoring the link between monetary policy transparency and green innovation. These findings emphasize that macroeconomic factors have a significant and dynamic influence on green innovation, with effects that vary in the short term and over subsequent periods.

Based on these findings, several suggestions and policy recommendations can be made to strengthen the effectiveness of monetary policy in promoting green innovation in Indonesia. First, Bank Indonesia should consider a more accommodative monetary policy, such as lowering interest rates or selectively increasing liquidity, with a focus on sectors that contribute to green innovation. In addition, central bank transparency and accountability need to be enhanced through institutional reforms that strengthen the sustainability mandate, such as creating and publishing sustainability-related key performance indicators (KPIs). A more transparent framework is also needed to support investment in the renewable energy and environmentally friendly technology sectors, such as offering more favorable reserve requirements for banks financing green projects. Bank Indonesia could take a more active role in supporting the government's climate change mitigation policies by aligning its monetary policy with national climate targets.

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Appendix

Appendix 1. Stationary Test

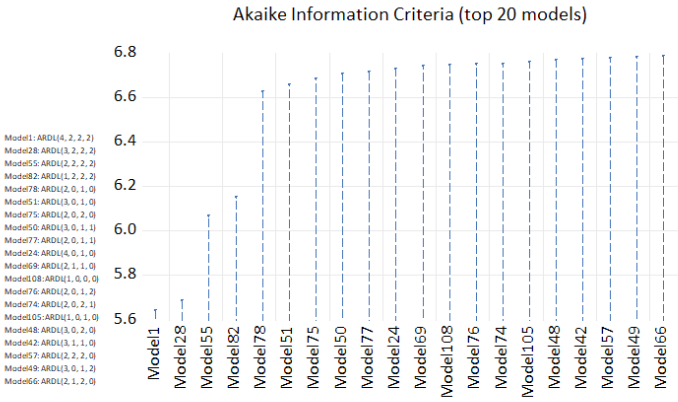
Intermediate Phillips-Perron test results UNTITLED

Series	Prob.	Bandwidth	Obs
IH	0.0229	0.0	20
I	0.0127	1.0	20
BM	0.3520	1.0	20
TBS	0.3827	1.0	20

Intermediate Phillips-Perron test results D(UNTITLED)

Series	Prob.	Bandwidth	Obs
D(IH)	0.0000	6.0	19
D(I)	0.0000	3.0	19
D(BM)	0.0013	1.0	19
D(TBS)	0.0260	1.0	19

Appendix 2. Optimal Lag Test



Appendix 3. Cointegration Test and Long-Run ARDL

Levels Equation
Case 2: Restricted Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
I	2.691307	1.155627	2.328872	0.1023
BM	3.900421	1.766876	2.207525	0.1144
TBS	6.531796	3.117919	2.094922	0.1272
C	-103.6090	53.25151	-1.945653	0.1469

EC = IH - (2.6913*I + 3.9004*BM + 6.5318*TBS - 103.6090)

F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
			Asymptotic: n=1000	
F-statistic	3.654322	10%	2.37	3.2
k	3	5%	2.79	3.67
		2.5%	3.15	4.08
		1%	3.65	4.66

Appendix 4. Short-Run ARDL Test

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
IH(-1)	1.969074	0.685285	2.873366	0.0639
IH(-2)	-0.298384	0.269402	-1.107580	0.3489
IH(-3)	0.645446	0.390841	1.651429	0.1972
IH(-4)	0.202159	0.279246	0.723949	0.5214
I	2.406146	0.558185	4.310663	0.0230
I(-1)	-3.763522	1.301375	-2.891957	0.0629
I(-2)	-2.728823	0.812993	-3.356516	0.0438
BM	-5.462659	1.702540	-3.208534	0.0490
BM(-1)	4.167040	1.052582	3.958875	0.0288
BM(-2)	-4.626373	1.481294	-3.123198	0.0523
TBS	-16.61521	8.210948	-2.023544	0.1362
TBS(-1)	27.47452	8.671154	3.168497	0.0505
TBS(-2)	-20.77651	6.535128	-3.179204	0.0501
C	157.3090	59.52339	2.642810	0.0775

R-squared	0.920881	Mean dependent var	17.77647
Adjusted R-squared	0.578034	S.D. dependent var	6.540884
S.E. of regression	4.248889	Akaike info criterion	5.643650
Sum squared resid	54.15917	Schwarz criterion	6.329825
Log likelihood	-33.97102	Hannan-Quinn criter.	5.711857
F-statistic	2.685978	Durbin-Watson stat	2.920833
Prob(F-statistic)	0.225622		

Appendix 5. Stability Test