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Driving Green Innovation in Emerging Markets: The Impact of Commissioners' Monitoring Competence with Audit Quality and Environmental Regulatory Pressure as Moderators

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ABSTRACT
This study aims to examine the effect of commissioners' monitoring competence on green innovation, as well as the moderating roles of audit quality and environmental regulatory pressure (PROPER). Using a quantitative approach with panel data from Indonesian basic materials companies during 2020–2024, the study employs panel regression analysis. The results show that commissioners' monitoring competence positively affects green process innovation and marginally affects green product innovation. PROPER significantly enhances both types of green innovation, while audit quality strengthens the relationship between monitoring competence and green innovation. These findings highlight the importance of governance and external pressure in promoting sustainable innovation.

Keywords:
green innovation, commissioners' monitoring competence, audit quality, environmental regulatory pressure, PROPER

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INTRODUCTION

Global climate change and increased greenhouse gas emissions have become major challenges to economic and environmental sustainability. Industrial activities, especially in the basic materials sector, contribute significantly to environmental degradation through carbon emissions, resource exploitation, and production waste (Li et al., 2018). In the global context, Indonesia is included in the group of countries with the largest contribution of carbon emissions, so it faces serious pressure to reduce greenhouse gas emissions, especially due to its high dependence on coal-based power plants (Hakim et al., 2025). Along with that, pressure from regulators, investors, and society is increasing, prompting companies to integrate sustainability practices as part of their business strategy as well as a means of gaining social legitimacy (Shahzad et al., 2020; A'zizah et al., 2024). Within this framework, a company's performance is no longer evaluated solely on the basis of financial aspects, but also on the basis of its contribution to environmental sustainability.

Despite the growing pressure on sustainability, companies face a dilemma between achieving economic performance and investing in environmentally friendly practices that often require high costs and uncertain outcomes. On the one hand, green strategies are believed to be able to increase the legitimacy and competitiveness of companies; on the other hand, large implementation costs can suppress short-term profitability (Agustia et al., 2019). This tension raises fundamental questions about what internal factors are able to drive companies to consistently adopt sustainability practices, particularly green innovation.

In response to these pressures, green innovation (GI) emerged as a key strategy in striking a balance between economic performance and environmental sustainability. GI includes the development of products and processes that are able to reduce environmental impact, improve resource efficiency, and minimize waste In response to these pressures, green innovation (GI) has emerged as a key strategy in achieving a balance between economic performance and environmental sustainability. GI includes the development of products and processes that are able to reduce environmental impact, improve resource efficiency, and minimize waste (Rennings, 2000; Kemp & Pearson, 2007). Operationally, GI is divided into green product innovation and green process innovation, which play a role in creating operational efficiency while improving the company's reputation (Saunila et al., 2018; Soewarno et al., 2019). In addition, GI is also an important means to gain legitimacy and competitive advantage amid increasing stakeholder expectations (Wang, 2022).

However, the success of the implementation of green innovation is not only determined by external pressures, but also by the company's internal mechanisms, especially corporate governance. The board of commissioners as a supervisory body has a strategic role in directing the company's policies, including investment and innovation decisions. Board characteristics such as board size, board independence, education, expertise, and board diversity reflect the supervisory capacity and decision-making quality of the board of commissioners (Jiang et al., 2023; Klarner et al., 2020). In the perspective of resource dependence theory, these characteristics enrich access to external resources, information, and networks, while stakeholder–agency theory emphasizes the role of boards in ensuring that stakeholder interests, including environmental aspects, are optimally met.

However, empirical findings related to the role of corporate governance in environmental performance and sustainability practices still show inconsistent results. Several studies have found that the independence of the board of commissioners has a positive effect on environmental disclosure (Solikhah et al., 2021; Wahyuningrum et al., 2020), while other studies found no significant effect (Hidayah et al., 2023; Sukirman et al., 2021). Similar inconsistencies also occur in other factors such as environmental costs and the quality of environmental disclosure (Adyaksana et al., 2022; Elviani et al., 2022). In addition, the results of research related to education, expertise, and the diversity of the board on sustainability practices also show differences in findings. This indicates that the influence of governance mechanisms on sustainability is not linear and may be influenced by contextual factors as well as interactions with other mechanisms.

In the context of developing countries such as Indonesia, these challenges are becoming increasingly complex. Although the level of ESG disclosure is relatively high, the quality and credibility of sustainability reports are still a concern, mainly due to the low level of independent assurance and the wide range of reporting standards used. This condition has the potential to cause information asymmetry and greenwashing practices, thus emphasizing the importance of the role of the company's internal supervisory mechanism. Indonesia also has unique governance characteristics through a two-tier board system, where the board of commissioners functions as an independent supervisor of the board of directors (Ariani et al., 2023). This structure provides a strategic position for the board of commissioners to ensure that the company's policies, including green innovation, are implemented effectively and accountably.

Based on these gaps, this study emphasizes the importance of commissioners' monitoring competence as a key determinant in encouraging green innovation. These competencies are proxied through a combination of the characteristics of the board, namely size, independence, education, expertise, and diversity, which together reflect the supervisory capacity and decision-making quality of the board of commissioners. In addition, this study integrates moderation variables in the form of corporate environmental performance measured through PROPER as well as audit quality to capture the interaction between internal mechanisms and external pressures. In particular, this study aims to examine the influence of the supervisory competence of the board of commissioners on green innovation proxied through green process innovation and green product innovation, as well as to examine the role of PROPER moderation and audit quality in these relationships. This study uses a sample of companies in the basic materials sector listed on the Indonesia Stock Exchange, considering that this sector has a high level of environmental sensitivity and is under stricter regulatory pressure than other sectors. Thus, this sector becomes a relevant context to test the effectiveness of corporate governance mechanisms in encouraging green innovation.

LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

Theoretical Framework

Research on the relationship between board characteristics and organizational performance is generally based on two main perspectives, namely Agency Theory and Resource Dependence Theory (Hillman & Dalziel, 2003; Yousaf et al., 2022). Agency theory emphasizes that the main role of the board is to perform the monitoring and control function of management in order to minimize conflicts of interest between managers and owners (Jensen & Meckling, 1976; Fama & Jensen, 1983). In this context, the separation between ownership and control provides an opportunity for managers to make decisions that are not always in line with the interests of shareholders, including in determining long-term investments such as green innovation which have high uncertainty (Naciti, 2019). Therefore, the existence of an effective board, demonstrated through adequate size, a high proportion of independence, and the quality of education and expertise, is crucial in ensuring that the company's strategic decisions remain aligned with long-term and sustainability interests.

On the other hand, Resource Dependence Theory views the board not only as a supervisory mechanism, but also as a strategic resource provider for the company (Pfeffer & Salancik, 1978). A board of commissioners that has a larger size, high independence, adequate level of education and expertise, and good diversity, is able to provide access to information, external networks, and strategic advice that companies need in dealing with the dynamics of the business environment (De Villiers et al., 2011; Liao et al., 2018; Bennouri et al., 2018). In the context of green innovation, the availability of external resources such as environmentally friendly technological knowledge, regulations, and best practices is very important (De Villiers et al., 2011; Shaukat et al., 2016). Board competencies formed from a combination of knowledge, skills, and experience (KSAOs) can be a source of competitive advantage that allows companies to develop green innovations more effectively (Asahak et al., 2018).

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In addition, Stakeholder Theory complements both perspectives by emphasizing that companies must consider the interests of various parties, including regulators, investors, society, and the environment (Freeman, 1984). In the context of sustainability, pressure from stakeholders encourages companies to adopt environmentally friendly practices, including green innovation, in order to maintain the company's legitimacy and reputation. A competent board of commissioners plays an important role in responding to these pressures by ensuring that the company's strategy is not only oriented towards economic profits, but also takes into account social and environmental aspects. Thus, the integration between the monitoring function (agency), resource dependence, and response to stakeholder pressure becomes a strong theoretical foundation in explaining how the competence of the board of commissioners can encourage the implementation of green innovation in companies.

HYPOTHESES DEVELOPMENT

Commissioners' monitoring competence is part of the board's competence which reflects the board's ability to carry out the supervisory function of management. The corporate governance literature shows that most research still focuses on the structural attributes of the board, such as size and independence, while aspects of board competencies that include knowledge, skills, experience, and work processes are relatively under-appreciated. In fact, the effectiveness of the board in carrying out its monitoring and advisory functions is highly determined by the quality of these competencies (Aguilera et al., 2015; Boivie et al., 2016). A competent board is not only able to oversee management, but also plays a role in providing strategic resources and policy direction for the company.

In the context of sustainability, companies are increasingly required to integrate green innovation as part of their business strategy. Green innovation includes efforts to develop processes and products that are more environmentally friendly, efficient in the use of resources, and able to reduce negative impacts on the environment. Because these innovations are complex, risky, and long-term-oriented, decisions related to green innovation are generally at the board level (Jain & Zaman, 2020; Nadeem, 2021). Therefore, the role of the board in the monitoring and advisory function is crucial in ensuring that management is committed to a sustainable innovation strategy.

A board of commissioners with high monitoring competence will be more effective in reducing opportunistic management behavior and ensuring that strategic decisions are aligned with the long-term interests of the company and its stakeholders (Hill & Jones, 1992; Boivie et al., 2016). In addition, based on resource dependence theory, a competent board is also able to provide access to information, networks, and resources needed to support the implementation of innovations, including environmentally friendly innovations (Pfeffer & Salancik, 1978; Aguilera et al., 2015). This competence allows the board to direct companies in developing green innovation strategies more effectively (Xie et al., 2019; Albort-Morant et al., 2017).

Thus, the higher the monitoring competence of the board of commissioners, the greater the company's ability to develop green innovation, both in the form of process innovation and product innovation. Based on these arguments, the following hypothesis is formulated:

H1a: Commissioners' monitoring competence has a positive effect on green process innovation.

H1b: Commissioners' monitoring competence has a positive effect on green product innovation.

Furthermore, the effectiveness of internal mechanisms such as the monitoring competence of the board of commissioners is inseparable from the role of external mechanisms. In conditions where internal mechanisms are not yet fully effective, external mechanisms play a role in reducing agency conflicts, aligning management interests, and improving the quality of strategic decision-making (Al-Najjar & Clark, 2017; Guo et al., 2020; Liang & Wang, 2025). Green innovation itself is a high-risk investment with relatively limited short-term economic benefits, so companies tend to have low incentives to adopt it without external pressure (He et al., 2021; Qi et al., 2021; Su et al., 2022).

In the Indonesian context, one of these external pressures is manifested through PROPER (Corporate Performance Rating Assessment Program in Environmental Management), which is a government policy to improve the

performance of corporate environmental management. PROPER assesses the company's compliance with environmental regulations and aspects beyond compliance, so that it reflects the level of transparency and accountability of the company in environmental management. Through a ranking system that is published to the public, PROPER is not only an evaluation tool, but also creates reputational pressure and scrutiny from stakeholders on the company.

As a form of environmental regulatory pressure, PROPER represents environmental regulatory pressure that encourages companies to adjust their business strategies to be more sustainability-oriented. In the perspective of institutional theory, regulatory pressures such as PROPER encourage companies to gain legitimacy by improving environmental practices, including through green innovation (Lin et al., 2025). In addition, the publication of PROPER results increases the visibility of the company's environmental performance, thereby strengthening pressure from stakeholders such as investors, consumers, and the government (Park et al., 2017; Harahap et al., 2023).

Companies with low PROPER ratings tend to face reputational risks and higher regulatory pressures, so they are encouraged to increase investment in green technologies and sustainable innovation to improve their performance (Teng et al., 2021; Ahsan et al., 2020). In contrast, highly-ranked companies have an incentive to maintain their reputation and credibility through strengthening green innovation practices. Thus, PROPER not only encourages green innovation directly, but also strengthens the effectiveness of internal mechanisms, including the role of the board of commissioners in the monitoring function.

In this case, when the board of commissioners has high monitoring competence, the existence of PROPER will further strengthen the incentive for the board to ensure that management executes a strategy that is aligned with the demands of environmental regulations. PROPER increases the intensity of external supervision and transparency, thereby increasing the impact of the board's monitoring function in encouraging the implementation of green innovation. In other words, PROPER strengthens the relationship between commissioners' monitoring competence and green innovation through increased regulatory pressures, stakeholder expectations, and reputational risks faced by companies.

Based on these arguments, the following hypothesis is formulated: H2a: PROPER strengthens the influence of commissioners' monitoring competence on green process innovation.

H2b: PROPER strengthens the influence of commissioners' monitoring competence on green product innovation.

Audit quality is a governance mechanism that plays a role in increasing transparency and reducing information asymmetry between management and stakeholders. In the context of innovation, especially green innovation, audit quality is important because innovation activities contain a high level of uncertainty and information asymmetry (Aboody & Lev, 2000; Hall, 2002). High-quality audits can increase the credibility of financial information and facilitate companies' access to external funding through lowering capital costs and increasing financing capacity (DeFond & Zhang, 2014; Robin et al., 2017; Javeed et al., 2022).

From the perspective of governance effect, high audit quality can strengthen the effectiveness of the monitoring function of the board of commissioners. More accurate and reliable information allows commissioners to carry out supervision more optimally in directing management to long-term investments, including green process innovation and green product innovation. In addition, improving the quality of information also reduces the risk of managers' careers in making innovative decisions, thereby encouraging the implementation of more sustainable innovation strategies (Hirshleifer et al., 2018).

However, audit quality can also cause managerial myopia effects. Strict audits limit managers' flexibility in performing accrual-based profit management, thus encouraging the reduction of real activities such as R&D investments to meet short-term profit targets (Bushee, 1998; Graham et al., 2005). Additionally, auditor conservatism can reinforce short-term orientation and potentially inhibit innovation investment (Chy & Hope, 2021). However, in the context of developing countries, the governance role of audit tends to be more dominant than the effects of myopia (Choi & Wong, 2007; Gul et al., 2010).

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Thus, the quality of the audit is expected to strengthen the influence of the supervisory board's monitoring competence on green innovation. Based on these arguments, the following hypothesis is formulated:

H3a. Audit quality strengthens the influence of commissioners' monitoring competence on green process innovation.

H3b. Audit quality strengthens the influence of commissioners' monitoring competence on green product innovation.

RESEARCH METHODS

This study uses a quantitative approach with an explanatory research type that aims to examine the causal relationship between commissioners' monitoring competence, audit quality, environmental regulatory pressure (PROPER), and green innovation. The focus of the research is to analyze the direct influence of the monitoring competence of the board of commissioners on green process innovation and green product innovation, as well as to examine the role of audit quality moderation and PROPER ranking in strengthening these relationships. The unit of analysis in this study is the company, with the data used in the form of secondary data in the form of panels (a combination of cross-section and time series data).

The research population includes all basic materials sector companies listed on the Indonesia Stock Exchange (IDX). This sector was chosen because it has a direct relationship with the exploitation of natural resources and a relatively high environmental impact, making it relevant in the study of green innovation and environmental regulatory pressures. The research sample was determined using purposive sampling techniques with the following criteria: (1) companies in the basic materials sector that publish annual reports or sustainability reports, (2) companies that disclose information related to environmental activities or green innovation, (3) companies that have complete data related to the characteristics of the board of commissioners, audit quality, and PROPER ratings, and (4) companies that did not experience delisting during the observation period. This technique is used to ensure that the data obtained is relevant and can be analyzed comprehensively.

The dependent variable in this study is green innovation which consists of two dimensions, namely green process innovation (GPROC) and green product innovation (GPROD). Green process innovation is measured using a disclosure index based on five indicators, namely reduction in energy and resource consumption, use of recycled materials or technology, implementation of environmental campaigns, use of pollution control tools, and adoption of pollution control technology. Meanwhile, green product innovation is measured through three indicators, namely product design free of harmful ingredients, the use of environmentally friendly packaging, and energy efficiency in product use. Each indicator was measured using a dummy (1 if disclosed, 0 if not), then summed into an index score (Xie et al., 2019).

The main independent variable is commissioners' monitoring competence (CMC), which is measured using a composite index of five board attributes, namely board size, board independence, education level, professional expertise, and gender diversity. Each component was measured using a dummy approach based on the industry median, i.e. 1 if it was above the median and 0 if it was below the median. The CMC value is obtained from the sum of all these components, which reflects the level of monitoring competence of the board in aggregate (Aguilera et al., 2015; Boivie et al., 2016).

This study uses two moderation variables. First, audit quality (AQ) is measured using dummy variables, namely 1 if the company is audited by a Big 4 Public Accounting Firm and 0 if it is audited by a non-Big 4 (DeFond & Zhang, 2014). Second, environmental regulatory pressures are proxied using the PROPER rating, which is a company performance assessment program in environmental management in Indonesia. The PROPER rating is converted into a numerical scale for econometric analysis purposes, with the categories Gold = 4, Green = 3, Blue = 2, Red = 1, and Black = 0. This scale reflects the level of compliance and intensity of environmental oversight that companies face, while also illustrating the institutional pressures on sustainability practices.

As a control variable, this study used firm size, profitability (ROA), and leverage. Company size

is measured using the natural logarithm of total assets, profitability is measured by the ratio of net income to total assets, and leverage is measured by the ratio of total debt to total assets. This control variable was chosen because it was empirically proven to influence innovation decisions and the company's environmental performance.

The measurement of the research variables is briefly presented in Table 1.

Table 1. Variable Measurement

Variable	Symbols	Indicators/Measurements	Coding / Scale	Data Source
Green Process Innovation	GPROC	1. Reduce energy and resource consumption 2. Use of recycled materials/ technologies 3. Environmental campaigns 4. Use of pollution control tools 5. Adoption of pollution control technology	Index score (dummy 1 if disclosed, 0 if not), then summed	Annual/ sustainability reports
Green Product Innovation	GPROD	1. Hazardous material-free product design 2. Eco-friendly packaging 3. Energy efficiency in product use	Index score (dummy 1 if disclosed, 0 if not), then summed	Annual/ sustainability reports
Commissioners' Monitoring Competence	CMC	Formed from several council attributes: size, independence, education, expertise, and gender diversity	Composite index (dummy sum of each component)	Annual report
Board Size	BSIZE_C	Number of commissioners	1 = > industry median; 0 = other	Annual report
Board Independence	BIND_C	Proportion of independent commissioners	1 = > industry median; 0 = other	Annual report
Education	B_EDUC_C	Proportion of commissioners educated ≥ S2	1 = > industry median; 0 = other	Annual report
Expertise	B_EXP_C	Proportion of commissioners with a professional background (finance, law, engineering, environment)	1 = > industry median; 0 = other	Annual report
Gender Diversity	BGEN_C	Gender diversity of the board	1 = there are ≥1 females; 0 = none	Annual report
Audit Quality	AQ	Quality of the company's external audit	1 = audited by the Big 4; 0 = non-Big 4	Annual report
Firm Size	SIZE	Company size	Ln (Total Assets)	Annual report
Profitability	LONG	Company profitability	Net profit / total assets	Annual report
Leverage	LEV	The company's leverage level	Total debt/total assets	Annual report

Research data was obtained through documentation techniques from annual reports and company sustainability reports accessed through the company's official website and the Indonesia Stock Exchange, as well as PROPER data obtained from official publications of the Ministry of Environment and Forestry. All data collected is then processed and analyzed using Stata software.

The data analysis technique used is panel data regression. The selection of the best panel model is carried out through the Chow test and the Hausman test to determine whether the model used is a common effect, fixed effect, or random effect. To ensure the validity of the model, a classical assumption test was carried out which included multicollinearity, heteroscedasticity, and autocorrelation tests. In addition, to improve the reliability of the estimation results, robust standard errors are used.

Hypothesis testing was carried out by constructing two main regression models according to dependent variables. The first model is used to test the influence on green process innovation, while the second model is for green product innovation. The regression equations used are as follows:

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Model 1:

$$GPROC_{it} = \alpha + \beta_1 CMC_{it} + \beta_2 AQ_{it} + \beta_3 PROPER_{it} + \beta_4 (CMC_{it} x AQ_{it}) + \beta_5 (CMC_{it} x PROPER_{it}) + \beta_6 SIZE_{it} + \beta_7 ROA_{it} + \beta_8 LEV_{it} + \varepsilon_{it} \quad (1)$$

Model 2:

$$GPROC_{it} = \alpha + \beta_1 CMC_{it} + \beta_2 AQ_{it} + \beta_3 PROPER_{it} + \beta_4 (CMC_{it} x AQ_{it}) + \beta_5 (CMC_{it} x PROPER_{it}) + \beta_6 SIZE_{it} + \beta_7 ROA_{it} + \beta_8 LEV_{it} + \varepsilon_{it} \quad (2)$$

The moderation effect was tested through the significance of the coefficient of the interaction variables, namely CMC×AQ and CMC×PROPER. Significant interaction coefficients showed that the moderation variable strengthened or weakened the relationship between commissioners' monitoring competence and green innovation. With this approach, the research is expected to be able to provide comprehensive empirical evidence on the role of corporate governance and regulatory pressures in encouraging the implementation of green innovation.

RESULTS AND DISCUSSION

Descriptive Statistical Test Results

Descriptive statistics are used to provide an overview of the characteristics of the research data. This analysis includes the mean values, standard deviations, minimum values, and maximums of each of the variables used in the study. The research sample comes from companies in the basic materials sector listed on the Indonesia Stock Exchange during the period 2020–2024. Based on the data collection process, the number of initial observations was 565 (113 companies × 5 years). However, after adjusting for the availability of data, the number of observations that can be used in this study became 542. Thus, the data used in this study is an unbalanced panel. The results of descriptive statistics are presented in Table 2.

Table 2. Descriptive Statistics

Variable	Obs	Red	Std. Dev.	Min	Max
GPROC	542	2,134	1,102	0	5
GPROD	542	1,287	0,856	0	3
CMC	542	2,876	1,214	0	5
AQ	542	0,412	0,492	0	1
CLEAN	542	2,156	0,923	0	4
SIZE	542	27,958	1,703	24,431	32,049
LONG	542	0,054	0,087	-0,321	0,289
LEV	542	1,015	1,141	0,002	6,588

Source: Stata processed data

Based on Table 2, the green process innovation variable (GPROC) has an average value of 2.134 out of a maximum total score of 5, which shows that the level of implementation of environmentally friendly process innovation in companies in the basic materials sector is still in the medium category. A minimum value of 0 indicates that there are still companies that have not disclosed green process innovation practices at all, while a maximum value of 5 indicates that there are companies that have fully implemented all indicators. The standard deviation of 1.102 reflects considerable variation between companies in the implementation of green process innovations.

Furthermore, the green product innovation (GPROD) variable has an average of 1,287 out of a maximum total of 3, which indicates that the development of environmentally friendly products is also still relatively limited. A minimum value of 0 and a maximum of 3 indicate a gap between companies in adopting green product innovation.

The standard deviation of 0.856 indicates that there is a difference in the level of implementation that varies considerably between the samples. These findings indicate that in general companies are more likely to adopt process innovation than product innovation, even though both are not optimal.

The commissioners' monitoring competence (CMC) variable has an average score of 2.876 out of a maximum of 5, which indicates that the supervisory competence of the board of commissioners is at a medium level. A minimum value of 0 indicates that there are companies with board characteristics that do not support the monitoring function, while a maximum value of 5 reflects the existence of a company with a very competent board structure. The standard deviation of 1.214 indicates a heterogeneity in the quality of the board of commissioners between companies.

For the moderation variable, audit quality (AQ) had an average of 0.412, which means that about 41.2% of the companies in the sample were audited by the Big 4 Public Accounting Firms. This shows that most companies still use non-Big 4 auditors. Meanwhile, the PROPER variable has an average value of 2.156, which indicates that in general the company is rated "blue", i.e. it has met the minimum standards of environmental compliance. A minimum value of 0 and a maximum of 4 indicates a variation in the level of environmental performance of the company, from non-compliant to those with excellent environmental performance.

On the control variable, SIZE had an average of 27,958 which indicates that the sample was dominated by large sized companies. The ROA variable has an average of 0.054, which indicates that the company is generally able to generate positive profitability, even though there are companies that suffer losses (minimum value -0.321). Meanwhile, the LEV has an average of 1.015 with a maximum value of 6.588, which indicates considerable variation in the company's funding structure, particularly in the use of debt. Overall, these descriptive statistics show a fairly high variation between companies, which supports the feasibility of the data for further analysis in empirical models.

Multicollinearity Test Results

To ensure that the regression model used in this study does not experience multicollinearity problems, testing is carried out through the analysis of correlation matrix between variables. This test aims to detect the presence of strong linear relationships among independent variables that have the potential to affect the accuracy of the model's estimates. The results of the test are presented in Table 3.

Table 3. Multicollinearity Test Results

Variable	GPROC	GPROD	CMC	AQ	CLEAN	SIZE	LONG	LEV
GPROC	1.000							
GPROD	0.512	1.000						
CMC	0.284	0.267	1.000					
AQ	0.118	0.103	0.203	1.000				
CLEAN	0.326	0.298	0.241	0.167	1.000			
SIZE	0.215	0.198	0.298	0.354	0.401	1.000		
LONG	0.142	0.156	0.176	0.095	0.128	0.221	1.000	
LEV	-0.121	-0.108	-0.084	-0.067	-0.052	0.081	-0.214	1.000

Source: processed data from Stata

Based on Table 3, all correlation coefficient values between variables are below the general threshold of 0.80, so it can be concluded that there is no indication of serious multicollinearity in this study model. The highest correlation occurred between the SIZE and PROPER variables of 0.401, which still showed a moderate relationship and was within safe limits.

The correlation between the main variables of the study showed a relatively low to moderate relationship. For example, the relationship between green process innovation (GPROC) and green product innovation (GPROD) of 0.512 indicates that the two variables are related as part of green innovation, but not high enough to give rise to the problem of multicollinearity. The commissioners'

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monitoring competence (CMC) variable also showed a moderate correlation with GPROC (0.284) and GPROD (0.267), reflecting a conceptual relationship without interfering with the model's estimation.

Furthermore, the audit quality (AQ) and PROPER variables showed a relatively low correlation with the other variables, indicating that the two variables provided different information in the model. Control variables such as SIZE, ROA, and LEV also do not show a strong relationship with each other, so they do not give rise to the potential for multicollinearity. Thus, it can be concluded that this research model meets the assumption of the absence of multicollinearity, so that all independent and control variables are suitable for use in further regression analysis.

Regression Test Results

Table 4. Regression Test Results (Green Process Innovation – GPROC)

GPROC	Coefficient	Std. Error	t-stat	p-value
CMC	0.0821	0.0314	2.61	0.009***
AQ	0.0415	0.0287	1.45	0.148
CLEAN	0.0678	0.0196	3.46	0.001***
CMC×AQ	0.0583	0.0261	2.23	0.026**
CMC×PROPER	0.0214	0.0148	1.45	0.147
SIZE	0.0126	0.0069	1.82	0.069*
LONG	0.0932	0.0715	1.30	0.195
LEV	-0.0284	0.0107	-2.65	0.008***
Adj R2	0.182			
Prob > F	0.0000			

Table 5. Regression Test Results (Green Product Innovation – GPROD)

GPROD	Coefficient	Std. Error	t-stat	p-value
CMC	0.0547	0.0298	1.84	0.066*
AQ	0.0621	0.0275	2.26	0.024**
CLEAN	0.0493	0.0187	2.64	0.008***
CMC×AQ	0.0715	0.0249	2.87	0.004***
CMC×PROPER	0.0332	0.0139	2.39	0.017**
SIZE	0.0104	0.0065	1.60	0.110
LONG	0.1186	0.0683	1.74	0.083*
LEV	-0.0217	0.0102	-2.13	0.033**
Adj R2	0.205			
Prob > F	0.0000			

The test results in Table 4 show that commissioners' monitoring competence (CMC) has a positive and significant effect on green process innovation (GPROC). This shows that the higher the monitoring competence of the board of commissioners, the more effective the company is in encouraging environmentally oriented process innovation. Thus, H1a is supported. However, the audit quality (AQ) variable does not have a significant effect directly on GPROC, indicating that audit quality does not always directly encourage green process innovation.

The PROPER variable has a positive and significant effect on GPROC, which shows that environmental regulatory pressures are able to encourage companies to improve process efficiency and the use of environmentally friendly technologies. For the moderation effect, the CMC×AQ interaction had a positive and significant effect, so H3a was supported, which means audit quality strengthened the role of the board's competence in driving process innovation. In contrast, CMC×PROPER interactions were not significant, suggesting that regulatory pressures do

not necessarily strengthen the board's role in the context of process innovation.

In Table 5, the results show that CMC has a positive effect but only at a significant level of 10% on green product innovation (GPROD), so that H1b is weakly supported. The AQ and PROPER variables are both positive and significant, indicating that audit quality and regulatory pressures play a role in driving the development of environmentally friendly products.

In contrast to the previous model, both moderation variables showed significant results. The interaction of CMC×AQ and CMC×PROPER has a positive effect on GPROD, so H3b is supported. This shows that both audit quality and regulatory pressure are able to strengthen the effectiveness of the board's competence in encouraging green product innovation. These findings indicate that product innovation is more sensitive to a combination of governance and external pressures than process innovation.

RESULTS AND DISCUSSION

The first hypothesis (H1a and H1b) states that commissioners' monitoring competence (CMC) has a positive effect on green process innovation (GPROC) and green product innovation (GPROD). Empirical results show that CMC has a positive and significant effect on GPROC and has a positive but weak effect on GPROD. These findings are consistent with the theoretical argument that the competence of the board of commissioners is an important factor in increasing the effectiveness of the monitoring and strategic decision-making function (Aguilera et al., 2015; Boivie et al., 2016). In the development of the previous hypothesis, it was explained that a competent board is able to reduce information asymmetry and opportunistic behavior of management, making it more effective in encouraging the implementation of long-term strategies such as green innovation. These results confirm that the role is stronger in process innovation that is internal and requires intensive supervision, compared to product innovation that is also influenced by external factors such as market demand (Xie et al., 2019).

The second hypothesis (H2a and H2b) states that environmental regulatory pressure (PROPER) has a positive effect on green innovation. The results of the study showed that PROPER had a positive and significant effect on GPROC and GPROD. This is in line with the institutional theory on which the hypothesis is based, where regulatory pressures encourage companies to adjust their business practices to gain social legitimacy (Lin et al., 2025). In the previous narrative, it was explained that PROPER as a public evaluation and transparency mechanism creates external pressure for companies to improve environmental performance. These empirical results support the argument, that companies that face higher regulatory pressures tend to increase green innovation as a form of compliance as well as a reputation strategy (Luo et al., 2022; Harahap et al., 2023).

The third hypothesis (H3a and H3b) examines the role of audit quality (AQ) as a moderation variable in the relationship between CMC and green innovation. Based on the development of the hypothesis, audit quality is predicted to strengthen the relationship through the governance effect mechanism, namely by increasing transparency and information quality so that the monitoring function of the board becomes more effective (DeFond & Zhang, 2014). The results showed that CMC×AQ interactions had a positive and significant effect on GPROC and GPROD, so that H3a and H3b were supported. These findings confirm that audit quality strengthens the role of the board of commissioners in driving green innovation through increased information credibility and reduction of information asymmetry. Thus, these results are consistent with the theoretical argument that high-quality audits can improve the effectiveness of corporate governance (Bushman & Smith, 2001).

However, hypothesis development also considers the managerial myopia effect, where high audit quality can encourage conservatism and short-term orientation that has the potential to inhibit innovation (Chy & Hope, 2021; Nguyen et al., 2020). This is reflected in the results of research where quality audit does not have a direct effect on GPROC, although it does affect GPROD. In other words, the role of audit is stronger as a reinforcing mechanism (moderator) than as a direct determinant of innovation. This strengthens the argument that the effects of audits on innovation are indirect and depend on the corporate governance context.

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In addition, the results of the PROPER moderation showed that the interaction between CMC and PROPER was only significant in GPROD, but not in GPROC. In the development of the previous hypothesis, it was explained that PROPER as regulatory pressure can strengthen the relationship between governance and innovation. However, empirical results show that these effects are stronger on product innovation than on process innovation. This indicates that regulatory pressures and public exposure are more effective in encouraging innovation that is visible and has a direct impact on stakeholder perceptions (Weng et al., 2015; Hidayat et al., 2024). Thus, although PROPER generally plays a role in promoting green innovation, its role as a moderator depends on the type of innovation the company is doing.

CONCLUSION

This study aims to examine the role of commissioners' monitoring competence (CMC) in encouraging green innovation, both in the aspects of green process innovation (GPROC) and green product innovation (GPROD), as well as examining the role of quality audit (AQ) moderation and environmental regulatory pressures proxied through PROPER. Based on the results of an empirical analysis of companies in the basic materials sector on the Indonesia Stock Exchange for the 2020–2024 period, it was found that the monitoring competence of the board of commissioners plays a role in increasing the implementation of green innovation, although not all relationships show consistent significance. This shows that the effectiveness of the board is not only determined by the structure, but also by the quality of the competencies possessed in carrying out the strategic oversight function.

Furthermore, the results show that quality audit and PROPER have a role as moderation variables, but their influence does not necessarily strengthen the main relationship consistently. In some models, quality audits are able to strengthen the relationship between board competencies and green innovation through improving information quality and governance mechanisms. However, under certain conditions, the effect becomes insignificant, which indicates a potential trade-off such as the emergence of short-term managerial behavior (managerial myopia). Similarly, PROPER as a form of environmental regulatory pressure suggests that regulatory compliance can drive innovation, but its effectiveness depends on the strategic response of individual companies.

This research has several limitations. First, the measurement of green innovation is based on disclosures in annual and sustainability reports, so it is highly dependent on the company's level of transparency and potentially contains disclosure bias. Second, the board's competency variables are measured using a characteristic-based index approach, which may not yet fully capture the real quality of the board's decision-making process. Third, this research only focuses on one industrial sector, namely basic materials, so the generalization of results to other sectors needs to be done carefully. In addition, the use of secondary data limits the ability to delve deeper into aspects of the company's internal behavior and dynamics.

Based on these limitations, further research is recommended to expand the scope of the sample to various industrial sectors in order to obtain a more comprehensive picture. In addition, the use of alternative measurement methods, such as green patent data or other quantitative indicators, can improve the accuracy of measuring green innovation. Future research may also consider other variables, such as market pressures, organizational culture, or management quality, as factors influencing the relationship between corporate governance and green innovation. Finally, a mixed-method approach or the use of primary data can provide deeper insights into the internal mechanisms that drive the implementation of green innovation at the enterprise level.

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