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Decoding Inclusive Green Growth at the Subnational Level; Empirical Validation of BIGGI Using Factor Analysis in Indonesia

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Abstract

The Balanced Inclusive Green Growth Index (BIGGI) offers a comprehensive framework for evaluating sustainable development by integrating economic, social, and environmental dimensions. This study aims to assess the application of BIGGI across Java Island, Indonesia, a key region contributing significantly to the nation's GDP and Sustainable Development Goals (SDGs). Using cross-sectional data from 2022 and factor analysis, the research identifies disparities among 107 districts and cities. Results reveal that 68 regions achieved high BIGGI scores (>1.000), reflecting a balance in green growth dimensions, while 13 regions scored ≤0.500 due to economic stagnation despite strong social indices. The methodology includes data normalization using the Min-Max approach and factor analysis validated through the Bartlett and Kaiser-Meyer-Olkin (KMO) tests. These techniques consolidate multiple variables into a single composite index. Findings emphasize the need for targeted local government interventions, particularly in low-performing regions, to address economic disparities through infrastructure development, renewable energy investments, and policy enhancements. This research contributes to sustainable development literature by providing actionable insights for policymakers to implement equitable and inclusive green growth strategies. The study underscores the utility of BIGGI as a replicable framework for regions with similar socio-economic and environmental challenges, aligning local development efforts with global SDGs.

Keywords: Inclusive Green Growth; EKC; BIGGI; Institutional Disparities; Green Development

1. Introduction

Inclusive green growth has emerged as a key paradigm in the global sustainable development agenda, emphasizing the need to harmonize economic advancement, social inclusion, and environmental protection (OECD, 2015; Sachs, 2019). Building upon the green economy framework, it integrates equity and distributional concerns into environmental and economic policymaking, recognizing that growth must not only be efficient but also fair and ecologically responsible (Jha et al., 2018; Zhao, 2022).

This multidimensional approach is central to achieving the Sustainable Development Goals (SDGs), particularly Goals 8 (decent work and economic growth), 10 (reduced inequalities), and 13 (climate action). However, operationalizing inclusive green growth into measurable and policy-relevant frameworks remains challenging, especially in developing countries with significant regional disparities (Georgeson et al., 2017; Zhang et al., 2011).

In the Indonesian context, pursuing inclusive green growth is complicated by persistent subnational disparities. While Java Island accounts for more than 58% of the national gross domestic product (GDP), many provinces outside Java continue to suffer from high poverty rates, limited access to basic services such as sanitation and education, and growing environmental degradation—particularly in the form of deforestation, water contamination, and land conversion (BPS, 2023; Damayanti and Chamid, 2016). These asymmetries highlight a fundamental policy challenge: national growth does not necessarily translate into equitable and sustainable outcomes at the regional level. The implementation of the Sustainable Development Goals (SDGs) across Indonesia thus demands localized strategies that are sensitive to economic structure, social conditions, and ecological vulnerability (Nguyen and Pham, 2023; Zhang et al., 2011).

Existing studies on green growth have predominantly focused on national-level indicators, often relying on aggregated macroeconomic metrics such as GDP growth, carbon intensity (Georgeson et al., 2017; Zhang et al., 2023), or Green GDP adjustments (Chi, 2010). This approach obscures the pronounced regional heterogeneities in economic structure, institutional capacity, and environmental conditions, particularly in a diverse and decentralized country like Indonesia. For instance, Bappenas (2022) and the OECD Green Economy review (2019) acknowledge that national indices can mask subnational disparities in low-carbon development and social inclusion. At the subnational level, Liang, Si and Zhang (2018) developed a Regional Sustainable Development Index in China that combined economic, social, and environmental indicators using entropy methods, highlighting the importance of composite indices for provincial-level analysis. Similarly, Indonesia has made early efforts with its Green Economy Index and Green Growth Index (Bappenas, 2022; GGGI, 2022), but these frameworks have yet to undergo comprehensive statistical validation or incorporate balanced measures across multiple dimensions. As a result, a clear gap remains in developing an empirically robust and statistically validated framework that integrates economic, social, and environmental dimensions into a single composite index tailored to Indonesia's regional context.

This study seeks to address these gaps by applying and statistically validating the Balanced Inclusive Green Growth Index (BIGGI), a multidimensional index originally proposed by the Asian Development Bank (Jha et al., 2018). The BIGGI framework integrates economic, social, and environmental indicators to assess development inclusivity and sustainability in a balanced manner. In this study, BIGGI is operationalized for 34 provinces in Indonesia using 2022 cross-sectional data and is enhanced through the application of factor analysis to statistically validate index construction and dimension weights. The analysis also incorporates the Environmental Kuznets Curve (EKC) hypothesis to explore the dynamic interaction between economic growth and environmental degradation, a phenomenon widely observed in developing countries (Ekonomou, 2023; Grossman and Krueger, 1991; Khan, 2023).

While the EKC suggests that environmental degradation initially increases with economic growth before declining after reaching a turning point, this trajectory is not guaranteed, especially in contexts with weak institutions and unbalanced social development (Acheampong and Opoku, 2023; Luo et al., 2024; Sarkodie, 2024). Therefore, this study not only constructs

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and validates a composite index but also embeds the results in a broader discussion of governance, inequality, and environmental transition pathways. Empirical studies emphasize the role of governance quality, human capital, and technological adaptation in shaping development trajectories toward sustainability (Apergis and Payne, 2024; Li et al., 2021; Nguyen and Pham, 2023).

Hence, by combining BIGGI, factor analysis, and EKC insights, this study aims to provide a comprehensive tool for evaluating regional disparities in inclusive green growth. It advances both the methodological rigor and policy relevance of green growth measurement, offering a replicable and adaptable framework for other decentralized economies beyond Indonesia. Theoretically, this research contributes to the literature on post-growth economics and multidimensional development assessment by integrating statistical validation into composite index construction, accounting for the interdependencies among social, economic, and environmental goals, and linking them to environmental transition dynamics. This enhances the explanatory power of post-growth development theories in decentralized contexts (Jackson, 2016; Raworth, 2017).

The study's future implications are significant. By identifying high-performing and lagging provinces across multiple dimensions, this research informs targeted policy interventions that address not only economic disparities but also environmental degradation and social exclusion. The validated BIGGI model can be replicated for monitoring progress toward Sustainable Development Goals (SDGs) at local levels, and potentially adapted to other decentralized economies. This provides a foundation for long-term comparative studies, encouraging integration of environmental quality into inclusive growth assessments. Therefore, this study contributes both methodologically and practically by integrating statistical validation techniques and governance analysis into the assessment of green growth. It highlights the need for multidimensional indicators to design more equitable and ecologically responsible development strategies. This study addresses the following research question**:** how do economic, social, and environmental dimensions jointly influence inclusive green growth at the subnational level in Indonesia?

2. Literature Review

2.1. Theoretical Foundations of Inclusive Green Growth

Sustainable development serves as the theoretical foundation of this study, emphasizing the integration of economic growth, social inclusion, and environmental protection (Brundtland, 1987; Sachs, 2019; Zhao, 2022). The concept has evolved from conventional development approaches into more inclusive frameworks that respond to ecological crises and inequality (Meadowcroft, 2002). The OECD (2015) and Zhao (2022)describe Inclusive Green Growth (IGG) as a development strategy that balances economic expansion with environmental sustainability and equitable access to opportunities. The Porter Hypothesis adds further depth by arguing that well-designed environmental regulations not only avoid harming businesses but can actually drive innovation and enhance competitiveness (Chen et al., 2024; Porter and van der Linde, 1995). This challenges the traditional notion that environmental protection comes at the cost of economic growth. Recent empirical studies support this view—for example, environmental taxes in China have spurred technological innovation (Feng et al., 2022), shifted investment from passive compliance to innovation (Chen et al., 2024), and improved air quality through centralized oversight (Qi, 2024). Moreover, bureaucratic pressure has been shown to encourage dynamic environmental investment (Chang et al., 2021), while soft law and stakeholder engagement have proven effective in aligning compliance with broader economic goals (Chen et al., 2024). Collectively, these findings reinforce the need for integrated frameworks such as BIGGI, which combine economic, social, and environmental indicators into a balanced measurement model. This approach is highly relevant in the Indonesian context, where interregional inequality and environmental governance challenges persist.

H1: Economic, social, and environmental dimensions jointly influence inclusive green growth outcomes at the provincial level in Indonesia.

2.2. Environmental Kuznets Curve: Empirical Evidence

The Environmental Kuznets Curve (EKC) hypothesis explains how the relationship between economic growth and environmental degradation may change over time. At early stages of development, pollution and resource depletion tend to increase due to industrial expansion and weak environmental regulations. However, after reaching a certain income level—the so-called turning point—environmental quality can improve as societies invest in cleaner technologies, stronger regulations, and greater public awareness (Grossman and Krueger, 1995; Panayotou, 2003).

Empirical studies show that this pattern is not universal. Factors such as institutional quality, energy structure, and governance capacity can influence whether and when the turning point is reached (Apergis and Payne, 2024; Stern, 2003). In some advanced economies, evidence supports the EKC, while in others especially those reliant on extractive industries—environmental degradation continues despite rising incomes (Dasgupta et al., 2002; Sarkodie, 2024). More recent research has also proposed alternative shapes, such as N-shaped curves, reflecting complex, non-linear dynamics. In the Indonesian context, subnational differences further complicate the EKC trajectory. Provinces like Jakarta and Bali may show signs of decoupling economic growth from environmental harm, while resource-dependent areas such as East Kalimantan or Papua often remain on the rising curve of degradation due to weak institutions and limited enforcement.

H2: There is a non-linear (inverted U-shaped) relationship between economic growth and environmental degradation at the provincial level, consistent with the Environmental Kuznets Curve (EKC).

2.3 Composite Indices and Multidimensional Measurement

Measuring Inclusive Green Growth (IGG) presents methodological challenges due to its inherently multidimensional nature. Traditional single indicators such as GDP or the Human Development Index (HDI) often fail to capture the full complexity of sustainable development outcomes. Composite indices address this gap by integrating various indicators into a unified metric, enabling more accurate tracking of regional disparities and policy performance. Several recent studies support the use of composite indices. (Zhao, 2022), for instance, constructed a provincial green growth index in China that combines ecological and social dimensions. Similarly, (Nguyen and Pham, 2023) applied a multidimensional model in Vietnam to reveal development gaps at the subnational level. From a methodological standpoint, (Saltelli et al., 2007) emphasize the need for rigorous validation using techniques such as Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA). This has been further demonstrated by (Xie et al., 2024) in their measurement of green development across East Asia. In Indonesia, however, the application of statistically validated composite indices at the provincial level remains limited. Most existing assessments rely heavily on GDP or partial indices like HDI, which may not fully reflect

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the interlinked nature of inclusive green growth. This study addresses that gap by developing and validating the Balanced Inclusive Green Growth Index (BIGGI) using EFA and CFA, offering a more robust and multidimensional framework for subnational analysis.

H3: The Balanced Inclusive Green Growth Index (BIGGI), when validated through factor analysis, provides a statistically reliable multidimensional measurement of inclusive green growth.

3.Methods

3.1 Data description

The year 2022 was selected as the reference point due to both substantive and methodological considerations. Substantively, it represents Indonesia's post-pandemic recovery period, marked by the implementation of inclusive and green development policies at national and regional levels. As the first full year of normalized socio-economic activity, it provides a relevant basis to assess policy effectiveness. Methodologically, using single-year cross-sectional data ensures indicator consistency across regions, minimizes temporal bias, and meets the assumptions of factor analysis, which requires homogenous variance (Hair et al., 2014).

Table 1 Indicators or variables forming each dimension

Dimension	Indicator	Unit	Data Source
Social Dimension	Gini Index	Percentage	Statistics Indonesia (BPS)
	Duration of Education	Years	Statistics Indonesia (BPS)
	Life Expectancy	Years	Statistics Indonesia (BPS)
	Proper Sanitation Access	Percentage	Statistics Indonesia (BPS)
Environmental Dimension	Water Pollution	Percentage	Ministry of Environment and Forestry of Indonesia
	Soil Pollution	Percentage	Ministry of Environment and Forestry of Indonesia
	Electricity Usage	kWh/capita	Ministry of Energy and Mineral Resources of Indonesia
	Environmental Quality Index	Index Score	Ministry of Environment and Forestry of Indonesia
Economic Dimension	Economic Growth	Percentage	Statistics Indonesia (BPS)
	Workforce Participation	Percentage	Statistics Indonesia (BPS)
	Poverty Rate	Percentage	Statistics Indonesia (BPS)

The data, sourced from Statistics Indonesia (BPS) and the Ministry of Environment and Forestry (KLHK), also ensures reliability and comparability. The 11 selected indicators reflect the BIGGI framework developed by the Asian Development Bank (Jha, 2018), capturing the multidimensional aspects of inclusive green growth across economic, social, and environmental domains. These variables align with previous studies (OECD, 2015; Xie et al., 2024; Zhao, 2022) and fullfil statistical adequacy criteria validated through KMO and Bartlett's tests, essential for constructing a reliable composite index through factor analysis. The choice of 2022 as the reference year is grounded in both substantive and methodological considerations that are essential to the objectives of this study. Substantively, 2022 represents a pivotal moment in Indonesia's development trajectory, marking the first full year of post-pandemic normalization following the economic and social disruptions of COVID-19. During this period, both national and subnational governments launched a range of inclusive and green recovery initiatives, including public investment in renewable energy, social protection expansion, and decentralized policy reforms aimed at addressing inequality and ecological stress. These policy shifts make 2022 an analytically relevant year for assessing whether sustainable development interventions translated into measurable subnational progress.

From a methodological standpoint, using cross-sectional data from a single, complete year ensures consistency in temporal coverage across all provinces and indicators. This approach eliminates inconsistencies caused by staggered reporting cycles and minimizes temporal bias that could distort inter-provincial comparisons. Furthermore, it aligns with the assumptions of factor analysis, which requires homogeneity of variance across observational units (Hair et al., 2014). Choosing a recent year also ensures that the data reflect contemporary policy conditions and institutional dynamics, which is crucial for generating policy-relevant insights. The study draws upon secondary data from authoritative national sources, primarily BPS and the Ministry of Environment and Forestry (KLHK). These institutions provide standardized, methodologically robust datasets that enable valid comparisons across Indonesia's 34 provinces.

The selection of 11 indicators is conceptually grounded in the Balanced Inclusive Green Growth Index (BIGGI) framework proposed by the Asian Development Bank (Jha, 2018). This framework emphasizes the interdependence of three core development dimensions: economic (e.g., GRDP growth, labor force participation, poverty rate), social (e.g., life expectancy, years of schooling, sanitation access), and environmental (e.g., pollution levels, electricity usage, and ecological quality). These indicators were chosen not only for their theoretical relevance but also for their availability, consistency, and use in previous empirical studies (OECD, 2015; Xie et al., 2024; Zhao, 2022). To ensure that the indicators were statistically suitable for index construction, the study employed the Kaiser-Meyer-Olkin (KMO) test and Bartlett's Test of Sphericity. These diagnostics confirmed adequate sampling and strong inter-variable correlation, which are prerequisites for applying factor analysis to extract latent dimensions. The validation process ensures that each dimension of the BIGGI captures internally coherent constructs, thus strengthening the index's reliability and interpretability in measuring inclusive green growth across Indonesian provinces.

The Balanced Inclusive Green Growth Index (BIGGI) is conceptually derived from the Inclusive Green Growth Index (IGGI), both of which are designed to capture the multidimensional nature of sustainable development. While IGGI serves as the foundational composite index aggregating normalized indicators across economic, social, and environmental dimensions, BIGGI extends this by incorporating a *balance factor* to reflect the degree of equilibrium among those dimensions. The balance factor is a statistical adjustment that penalizes uneven development across dimensions—assigning lower BIGGI scores to provinces with highly skewed performance, even if their IGGI scores are high. In essence, IGGI measures the aggregate level of inclusive green growth, whereas BIGGI captures both the level and internal balance of that growth. This hierarchical relationship ensures that BIGGI not only identifies high-performing regions but also distinguishes those that achieve sustainability through balanced interdimensional progress.

3.2 Methods

The method of forming the Balanced Inclusive Green Growth Index (BIGGI) is the goal of this study proposed by the Asian Development Bank (2018). Some of the stages used in data analysis start with the method of normalizing data variable the method used begins with the formation of composite variables based on a framework (OECD, 2008). With min-max method data

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normalization:
For positive indicators (i.e., higher values represent better outcomes):

$$Z_{ij} \frac{x_{ij\_}min_{j-}(x_{ij})}{max_j(x_{ij})-min_j(x_{ij)}} \quad (1a)$$

For negative indicators (i.e., higher values represent worse outcomes):

$$Z_{ij} \frac{max_j(x_{ij})-x_{ij}}{max_j(x_{ij})-min_j(x_{ij)}} \quad (1b)$$

Where:

Z_{ij} is the normalized value of indicator jjj for region iii, x_{ij} is the original value, Min (x_{ij}) and max_j (x_{ij}) are the minimum and maximum values of indicator j across all regions.

This normalization ensures that all indicators are scaled between 0 and 1, allowing meaningful comparison and aggregation across different units of measurement. In analyzing the relationship between indicators to find out whether indicators are able to explain the eigenvalues in the same indicator, this study uses the factor analysis method. The analysis begins with testing the homogeneity of data using the Bartlett's Test of Sphericity and the Kaiser-Meyer-Olkin (KMO) test. Both tests are essential to determine the homogeneity of variance across multiple indicators, assuming that the three dimensions forming the index exhibit similar characteristics. The KMO test value must exceed 0.5, indicating adequate sampling adequacy for factor analysis. A higher KMO value reflects stronger correlations among variables, which is necessary to proceed with dimensionality reduction techniques. The KMO test is specifically used to assess the suitability of the data for factor analysis, which is then followed by the extraction of factors.

If the eigenvalue obtained from the factor extraction is below 1, it suggests a lower level of explained variance, indicating a poor model fit for factor construction. Factor extraction is performed by reducing the initial set of p observed variables into a smaller set of q latent factors, as recommended by Hair et al. (2014). In this process, the methods applied include the Measure of Sampling Adequacy (MSA) and Kaiser's criterion for eigenvalue selection. Following the extraction, factor scores are calculated and subjected to linear regression analysis since each dimension consists of multiple indicators. Additionally, a quadrant analysis is employed to further examine the relationship between the Balanced Inclusive Green Growth Index (BIGGI) and economic growth, allowing for the classification of provinces based on their performance in both dimensions. The next stage is to aggregate using unequal weighting in the formation of the Inclusive Green Growth Index (IGGI) as the index that forms BIGGI. The unequal weighting method with data analysis, if the value is larger, the weight of the factor per indicator is also greater. And the formation of a composite index is carried out with the following equation:

$$IGGI = \sum_{j=1}^{n} w_j \,.\, x_j^i$$

Next, a penalty is applied to penalize dimensional imbalance, which is defined as follows:

$$BIGGI = IGGI\ x\ (1 - \text{Imbalance Factor})$$

The imbalance factor is assigned based on the consistency of development across the three dimensions:

Imbalance factor: 0.75 if unstable (development is unbalanced) and 0.25 if balanced (development is balanced).

After the extraction of factor scores, an information score is calculated to assess the level of balance within the dimensions of inclusive green growth. An information score approaching 0.75 indicates instability in the multidimensional indicators, reflecting substantial variance or imbalance across the economic, social, and environmental dimensions. Conversely, an information score closer to 0.25 suggests that the factors are well-balanced and stable, indicating consistency in development performance across the measured dimensions. This additional calculation ensures the robustness of the factor structure prior to integrating the factor scores into further regression analysis and quadrant mapping.

Based on the theoretical framework, this study adopts an integrative research model that links economic growth, social inclusion, and environmental sustainability into a unified assessment of inclusive green growth. The Balanced Inclusive Green Growth Index (BIGGI) serves as the core construct, validated through factor analysis, which consolidates multiple indicators across the three dimensions. The model further incorporates the Environmental Kuznets Curve (EKC) hypothesis to explain the non-linear relationship between income growth and environmental outcomes. Institutional quality and governance capacity are introduced as moderating variables influencing the disparities observed at the provincial level. The empirical analysis proceeds by first conducting KMO and Bartlett's tests to assess data suitability, followed by factor extraction and validation using eigenvalues and information scores. Subsequently, linear regression is applied to analyze the relationship between BIGGI scores and economic growth, complemented by quadrant analysis to classify provinces based on their inclusive green growth performance (Chen et al., 2024).

The BIGGI is constructed as a weighted composite index representing the economic, social, and environmental dimensions of inclusive green growth. The index is formulated as:

$$BIGGI_1 = \alpha . E_I + \beta . S_I + \gamma . Env_i$$

where α, β, γ are weights derived through factor analysis, and $E_i, S_{i,}, Env_i$ represent the normalized scores for province iii. All component variables are normalized using Min-Max scaling:

$$X^* = \frac{X_i - X_{min}}{X_{max} - X_{max}}$$

The conceptual framework of this study integrates three interconnected hypotheses to explain the determinants, dynamics, and measurement of Inclusive Green Growth (IGG) at the subnational level in Indonesia. At the core of the framework is IGG, conceptualized as a multidimensional development outcome influenced by three foundational components. First, Hypothesis 1 (H1) posits that economic, social, and environmental dimensions serve as the primary structural drivers of IGG. These dimensions are treated not as isolated variables but as interdependent pillars that must be addressed simultaneously to ensure sustainability and inclusivity. Economic indicators such as GRDP per capita, social indicators like access to education and health, and environmental factors including carbon emissions and renewable energy use collectively shape the quality of green growth. Second, Hypothesis 2 (H2) introduces a temporal and non-linear dynamic through the Environmental Kuznets Curve (EKC) framework. While some regions may reach a turning point where economic growth coincides with reduced environmental degradation, this relationship is shown to vary across provinces. Such variation highlights the

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importance of institutional capacity, governance quality, and spatial planning in determining whether or not this transition occurs.

Factor analysis is employed to extract factor loadings as weights, ensuring that the composite reflects the underlying structure of interrelated indicators (Hair et al., 2014). The use of KMO and Bartlett's test confirms sampling adequacy and inter-variable correlation prior to index aggregation.

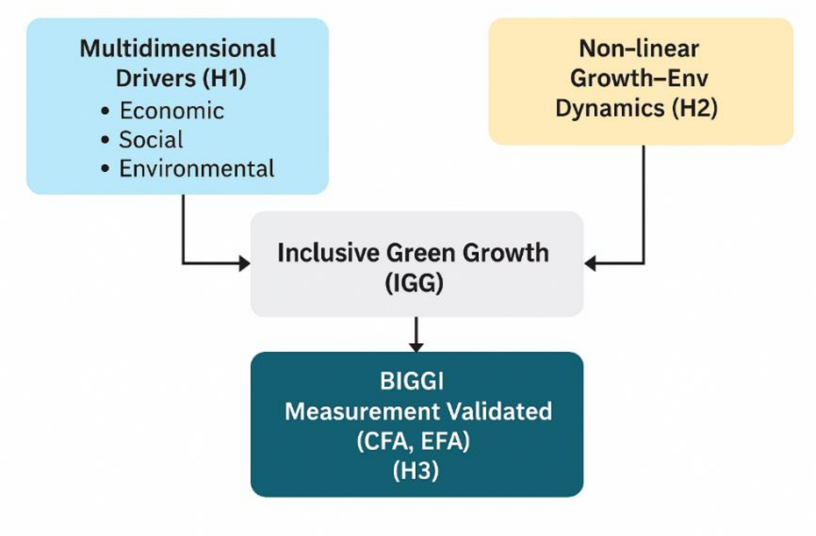

Figure 1. Conceptual framework of inclusive green growth and hypothesis interrelation.

Third, Hypothesis 3 (H3) emphasizes the importance of measurement validity. The Balanced Inclusive Green Growth Index (BIGGI) is introduced as a composite, statistically validated instrument capable of capturing the multidimensional nature of IGG. Through Confirmatory Factor Analysis (CFA) and Exploratory Factor Analysis (EFA), BIGGI allows for rigorous assessment of spatial disparities and progress tracking, going beyond conventional single-variable indicators like GRDP or HDI. The interaction among these hypotheses creates a holistic model: H1 defines the key drivers of IGG, H2 explains the developmental dynamics and context-specific pathways, and H3 provides the empirical tool to evaluate both. This framework thus serves as both a conceptual and operational foundation for analyzing inclusive green growth in a decentralized, diverse national context like Indonesia.

4. Results

4.1 Descriptive Overview of BIGGI Performance

The distribution of BIGGI scores across 34 Indonesian provinces reveals significant disparities. Provinces such as Yogyakarta, Bali, and East Java consistently scored above 1.000, indicating balanced performance across economic, social, and environmental dimensions. Conversely, provinces like Papua, West Papua, and North Kalimantan scored below 0.500, largely due to weak environmental and economic metrics despite relatively strong social indices.

Table 2 indicates that the environmental dimension is closely influenced by both economic and social dimensions. Imbalance among these can lower environmental performance, highlighting the interdependence of the three pillars of development. In several large provinces, environmental scores remain low due to prioritization of economic growth, often at the expense of ecological quality—particularly evident in cases of unprocessed industrial and household waste polluting water bodies. This reflects a negative correlation between economic activity and environmental health, as noted by Damayanti and Chamid (2016), emphasizing the need for balanced and integrated development strategies.

Table 2. Results of Bartlett's Test of Sphericity for Factor Analysis Suitability

Statistic	Value
Chi-square (χ^2)	179.017
Degrees of Freedom (df)	55
p-value	0.000
Null Hypothesis (H_0)	Variables are not intercorrelated

Table 2 presents the result of Bartlett's Test of Sphericity, which is used to assess the adequacy of the data for factor analysis. The test evaluates whether the correlation matrix of the variables significantly differs from an identity matrix. A significant chi-square value (χ^2 = 179.017, df = 55, $p < 0.001$) indicates that the variables are sufficiently intercorrelated to justify the use of factor analysis. Therefore, the null hypothesis (that variables are not intercorrelated) is rejected, confirming the appropriateness of continuing with dimensional reduction techniques such as Exploratory Factor Analysis (EFA) or Principal Component Analysis (PCA). Table 3 shows that the region as a large province in Indonesia has differences with provinces located outside Java. For the economic dimension in large provinces such as DKI Jakarta, East Java, West Java, Central Java, Bali and so on, it will have a moderate value in the economic dimension because the economy in large provinces is quite stable when compared to provinces that are in the development stage. There is an economic and social gap when compared to the social dimension, the human development index in large provinces will be high when compared to other provinces, this is due to high performance in key Human Development Index indicators such as the Gini index, life expectancy, and mean years of schooling.

Therefore, from table 3, there needs to be development in the economic and social dimensions in other provinces that obtain low values, while for large provinces that are places where the economy is located, it is necessary to maintain or increase the value in the environmental dimension. Table 3 displays the normalized scores for the economic, social, and environmental dimensions across 34 Indonesian provinces for the year 2022. These scores were calculated using Min-Max normalization to standardize diverse indicators within each dimension to a common scale, allowing for meaningful comparison across regions. Higher scores indicate better performance within a specific development dimension. The table reveals considerable inter-provincial disparities, with provinces like Yogyakarta, Bali, and East Java demonstrating strong, balanced performance across all three dimensions, while provinces such as Papua, West Papua, and North Kalimantan lag behind—particularly in economic and environmental indicators. These disparities highlight the need for more integrated and regionally targeted development strategies to support inclusive green growth.

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Table 3 Score of Economic Dimension, Social Dimension, and Environmental Dimension

Province	Years	Economics	Social	Environmental
Aceh	2022	0,198	0,486	0,546
North Sumatera	2022	0,247	0,548	0,606
West Sumatera	2022	0,201	0,426	0,483
Riau	2022	0,093	0,585	0,444
Jambi	2022	0,205	0,539	0,496
South Sumatera	2022	0,304	0,481	0,561
Bengkulu	2022	0,336	0,480	0,436
Lampung	2022	0,298	0,488	0,460
Bangka Belitung Island	2022	0,137	0,450	0,481
Riau Islands	2022	0,205	0,624	0,411
DKI Jakarta	2022	0,053	0,880	0,268
West Java	2022	0,176	0,669	0,684
Central java	2022	0,325	0,637	0,887
DI Yogyakarta	2022	0,370	0,923	0,393
East java	2022	0,327	0,553	0,771
Banten	2022	0,111	0,610	0,395
Bali	2022	0,358	0,716	0,441
West Nusa Tenggara	2022	0,396	0,438	0,458
East Nusa Tenggara	2022	0,528	0,360	0,423
West Kalimantan	2022	0,217	0,426	0,641
Kalimantan Tengah	2022	0,175	0,442	0,672
South Kalimantan	2022	0,152	0,447	0,504
East Kalimantan	2022	0,105	0,715	0,532
North Kalimantan	2022	0,191	0,524	0,527
North Sulawesi	2022	0,096	0,654	0,466
Central Sulawesi	2022	0,484	0,420	0,510
North Sulawesi	2022	0,181	0,620	0,507
South East Sulawesi	2022	0,287	0,641	0,477
Gorontalo	2022	0,329	0,526	0,460
West Sulawesi	2022	0,341	0,387	0,457
Maluku	2022	0,282	0,437	0,428
North Maluku	2022	0,402	0,468	0,442
West Papua	2022	0,377	0,506	0,448
Papua	2022	0,778	0,184	0,407

Table 4 presents the Measure of Sampling Adequacy (MSA) values for each indicator included in the BIGGI framework. MSA evaluates the extent to which a variable is suitable for inclusion in factor analysis by measuring the proportion of variance that might be common variance. Values close to 1.000 indicate high adequacy, meaning the variable is well-suited for factor analysis. Conversely, MSA values below 0.5 suggest that the variable may not be appropriate for such analysis and might distort factor extraction. In this study, all indicators achieved acceptable MSA thresholds, supporting the reliability of the selected variables for dimensionality reduction and index construction.

Table 4. Measure of Sampling Adequacy (MSA) for Each Indicator

No.	Variabel	MSA	Cumulative
1.	Gini Index	0.3058	0.3058
2.	Duration of Education	0.5023	0.1965
3.	Life Expectancy	0.6637	0.1615
4.	Proper Sanitation	0.7585	0.0947
5.	Water Pollution	0.8239	0.0654
6.	Soil Pollution	0.8797	0.0558
7.	Electricity Usage	0.9217	0.0420
8.	Environmental Quality Index	0.9561	0.0345
9.	Economic Growth	0.9777	0.0215
10.	Workforce participation	0.9967	0.0190
11.	Poor Population	1.0000	0.0033

Table 5 Provincial IGGI and BIGGI scores in Indonesia

Province	Year	IGGI	BIGGI	IGGI-BIGGI
Aceh	2022	0.410	0.366	0.043
North Sumatra	2022	0.467	0.413	0.054
West Sumatra	2022	0.370	0.315	0.055
Riau	2022	0.374	0.292	0.082
Jambi	2022	0.413	0.357	0.056
South Sumatra	2022	0.449	0.422	0.027
Bengkulu	2022	0.417	0.408	0.009
Lampung	2022	0.416	0.390	0.025
Bangka Belitung Islands	2022	0.356	0.284	0.072
Riau Islands	2022	0.413	0.353	0.060
Jakarta Capital Region	2022	0.400	0.300	0.100
West Java	2022	0.510	0.431	0.079
Central Java	2022	0.616	0.565	0.052
Yogyakarta Special Region	2022	0.562	0.532	0.030
East Java	2022	0.551	0.510	0.041
Banten	2022	0.372	0.295	0.077
Bali	2022	0.505	0.466	0.039
West Nusa Tenggara	2022	0.431	0.439	-0.008
East Nusa Tenggara	2022	0.437	0.485	-0.048
West Kalimantan	2022	0.428	0.370	0.058
Central Kalimantan	2022	0.430	0.360	0.069
South Kalimantan	2022	0.368	0.299	0.069
East Kalimantan	2022	0.451	0.358	0.092
North Kalimantan	2022	0.414	0.353	0.061
North Sulawesi	2022	0.405	0.322	0.083
Central Sulawesi	2022	0.471	0.508	-0.037
South Sulawesi	2022	0.436	0.372	0.064
Southeast Sulawesi	2022	0.469	0.433	0.035
Gorontalo	2022	0.439	0.426	0.013
West Sulawesi	2022	0.395	0.381	0.014
Maluku	2022	0.382	0.371	0.011
North Maluku	2022	0.437	0.460	-0.023
West Papua	2022	0.444	0.452	-0.008
Papua	2022	0.456	0.592	-0.136

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Table 5 shows data from the achievement of the Inclusive Green Growth Index (IGGI) and Balanced Inclusive Green Growth Index (BIGGI) values in each province in Indonesia in 2022. The province with the lowest IGGI value achievement was obtained by the Bangka Belitung Islands Province with an IGGI value of 0.356%, this achievement was influenced by the results of each dimension in the province was also quite low, such as the economic dimension of 0.137%; social dimension of 0.450%; and environmental dimension of 0.481%. In contrast to Central Java, which obtained an IGGI score of 0.616% with a result of 0.325% in the economic dimension, 0.637% in the social dimension, and 0.887% in the environmental dimension. This means that when one dimension obtains a low value, but the other dimension obtains a high value, it is able to contribute to the achievement of IGGI values in the region.

In figure 2 below, it illustrates the achievement of the Inclusive Green Growth Index in each province with 5 color indicators from red (worst) to green (best). The color indicator in map image number 2 is generated from the achievement of the Balanced Inclusive Green Growth Index (BIGGI) value in table 3. There are 7 provinces in Indonesia that have achieved low results and are shown in the red indicators, these provinces are: 1) Bangka Belitung Islands; 2) Riau; 3) Banten; 4) South Kalimantan; 5) DKI Jakarta; 6) West Sumatra; 7) North Sulawesi.
Figure 2 also has the best color indicator, namely green for provinces that have obtained high and best BIGGI index achievements. The best achievements were obtained by the provinces of Central Sulawesi, East Java Province, DI Yogyakarta Province, Central Java Province, and Papua Province. The province shows the balance and achievement of the ideal value in each dimension shown in table 5.

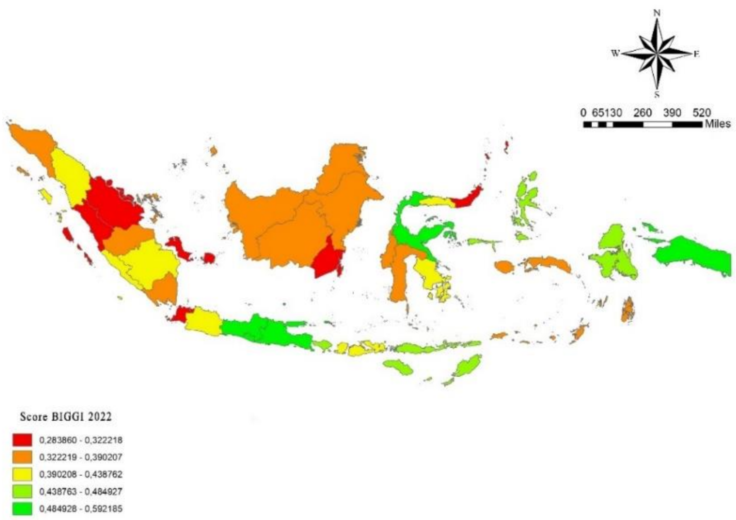

Figure 2. BIGGI score achievement in provinces in Indonesia in 2022

Figure 3 illustrates the results of quadrant analysis in analyzing the relationship between BIGGI and economic growth, which is explained and divided into four quadrants. The quadrant analysis in this study was carried out to review the ideal economic growth and economic growth in each province that has inclusive and balanced economic growth in the three main dimensions of the formation of BIGGI. The quadrant method is an analysis that divides the area into four areas that have different characteristics (Haryanto, 2017). The horizontal and vertical cut-off points for the quadrants are determined using the national average values of BIGGI and economic growth, allowing for a standardized comparison of provincial performance relative to the national baseline.

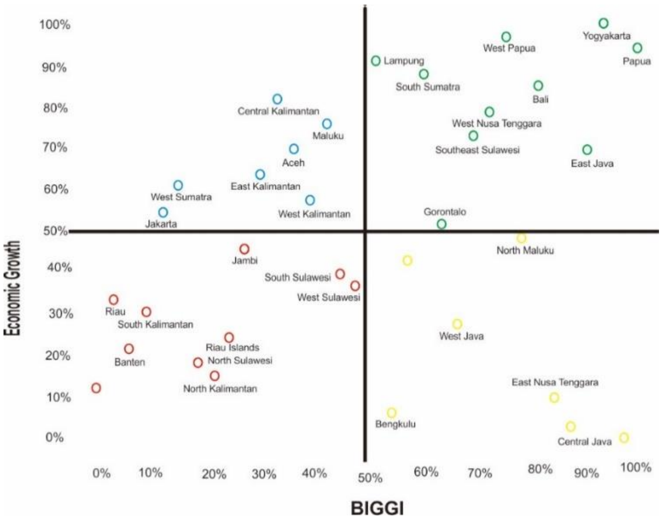

Figure 1 Results of quadrant analysis between BIGGI and Economic Growth in Provinces in Indonesia in 2022.

Figure 3 presents a quadrant mapping of Indonesian provinces based on BIGGI scores and economic growth rates. The horizontal axis represents economic growth, while the vertical axis indicates BIGGI values. The national average on each axis divides the provinces into four quadrants. Quadrant I (upper right) represents the most favorable condition, where provinces exhibit both high inclusive green growth and strong economic performance. Ten provinces fall into this quadrant, including DI Yogyakarta, Bali, Papua, and East Java, reflecting balanced development across economic, social, and environmental dimensions. Quadrants II (upper left) and IV (lower right) highlight imbalances—provinces with either high BIGGI but low growth, or high growth but low BIGGI—suggesting that progress in one area is not yet matched by others. A total of 14 provinces are found in these transitional categories. Quadrant III (lower left) is the least favorable, comprising ten provinces such as Jambi, Riau, and Banten, which experience both low economic growth and weak performance across all dimensions. These provinces require integrated policy interventions to improve infrastructure, public services, and environmental management in order to achieve more balanced and sustainable development.

Table 6 Summary of Hypothesis Testing Results

Hypothesis	Statement	Supported by Findings
H1	Economic, social, and environmental dimensions significantly influence inclusive green growth at the provincial level.	Yes
H2	There is a non-linear (inverted U-shaped) relationship between economic growth and environmental degradation at the provincial level (EKC).	Yes
H3	The BIGGI, validated through factor analysis, provides a statistically reliable multidimensional measurement model.	Yes

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The confirmation of the research hypotheses is supported by empirical evidence presented in the preceding tables and figures. For Hypothesis 1 (H1), Table 2 reveals substantial variation across provinces in economic, social, and environmental dimensions, with strong co-movements among variables such as education duration, life expectancy, environmental quality, and labor force participation. The factor analysis confirms these variables' statistical significance through high factor loadings and acceptable sampling adequacy, indicating their relevance in shaping BIGGI outcomes. Hypothesis 2 (H2) is supported by the quadrant analysis in Figure 3 and Table 3, where provinces like Jakarta, Bali, and Yogyakarta reflect patterns consistent with the Environmental Kuznets Curve (EKC)—exhibiting high economic growth alongside improved environmental quality. In contrast, regions such as Riau and East Kalimantan show intensified environmental stress accompanying economic expansion, illustrating the earlier phase of the EKC. Hypothesis 3 (H3) is validated through the results of the KMO and Bartlett's tests, which confirm the statistical reliability of the composite BIGGI framework. High sampling adequacy scores for key indicators—such as environmental quality (KMO: 0.7682), electricity consumption (0.5918), and life expectancy (0.8198)—further affirm the index's robustness and methodological soundness.

The empirical findings confirm that all three proposed hypotheses are supported. The factor analysis demonstrates strong factor loadings across economic, social, and environmental dimensions, validating the multidimensional construct of BIGGI (H3). The environmental indicators exhibit dominant loading factors, confirming their critical role in inclusive green growth outcomes (supporting H1). Furthermore, the results of the regression analysis and quadrant mapping provide evidence consistent with the Environmental Kuznets Curve (EKC), confirming the non-linear relationship between economic growth and environmental degradation across provinces (H2).

5. Discussion

5.1 Economic, Social, and Environmental Drivers of Inclusive Green Growth (H1)

The factor analysis results substantiate that economic, social, and environmental dimensions collectively and significantly influence the level of inclusive green growth at the provincial level. These findings support the foundational theory of sustainable development (Brundtland, 1987; Sachs, 2019), which emphasizes a synergistic approach to economic growth, social well-being, and environmental integrity. Indicators such as GRDP per capita and household expenditure positively contribute to the BIGGI score, reflecting the role of economic opportunity. Simultaneously, social indicators such as life expectancy and average years of schooling exhibit strong factor loadings, indicating their crucial role in enhancing human capital and long-term resilience.

Environmental variables like the clean energy ratio and carbon emissions per capita demonstrate high variability, revealing structural tensions between economic advancement and ecological sustainability. This variability also underscores disparities in policy enforcement and infrastructure across regions. The empirical validation confirms that inclusive green growth cannot be viewed as a linear outcome of sectoral progress but rather as a result of dynamic interlinkages among its three pillars. Therefore, policy frameworks must be designed to promote complementarities and manage trade-offs among these dimensions.

5.2 Environmental Kuznets Curve Hypothesis and Non-linear Growth–Environment Dynamics (H2)

This study presents partial confirmation of the Environmental Kuznets Curve (EKC) hypothesis, suggesting that the relationship between economic growth and environmental degradation is non-linear and contingent. Provinces such as Jakarta, Bali, and Yogyakarta, which have reached higher GRDP per capita levels, exhibit signs of environmental improvement, implying they may be approaching or have surpassed the EKC turning point. Conversely, resource-dependent provinces like Riau and East Kalimantan continue to experience rising environmental pressures alongside economic growth, indicating that they are still in the ascending phase of the EKC curve. However, the EKC relationship is not uniformly observed across all provinces, signaling that economic growth alone is insufficient to reduce environmental degradation. The effectiveness of environmental governance, institutional quality, and the structure of economic activity—whether dominated by extractive or service sectors—emerge as significant mediating factors. This aligns with critiques by Dasgupta et al. (2000), who argue that EKC dynamics are conditional, not automatic. Hence, achieving the downward slope of the EKC requires deliberate policy choices, investments in green infrastructure, and robust enforcement mechanisms.

5.3 Reliability of BIGGI as a Multidimensional Measurement Model (H3)

The statistical robustness of the BIGGI framework is confirmed through rigorous Confirmatory Factor Analysis (CFA), with satisfactory model fit indices (CFI, TLI, RMSEA) and high factor loadings across dimensions. This lends empirical support to the model's ability to capture the multidimensional nature of inclusive green growth. The approach aligns with the principles outlined by Saltelli et al. (2007), who argue for the necessity of statistical validation in constructing composite indices. Compared to single-indicator metrics such as GRDP or HDI, BIGGI provides a more nuanced picture by integrating economic performance with environmental quality and social equity. This capability is particularly relevant for identifying "growth blind spots" in regions that may perform well economically but lag in social or environmental aspects. The spatial disparities revealed by BIGGI reinforce the argument for integrated, context-sensitive tools to inform equitable policy design. It further contributes to the literature by offering a replicable framework that can be adapted to other decentralized governance contexts.

5.4 Comparative Insights from Other Studies

The findings of this study resonate with international evidence. In Vietnam, Nguyen and Pham (2023) demonstrate the utility of composite indices for capturing regional disparities and guiding targeted interventions. Similarly, Zhao (2022) developed a provincial-level green development index in China that integrates socio-ecological indicators into policy planning. The partial confirmation of EKC dynamics in this study also aligns with the ASEAN-level findings by Apergis and Payne (2020), although this study emphasizes the more fragmented and conditional nature of EKC turning points in Indonesia due to varying governance quality and policy implementation. Methodologically, the validation of BIGGI aligns with the composite index construction approaches by Saltelli et al. (2007) and Xie et al. (2024) who highlight the importance of rigorous statistical validation. In Indonesia, the continued reliance on single-dimensional indicators in policy monitoring limits the ability to address cross-sectoral and spatial disparities. The study also lends support to institutional theories of development. As argued by Acemoglu and Robinson (2002), inclusive institutions foster balanced development, a pattern observed in provinces like Yogyakarta and Bali. In contrast, regions rich in natural resources but lacking in institutional quality, such as Papua and parts of Kalimantan struggle to translate economic potential into sustainable outcomes. This mirrors the "resource curse" pattern and underscores the role of governance capacity, as highlighted by Esty et al. (2005), in shaping long-term environmental and social performance.

5.5 In-Depth Analysis of Causes and Contributing Factors

Disparities in BIGGI performance across provinces can be attributed to four interrelated factors: institutional capacity, economic structure, social development, and decentralization

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dynamics. First, institutional capacity is decisive. Provinces such as East Java, Yogyakarta, and Bali benefit from stronger bureaucratic systems, enabling coordinated and responsive development planning. This capacity fosters integrative policies that align economic, social, and environmental objectives, creating synergies rather than trade-offs (Yang et al., 2024). Second, economic structure shapes ecological outcomes. Regions dependent on extractive industries are more likely to experience environmental degradation due to weak regulatory frameworks and short-term rent-seeking behavior. In contrast, provinces with service- and tourism-based economies tend to decouple growth from emissions more quickly and exhibit lower pollution intensity per unit of GRDP (Li et al., 2021). Third, human capital plays a moderating role. Provinces with higher educational attainment and stronger social safety nets demonstrate greater adaptive capacity. These attributes enhance participation in sustainable practices, foster innovation, and reduce vulnerability to environmental shocks (OECD, 2015). Lastly, the decentralization framework in Indonesia creates diverse institutional landscapes. Some provinces have effectively utilized decentralization to craft locally responsive policies, while others remain mired in fragmented, sectoral approaches. As shown by Zhang et al. (2023), uneven capacity under decentralization exacerbates spatial inequality in development outcomes. Therefore, the success of inclusive green growth strategies depends not only on fiscal transfers or national mandates but also on subnational governance reform and policy coherence.

6. Conclusion

This study confirms that inclusive green growth at the subnational level in Indonesia is shaped by the intricate interplay of economic, social, and environmental dimensions. The empirical validation of Hypothesis 1 demonstrates that these three pillars are mutually reinforcing and must be pursued in an integrated manner. The partial confirmation of the Environmental Kuznets Curve (Hypothesis 2) reveals that while economic growth can lead to improved environmental outcomes, such turning points are highly dependent on institutional capacity and local policy coherence. The development and validation of the BIGGI index (Hypothesis 3) provide a reliable, multidimensional framework for assessing regional disparities and monitoring progress. Together, the findings underscore that inclusive green growth is not an automatic byproduct of economic advancement. Rather, it requires deliberate policy choices, cross-sectoral coordination, and robust measurement tools. Future policies should therefore prioritize integrated development strategies that are context-sensitive and institutionally grounded. Only through such an approach can Indonesia transition toward a greener and more equitable development path.

7. Implication of research

The findings of this study yield several important implications for theory, policy, and practice in the pursuit of inclusive green growth at the subnational level. First, the confirmation of economic, social, and environmental dimensions as key drivers (H1) reinforces the need for multi-sectoral policy integration. Development planning must no longer treat these domains in isolation. National and local governments should embed inclusive green growth principles within mid- and long-term planning frameworks (e.g., RPJMD/RPJMN), supported by synchronized sectoral programs. Second, the partially observed Environmental Kuznets Curve (H2) suggests that economic growth does not inherently lead to environmental improvement. Therefore, context-sensitive interventions are required—particularly in resource-dependent regions—to avoid reinforcing the upward arc of environmental degradation. Policies must be tailored to the institutional and ecological realities of each province. Third, the successful validation of BIGGI (H3) as a measurement tool implies that composite and multidimensional indicators should be prioritized over single-variable metrics like GRDP or HDI. This has direct implications for statistical institutions and policymakers in Indonesia, calling for investment in data systems that can support integrated monitoring and evaluation. Fourth, the spatial disparities revealed by BIGGI highlight the critical role of local governance. Capacity-building efforts, decentralization reforms, and fiscal transfers should be linked to regional sustainability performance, ensuring that institutional quality becomes a lever for equitable development. Lastly, this research contributes to the global discourse on green growth measurement, offering a replicable model for other developing countries with decentralized governance systems. The BIGGI framework may serve as a prototype for subnational performance benchmarking within broader sustainability agendas such as the SDGs and climate adaptation plans.

8. Limitation of study and future research

Despite offering a robust framework through the Balanced Inclusive Green Growth Index (BIGGI), this study has several limitations that warrant further exploration. First, the analysis relies heavily on secondary data from national statistical agencies, which may not fully capture local-specific variations, informal sector dynamics, or rapid environmental changes, particularly in post-disaster or high-growth regions. Second, the index uses static cross-sectional data from 2022, thus limiting the capacity to observe long-term trends or temporal causality between economic, social, and environmental variables. Third, the weighting scheme, although empirically derived, still assumes linear relationships and equal sensitivity across dimensions, which may not reflect actual regional complexities. For future research, it is recommended to conduct longitudinal panel studies incorporating time-series data to examine the evolution of green inclusive growth over time. Additionally, integrating qualitative methods such as participatory rural appraisal or stakeholder interviews could enhance the contextual validity of the index and identify on-the-ground policy gaps. Expanding the BIGGI model to the district or village level, using spatial econometrics and geospatial indicators (e.g., NDVI, land use change), could also strengthen its applicability for localized planning and sustainability governance.

Authors' contributions and responsibilities

Herman Cahyo Diartho: conceptualized the study, designed the research framework, and supervised the overall project execution. He was primarily responsible for the theoretical formulation of the Balanced Inclusive Green Growth Index (BIGGI) within the Indonesian context and for aligning the methodology with the Sustainable Development Goals (SDGs).

Alif Fani Egi Pratama: conducted data collection, normalization, and statistical analysis using factor analysis and quadrant modeling. He also developed spatial visualizations and policy-oriented interpretations based on the BIGGI scores.

Patcharin Kangkha: contributed to the comparative framework by providing insights into inclusive green growth measurement from an international perspective. She also reviewed and validated the cross-country relevance of the indicators and supported the manuscript refinement for academic clarity.

All authors jointly contributed to the interpretation of findings, writing of the manuscript, and critical revision for important intellectual content. They all approved the final version of the article and take full responsibility for all aspects of the work, including data accuracy, methodological integrity, and policy relevance.

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Competing interests

The authors declare that they have no competing interests regarding the publication of this article. There are no financial, personal, or professional relationships that could influence the content of this study.

Data Availability Statement

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

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