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Balancing Growth and Green: The Role of Forests, Fiscal Transfers, and Sectoral Growth in Indonesia's Environmental Quality

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ABSTRACT

This study examines how forest area, fiscal decentralisation, and sectoral economic growth affect environmental quality across Indonesian provinces. Forests are categorised into conservation, protected, and production areas. Fiscal decentralisation is analysed through natural resource revenue-sharing and local government environmental expenditures, while economic activity is segmented into the primary, secondary, and tertiary sectors. The analysis uses a dynamic panel dataset of 33 provinces from 2017 to 2022. To address potential endogeneity, the study employs a multi-stage estimation strategy, starting with Pooled OLS and Fixed Effects models, followed by the Durbin-Wu Hausman test to justify the use of a dynamic Generalised Method of Moments (GMM) framework, with System-GMM selected as the final estimator. The results indicate that natural resource revenue-sharing has a positive effect on environmental quality. However, economic growth across all sectors negatively impacts environmental outcomes, while environmental protection expenditure shows no significant effect. These findings emphasize the need to adjust decentralised fiscal policies to focus more on ecological outcomes and steer more sustainable regional development.

Keywords: Ecological Economics, Environmental Economics, Fiscal Decentralisation, Green Budgeting, Sustainable Development

JEL Classification: H61, O44, Q01

INTRODUCTION

The quality of the environment is significantly important to the life and health of humans due to its connections with the condition of air, water, and soil surfaces (Huttmanová et al., 2019). Different types of anthropogenic activities impact the assessment and evaluation of environmental quality by employing a variety of indicators and techniques. In OECD countries, environmental quality assessment is done with multi-criteria decision analysis, and men and women within the countries are rated as environmental leaders and laggards (Arsu & Ayçin, 2021). Some empirical research sheds light on the assessment and the relevance of the environment's quality for people's living space, but they do not tell how to raise the environmental quality concretely.

The green economy concept is a development policy principle that focuses on the importance of economic development, taking into account ecological and social matters. Within this concept, "sustainable development" is a term that is used as a criterion for a model of development that includes economic, social, and environmental dimensions and interrelations. Sustainable development, in turn, provides solutions that consider the needs of future generations. In environmental terms, economic growth goes beyond the short-term and medium to long-term achievements, which must be environmentally friendly while fostering the use of renewable resources.

The notion of a green regional economy is of great importance for managing regional development in the context of regional economic policy. The incorporation of ecological factors into the economy is gaining more attention lately, particularly due to mounting environmental pressures and sustainability targets seeking balance. Earlier ideas like steady-state economics highlighted the importance of ecological limits to growth, but contemporary progress in ecological economics places additional focus on post-growth perspectives, sustainable macroeconomics, and system frameworks (Kurz, 2019).

Economic growth and environmental quality are interlinked. Research suggests that sustained economic growth is favourable for the environment, improving overall conditions while decreasing degradation, but population growth worsens deterioration (Adem et al., 2020). An inverted U-shaped relationship exists between economic growth and environmental quality, suggesting higher levels of economic growth may lead to associated environmental damage. Further research supports the need to develop appropriate policies aimed at population control while enforcing

stronger environmental measures to achieve sustainable economic growth (Utomo et al., 2024).

The Kuznets Environmental Curve hypothesis proposes that degradation of the environment intensifies with economic growth until a certain income level is achieved, at which point it decreases (Setiawan & Anwar, 2022). While the various facets of economic growth have proven to impact environmental well-being, other worldwide factors, such as trade liberalisation and globalisation are equally important. As noted in the work of (Twerefou et al., 2017), globalisation appears to have a comparatively greater negative impact on the environment than its effect on wealth, particularly in developing nations.

The focus of empirical studies has shown that economic development and environmental quality diverge from one another, presenting challenges to public policy and constructive policies toward sustainable growth. It is important to state that this understanding does not endorse convergence on the essence of the relationship, and so further examination is required to grasp the dynamics of economic development and environmental quality fully.

It has been shown that public sector environmental investment does noticeably reduce ecological deficits, thus having a positive impact on the quality of the environment. According to (Basoglu & Uzar, 2019), greater public expenditure worsens the environmental deficit, while spending on environmental initiatives helps in recovering it. This illustrates the importance of public expenditure policies that are aimed at enhancing overall environmental consumption. Fiscal decentralisation enhances sustainability through targeted CO emission and ecological footprint reduction, which contributes to building sustainability resilience. The use of both tiers of fiscal decentralisation has been shown to improve the environment by reducing CO emissions, thereby establishing a positive relationship between fiscal decentralisation and environmental quality (Fajri et al., 2023).

Offer suggestions/findings for attaining overall environmental sustainability instead, which includes the adoption of green energy and the central government empowering local governments through delegated authority to administer a green energy programme. This focuses on the emphasis of green forestry in the enhancement of the environment. Green energy initiatives at subnational levels necessitate suitable fiscal structures that encourage subnational authorities to act. In this regard, fiscal decentralisation is crucial in enhancing the environmental governance and sustainable development of a region because it permits regions to prioritise expenditure on green initiatives that are responsive to local environmental needs. Such a relationship between a decentralised fiscal policy and environmental outcomes rebounds to the region (Aliamutu & Mkhize, 2024).

Public spending has been shown to aid in the reduction of CO emissions, thereby improving air pollution and the quality of the environment, which indicates that

government expenditure can help positively impact the environment. CO and NOx emissions, which are enhanced during periods of economic growth and advancement of democratic governance, have also been observed to decline considerably due to government expenditures, demonstrating government expenditure's ability to control pollution (Zhang et al., 2017).

Evidence presented above shows that the deterioration or improvement of the environment has a significant bearing on the movement of the fiscal balance, with spending having an active role in augmenting the quality of the environment. Fiscal decentralisation, on the other hand, is found to have a positive environmental sustainability causality, while green initiatives coupled with government spending tend towards improving the environment. However, it is crucial to emphasise that while the literature gives helpful insights, it does not thoroughly cover the aspects of fiscal decentralisation that directly involve natural resources.

On the other hand, forests provide economic benefits to communities, are vital in slowing climate change rate, and have a worldwide beneficial impact on water quality by serving as a barrier to air pollution and deposits. According to (Lafforgue, 2018), trees enhance soil structure and its ability to absorb and retain suspended matter, contaminants, and minerals, resulting in higher-quality groundwater in forest soil compared to other types of soil. Forests act as a barrier against pollution and help to maintain the quality of groundwater and surface water that flows through them.

Preserving forest areas positively affects environmental quality by safeguarding water resources and decreasing pollutants (Lafforgue, 2018). Deforestation negatively impacts the environment by affecting ecosystem processes like water management and carbon storage (Jaskulak & Grobelak, 2021; Tapia et al., 2013). Biodiversity enhances environmental quality in forest regions by boosting ecosystem services and promoting higher biomass output (Rybar & Bosela, 2023; Tapia et al., 2013).

Forest remnants' environmental quality is affected by their size, configuration, and connectedness, which are crucial aspects for evaluating their general well-being and longevity (Cardoso et al., 2023; Da Silva & Longo, 2020; Hou et al., 2020; Longo et al., 2019; Safe'i et al., 2022). However, there are still few studies that directly address the specific relationship between forest areas and environmental quality. Therefore, while the literature provides valuable insights into various aspects of forest quality and assessment of the environment, it does not directly address a specific relationship between environmental and forest quality.

Environmental indicators can be classified as specific (related to the natural or human-made environment), composite, or personal. Environmental indicators specific to natural environments include those related to climate change, air and water quality, biodiversity, and more, while indicators for anthropogenic environments are related to socio-economic factors (Banzhaf et al., 2014). This research contributed to the elaboration of their impact on environmental quality.

The factors influencing environmental quality are intricate and interwoven, necessitating a comprehensive strategy for effective resolution. The Environmental Kuznets Curve hypothesis elucidates the relationship between economic expansion and environmental quality. However, the influence of fiscal decentralisation and forest area in shaping this relationship has not been thoroughly explored. These elements should be considered in designing policies such as eco-based fiscal transfers, decentralised environmental regulation frameworks, and incentives for sustainable forest management at the sub-national level.

For instance, Brazil has implemented ecological fiscal transfers that reward municipalities for maintaining forest cover, while China has introduced decentralised fiscal policies to reduce emissions at the regional level. These international examples demonstrate how integrating environmental and economic priorities through localised fiscal instruments can improve environmental quality outcomes.

Thus, the study contributes to the empirical debate on the quality of the living environment as determined by forest area, green budgeting, and economic growth disaggregated into three sectors. However, the combined effects of fiscal decentralisation, forest area typology, and sectoral economic growth on environmental quality remain underexplored in the context of decentralised governance in Indonesia. This gap limits our understanding of how policy instruments interact in shaping ecological outcomes at the regional level. Therefore, the study aims to investigate the impact of the forest area (conservation, protection, and production), green budgets (environmental protection expenditure and natural resource transfer), and economic growth (primary, secondary, and tertiary sectors) on environmental quality.

METHOD

Environmental indicators are used to monitor and evaluate environmental performance (Gareiou et al., 2023). This study utilises the Environmental Quality Index (IKLH) as an indicator for environmental management, which integrates the ideas of the EQI (Eco-Quality Index) and the Environmental Performance Index (EPI). IKLH can assess the effectiveness of environmental quality enhancement projects and serve as informational material to aid in policy development for environmental protection and management.

The IKLH is a nationwide environmental management performance indicator that represents the overall environmental situation in Indonesia. In its development, the calculation of the IKLH continues to undergo perfection according to the needs and capabilities of all stakeholders. Starting in 2020, the IKLH indicator will include four (four) sub-indicators or indices: (1) Water Quality Index (IKA), (2) Air Quality Indices (IKU), (3) Soil Quality Indexes (IKL), and (4) Seawater Quality Index (IKAL).

IKAs are determined by assessing wastewater characteristics, including biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), oxygen dissolution (DO), pH, total phosphate, NO3, and even faecal coli. We measure ICUs based on SO2 and NO2 gas parameters. ICL measurements are based on the area covered by forests and bushes in forest areas, the area of protection function.

The initial variable being clarified is the forest area, which in this research denotes the area of forest per function as outlined in the Forest Decision Sheet provided by the Minister of Environment and Forestry. This includes conservation forest areas, protected forests, and productive forests.

The following variable in this study is fiscal decentralisation policy, which is measured by the natural resource transfer and expenditure functions of the local government and provincial government in an area. The Fiscal Balance Transfer (Revenue Sharing Fund, DBH) is a fund derived from national income provided to regions based on a specific percentage to support the region's requirements in the context of decentralisation. DBH aims to enhance the vertical equilibrium between the central and regional areas by focusing on the producing area's potential. The DBH is divided depending on origin and distributed based on real revenue. Money indicates that DBH distributes money based on the actual receipts for the current budget year as per Act 23 of Law 33/2004. These categories of DBH consist of tax DBH and natural resource DBH. This study refers to the DBH of natural resources such as forests, minerals, coal, oil and gas, geothermal energy, and fisheries. The Natural Resources Department of Behavioural Health is divided based on the exchange of producing regions, with a larger amount going to such regions and the remaining portion allocated to other areas within the province as defined by law.

Economic expansion influences the quality of the living environment. The Kuznets environmental curve illustrates the relationship between environmental quality and economic growth, suggesting that environmental quality can improve alongside economic progress, particularly in developing nations (Song et al., 2021). However, the complex and dynamic concept of environmental quality requires a comprehensive approach to evaluation (Banzhaf et al., 2014; Franzese et al., 2018). Thus, this study is disaggregated into three major sectors of the economy measured by GDP by industrial origin, namely the primary, secondary, and tertiary sectors.

The primary economic sector consists of (a) Agriculture, Forestry, and Fishing and (b) Mining and Quarrying. The secondary economic sector consists of (c) Manufacturing, (d) Electricity and Gas, (e) Water supply, sewage, Waste Management and Remediation Activities. The tertiary economic sector consists of: (f) Construction, (g) Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles, (h) Transportation and Storage, (i) Accommodation and Food Service Activities, (j) Information and Communication, (k) Financial and Insurance Activities, (l) Real Estate Activities, (m,n) Business Activities, (o) Public Administration and Defence; Compulsory Social Security,

(p) Education, (q) Human Health and Social Work Activities, (r,s,t,u) Other Services Activities.

The control variables are population and investment. The relationship between the population and its surroundings greatly influences the quality of life (Celemín et al., 2013; Dociu & Ratezanu, 2013; Mariani et al., 2019). The findings from (Duodu et al., 2021; Ganda, 2020) provide valuable insights into the complex relationship between investment and the quality of the living environment.

This study used a macro-level panel dataset to examine the effect of forest areas, green budgeting, and economic growth on environmental quality. The panel's dataset covers the period 2017–2022 for 34 provinces across Indonesia. However, the data for East Kalimantan Province and North Kalimantan Province use one combined data set. North Kalimantan Province was once an area of East Kalimantan Province; therefore, the availability of forest area data for North Kalimantan Province is already included in East Kalimantan Province data. Therefore, the number observed becomes 33 provinces.

Table 1. Variable Definitions

Variable Name	Abbreviation	Measurement	Unit	Source
Environmental Quality	Envir (IKLH)	It is a composite value of the water quality index, air quality index, land quality index, and sea water quality index.	Index	Ministry of Environment and Forestry, Republic of Indonesia
Environmental Protection Expenditure	Envir Expen	Local government expenditure on environmental protection.	Rupiah	Ministry of Finance, Republic of Indonesia
Revenue Sharing Transfer of Natural Resources	NR Transfer (DBH SDA)	Fiscal balance transfers from the central government to regions covering the forestry, mineral and coal, oil and gas, geothermal exploitation, and fisheries sectors.	Rupiah	Ministry of Finance, Republic of Indonesia
Conservation Forest	Con Forest	Area of land conservation forest.	Hectare	Ministry of Environment and Forestry, Republic of Indonesia
Protected Forest	Prot Forest	A protected forest area.	Hectare	Ministry of Environment and Forestry, Republic of Indonesia
Production Forest	Prod Forest	The production forest area consists of a limited production forest, a permanent production forest, and a convertible production forest.	Hectare	Ministry of Environment and Forestry, Republic of Indonesia

Variable Name	Abbreviation	Measurement	Unit	Source
Primary Economic Sector	Prim Econ	Gross Domestic Regional Bruto (GDRP) at 2010 constant market prices by primary sector industrial origin.	Rupiah	Badan Pusat Satistik (BPS – Statistics Indonesia)
Secondary Economic Sector	Sec Econ	Gross Domestic Regional Bruto (GDRP) at 2010 constant market prices by secondary sector industrial origin.	Rupiah	Badan Pusat Satistik (BPS – Statistics Indonesia)
Tertiary Economic Sector	Ter Econ	Gross Domestic Regional Bruto (GDRP) at 2010 constant market prices by tertiary sector industrial origin.	Rupiah	Badan Pusat Satistik (BPS – Statistics Indonesia)
Investment	Invest	Establishment of Gross Domestic Fixed Capital at 2010 Constant Market Prices.	Rupiah	Badan Pusat Satistik (BPS – Statistics Indonesia)
Population	Pop	Population aged 15 years to top.	Person	Badan Pusat Satistik (BPS – Statistics Indonesia)

This study uses a panel regression approach to examine the effect of forest areas, green budgeting, and economic growth on environmental quality. Given that the unique qualities of each region are probably not random and could impact the outcome variables, it is necessary to account for them in our panel regression model. In this specification, the consequences of the outcome will not impact the province's individual fixed characteristics. In general, we specify the fixed-effect model as follows:

$$Y_{it} = \alpha_0 + \alpha_i X_{it} + \mu_t + \varepsilon_{it} \quad \text{.....(1)}$$

where Y_{it} is the dependent variable for province i at time t, X_{it} is a set of predictors, α_0 is the intercept specific to each entity, and α_i are the coefficients for the independent variables in X_{it}. μ_t represents the error term specific to the financial entity, while ε_{it} represents the overall error term. Determine if using an instrumental variable is necessary by assessing whether a set of estimates generated by least squares is consistent. (Davidson & Mackinnon, 1989) propose using an expanded regression test (Durbin-Wu-Hausman test) by adding the residuals of each endogenous right-hand side variable, along with all exogenous variables, to the original model.

An endogeneity test was conducted to evaluate the coherence of the panel ordinary least squares (POLS) and fixed-effect models' results. The presence of endogeneity in individual regressors is detected by the Durbin-Wu-Hausman test (Anwar et al., 2024). The explanatory variable should ideally be independent of the error term. This test assesses the relationship between the residuals and the explanatory variable. A Durbin-Wu Hausman test is performed to detect endogeneity in the regression. The best way

to deal with endogeneity in models is to use dynamic panel data estimation (Arellano & Bond, 1991; Blundell & Bond, 1998). We utilise Stata software to conduct econometric estimations, including POLS estimation, fixed-effect estimation, endogeneity test, and generalized method of moment (GMM) estimation.

The model is made dynamic by including the influence of environmental quality at period *t-1* on the environmental quality at period *t*, which helps in resolving endogeneity difficulties in the estimation:

$$Envir_{it} = \alpha_0 + \alpha_1 Envir_{it-1} + \alpha_2 Con\ Forest_{it} + \alpha_3 Prot\ Forest_{it} + \alpha_4 Prod\ Forest_{it} + \alpha_5 Envir\ Expen_{it} + \alpha_6 NR\ Transfer_{it} + \alpha_7 Prim\ Econ_{it} + +\alpha_8 Sec\ Econ_{it} + \alpha_9 Ter\ Econ_{it} + \alpha_{10} Invest_{it} + \alpha_{11} Pop_{it} + \varepsilon_{it} \quad \text{.....(2)}$$

where *Envir* as a dependent variable is the environmental quality. Further explained by the variable *Con Forest* is conservation forest, *Prot Forest* is protected forest, *Prod Forest* is production forest, *Envir Expen* is environmental expenditure, *NR Transfer* is revenue sharing transfer of natural resources, *Prim Econ* is primary economic sector, *Sec Econ* is secondary economic sector, *Ter Econ* is tertiary economic sector. *Invest* and *Pop* are control variables for investment and population. *i* is the province cross-section. *t* is a period. All variables are in terms of the natural logarithms.

The POLS method can produce an inconsistent yet highly correlated estimate. Therefore, the transformation can employ an instrumental variable method with the difference serving as the instrument. Blundell & Bond (1998) noted that the initial distinction of The FD-GMM estimator may be influenced by limited sample bias. To detect restricted sample bias, one can compare the findings obtained from FD-GMM with those from alternative estimators of the autoregressive parameters. Pooling least squares estimation in an autoregressive model with individual-specific effects can lead to an upwardly biased estimate. Fixed-effect models tend to underestimate predictions, resulting in more reliable estimations when comparing pooled least square and fixed-effect techniques. The FD-GMM estimator can have a downward bias when a weak instrument is present, and the estimator is close to or below the fixed effect.

Endogeneity problems can result in biased and inconsistent estimators when there is a lag in the dependent variable. (Arellano & Bond, 1991) suggested that more instruments may be acquired in the dynamic panel data model by utilising the orthogonality constraint between the lagged value y_{it} and disturbance v_{it}. (Blundell & Bond, 1998) emphasised the significance of incorporating beginning conditions in generating an effective estimator from a dynamic panel data model with a small *t*. The Sys-GMM system can address the issue of weak instruments in the FD-GMM estimator. (Blundell & Bond, 1998) stated that a weak instrument with a high number of parameters caused the estimator's bias and imprecision. By imposing additional constraints on the initial condition process, the estimator can be enhanced by using the difference lag as the instrument for the equations. The GMM model uses criteria

like the Sargan and the Arellano-Bond tests to select the best model (Ginanjar et al., 2020).

In a dynamic panel-data framework, the consistency of the estimator depends on the validity of instruments and the absence of second-order autocorrelation in residuals. The Arellano-Bond test helps detect autocorrelation in differenced residuals, while the Sargan test assesses the validity of the instruments used. Both tests are used to evaluate the appropriateness of GMM estimators, which address endogeneity through internal instrumentation.

RESULT

We employed POLS and fixed-effect calculations, acknowledging the potential bias introduced by endogeneity. For instance, a rise in local government spending on environmental protection activities in a region with poor environmental conditions may result in a non-significant negative connection. Furthermore, poor environmental quality during economic expansion might lead to higher spending on environmental protection measures, which may reduce the need for extensive monitoring of economic activities and lower environmental quality standards. Exclusion of variables that may create bias is a possible reason for endogeneity, as it is difficult to account for all environmental quality parameters.

Table 2. POLS and fixed-effect estimation results

Variable	POLS			Fixed-Effect		
	Coefficient	t	P > | t |	Coefficient	t	P > | t |
Con Forest	0.0205255	0.29	0.775	0.0205255	0.38	0.706
Prot Forest	1.0165118	1.31	0.193	1.0165118**	3.32	0.002
Prod Forest	0.5934903	1.25	0.213	0.5934903**	3.14	0.004
Envir Expen	-0.0197391	- 1.31	0.194	-0.0197391	- 1.32	0.198
NR Transfer	0.0074260	1.41	0.16	0.0074260	0.68	0.498
Prim Econ	-0.2121258*	- 2.29	0.024	-0.2121258	- 1.40	0.171
Sec Econ	0.0847177	1.08	0.282	0.0847177	1.28	0.208
Ter Econ	0.0977534	0.55	0.581	0.0977534	0.57	0.574
Invest	-0.1020195	- 1.31	0.192	-0.1020195	- 1.57	0.126
Pop	-0.7598681	- 1.90	0.059	-0.7598681	- 1.28	0.209
_cons	-4.6618272	- 0.24	0.807	-2.9922724	- 0.27	0.787
Nb. of observation	198			198		
Nb. of cross-section	33			33		
F	22.819274***			35354.076***		
Prob > F	0.0000			0.0000		
R^2	0.8773			0.6432		
Durbin-Wu Hausman test						
F	8.43**			4.62*		
Prob > F	0.0043			0.0393		

Legend: * p<0.05; ** p<0.01; *** p<0.001

We employed POLS and fixed-effect calculations, acknowledging the potential bias introduced by endogeneity. For instance, a rise in local government spending on environmental protection activities in a region with poor environmental conditions may result in a non-significant negative connection. Furthermore, poor environmental quality during economic expansion might lead to higher spending on environmental protection measures, which may reduce the need for extensive monitoring of economic activities and lower environmental quality standards. Exclusion of variables that may create bias is a possible reason for endogeneity, as it is difficult to account for all environmental quality parameters.

Table 3. First difference and system GMM estimation results

Variable	FD-GMM			Sys-GMM		
	Coefficient	z	P > | z |	Coefficient	z	P > | z |
Envir L1.	0.3599164***	4.18	0.000	0.6370590***	7.15	0
Con Forest	1.0728167	0.47	0.640	0.0546277	0.55	0.583
Prot Forest	-1.8613102	- 1.10	0.271	0.0835390*	1.97	0.048
Prod Forest	-2.1256078	- 0.66	0.510	0.0360111	0.33	0.739
Envir Expen	-0.0141682*	- 2.19	0.029	-0.0130404	- 1.34	0.180
NR Transfer	0.0076838	1.23	0.220	0.0151808*	2.53	0.011
Prim Econ	0.0288898	0.33	0.745	-0.1219956**	- 3.22	0.001
Sec Econ	0.0004078	0.01	0.996	-0.2860017**	- 2.77	0.006
Ter Econ	-0.2862800**	- 3.27	0.001	-0.1950046*	- 2.10	0.036
Invest	-0.0536147	- 1.57	0.115	0.1829787**	2.66	0.008
Pop	1.4123377***	4.97	0.000	0.9329974***	3.90	0.000
_cons	25.492618	0.70	0.484	-11.523704**	- 3.26	0.001
Arellano-Bond test						
AR(1) z	-1.7387			-1.9803*		
Prob > z	0.0821			0.0477		
AR(2) z	-0.02021			-.93837		
Prob > z	0.9839			0.3481		
Sargan test						
chi^2	14.011946			17.931295		
Prob > chi^2	0.1219			0.1601		

Legend: * p<0.05; ** p<0.01; *** p<0.001

Table 3 presents the estimation results using both FD-GMM and Sys-GMM methods, with the latter preferred due to stronger statistical consistency and the validity of instruments. The findings show that environmental quality in the previous period has a significant positive effect on current environmental outcomes, indicating a level of persistence over time. Among the different forest area typologies, only protected forest areas exhibit a significant positive impact on environmental quality, while conservation and production forests do not yield statistically significant effects. Furthermore, environmental protection expenditure does not show a significant

influence on environmental quality, which may suggest inefficiencies in allocation or the presence of delayed impacts not captured within the study period.

In contrast, natural resource transfers (*Dana Bagi Hasil Sumber Daya Alam*/DBH SDA) are found to significantly enhance environmental quality, reinforcing the relevance of fiscal decentralisation in ecological management. The results also reveal that economic growth across all sectors—primary, secondary, and tertiary—negatively affects environmental quality, lending support to the Environmental Kuznets Curve hypothesis in the Indonesian context. Interestingly, both investment and population growth are associated with improvements in environmental indicators, potentially reflecting stronger institutional responses or increased environmental awareness accompanying urban and capital development. Overall, these results emphasise the importance of aligning fiscal policy, forest governance, and economic strategies with long-term environmental sustainability objectives.

The Sys-GMM estimation results in Table 3 show that the previous period's environmental quality had a significant positive effect on the current period. Protected forest areas have a significant positive effect on environmental quality, while conservation and production forest areas do not have a significant effect. Expenditure on environmental protection does not have a significant effect on environmental quality, which may reflect several possible factors. Environmental budgets may not be efficiently allocated toward impactful programs, and a significant portion could be used for administrative or non-environmental purposes.

There may also be a time lag between the implementation of expenditures and observable improvements in environmental quality, which is not fully captured within the short-term panel structure. In line with (Basoglu & Uzar, 2019), this result may suggest that local environmental spending requires better targeting, adequate scale, and more outcome-oriented monitoring mechanisms to be effective. Meanwhile, natural resource transfer has a significant positive effect. Economic growth in all sectors, both primary, secondary, and tertiary, has a significant negative effect on the quality of the environment. Furthermore, investment and population have a significant positive effect.

The results of the Arellano-Bond test on the Sys-GMM estimation stated that the AR(1) significance test with a probability of 0.0477 showed significant results, and the AR(2) significance test with a probability of 0.3481 was not statistically significant, which is a desirable outcome. This confirms the absence of second-order autocorrelation in the differenced residuals, supporting the consistency of the estimator. Furthermore, the results of the Sargan test with a probability of 0.1601 show insignificant results, stating that the estimator with Sys-GMM estimation uses a valid instrument. Both test results state that Sys-GMM estimation meets all the criteria of the correct dynamic panel-data estimation so that analysis with the Sys-GMM estimation approach can be concluded.

DISCUSSION

Estimates with the dynamic panel-data approach using Sys-GMM estimates in this study showed robust results, where based on both the Sargan test and the Arellano-Bond test results stated that the assumption is consistent and assumptions on the model using valid instruments so that the results can be concluded (Anwar et al., 2024; Arellano & Bond, 1991; Blundell & Bond, 1998; Ginanjar et al., 2020; Setyadi et al., 2023).

The results indicate that protected forest areas have a positive impact on environmental quality. This finding reinforces (Lafforgue, 2018) finding that forest conservation has a positive impact on environmental quality by protecting water resources and reducing pollution. These results are also consistent with the findings of (Jaskulak & Grobelak, 2021; Tapia et al., 2013) that deforestation has a negative impact on the quality of the environment by disrupting ecosystem functions such as water regulation and carbon storage.

The implications, according to (Rybar & Bosela, 2023; Tapia et al., 2013), are that biodiversity plays a crucial role in improving environmental quality by enhancing ecosystem services and biomass production. This contributes to better living environments, particularly in forested areas.

We also found significant evidence regarding fiscal decentralisation policies. Natural resource transfers (DBH SDA) positively influence environmental quality, suggesting that regional environmental outcomes improve alongside increased resource-based fiscal support. These findings are consistent with Hu et al. (2023), Ji et al. (2021), Alam (2024), Kuai et al. (2019), who showed that fiscal decentralisation fosters environmental sustainability. However, those studies did not specifically assess the direct link between natural resource-based fiscal transfers and ecological outcomes, and this study helps fill that gap.

In the context of Indonesia's fiscal decentralisation, one key agenda of the national green economy is integrating environmental goals into local governance through the Environmental Quality Index (IKLH) as part of the national medium-term development plan (RPJMN). The ecological-based fiscal balance transfer policy has been framed under the principles of delegation, externality, accountability, efficiency, and national strategic interests. In this structure, compulsory non-basic services encompass the management of the environment, while forestry management is voluntary.

Additionally, these policies seek to offset the imbalance between the growth of a particular region's economy and the deterioration of the environment. The transfers are meant to reduce interregional fiscal equity imbalances caused by differences in natural resources, productivity, and the scale of the economy. Implemented from an environmental and forestry perspective, such transfers increase local government peripheral attention commitment towards externalities and economic inefficiencies.

These policies integrated into the region's ecosystem attempt to achieve vertical fiscal imbalance correction; at the same time, they aim to allocate the environmental costs arising from extractive activities into the system. Unfortunately, in this study, the transfer of ecological policy into local environmental expenditure (APBD) has not shown a significant effect. This finding diverges from Basoglu & Uzar (2019), Hazem et al. (2023), and (Halkos & Paizanos, 2017). It suggests that environmental and forestry spending must be restructured to focus on efficiency and tangible ecological outcomes, such as habitat restoration, river rehabilitation, waste management, mangrove and forest reforestation, plantation renewal, sustainable agriculture, and renewable energy development.

When disaggregated by sector, economic growth in the primary, secondary, and tertiary sectors all negatively affect environmental quality. Though counterintuitive, this reflects the reality in many developing countries, where economic expansion increases energy use, pollution, and urban sprawl. In the absence of sufficient green investment and governance, growth is likely to worsen environmental deterioration, supporting the Environmental Kuznets Curve (EKC) hypothesis.

In developing countries like Indonesia, economic growth continues to stabilise, improving living standards, which brings environmental challenges. Studies by Li et al. (2015), Singh and Yadav (2021), and Adem et al. (2020) have confirmed the U-shaped relationship between growth and environment, recommending policies to control population dynamics and enhancing environmental protection measures towards unsustainable growth.

Singh and Yadav (2021), along with Kuai et al. (2019), confirm the distinct lack of growth and development in governance in many developing regions, along with a pronounced increase in the decline of environmental conditions. Fiscal and governance arrangements can either mitigate or worsen deteriorating environmental conditions depending on their designs. Weaker institutional frameworks tend to suffer, while better-performing states that target environmental spending alongside decentralised incentives tend to perform better.

The EKC hypothesis illustrates that environmental degradation increases relative to income but declines after certain thresholds are reached (Kurniawan et al. 2021; Singh & Yadav, 2021). Alongside this, some scholars show that globalisation tends to do more environmental harm than good economically (Twerefou et al., 2017).

Costanza and Daly (1992) remind us that an economic system needs to be managed within the ecological limits of its constituents. Using these communal resources sustainably goes well with Ostrom et al.'s (1992) conception of governance of common-pool resources, where local communities actively maintain and reclaim natural resources such as forests. This idea resonates strongly with Indonesia's deconcentrated governance system.

Even though constructs of a green economy are being integrated into subnational and regional frameworks, strong resistance from conventional economic policies limits effective implementation. Conflicts exist between other highly productive activities and environmental constraints. For regions with dense forest cover, including protected ones, opportunities stemming from economic activity are often curbed by conservation dictates, establishing a policy conundrum that needs thoughtful design.

These findings strongly reinforce the case for environmental factors to be included in the fiscal policy framework in more centralised governance structures. More green fiscal policies should aim to focus intergovernmental transfers on defined ecological bases, enhance environmentally protective outcomes at the subnational level, and improve resource distribution with tangible progress in ecological parameters.

Examples of such frameworks may include ecological fiscal transfers (EFTs), performance grants for the environment, and specified expenditures for restoration and renewable energy projects. This would allow for fiscal instruments to not only diminish disparities but also steer subnational governments toward greater sustainability in the long term.

CONCLUSION

The research enhances the understanding of the interaction between different types of forest areas, fiscal decentralisation, and subnational-level economic growth with regard to environmental quality at the subnational level. Existing literature has examined fiscal decentralisation and environmental sustainability; however, very few have investigated the impact of natural resource-based fiscal transfers on the mediating role of the instrument. This is a significant contribution, particularly concerning the fiscal structure of Indonesia.

This confirms the case that protected forest areas and the transfers of natural resources assist in improving environmental quality. In contrast, economic growth, particularly in the secondary and tertiary sectors, has adverse effects, reflecting a typical Environmental Kuznets Curve (EKC) dynamic. Additionally, expenditure on environmental protection remains ineffective, potentially due to poor targeting or inefficiencies in budget allocation.

These outcomes highlight the multidimensional nature of environmental governance under decentralisation. Fiscal instruments must be redesigned not only to address vertical and horizontal imbalances but also to internalise ecological values. Strengthening the link between fiscal incentives and ecological performance, particularly through forest-related transfers, could enhance the role of subnational governments in environmental protection.

From a policy perspective, these findings support the development of green fiscal frameworks that are incentive-based and performance-oriented. Governments can

adopt ecological fiscal transfers, conditional grants, or earmarked environmental funds to promote sustainability goals. In doing so, fiscal policy becomes a strategic lever not only for development financing but also for advancing environmental resilience and long-term ecological balance.

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