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ARTICLE

Spillover Effect of Development Performance on Environmental Quality in Sumatra, Indonesia

The Role of Democracy and the Adverse Impacts of Economic Activity

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Abstract: Environmental issues are increasing as human activities damage ecosystems and trigger climate change. This increasing pressure has led to a concentration on development that is not only economically and socially but also environmentally oriented. In line with the spirit of the WCED in 1987, this study aims to assess the direct and spillover impacts of development performance on environmental quality in Sumatra Island. Observations from 2015 to 2022. The data used is panel data derived from the Indonesian government authorities. The research method uses a spatial autoregressive model with one nearest neighbor weighting. Previously, a cross-section dependence test was conducted to ensure the presence of spatial effects in the model. The result showed that increasing the proportion of highly educated workers will improve environmental quality in the observation province and improve the environment in the nearest neighboring province. Democracy also has strong positive direct and spillover effects. An increase in the dependency burden of workers will improve environmental quality in the observation province, with weak spillover effects. Conversely, an increase in real GRDP per capita decreases environmental quality and affects environmental quality in neighboring regions. Four determinants have a strong total effect. Meanwhile, population density and regional expenditure have no significant effect. The implication of this study is the need for intervention from the authorities to change the perspective on economic activity and regional expenditure as a whole so that economic value added does not come at the expense of the environment.

Keywords: Environment; Spillover; Economic Activity; Democracy; Education.

1. Introduction

According to projections, in the next fifty years, about 30% of the world's population will live in regions with temperatures over 29 degrees Celsius unless there are solutions to reduce their spread. Half of the population with the lowest income accounts for only 12% of total emissions, and the other half, which includes the 10% of the richest people in the world, has driven production systems that have destabilized the environment, with the poor being the most affected (Tooze, 2023). Economic activity impacts environmental quality (Badunenko et al., 2023; Galeotti, 2007; Grossman & Krueger, 1991; Rizzati et al., 2023; Xie et al., 2023; Yan et al., 2022). Environmental conditions are also related to education, democracy, population density, and government spending (Du et al., 2022; Farzin & Bond, 2006; Galinato & Galinato, 2016; Wu et al., 2022; Zhu, 2023). As the second largest economic contributor after Java, Sumatra Island has a development intensity that tends to be increasing. This increase can cause pressure on environmental issues.

Humans are very dependent on the natural environment. But nature is not doing well at the moment. The damage caused by human activities makes us need to improve more seriously, to carry out a development process that is in line with maintaining environmental quality. Rising living standards contribute to the burden on the environment (Taušová et al., 2020). On the other hand, the issue of the attractiveness of cities and the importance of eco-city has come to the fore (Cleave & Arku, 2020; de Jong et al., 2018; Ingallina, 2019; D.-Y. Kim & Ho, 2022; Ma et al., 2020; Mihardja et al., 2019; Sonn & Park, 2023; Taušová et al., 2020; Vorobyov & Shilo, 2021).

Global warming and climate change are caused by human behavior, so it is necessary to understand the aspects that shape pro-environmental behavior and can adapt during an ongoing environmental crisis is needed (Herdiansyah et al., 2018; Mackay & Schmitt, 2019). This behavior can be encouraged by the emergence of a sense of unity with nature (Mayer & Frantz, 2004; Perkins, 2010).

Evidence suggests that, while there is no clear pattern associated with overall economic growth, there is a clear correlation between certain environmental indicators and per capita income. Environmental quality directly affects human well-being, and an increase in income is usually associated with decreased environmental degradation. However, economic growth results in a steady decline in environmental quality when the costs of environmental degradation can be externalized (Shafik & Bandyopadhyay, 1992).

Setianingtias et al. (2019) analyzed the relationship between indicators and dimensions of sustainable development (SDGs) in Indonesia. The results show a significant relationship between the economic and environmental dimensions and social and environmental. However, the relationship between the institutional pillar and the environment is not significant.

This study aims to examine the direct effects of determinant variables on environmental quality in Sumatra Island and the spillover effects to neighboring provinces due to changes in determinant variables. Unlike previous studies, this study examines the effects of the determinants on environmental quality with an island-scale spatial model to enrich perspective. The study also uses the proportion of highly educated workers to look more specifically at the impact of university graduates in contributing to environmental issues. Previous studies have examined education's impact on the environment with different variables and techniques. Studies examining the link between the level of democracy and environmental quality in Indonesia are limited. The insignificant role of institutions in previous studies will be tested again in this study with the proxy variable of democracy and regional expenditure per

capita. The findings of the interaction between the variables studied are expected to strengthen or correct the implementation of the Sustainable Development Goals (SDGs) in Indonesia in general.

2. Methods

This research is quantitative in the form of panel data. The study uses secondary data from the Central Bureau of Statistics, the Indonesian Ministry of Environment, and the Indonesian Ministry of Finance. The response variable in this study is the environmental quality index (IKLH). In contrast, the predictor variables include real GRDP per capita, proportion of highly educated workers, worker dependency burden ratio, population density, democracy, and regional expenditure per capita. The study observed the island of Sumatra from 2015 to 2022.

The study uses a spatial autoregressive (SAR) model to answer whether or not there is a direct effect caused by predictor variables on environmental quality and its spillover effect on other provinces. Before going there, several tests were conducted to detect the presence of spatial dependence in the model. The tests were conducted through Breusch-Pagan LM test, Pesaran CD test, and Moran test. The SAR model requires a weight matrix that serves to capture the spatial effect of environmental quality in the observed province on its neighboring provinces due to changes in the determining variables. The Moran test serves to ensure the existence of cross-section dependence of the matrix formed.

The ordinary least squares method approach assumes that the intercepts and regressor coefficients are considered constant for all cross-section and time units. One way to pay attention to this is to include dummy variables to provide different parameter values across cross-section and time series units. The approach of including dummy variables is the Least Square Dummy Variable (LSDV) or covariance model. A frequent approach is to allow the intercept to vary between cross-section units but still assume that the slope of the coefficient is constant between cross-section units (Gujarati & Porter, 2009). The equation model with LSDV is as follows:

$$iklh_{it} = \beta_1 + \beta_2 percapita_{it} + \beta_3 education_{it} + \beta_5 kp_{it} + \beta_6 kp_{it} + \beta localexp_{it} + democracy_{it} + u_{it} \quad (1a)$$

While the equation model of the random effect model (Generalized Least Square) is as follows:

$$iklh_{it} = \beta_1 + \beta_2 percapita_{it} + \beta_3 education_{it} + \beta_5 dep_{it} + \beta_6 kp_{it} + \beta_7 localexp_{it} + democracy_{it} + w_{it} \quad (1b)$$

Where *iklh* is the environmental quality index, *percapita* is real GRDP per capita, *education* is the distribution of highly educated workers, *dep* is the ratio of worker dependency burden, *kp* is population density, *localexp* is regional expenditure per capita, and *democracy* is the provincial democracy index. Meanwhile, *i* is each province in Sumatra, *t* is the period 2015-2022, and *w* is the combined error of individual specific and idiosyncratic error.

Statistical model selection is done so that the estimates obtained can be as efficient as possible. The test was carried out using the Hausman test to choose the best model between the fixed effect and random effect models. The basis for rejecting H_0 using the Hausman statistic is formulated as follows:

$$X^2 (K) = ((b - \beta)'[Var(b - \beta)^{-1}(b - \beta) \quad (2)$$

Where b is the random effect coefficient, and β y is the fixed effect coefficient? The Hausman statistic spreads chi-square, if the X^2 value of the test result is greater than $X^2 (K,\alpha)$ (K = number of independent variables), or $P\text{-}Value < \alpha$, then there is enough evidence to reject H_0 and vice versa.

Several options can be taken to diagnose the presence or absence of dependence or interrelationships between individuals in the cross-section elements. The spatial correlation tests include Moran, the LM test by Breusch Pagan, and the CD Pesharan test (Firdaus et al., 2024).

If there is a strong indication of cross-section dependence in the model, then the next step is to build a weight matrix. The weight matrix used is the K-Nearest Neighbor (KNN) assumption with a number of 1 neighbor, taking into account the Moran test value and the significance level of the spatial model. These weights reflect the importance of the distance between the tested data and its neighbors in the calculation of the final result (Anselin, 2005; Anselin & Rey, 2010; Firdaus et al., 2024). The calculation of the inverse distance matrix is as follows:

$$w_{ij} = \frac{w_{ij*}}{\Sigma_j w_{ij*}} \quad (3)$$

Where w_{ij} is the inverse value of the distance of the spatial unit of province i to the spatial unit of province j (d_{ij}), or it can be written w_{ij^*} is $1/d_{ij}$ α, where α is a power of 1, 2, ..., n.

Spatial lag model or spatial autoregressive (SAR) model indicates that the dependent variable depends on the observed independent variable and the dependent variable at the nearest unit, and the residuals are independent, identical, and normally distributed with zero mean and varian σ^2.

$$iklh_{it} = \delta \sum_{j=1}^{N} w_{ij} iklh_{jt} + percapita_{it}\beta + education_{it}\beta + dep\beta + kp_{it}\beta + localexp_{it}\beta + democracy_{it}\beta + \varepsilon_{it} \quad (4)$$

Where w_{ij} is the standardized spatial weight of the *i-th* row of the *j-th* column, *iklh* is the environmental quality index, *percapita* is the real GRDP per capita, *education* is the distribution of highly educated workers, *dep* is the worker dependency burden ratio, *kp* is population density, *localexp* is local expenditure per capita, *democracy* is democracy index, β is the coefficient of independent variables, δ is the coefficient of spatial lag parameter, and ε is error, the spillover effect coefficient obtained from the interaction between the direct effect coefficient, δ, and w_{ij}.

The variables used in this study include the environmental quality index. This index describes the condition of water quality (IKA), air quality (IKU), and land cover quality (IKTL) in provinces located on the island of Sumatra. The calculation of this index is as follows:

$$IKLH = (30\% \times IKA) + (30\% \times IKU) + (40\% \times IKTL) \quad (5)$$

Next is the real GRDP per capita. The real Gross Regional Domestic Product (GRDP) per capita used in this study is at constant 2010 prices. The real GRDP per capita value in question is the real GRDP per capita value of each province in Sumatra Island in 2015-2022. The unit of real GRDP per capita is the Indonesian Rupiah (IDR), which is calculated by the following formula:

$$Real\ GRDP\ per\ capita = \frac{GRDP\ constant\ price_t}{Population\ in\ the\ middle\ of\ the\ counting\ year} \quad (6)$$

Then, democracy index, is a composite indicator that shows the level of democracy development in Sumatera Island. The level of achievement is measured based on the implementation and development of three aspects of democracy, namely: Civil Liberties, Political Rights, and Democratic Institutions. The measurement scale is from 0 to 100. Data was obtained from the Central Bureau of Statistics, which was transformed into a natural logarithm form.

The other variable is the proportion of highly educated workers. This variable is the distribution of highly educated workers to the total number of workers in Sumatra in 2015-2022. What is meant by highly educated workers is the working population who have studied at least a diploma level. The data comes from the Central Bureau of Statistics, which transforms percent units into natural logarithms. The formula is as follows:

$$Proportion\ of\ highly\ educated\ workers = \frac{Number\ of\ workers\ with\ diploma\ and\ above}{Total\ workers} \times 100 \quad (7)$$

Worker dependency burden is measured by comparing the total number of people not working to the total number of workers. The value of the dependency ratio in this study covers each province in Sumatra for the 2015-2022 period. The unit is in the form of a ratio that is transformed into the natural logarithm. An illustration of the calculation is as follows:

$$Worker\ dependency\ burden\ ratio = \frac{total\ non-workers}{Total\ workers} \times 100 \quad (8)$$

Population density is the number of people per unit area. The population density in this study is taken from each province in Sumatra for the period 2015-2022. The units of this variable are ratios transformed into natural logarithm form, and the calculation description is as follows:

$$Population\ density = \frac{Total\ population\ of\ the\ province_t}{Total\ area\ of\ the\ province} \quad (9)$$

Lastly, regional expenditure is budget expenditure for acquiring fixed assets and other assets that provide benefits for more than one accounting period. The posture of regional expenditure includes capital expenditure, expenditure on goods and services, personnel expenditure, and other expenditures. The regional expenditure used in the calculation is regional expenditure per population, which can be obtained by dividing total regional expenditure from APBD by the total population in the province. The unit of this data is the Indonesian Rupiah (IDR), which is transformed into a natural logarithm form.

$$Local\ expenditure\ per\ capita = \frac{Local\ Expenditure_t}{Total\ population\ of\ the\ province_t} \quad (10)$$

3. Results and Discussion

3.1. Performance of Environmental Quality and Determinant Variables

Table 1 illustrates the development of environmental quality and its determining variables in Sumatra Island from 2015 to 2022. Aceh Province has the best environmental quality among other provinces, with an average index value of 75.86, followed by Riau Islands and Bengkulu. Meanwhile, the poorest environmental quality is in Lampung Province, which has an index value of 62.55. This value is far below the average geometry value of Sumatra. If broken down into 2 categories based on the average value, then as many as 5 provinces have better environmental quality because they have index values above the geometric mean. The provinces in question include Aceh, West Sumatra, Bengkulu, Bangka Belitung, and Riau Islands. While other provinces such as North Sumatra, Riau, Jambi, South Sumatra, and Lampung have worse environmental quality.

Riau Island Province has the highest real output per capita, with IDR 82.3 million. At the same time, Bengkulu Province has the lowest real GDP per capita, with an IDR 22.5 million. South Sumatra Province has the highest democracy index, while the lowest is in West Sumatra Province. The proportion of highly educated workers is highest in Aceh Province, while the lowest is in Lampung. Bengkulu Province has the lowest work dependency burden ratio, while Aceh Province has the highest. Jambi Province has the lowest population density, while Riau Island is the most densely populated. Aceh Province has the highest local expenditure per capita compared to other provinces, while the lowest local expenditure is in Lampung Province. North Sumatra is the only province whose performance is always worse; in other words, its performance score is always less than the geometric mean of Sumatra Island.

Table 1. Geomean Environmental Quality Performance and Determinant Variables 2015-2022

Province	IKLH	Real GRDP per capita (thousand IDR)	Democracy	Proportion of highly educated workers (%)	Worker dependency burden ratio	Population density	Regional expenditure per capita (thousand IDR)
Aceh	75.86	24,252	75.60	16.86	135.87	90.23	2,575,789
North Sumatra	68.22	35,239	69.84	12.07	116.58	200.77	808,602
West Sumatra	68.49	30,111	69.37	15.30	116.06	128.67	1,059,834
Riau	64.60	73,783	73.76	13.04	127.31	75.31	1,275,088
Jambi	67.01	40,565	72.22	12.10	107.53	72.29	1,177,279
South Sumatra	67.46	35,783	78.12	10.39	107.31	92.14	932,902
Bengkulu	70.04	22,496	73.53	12.79	95.99	98.34	1,393,372
Lampung	62.55	26,925	71.44	8.69	101.37	250.52	781,264
Bangka Belitung	68.84	36,006	76.72	10.99	104.19	87.73	1,636,786
Riau Islands	70.43	82,336	76.91	15.93	135.61	269.63	1,532,961
Geomean	68.27	37,424	73.70	12.60	114.09	122.48	1,244,838

Source: *Statistics Indonesia (2023) and Ministry of Environment and Forestry of the Republic of Indonesia (2020)*

Description: *Green color means better than average performance, yellow color means worse than average performance.*

3.2. Direct and Spillover Effect

The first step is to conduct and test a static panel regression. The result of the Hausman test shows a p-value of 0.298, where the random effect is the best model,

which is then used to test for heteroscedasticity, serial correlation, and cross-section dependence. Through the Breusch-Pagan test, the p-value is 0.165 or above 5% alpha, where the variance of the residuals tends to be constant. The test results through the Breusch-Godfrey/Wooldridge test obtained a p-value of 0.006, meaning that the model's residuals have autocorrelation between times. Then, testing cross-section dependence through the Breusch-Pagan LM and Pesaran CD test shows the same decision, that the model built has spatial dependence between cross-sections.

Table 2. Result of Panel Data Regression Model Test, Autocorrelation and Cross Section Dependence Result

Tests	p-value	Decision
Best panel model (Hausman test)	0.298	Random effect model
Heteroscedasticity test (Breusch-Pagan test)	0.165	**Homoscedasticity**
Serial correlation (Breusch-Godfrey/Wooldridge test)	0.006	**There is autocorrelation**
Cross-section dependence (Breusch-Pagan LM test)	6.273e-08	**There is cross section dependence**
Cross-section dependence (Pesaran CD test)	9.997e-07	**There is cross section dependence**

Source: *Data processing results, 2024*

The Moran test results yielded a p-value of 0.015 on the weight matrix with 1 neighbor. This result confirms that there is a spatial dependence of iklh with the number of neighbors of 1 at the 5% level. The next step is to conduct a Hausman test to select the best model from the panel data formed. The result shows that the p-value is 0.870 where the random effect model will be used in spatial autoregressive (SAR) modeling. The p-value of the lambda SAR model is 0.010, where this model with a weighting matrix of 1 nearest neighbor can be relied upon to explain the spatial interaction of environmental quality between provinces.

Table 3. Results of Moran Test, Hausman Test and Lambdha of SAR Model KNN-1

Tests	p-value	Decision
Moran test	0.015	There are spatial dependencies
Hausman test	0.870	Random Effect
Lambda	0.010 *	Model significant

Source: *Data processing results, 2024*

The regression results of the spatial autoregressive (SAR) model show that real GDP per capita, the proportion of workers with higher education, and democracy have significant direct effects, indirect effects, and total effects at the 10% level. Meanwhile, the worker dependency ratio is significant in the direct effect and total effect but has a weak spillover effect. Meanwhile, population density and regional expenditure per capita have no significant effect on environmental quality, either in province i or its effect on province j.

Table 4. P-Value Results of Spatial Autoregressive Model (SAR)

Variable	Direct Effect	Indirect Effect	Total Effect
Log(percapita)	0.001***	0.049**	0.001***
log(education)	0.001***	0.046**	0.001***
log(dependency)	0.083*	0.171	0.085*
log(density)	0.466	0.497	0.463
log(regionalexp)	0.736	0.771	0.740
log(democracy)	7.973e-06***	0.034**	2.6863e-0***

Source: *Data processing results, 2024*

3.2.1. Real GRDP per Capita

Real output per capita has been proven to have a strong direct and spillover effect. An increase in real output per capita in province i by 1% will reduce environmental quality in the province by 0.065%. A decrease in environmental quality due to an increase in real GRDP per capita in province i will cause a decrease in environmental quality in province j by 0.012%. Changes in real GRDP per capita have a widespread effect on reducing environmental quality on the island of Sumatra by 0.077.

These results support previous findings (Galeotti, 2007; Shafik & Bandyopadhyay, 1992; Yan et al., 2022) and reinforce the thesis with specific findings of spillover effects. Production and consumption activities that, because of environmental impacts, result in costly development, and there is a need to rethink the habit of economic activity that tends to be limitless before it causes damage that leads to regret.

Employment that leads to environmental friendliness needs to be promoted, which is in line with the go green process (Dordmond et al., 2021; King & Shackleton, 2020). In urban areas, the development of urban forests and city branding that create coolness and aesthetics can be an option to reduce energy costs and strengthen property values. But if not careful and disrupts the existing forest ecosystem, development can actually damage the environment (Ibrahim et al., 2023; Soesanta et al., 2023; Sulistiowati et al., 2023).

3.2.2. Proportion of Highly Educated Workers

The proportion of highly educated workers has a significant effect, where an increase in its proportion in province i by 1% will increase environmental quality in the province by 0.150%. This change causes an increase in environmental quality in the nearest neighboring province by 0.028%. The interaction of education on environmental quality in Sumatra has a broad impact of 0.178%.

This result is in line with previous findings that increasing levels of human capital are positively associated with environmental quality (D. Kim & Go, 2020; Zhu, 2023). The proportion of highly educated workers in Sumatra Island is still relatively small, with an average of 12.82% of the total number of workers. There needs to be an effort to increase the level of education of workers so that the economic activities carried out can be more associated with improving environmental quality in Sumatra more broadly.

3.2.3. Worker Dependency Burden Ratio

An increase in the ratio of worker dependents in province i by 1% will increase the environmental quality in the province by 0.126%. Changes in environmental quality in province i due to changes in the worker dependency ratio do not have a significant spillover effect on neighboring provinces. However, if all provinces have the same value of change in the burden of dependent workers, it will impact changes in environmental quality in Sumatra by 0.150%.

The positive effect of the worker dependency ratio can be understood as the higher the ratio, the smaller the proportion of workers compared to the non-working population. This further reinforces that the orientation of economic activity that supports the absorption of more labor is more damaging to the environment. If referring to data movement, some provinces, such as Riau and South Sumatra, show a more consistent unidirectional interaction throughout the observation period. Bengkulu and Lampung have similar patterns in most years of observation, while other provinces tend to be more dynamic. This result is in line with the findings on the impact of increasing real output per capita on environmental degradation. Strengthening the implementation of

regulations from authorities, both government, financial institutions, and companies, to support environmentally oriented economic activities is absolutely necessary so that the impact of an increasing economy does not further sacrifice the environment. The presence of Law No. 32 of 2009 on Environmental Protection and Management, OJK Regulation No. 51/POJK.03/2017 on the Implementation of Sustainable Finance for Financial Services Institutions, Issuers, and Public Companies, and several other regulations can create a fence for economic activities carried out.

3.2.4. Democracy

Democracy has the greatest level of influence in explaining environmental quality in Sumatra, where an increase in the democracy index in the observation province by 1% will increase environmental quality by 0.471%, with a spillover effect of 0.089%. Changes in the democracy index have a spillover effect on the island of Sumatra of 0.560%.

This result is different from the findings by Setianingtias et al. (2019), where democracy as one part of the institutional pillar has the strongest influence in explaining environmental quality. This finding is in line with the study of Farzin and Bond (2006), which illustrates the role of democracy in providing channels of preference for environmental issues that have a positive impact on environmental quality. Strengthening the democratic climate in a province that has a good impact on environmental issues has the opportunity to spread its enthusiasm to other regions to become a best practice at the implementation level. This condition will further improve the climate for sustainable development on the island of Sumatra. Capturing the aspirations of all parties through engagement channels can encourage sustainable development based on local potential (Anam et al., 2024; Manoby et al., 2023; Nurdin & Baharuddin, 2023; Simandjorang et al., 2022; Wirawan, 2018). Transparency by the government, including in its environmental management, reflects the strengthening of democracy from the institutional side (Fatoni, 2020). Several democracy index indicators such as the guarantee of freedom of assembly, association, expression, and opinion; a free press in carrying out its duties and functions; public participation in influencing public policy through representative institutions; anti-monopoly of economic resources; access to public information; government guarantees for environmental preservation and community living space; and the performance of the legislature, judiciary, and bureaucracy are to become a bulwark against human activities that tend to damage the environment.

3.2.5. Population Density

Population density does not significantly influence explaining environmental quality in Sumatra, either from the direct effect, indirect effect, or total effect generated. Regarding the data, some densely populated provinces, such as North Sumatra and Lampung, have worse environmental quality. However, a different condition is experienced by Riau Island, where the density level is the highest in Sumatra. Still, it has much better environmental quality than the two previous provinces, even though the value of environmental quality is the second highest after Aceh. Several provinces, such as Riau, Jambi, South Sumatra, and Bengkulu, have relatively low population densities but poorer environmental quality. This indicator does not capture the extent to which the concentration of population density in a province is spread out, which would have the opportunity to clarify the impact of the density level. For example, North Sumatra and Riau's provinces are concentrated in Medan and Pekanbaru's cities, and these cities allegedly contribute significant environmental impacts at the provincial level. Migration patterns from residents of surrounding areas still part of

the province obscure the impact at the provincial level. The increasing practice of sustainable development in some areas is suspected to be one of the causes of the emergence of various data interactions from the provinces above. This variation causes an insignificant effect on density, but the direction is already positive, which is indicated by the coefficient value.

3.2.6. Regional Expenditure per Capita

Likewise, regional expenditure per capita does not have a significant direct effect, spillover effect, or total effect in explaining environmental quality on the island of Sumatra. The study results are in line with the findings of Setianingtias et al. (2019) where there is no significant relationship between institutional pillars and the environment, and relatively different from Munawaroh and Fajri's findings (2023), which show fiscal decentralization can improve environmental quality. However, it differs from previous studies' results that show a strong influence of government spending in explaining environmental quality (Galinato & Galinato, 2016; Islam & López, 2015). Expenditure orientation among regional apparatus organizations tends to have a partial impact that only accommodates their apparatus units' main tasks and functions, resulting in a weak expenditure impact on environmental quality issues in Sumatra. Government management and regulations that are oriented towards Good Environmental Governance are the right step, including orientation in spending (Adlin, 2021; Giroth et al., 2021; Juwono & Damara, 2020; Magriaty et al., 2020; Renaldi & Frinaldi, 2022; Schienke, 2012).

Table 5. Coefficients of Spatial Autoregressive Model (SAR)

Variable	Direct Effect	Indirect Effect	Total Effect
Log(percapita)	-0.065***	-0.012**	-0.077***
log(education)	0.150***	0.028**	0.178***
log(dependency)	0.126*	0.024	0.150*
log(density)	0.010	0.002	0.012
log(regionalexp)	0.003	0.001	0.003
log(democracy)	0.471***	0.089**	0.560***

Source: *Data processing results, 2024*

4. Conclusion

The study concludes that democracy has the strongest positive direct and spillover effects on improving environmental quality. Increasing the proportion of highly educated workers will improve environmental quality in the observed province and impact improving environmental quality in its immediate neighboring provinces. An increase in labor dependency burden will improve environmental quality in the observed province, with weak spillover effects. Conversely, an increase in real GRDP per capita will decrease environmental quality in the observed province and impact the environmental quality of its closest neighbors. The four determinants have a strong total influence in explaining environmental quality. Meanwhile, population density and regional expenditure have no significant effect.

The interaction of environment with real GRDP per capita supports the arguments of Galeotti (2007) and Yan et al. (2022) with additional evidence that economic activity in one region also adversely affects environmental quality in nearby regions. This study supports the argument of Farzin and Bond (2006) and refutes the findings of Setianingtias et al. (2019) which actually illustrates the strong role of democracy as an institutional proxy in influencing the environment.

The implication of this research is the need for intervention from the authorities to change the perspective on economic activity and regional spending as a whole so that economic value added does not come at the expense of the environment. The central government can play a role in expanding spillover effects by building institutions that increasingly safeguard freedom, equality, and professionalism with more substantive democratic practices. Expanding opportunities for access to higher education is also recommended. Conversely, the negative spillover effects of productivity need to be altered by the central and local governments by increasing supervision over economic activities, and tightening business licenses especially for companies with medium and high environmental risks. Local governments can improve environmental quality by strengthening pro-environmental channels of democracy, redirecting local spending towards expanding green spaces, including more environmentally friendly procurement, and supporting scholarships to universities for high achievers and underprivileged citizens. Businesses, philanthropies, and other community groups can contribute by familiarizing themselves with pro-environmental activity patterns.

This study has several limitations, including the limited time span of observation, which causes limitations in capturing the movement of interactions between the variables tested. In terms of methods, determining the most appropriate spatial interaction requires a longer time, considering that there are many possible spatial methods which can enrich information about the interaction of related variables and become an entry point for further research.

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