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ORIGINAL RESEARCH PAPER

Impacts of environmental quality and employment resilience during the coronavirus disease 2019 recession and recovery

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ABSTRACT

BACKGROUND AND OBJECTIVES: The unanticipated effects of the economic decline resulting from the coronavirus create both challenges and opportunities for assessing the ability of regions to achieve a balance between their economic demands and the preservation of the environment amidst the upheaval brought about by the pandemic. The objective of this study is to assess the spatial distribution of both the environmental quality index and the employment resilience index within the 34 provinces of Indonesia. This study examines the factors that may influence the environmental quality index during the recession and recovery periods due to coronavirus disease 2019.

METHODS: The present study applies multiple linear regression techniques. The cross-sectional data for this analysis were acquired from the Central Bureau of Statistics, which includes information from 34 provinces in Indonesia during the years 2020 and 2021. This study compares the results of factors that influence the environmental quality index in the 2020 period when the recession was due to coronavirus (resistance dimension) with the 2021 period when the recovery was due to coronavirus (recovery dimension).

FINDINGS: Employment resilience, gross regional domestic product rowth rate, technology and information, population, population density, and the coronavirus recovery rate influence the environmental quality index during the recession and recovery periods due to coronavirus disease 2019, with respective contributions of 75.02 percent and 83.59 percent. In the years 2020 and 2021, the environmental quality index predominantly fell within the good category; however, this distribution was not uniform across the 34 provinces in Indonesia. The categorization of economic resilience and recovery indicates that a majority of provinces in Indonesia are primarily characterized by the group exhibiting positive values in both economic resistance and recovery. Partially, during the recession and recovery periods due to coronavirus disease 2019, technology and information, population, and population density negatively impacted the environmental quality index. During the recovery intervals linked to the coronavirus disease 2019, the recovery index indicated a favorable influence on the environmental quality index.

CONCLUSION: Employment resilience, gross regional domestic product rowth rate, technology and information, population, population density, and the coronavirus recovery rate influence the environmental quality index during the recession and recovery periods due to coronavirus disease 2019. Environmental quality index achievement remains uneven across the 34 provinces in Indonesia. Comparable findings indicate that the economic downturn resulted in diverse responses regarding employment resilience across different geographical areas. Numerous obstacles emerge in the pursuit of sustainable growth. The strategy involves fostering and bolstering support for the green economy, alongside promoting labor development in the renewable energy field, underpinned by heightened investment in green infrastructure.

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INTRODUCTION

The environmental issue has now become an interesting topic in studying how a region can grow sustainably. The pandemic of coronavirus disease 2019 (Covid-19) has engendered a variety of environmental consequences, encompassing both advantageous and adverse outcomes. The economic decline associated with the pandemic has resulted in unforeseen advancements in the environmental quality (Girdhar *et al.,* 2021). The halt of industrial operations and the decrease in human mobility resulted in a significant decline in pollution levels within Vembanad Lake, recognized as one of the most contaminated freshwater lakes in India (Yunus *et al.,* 2020). Rushayati *et al.* (2020) also noted that the Jabodetabek agglomeration area, one of the Java Ecoregion areas with low air quality, experienced significant air quality improvement during the implementation of emergency public activity restrictions (PPKM). Another positive impact was reported by Praveena and Aris (2021) and (Kamyab *et al.,* 2022), who highlighted improvements in air and water quality due to the Covid-19 pandemic. Contrary to earlier research, the rise in waste generated from personal protective equipment (PPE) has adversely affected the environment throughout the Covid-19 pandemic (Norouzi and Bashashjafariabadi, 2021). The increase in Covid-19 patients has led to a rise in the volume of hazardous waste (Firmansyah *et al.,* 2021). Elevated levels of medical waste and ineffective waste management strategies may contribute to the potential spread of Covid-19 (Abu-Qdais *et al.,* 2020). The lockdown implemented in response to the coronavirus disease-2019 has caused a reduction in activities and the cessation of recycling programs associated with waste management (Zambrano-Monserrate *et al.,* 2020). The environmental quality index (EQI) is a measure of environmental quality in a region of Indonesia. Data shows that the EQI of Indonesia increased by 3.72 points from 66.55 in 2019 to 70.27 in 2020. The increase in the environmental quality index was not evenly distributed across all regions in Indonesia. Based on the 2021 EQI report, some provinces experienced a decline in their EQI value in 2020 (KLHK, 2021). This has driven to explore the factors that may influence the environmental quality index in 34 provinces in Indonesia particularly in light of the challenges posed by the Covid-19. In Indonesia, employment resilience is a critical factor for the stability of the country's economy and social structure. The shock caused by the pandemic has raised the challenge of how quickly Indonesian employment can react and recover from disruptions (recession). Resilience itself is a useful concept for assessing how a region is affected by a recession (Martin *et al.,* 2016). Martin *et al.* (2016) identified three different dimensions of regional economic resilience; a) resistance (indicating the sensitivity of the regional economy to economic shocks); b) recovery (indicating how quickly the regional economy recovers from disruptions); c) reorientation and renewal, which is the ability of a region to adapt in response to shocks and return to its growth path before the recession. Statistical evidence indicates that 1.84 percent, equating to 301.09 thousand employees, experienced job loss in 2020 as a direct consequence of the COVID-19 pandemic (Badan Pusat Statistik, 2021). This data confirms that the Covid-19 shock can pose a significant challenge to the employment sector in Indonesia. The present study investigates the concept of regional resilience, emphasizing the relationship between regional employment and environmental quality. This relationship is explored through two key dimensions: resistance, which assesses the regional economy's susceptibility to economic shocks or downturns, and recovery, which evaluates the rapidity of the regional economy's recovery from such disruptions or recessions, especially in light of the Covid-19. Xaisongkham and Liu (2024) and Bai *et al*. (2021) argued that an increase in the employment has a positive impact on the environment. Other study shows different results, indicating that an increase in employment can reduce environmental quality (Zhong and Su, 2021). Another observation reveals that the escalation of average working hours, driven by an increase in employment, correlates with a rise in carbon dioxide (CO_2) emissions (Fremstad *et al.,* 2019). This is interesting and could be a novel aspect of this research, considering that the role of employment in influencing environmental quality from both recession and recovery perspectives has not yet been a primary focus in studies conducted in Indonesia. Another factor that could affect environmental quality is the gross regional domestic product (GRDP) growth rate. Boosting economic growth often comes at the expense of environmental quality. Rapid economic growth can lead to the over-

exploitation of natural resources, resulting in environmental degradation (Wawrzyniak and Doryń, 2020). This aligns with research showing that increased economic activity gross domestic product (GDP) can lead to higher carbon dioxide emissions (Ekonomou and Halkos, 2023). Other findings also indicate that economic growth impacts the environmental quality index (Amar *et al.,* 2024). The environmental kuznets curve (EKC) theory, developed by Grossman and Kruger, states that there is an inverted U-shaped relationship between per capita income levels (measured by GRDP) and environmental degradation. Once a particular level of income is achieved, there is a corresponding rise in investments directed towards eco-friendly technologies and the enforcement of stricter environmental policies, leading to a decrease in environmental degradation. Rahman *et al.* (2022) and Butarbutar (2023) stated that GRDP has a positive impact on the environment. According to this theory, elevated levels of GRDP may enable and motivate countries or regions to enhance their investments in efforts aimed at environmental preservation (Tang and Wang, 2023). Technology plays a crucial role in linking the economy and the environment. With technological advancement, it is expected to become a key driver in reducing the environmental impact of economic activities. Zhong and Su (2021) and Bai *et al.* (2021) showed that technological changes toward low-carbon technologies slow the growth of carbon dioxide emissions. In contrast, employing technologies that are detrimental to the environment and characterized by high resource consumption can lead to an increase in environmental pollution. This aligns with the research by Awad and Saadaoui Mallek (2023), which suggests that Information and communication technology negatively impacts the environment. Another factor that can influence the environmental quality index is demographic factors. In Indonesia, substantial population growth tends to exert greater strain on natural resources, potentially resulting in environmental degradation if adequate management strategies are not implemented. This aligns with research by Woodard *et al.* (2019), which suggests that population negatively impacts the environment. According to Alnour *et al.* (2022), densely populated urban areas also face greater challenges in maintaining environmental quality. High population density regions often demand significant resources, which consequently contributes to an increase in both waste production and pollution levels. This study incorporates the Covid-19 patient recovery variable, adding novelty to the research. Other studies generally do not directly include this variable when assessing its environmental impact. The recovery of Covid-19 patients presents both challenges and opportunities for environmental quality. Khalid *et al.* (2021) argued that the Covid-19 outbreak prompted a response to consider environmental aspects to support sustainable economic activities. In contrast, the reactivation of various activities and enhanced mobility could reintroduce difficulties regarding environmental quality. It is essential to focus on sustainable economic recovery strategies. Good economic policies must consider their impact on the environment, while environmental policies must also account for economic needs. By considering factors such as employment resilience, gross regional domestic product growth rate, technology, demographic conditions, and the impact of the Covid-19 pandemic, it is hoped that effective strategies can be designed to maintain a balance between human needs and environmental sustainability. This study seeks to investigate the distribution patterns of the environmental quality index and the employment resilience index within the 34 provinces in Indonesia. This study also examines factors that may affect the EQI during the recession and recovery from Covid-19. This study hypothesizes that Covid-19 has had a significant effect on the improvement of environmental quality in multiple regions. The second hypothesis suggests that the expansion of employment sectors is a critical factor influencing the extent of economic resilience and recovery during the Covid-19 pandemic. The third hypothesis is that the employment resistance index (RESIS), recovery index (RECOV), gross regional domestic product growth rate, information and technology, population, population density, and the recovery rate of Covid-19 patients significantly influence the environmental quality index during the recession caused by Covid-19. The fourth hypothesis posits that various factors, including the employment recovery index, the growth rate of gross regional domestic product, advancements in information and technology, population metrics, population density, and the recovery rate of patients affected by Covid-19, have a significant impact on the

Table 1: Description and expected signs of the EQI 2020 variables

Variable and unit	Operational definition	Expected effects on EQI 2020
Variable dependent		
Environmental quality index	The environmental quality Index for the year 2020	
Variable independent		
Resis (index)	Resistance is a concept that potentially examines how a region is affected by a recession.	+
Gross regional domestic product growth rate in percent (%)	Growth in the production of goods and services in an economic area within a certain time interval.	-
Information and technologies (%)	Percentage of the population that owns a mobile phone, computer, and accesses the internet	+
Population (person)	Total population, expressed in thousands of people or millions of people.	-
Population density (person)	The number of inhabitants per square kilometer of area.	-
Recovery rate (%)	The recovery rate of coronavirus disease-2019 patients by province.	+

Table 2: Description and expected signs of the EQI 2021 variables

Variable and unit	Operational definition	Expected effects on EQI 2021
Variable dependent		
Environmental quality index	The environmental quality Index for the year 2021.	
Variable independent		
Recov (index)	Recovery is a concept that potentially examines how a region recovers from a recession.	+
Gross regional domestic product growth rate (%)	Growth in the production of goods and services in an economic area within a certain time interval.	-
Information and technologies (%)	Percentage of the population that owns a mobile phone, computer, and accesses the internet	+
Population (person)	Total population, expressed in thousands of people or millions of people.	-
Population density (person)	The number of inhabitants per square kilometer of area.	-
Recovery rate (%)	The recovery rate of coronavirus disease-2019 patients by province.	+

environmental quality index throughout the recovery phase from the pandemic. This study was conducted in 34 provinces in Indonesia in 2020 during the Covid-19 recession and 2021 during the Covid-19 recovery.

MATERIALS AND METHODS

Table 1 presents the operational definitions of the dependent and independent variables in Eq. 4 during the Covid-19 recession.

Table 2 presents the operational definitions of the dependent and independent variables in Eq. 5 during the Covid-19 recovery.

Regional employment resistance index

The measurement of the resistance index of the employment data from 2019 and 2020, using Eq. 1 (Cainelli *et al.,* 2019; Ezcurra and Rios, 2019):

$$Resis_i = \frac{\left(\Delta E_i^{\text{Contraction}}\right) - \left(\Delta E_i^{\text{Contraction}}\right)^{\text{Expected}}}{\left|\left(\Delta E_i^{\text{Contraction}}\right)^{\text{Expected}}\right|} \quad (1)$$

Where;

$Resis_i$ is the resistance index of i province; $\Delta E_i^{\text{Contraction}}$ is contraction changes of i province employment; $\Delta E_i^{\text{Contraction}^{\text{Expected}}}$ is contraction change of national employment and $\left(\Delta E_i^{\text{Contraction}}\right)^{\text{Expected}}$ as contraction change of national employment (absolute value).

Regional employment recovery index

The measurement of the recovery index of the employment data from employment data from 2020

and 2021, using Eq. 2 (Cainelli *et al.,* 2019; Ezcurra and Rios, 2019):

$$Recov_i = \frac{\left(\Delta E_i^{Recovery}\right) - \left(\Delta E_i^{Recovery}\right)^{\text{Expected}}}{\left|\left(\Delta E_i^{Recovery}\right)^{\text{Expected}}\right|} \quad (2)$$

Where; $Recov_i$ is the recovery index of i province; $\Delta E_i^{Recovery}$ is recovery changes of i province employment; $\Delta E_i^{Recovery\,\text{Expected}}$ is recovery change of national employment and $(\Delta E_i^{Recovery})^{\text{Expected}}$ is recovery change of national employment (absolute value).

Multiple linear regression analysis

This quantitative research is conducted using the multiple linear regression analysis method. Multiple linear regression is a statistical technique used to analyze the relationship between one dependent variable and two or more independent variables (Gujarati and Poter, 2009). The parameters in multiple linear regression are typically estimated using the ordinary least squares (OLS) method, which seeks to minimize the sum of squared errors. For cross-sectional data, the classical assumptions include tests for normality, multicollinearity, and heteroskedasticity. The study utilizes cross-sectional data sourced from the central bureau of statistics, encompassing 34 provinces in Indonesia, with information collected during the years 2020 and 2021. This study aims to compare the factors influencing the environmental quality index during the recession period caused by Covid-19 in 2020 (resistance dimension) with the recovery period in 2021 (recovery dimension) following the Covid-19 recession. This analysis focuses on several independent variables, including the resistance index, recovery index, the growth rate of gross regional domestic product, total population, population density, technology and information factors, as well as the recovery rate of individuals affected by Covid-19, as defined in Eq. 3 (Gujarati and Poter, 2009):

$$Yi = \beta_1 + \beta_2 X_{2i} + \beta_3 X_{3i} + u_i \quad (3)$$

Where; Yi is the dependent variable;; $X2i$, $X3i$ are independent variables; $\beta 1$ is the intercept term; β2,β3 are the coefficients for the independent variables and ui is the error term.

This study uses the multiple linear regression analysis method with the following model, using Eqs. 4 and 5 (Gujarati and Poter, 2009):

$$\text{EQI_2020}_i = \beta_1 + \beta_2 \text{RESIS}_i - \beta_3 \text{LGRDP}_i + \beta_4 \text{IT}_i - \beta_5 \text{POP}_i - \beta_6 \text{PD}_i + \beta_7 \text{RR}_i + u_i \quad (4)$$

$$\text{EQI_2021}_i = \beta_1 + \beta_2 \text{RECOV}_i - \beta_3 \text{LGRDP}_i + \beta_4 \text{IT}_i - \beta_5 \text{POP}_i - \beta_6 \text{PD}_i + \beta_7 \text{RR}_i + u_i \quad (5)$$

Where;

EQI = Enviroment quality index
RESIS = Resistance index
RECOV = Recovery index
LGRDP= Gross regional domestic product growth rate
IT = Information and technologies
POP = Population
PD = Population density
RR = Recovery rate of coronavirus disease-2019 patients

RESULTS AND DISCUSSION

Spatial distribution of environmental quality index

Based on EQI data, the spatial distribution across 34 provinces in Indonesia was categorized and analyzed. The spatial distribution of the EQI for the years 2020 and 2021 generally showed improvement, with most regions falling into the "good" category. Indonesia's EQI increased from 66.55 in 2019 to 70.27 in 2020 and 71.41 in 2021, although this improvement was not uniform across all regions. Lockdowns instituted during the pandemic contributed to a substantial decline in pollution levels in diverse áreas (Masum and Pal, 2020). Other findings also indicate a reduction in emissions during the lockdown period (Gupta *et al.,* 2020) . Rushayati *et al.* (2020) also noted that the Jabodetabek agglomeration area, one of the Java Ecoregion areas with low air quality, experienced significant air quality improvement during the implementation of emergency public activity restrictions (PPKM). The 2020 EQI data showed that 12 provinces were in the "moderate" category, including Bengkulu, South Sumatra, North Sumatra, Lampung, East Java, Central Java, DI Yogyakarta, Banten, West Java, DKI Jakarta, Riau, and South Kalimantan. The 2021 EQI data showed that 10 provinces were in the "moderate" category, including South Sumatra, West Nusa Tenggara, Jambi, Lampung, East Java,

Central Java, DI Yogyakarta, Banten, West Java, and DKI Jakarta. Figs. 1 and 2 highlight that DKI Jakarta had the lowest EQI compared to other provinces. In DKI Jakarta, the substantial population density contributes to a rise in consumption, which presents several environmental risks. Additionally, this dense population fosters greater mobility requirements, prompting the need for transformative innovations, including the implementation of electric vehicles, which can address the challenges associated with sustainable transportation (Farajnezhad *et al.*, 2024). The Covid-19 pandemic led to an increase in the EQI in provinces on Java Island, with the average EQI rising from 52.68 in 2019 to 62.07 in 2020 (KLHK, 2022). In 2021, there was a decline in EQI in Central Java and DI Yogyakarta. To conclude, Java Island recorded the lowest EQI, which is below the average observed at the national level. The significant decline in the EQI value for Java Island can be attributed to the low land quality index (LQI), which is categorized as "poor" and records an average score of 37.46. The low LQI in the Java Ecoregion is due to the disproportionate balance between vegetated land and built-up areas. An expanding population has intensified the demand for land, prompting the alteration of forested landscapes into constructed environments and additional infrastructural projects (KLHK, 2022). In 2021, during the recovery period from Covid-19, the EQI values in the provinces of Bangka Belitung Islands, Jambi, and Aceh showed a decline. This was marked by weak synergy in environmental management in these regions. In these areas, the environmental problems can be attributed to intensified social and economic activities, which have contributed to a deterioration in air quality, a reduction in the quality and quantity of water resources, and an escalation in domestic waste and pollution levels. Bali and West Nusa Tenggara also showed a decline in EQI values. The environmental issues in these regions were largely because Bali and West Nusa Tenggara are tourist destinations. The significant level of human activity in these regions exerts considerable pressure on the environment, as

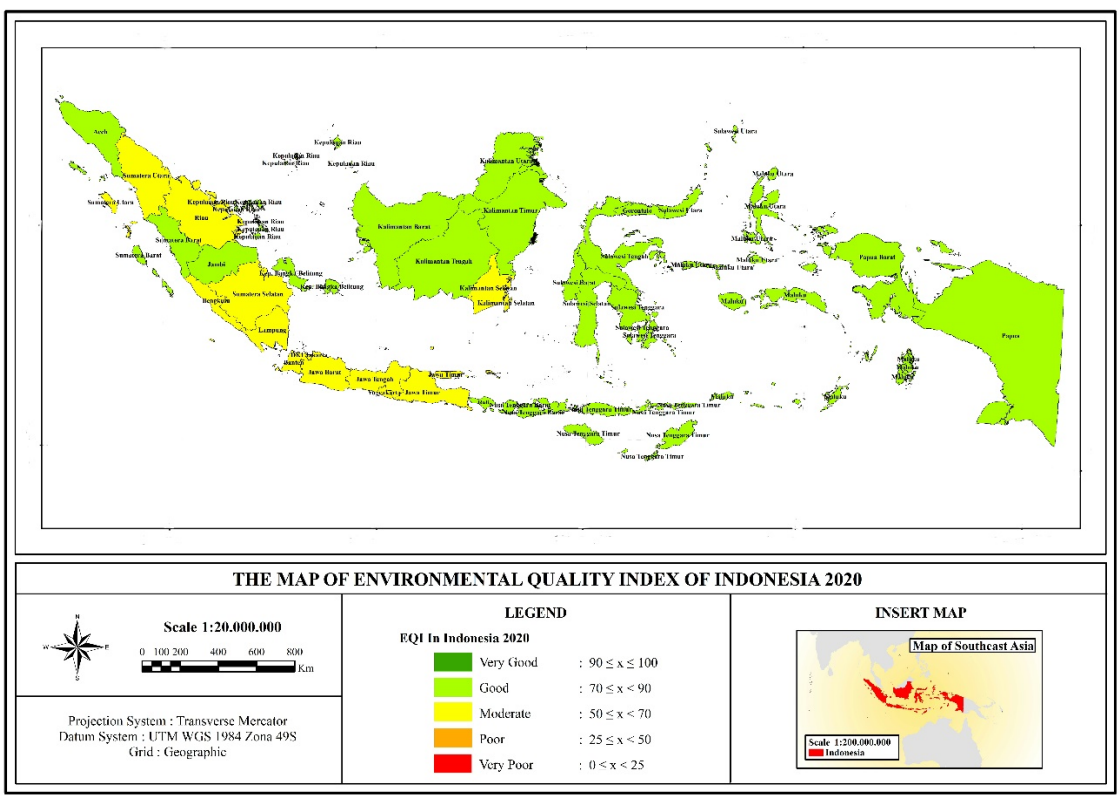


Fig. 1: Spatial distribution of the environmental quality index in 34 Provinces of Indonesia in 2020

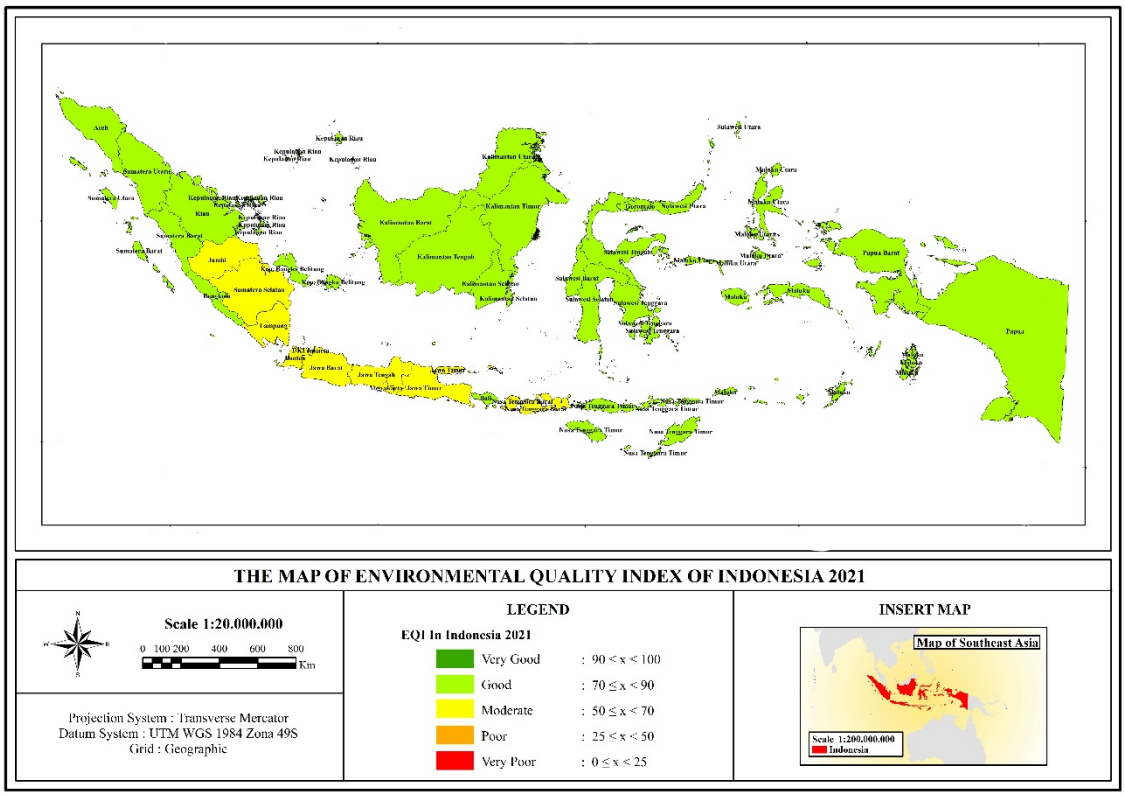


Fig. 2: Spatial distribution of the environmental quality index in 34 Provinces of Indonesia in 2021

evidenced by the rising accumulation of waste in Bali. This situation calls for greater attention from local governments to improve environmental management. In general, the EQI values in Kalimantan, Sumatra, and Papua indicate good environmental quality with scores above the national average. East Kalimantan Province experienced a decline in EQI in 2021, which was caused by pollution resulting from industrial, mining, agricultural, and domestic activities. Central and regional government policies play an essential role in sustaining and reinforcing the synergy of environmental management. Their effectiveness is contingent upon the proper implementation of established regulations and policies, particularly those pertaining to land conservation, pollution control, and waste management. Strengthening regulations as a concrete step to preserve environmental quality can be achieved through reinforcing laws on land conversion, strict supervision of industrial activities, and supporting the development of green infrastructure to help improve environmental quality.

Classification of economic resistance index and economic recovery Index

The coronavirus disease-2019 pandemic that continues to increase in 2020 has an impact on the economy of a region. The measures taken to enforce a lockdown during the Covid-19 pandemic led to substantial economic downturns and extensive interruptions in industrial operations (Caraka *et al.*, 2019). The ability of a region to withstand shocks plays a crucial role in ensuring the stability of its economic framework. Based on the value of resistance and recovery (Figs. 3 and 4), 34 provinces in Indonesia can be divided into four categories. Most areas in Indonesia, including the provinces of South Sumatra, Central Kalimantan, Riau Islands, Southeast Sulawesi, Riau, Banten, West Nusa Tenggara, Maluku, North Maluku, East Nusa Tenggara, and West Papua are included in the positive value economic resistance and recovery group.

Among the provinces, West Papua stands out with the highest resistance level, reflected in its resistance

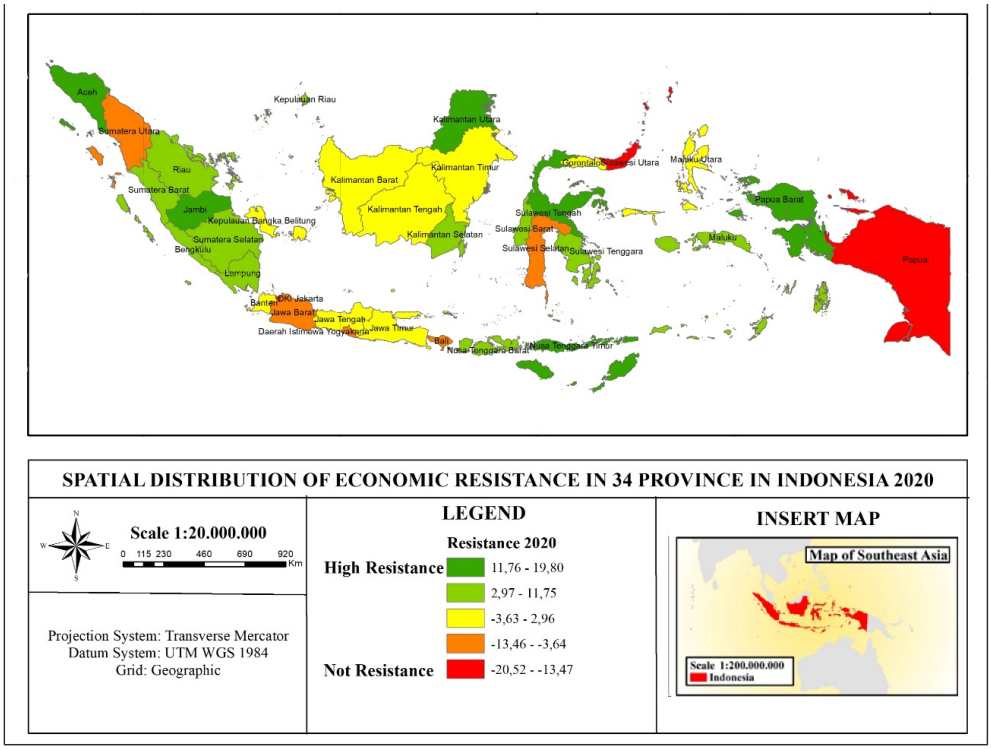


Fig. 3: Spatial distribution of economic resistance in 34 Provinces of Indonesia in 2020

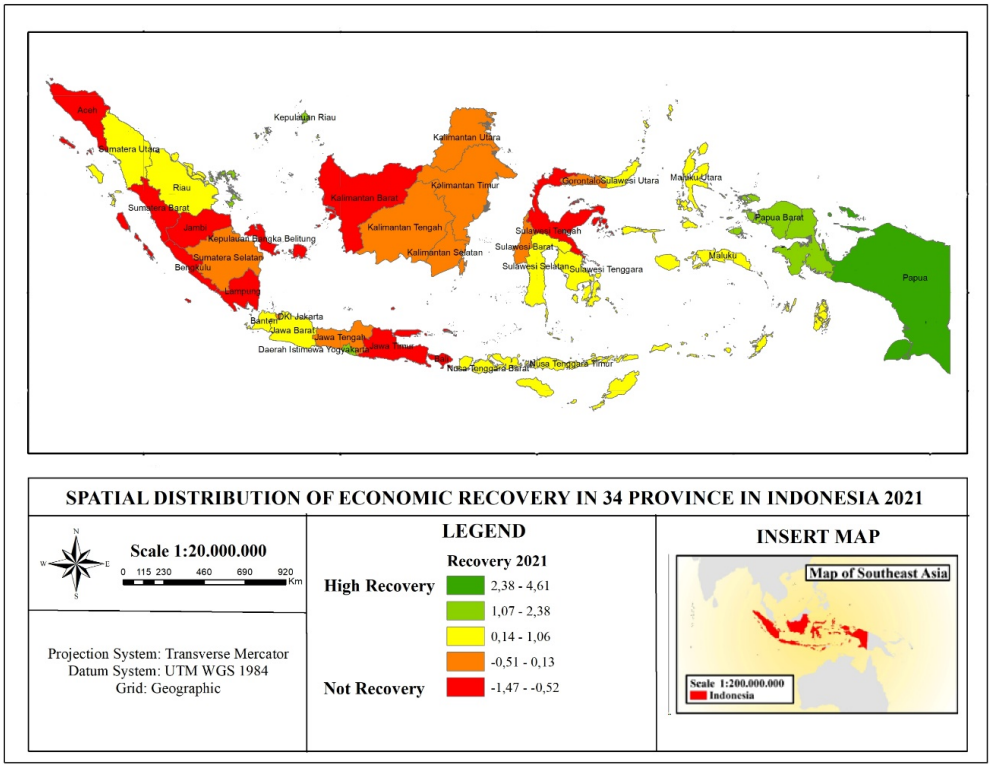


Fig. 4: Spatial distribution of economic resistance in 34 provinces of Indonesia in 2021

index score of 23.1654 points. The continuous rise in labor force absorption indicates that, despite not reaching optimal conditions, there is a significant growth trajectory. The working population increased by 5.18% year on year (YoY) to 459,350 people. This is due to job shifts during the Covid-19 pandemic. In line with this, this is supported by the increasing number of people working in agriculture and industry which increased by 9.16% (YoY) and 36.92% (YoY) respectively compared to August 2019 (LPP Provinsi Papua Barat, 2021). West Papua exhibits a positive economic recovery value of 1.6206, suggesting a rebound following the challenges posed by the coronavirus disease 19 pandemic. This recovery is substantiated by BPS data, which reveals a 5.17% increase in the working population compared to the previous year, totaling 483,681 individuals in 2021 (Badan Pusat Statistik, 2022). The biggest contributor to employment is agriculture, forestry, and fisheries. When assessed against the fourth quarter of 2020, the mining and quarrying industry has shown a notable enhancement in its performance (LPP Provinsi Papua Barat, 2022). The negative resistance-positive recovery groups are the provinces of North Sumatra, West Java, DI Yogyakarta, North Sulawesi, South Sulawesi, and Papua. Papua Province has the lowest resistance index value compared to other provinces with a figure of -22.9598 points. Data from the Bureau of Labor Statistics indicates that the onset of Covid-19 has led to an increase in unemployment, affecting 8,559 individuals. Furthermore, in the year 2020, a total of 216,617 employed resilience experienced a decrease in their working hours as a direct consequence of the pandemic (Badan Pusat Statistik, 2021). This is because companies prefer to implement efficiency by laying off workers who do not have a strategic impact on the company. Papua Province has a positive economic recovery value of 4.733. The increase in the workforce is evident, as the number of employed individuals rose from 1.69 million in 2020 to 1.89 million in 2021 (LPP Provinsi Papua, 2022). The positive resistance-negative recovery groups are Aceh, West Sumatra, Jambi, West Kalimantan, Bengkulu, East Kalimantan, Lampung, South Kalimantan, West Sulawesi, and Central Sulawesi. Micro, small, and medium enterprises (MSMEs) are considered to be resistant in dealing with various previous crises, although the crisis due to Covid-19 is currently putting enormous pressure on them. The growing significance of micro, small, and medium enterprises (MSMEs) is believed to have enabled regions to endure challenging times and subsequently recover, largely due to their substantial contribution to employment. The Aceh recovery index still shows a negative value of -0.97 points. This is because household incomes in Aceh Province are still not diversified so that it has a high risk of exposure to shock. Based on data on the distribution of financing to support regional recovery in Aceh Province, 55.11% is still dominated by consumer loans (LPP Provinsi Aceh, 2022). The negative resistance-negative recovery groups are the provinces of Bali, Bangka Belitung Islands, Gorontalo, Central Java, DKI Jakarta, and East Java. DKI Jakarta has the second lowest resistance index value after Papua and a negative recovery value with respective figures of -16.06 and -0.17 points. Based on data, the working-age population experienced reduced working hours by 35.91%, and 1.66% were recorded as temporarily not working due to the coronavirus disease-2019 pandemic in Jakarta (LPP Provinsi DKI Jakarta, 2021). The shopping centers experienced a temporary shutdown as part of the emergency response measures implemented during the Covid-19 pandemic. The re-opening of shopping malls in Jakarta, which commenced in June 2020, has failed to stimulate a resurgence in the business sector. This lack of progress is largely due to alterations in consumer spending habits, the community's income levels remaining below pre-pandemic standards, and continued restrictions on visitor capacity within the malls.

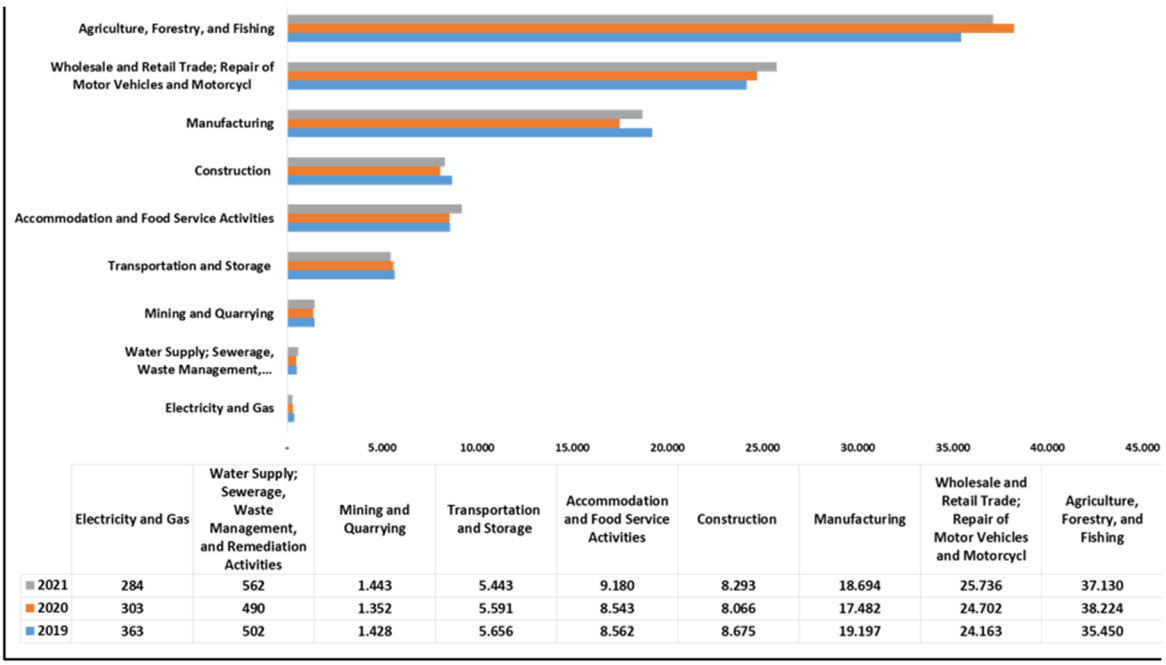
Overall, the stability of employment during the Covid-19 pandemic was enhanced by an uptick in the number of individuals employed in the sectors of agriculture, forestry, and fisheries. According to Fig. 5, these sectors contributed the highest labor absorption compared to others. This significant contribution not only provided employment but also influenced environmental practices in the region. Key determinants of environmental quality included the implementation of sustainable land management strategies and the judicious use of resources, both of which adhered to the tenets of conservation. The pandemic spurred various innovations to stabilize both the economy and the environment, positively impacting labor's influence on the environment. Xaisongkham and Liu (2024) and Bai *et al.* (2021) also

showed that labor can have a positive impact on the environment. According to Bowen and Stern (2010), the 2008-2009 crisis provided opportunities to strengthen environmental policies and initiate green investments for environmental improvement. Bakaki and Bernauer (2018) added that there are still many opportunities to develop environmental policies during economic recessions.

Results of multiple linear regression testing on environmental quality index 2020 and 2021

In Tables 3 and 4, the results of the descriptive statistics are obtained from the dependent and independent variables.

The fundamental assumptions associated with cross-sectional data analysis encompass the normality assessment, the examination of multicollinearity, and



	Electricity and Gas	Water Supply; Sewerage, Waste Management, and Remediation Activities	Mining and Quarrying	Transportation and Storage	Accommodation and Food Service Activities	Construction	Manufacturing	Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycl	Agriculture, Forestry, and Fishing
2021	284	562	1.443	5.443	9.180	8.293	18.694	25.736	37.130
2020	303	490	1.352	5.591	8.543	8.066	17.482	24.702	38.224
2019	363	502	1.428	5.656	8.562	8.675	19.197	24.163	35.450

Fig. 5: Spatial distribution of economic resistance in 34 provinces of Indonesia in 2021 (Badan Pusat Statistik, 2022)

Table 3: Description statistics of the EQI 2020 variables

Variable	Mean	Maximum	Minimum	SD
Environmental quality index	71.010	79.750	52.980	5.621
Resistance index	3.341	19.795	-20.518	9.830
Gross regional domestic product growth rate	-1.239	5.350	-9.330	2.412
Information and technologies	38.503	50.635	24.290	5.223
Population	7,947	48.274	701	11.291
Population density	739	15.907	9	2.708
Recovery rate of Covid-19 patients	78.056	92.540	52.510	11.699

Table 4: Description statistics of the EQI 2021 variables

Variable	Mean	Maximum	Minimum	SD
Environmental quality index	72.237	81.800	54.430	5.558
Recovery index	0.195	4.614	-1.474	1.140
Gross regional domestic product growth rate	4.177	16.400	-2.470	3.583
Information and technologies	39.150	52.850	22.665	5.515
Population	8.020	48.782	713	11,377
Population density	744	15.978	9	2.721
Recovery rate of Covid-19 patients	96.708	98.370	91.140	1.629

the evaluation of heteroskedasticity. The normality of the data distribution can be assessed using the Jarque-Bera value. Based on the normality test results in Table 5, all variables have a probabilitas (Prob.) value greater than their significance level (α = 5%), indicating that the data in this study is normally distributed.

The multicollinearity test between variables is presented in Table 6. The tabulated findings demonstrate that multicollinearity is not an issue among the variables, as the variance inflation factor (VIF) values for all variables are less than 10.

Next, the heteroskedasticity test is presented in Table 7. The results show that the Prob. Observation R-squared is greater than the alpha level of 0.05, indicating that this model can predict the observed values accurately.

Table 8 presents the results obtained from the analysis regarding the various factors that influence the environmental quality index.

The estimation results produced the EQI_2020 and EQI_2021 equation models as shown in Eqs. 6 and 7 (Gujarati and Poter, 2009):

$$\mathrm{EQI}_{2020_i} = 101.960 + 0.009\mathrm{RESIS}_i - 0.250\mathrm{LGRDP}_i - 0.204\mathrm{IT}_i - 2.931\mathrm{POP}_i - 5.756\mathrm{PD}_i - 0.005\mathrm{RR}_i \quad (6)$$

$$\mathrm{EQI}_{2021_i} = 137.185 + 0.629\mathrm{RECOV}_i - 0.110\mathrm{LGRDP}_i - 0.158\mathrm{IT}_i - 3.605\mathrm{POP}_i - 5.470\mathrm{PD}_i - 0.347\mathrm{RR}_i \quad (7)$$

According to the findings illustrated in Table 8, the probability of the F-statistic indicates a noteworthy effect. This means that the resistance index, LGRDP, IT, population, population density, and coronavirus disease-2019 recovery rate influence the environmental quality index during the recession. Findings from the EQI_2 estimation reveal that factors such as the recovery index, LGRDP, information technology, demographic variables, population density, and the recovery rate associated with Covid-19 significantly affect the environmental quality index. This confirms the validity of the alternative hypotheses in Eqs.6 and 7 of this study. The R-squared for the EQI_2020 model is 0.7502. This means that the resistance index, LGRDP, IT, population, population density, and Covid-19 recovery rate contribute 75.02% to the environmental quality index, while the remaining 24.98% is influenced by other factors not included in the model. In the 2021 EQI model, the R-squared value is 0.8359, indicating that the recovery index, LGRDP, IT, population, population density, and Covid-19 recovery rate contribute 83.59% to the environmental quality

Table 5: Normality test results on environmental quality index

Test	EQI_2020	EQI_2021
Jarque-Bera	0.7028	1.3327
Prob.	0.7036	0.5135

Table 6: Multicollinearity test results on environmental quality index

Test	Centered VIF EQI_2020	Centered VIF EQI_2021
Resistance index (RESIS)	1.2002	
Recovery index (RECOV)		1.2692
Gross regional domestic product growth rate (LGRDP)	1.5801	1.4068
Information and technologies (IT)	1.8957	1.6741
Population (POP)	2.1207	2.2911
Population density (PD)	2.6352	2.3830
Recovery rate of coronavirus disease-2019 patients (RR)	1.2640	1.3232

Table 7: Heteroskedasticity test results on environmental quality index

Test	EQI_2020	EQI_2021
Observation R-squared	7.4395	5.7137
Prob.	0.2821	0.4560

Table 8: Results of multiple linear regression testing on environmental quality index 2020 and 2021

Test	EQI_2020	EQI_2021
RESIS	-0.0093 (0.0545)	
RECOV		0.6298* (0.3870)
LGRDP	-0.2509 (0.2547)	-0.1109 (0.1297)
IT	-0.2047* (0.1289)	-0.1582** (0.0919)
POP	-2.9317** (1.6118)	-3.6054*** (1.3452)
PD	-5.7561*** (1.1460)	-5.4704*** (0.8765)
RR	-0.0053 (0.046)	-0.3472 (0.2767)
C	101.9601 (7.6035)	137.1854 (28.0474)
Observation	34	34
F-Statistic	17.5226***	29.0229***
R-squared	0.7502	0.8359

Notes: *= Probability value (p-value) less than (<) 0.1; **=p-value<0.05; ***=p-value<0.01; the coefficient of regression is the number that is not in parentheses; Standard Eeror (SE) in parentheses

index, while the remaining 16.41% is influenced by other factors not included in the model. According to the initial results of the calculations, the resistance index failed to demonstrate a statistically significant impact on the EQI. The outbreak of the Covid-19 caused a decrease in the labor force in eight out of nine economic sectors within Indonesia. The determined resistance index demonstrated an inconsistent level of resilience throughout the 34 provinces in Indonesia (Fig. 3). Provinces that were categorized as resistant to the Covid-19 shock were characterized by an increase in the workforce in the agriculture, plantation, and fisheries sectors (Badan Pusat Statistik, 2021). The expansion of the workforce did not lead to an enhancement in the EQI. While there was a rise in the EQI in 2020, this improvement was not evenly spread across different regions. Significant contributions to greenhouse gas emissions arise from the agriculture, plantation, and fisheries sectors (KLHK, 2022). These findings support the neoclassical economic theory, which posits that changes in economic variables, such as employment, do not directly influence the environment. This analysis clarifies that the incongruence between employment resilience and the progress of the EQI caused the resistance index to have an insignificant effect on the EQI. This finding aligns with the studies by Wang and Li (2021) and Adesina and Muteba Mwamba (2019) which also found no significant influence of the employment on the EQI. Given the constraints of the data utilized in this study, an investigation incorporating long-term data may enable the employment resistance index to exert a substantial influence on environmental sustainability over an extended period. In contrast to 2020, during the Covid-19 recovery period in 2021, the recovery index showed a positive impact on the EQI. Each one-point increase in the recovery index was associated with a 0.6298-point increase in the EQI during the Covid-19 recovery period. The economic downturn resulting from the Covid-19 necessitated the emergence of numerous innovations in economic activities, which were specifically designed to improve efficiency and decrease social contact, thereby curtailing the potential spread of the virus. Data shows that the workforce increased by 2.6 million in 2021. This increase was in line with the EQI, which grew to 72.24 in 2021. The increase in the workforce led to better environmental conditions, positively affecting the environmental quality index. This aligns with the research by Xaisongkham and Liu (2024) and Bai *et al.* (2021), which explains that the employment positively impacts EQI. The GRDP growth rate did not show a significant impact on EQI during the 2020

recession and the 2021 recovery period. In Indonesia, the Agriculture, Forestry, and Fisheries sectors continue to play a pivotal role in the economy, representing 40% of the GDP in 2020 and experiencing a slight decline to 38.8% in 2021 (Badan Pusat Statistik, 2021). The EKC mechanism is less effective in explaining the growth-environment relationship in resource-dependent countries. The EKC theory may not fully apply to guide Indonesia's environmental and economic policies. Badeeb *et al.* (2020) added that resource-based countries do not follow the EKC pattern. The findings of this research substantiate the natural resource curse (NRC) paradox, which posits that a state's reliance on natural resources for revenue does not inherently lead to successful sustainable development (Rahma *et al.,* 2021). This aligns with research by Uddin (2021) and Arnaut and Lidman (2021) which also found no correlation between GDP and environmental quality. These findings emphasize the need to reconsider sustainable development strategies. It is essential for forthcoming policies to emphasize economic advancement that encourages sustainable methodologies in leading sectors such as agriculture, forestry, and fisheries. To diminish dependence on natural resources in the aftermath of the pandemic, it is essential to pursue investments in green technology alongside efforts to diversify the economy. The percentage of technology and information showed a significant negative impact on EQI during the 2020 recession caused by Covid-19 and the 2021 recovery period. Each one-percent increase in IT was associated with a 0.2047-point decrease in EQI during the recession and a 0.1582-point decrease in EQI during the Covid-19 recovery period. The rising proportion of the population in Indonesia that possesses mobile phones and computers, along with their access to the internet, has led to a heightened demand for electricity. Power generation in Indonesia is still predominantly fueled by fossil sources such as coal as the primary energy sources. This reliance on fossil fuels has led to IT contributing negatively to the EQI. This study's outcomes lend credence to the Jevons Paradox, which posits that despite the numerous benefits associated with technological advancements, such progress can inadvertently exacerbate environmental degradation through increased electricity consumption in fossil fuel-dependent regions. This finding also aligns with the studies by Awad and Saadaoui Mallek (2023) and Esquivias *et al.* (2022), which indicate that IT has a detrimental impact on the environment. The results indicate that population negatively affected the EQI during both the recession and recovery periods caused by Covid-19. For every additional person in the population, there was a notable decrease of 2.9317 points in the EQI throughout the recession, and a more pronounced decrease of 3.6054 points in EQI was observed during the recovery period following the Covid-19. Overall, the highest population in Indonesia is Java Island, with more than 56% of the total population, followed by Sumatra Island with over 21% in 2020 and 2021. The significant population in Java contributes to an escalated need for land, prompting the conversion of forested areas into developed regions and other infrastructural projects. Data shows that the low EQI in Java is due to the low LQI indicator, which falls into the "poor" category, with an average score of 37.46 points (KLHK, 2022). The low LQI in the Java Ecoregion is due to the disproportionate balance between vegetated land and built-up areas. This situation is evident in Sumatra and other parts of Indonesia, where the rise in population is a significant factor in the degradation of environmental conditions. Data shows that the population increased by 2.478 million people during the coronavirus disease-2019 recovery period in 2021, which could put additional pressure on environmental quality in Indonesia (Badan Pusat Statistik, 2022). This aligns with the research by Woodard *et al.* (2019) and Sharif *et al.* (2023), which also found that population negatively impacts the environment. Population density during the coronavirus disease2019 recession also negatively affected the EQI. During the recession linked to the Covid-19, each additional person per square kilometer in population density was found to be associated with a decline of 5.7561 points in the EQI. Regions with high population density require large resources, which in turn can increase waste and pollution. In spite of the lockdown policies enacted during the Covid-19, consumption remained ongoing throughout the pandemic period. Plastic waste in Indonesia has shown an increase during the Covid-19 pandemic (Herdiansyah and Nuraeni, 2024). Parashar and Hait (2020), also added that online shopping increased during coronavirus disease-2019, leading to a rise in plastic waste used in packaging goods and food

purchased online. During the recovery period from the Covid-19, an increase in population density was found to adversely impact the EQI. Notably, each additional person per square kilometer correlated with a reduction of 5.4704 points in the EQI. This aligns with the research by Aida *et al.* (2022) and Ghezelbash *et al.* (2024), which state that regions with high population density face greater challenges in maintaining environmental quality. The high or low recovery rate of Covid-19 patients did not directly contribute to the EQI in Indonesia. The high or low recovery rate of Covid-19 patients did not directly contribute to the EQI in Indonesia. This is consistent with the findings by Wang and Su (2020), who stated that Covid-19 patient cases do not directly affect the environment. Mkono *et al.* (2022) added that people affected by coronavirus disease-2019 were less likely to consider environmental aspects.

CONCLUSION

Based on the research results, it can be concluded that the spatial distribution of EQI in 2020 and 2021 showed improvement. Data indicates that Indonesia's EQI increased from 66.55 in 2019 to 70.27 in 2020 and 71.41 in 2021. The rise in the environmental quality index was not uniformly experienced throughout all regions of Indonesia. Java Island still has the lowest EQI values and shows figures below the national average. The low EQI values in Java were caused by the high population, leading to an imbalance between vegetated land and built-up land. Second, the recession generated diverse reactions throughout the various geographical areas of Indonesia. According to its classification, a significant number of provinces in Indonesia are identified as belonging to the category characterized by favorable economic resilience and recovery metrics. West Papua had the highest level of resistance compared to other provinces, with the largest contributors to employment being the agriculture, fisheries, and forestry sectors. The majority of provinces exhibiting negative recovery and resistance groups are located on Java Island. DKI Jakarta ranks second lowest in terms of resistance index value, following Papua. This is due to the reduction in working hours and unemployment due to the Covid-19 shock. The reestablishment of malls in Jakarta has not effectively contributed to economic revitalization, as it is hindered by inconsistent household income levels, shifts in consumption trends, and ongoing restrictions on visitor capacity within these retail spaces. The third conclusion indicates that the resistance index, GRDP growth rate, IT, population, population density, and the Covid-19 recovery rate influence the environmental quality index during the recession with a contribution of 75.02%. Partially, the impact of IT on EQI is -0.204 points. The reliance on non-renewable energy sources to operate phones and the internet negatively affects EQI. The impact of population on EQI is -2.931 points. The rising population has heightened the demand for land, resulting in significant environmental degradation. The impact of population density on EQI is -5.756 points. Areas with high population density require more resources, leading to increased waste and pollution. The environmental quality index was not influenced by several other variables, including the resistance index, the growth rate of GRDP, and the recovery rate of individuals affected by Covid-19. The fourth conclusion indicates that the recovery index, GRDP growth rate, IT, population, population density, and the Covid-19 recovery rate influence the environmental quality index during the recovery period from the Covid-19 recession, with a contribution of 83.59%. Partially, the impact of the recovery index on EQI is 0.629 points. As a result of the Covid-19, the recovery period served as a catalyst for the public to pursue a range of innovative approaches to improve the efficiency of economic activities.. Data also shows an increase in the workforce accompanied by an increase in EQI in 2021. The impact of IT on EQI is -0.158 points, while the impact of population is -3.605 points, and population density is -5.470 points. During the recovery period, the findings related to technology and information, alongside population and population density, reflected trends that were consistent with the estimates established during the onset of the Covid-19 crisis. Other variables that did not show an impact on the environmental quality index include the GRDP growth rate and the coronavirus disease-2019 patient recovery rate. The findings of this research are expected to make a significant contribution to the fields of environmental and economic studies. Indonesia's vision to achieve net-zero emissions by 2060 is a concrete step toward sustainable growth. Nonetheless, issues such as economic disturbances, significant rates of land conversion, and reliance on non-renewable energy sources emphasize the critical need for enhanced

policies to effectively confront future challenges. The recommended policies for the government include sustainable natural resource management through the implementation of binding laws in each region. The government should also collaborate with the private sector to support green infrastructure investment in Indonesia. Diversification and expansion of employment in the renewable energy sector should also be enhanced to build economic resilience against recessions. The government must take measures to regulate population growth and density by refining family planning strategies and implementing controlled migration policies. Future researchers are encouraged to enhance theoretical and empirical studies by incorporating current issues and expanding the scope of discussions. It is expected that other elements, such as investment, taxation, and governmental policies, will contribute significantly to the relevant academic discourse. Future research should also explore the relationship between employment resilience and other factors affecting the environmental quality Index over longer periods to better understand long-term impacts and dynamics.

AUTHOR CONTRIBUTIONS

D.O. Ayuningsih conceptualised the central research idea, designed the research, wrote and revised the article. L. Hakim provided the theoretical framework, revisions, supervised research progress and approved the article submissionand. A. Suryantoro helped in the literature review, revisions, supervised research progress and approved the article submission. I. Mafruhah helped in the literature review and improvement of the manuscript. S. Hassan reviewed and improvement of the manuscript. E. Gravitiani reviewed and prepared the maps. N.Q. Fathoni provided the designed the research and collected data. A.I. Hakim helped in improvement of the manuscript.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy have been completely observed by the authors.

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ABBREVIATIONS

%	Percent
BPS	Central bureau of statistics
CO_2	carbon dioxide
COVID-19	Coronavirus disease 2019
EKC	Environmental kuznets curve
Eq.	Equation
EQI	Environmental quality index
Fig.	Figure
GDP	Gross domestic product
GRDP	Gross regional domestic product
IT	Information and technologies
LGRDP	Gross regional domestic product growth rate
LQI	Land quality index

MSMEs	Micro, small, and medium enterprises
NRC	Natural resource curse
PD	Population density
PPE	Personnel protective equipment
PPKM	Emergency public activity restrictions
POP	Population
Prob.	Probability
RECOV	Recovery index
RESIS	Resistance index
RR	Recovery rate of coronavirus disease-2019 patients
SD	Standard deviation
SE	Standard error
VIF	Variance inflation factor
YoY	year on year

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