

CLIMATE CHANGE AND EMPLOYMENT DYNAMICS IN DEVELOPING REGIONS: EVIDENCE FROM JAVA ISLAND

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Abstract

Climate change poses not only environmental threats but also substantial socioeconomic impacts, including employment. This study investigates the influence of climate change on the open unemployment rate (TPT) in Java Island, Indonesia, from 2015 to 2024. Climate change is measured using annual average temperature and rainfall, while unemployment is represented by provincial-level TPT.

Java Island was selected due to its central role in Indonesia's economy, contributing the highest share of the national GDP. However, it paradoxically hosts three of the ten provinces with the highest unemployment rates—West Java, Banten, and DKI Jakarta—raising concerns about the inclusiveness of growth in the region.

The study uses panel data from six provinces (Jakarta, Banten, West Java, Central Java, Yogyakarta, and East Java). It applies the Panel Autoregressive Distributed Lag (Panel ARDL) method to examine both short- and long-term dynamics. This method is particularly suitable because it captures temporal lags and accommodates regional heterogeneity.

The novelty of this study lies in the application of Panel ARDL in the context of Indonesia's regional labor market and climate interaction—an approach rarely used in prior research, which often focuses on national-level analyses or omits dynamic lag structures. By narrowing the focus to Java Island, this research also highlights subnational disparities often overlooked.

This study contributes to the empirical literature on climate–labor linkages and supports the Sustainable Development Goals (SDGs), especially Goal 8 (Decent Work) and Goal 13 (Climate Action), by offering insights for climate-resilient employment policy.

Keywords: climate change, unemployment, rainfall, temperature, Panel ARDL

INTRODUCTION

Sustainable development is a global agenda agreed upon through the Sustainable Development Goals (SDGs), with the main objective of improving the welfare of the world's population in a fair, inclusive, and environmentally conscious manner (Bappenas, 2015). This study relates to two SDGs, namely decent work and climate change. According to the Meteorology, Climatology, and Geophysics Agency (BMKG), climate change causes negative effects such as rising sea levels, increased risks of hydrometeorological disasters, increased risks of infectious diseases, reduced biodiversity, decreased quality of life for communities, and reduced productivity in the agricultural sector, which impacts labor absorption (BMKG, 2024). Additionally, rising temperatures and changes in rainfall patterns are projected to reduce Indonesia's Gross Domestic Product (GDP) growth by up to 10% due to productivity disruptions, infrastructure damage, and increased adaptation and disaster recovery costs (Ministry of Finance, 2024). Nordhaus (2018) emphasizes that rising temperatures could increase damage by up to 8.5% of GDP, with developing countries bearing the brunt of the impact.

Indonesia's economy is highly dependent on the island of Java, which contributes 58% to Indonesia's GDP (BPS, 2024b). Ironically, three of the six provinces on Java—Banten, Jakarta Special

Region, and West Java—are among the ten provinces with the highest unemployment rates in Indonesia (BPS, 2024). This phenomenon indicates that economic growth has not been fully accompanied by inclusive job creation.

One factor influencing this dynamic is the changing labor force structure due to climate pressures and urbanization. The agricultural sector is the largest employer in Indonesia, with 40.7 million workers (BPS, 2024a). The agricultural sector is highly vulnerable to climate change. This increases the potential for labor migration and reduced working hours (Huang et al., 2020; Cruz, 2024). Java Island has experienced a 1.63% annual decline in agricultural land (Prasada et al., 2022). Meanwhile, the proportion of workers in the agricultural sector has decreased from 56% to 34%, while the number of jobs in the industrial sector has increased from 10% to 13% (Wihardja, 2016). This situation indicates a shift of workers from the agricultural sector to other sectors, particularly industry.

The sectoral shift has not guaranteed labor inclusivity, as evidenced by Indonesia having the highest unemployment rate in Southeast Asia (IMF, 2024). Java, half of whose provinces are among the ten provinces with the highest unemployment rates in Indonesia (BPS, 2024). Additionally, although the industrial sector is not as vulnerable as the agricultural sector, it still faces disruptions due to climate change, such as distribution challenges caused by extreme weather. Industries processing agricultural products also face difficulties, as extreme weather can lead to crop failures, disrupting the supply chain of raw materials (Nugraha, 2024).

Based on these phenomena, research on the relationship between climate change and unemployment in six provinces on the island of Java is needed. Climate change in this study is measured through two independent variables, namely changes in average annual temperature and annual rainfall, as supported by research by Liu, T. Y. & Lin, (2023); Marafa (2024); Cruz (2024); Liu, Y. et al (2020); Huang et al., (2020); Hsiang, (2016); Iqbal (et al., 2016) and Priyanto, (2021), which state that these variables influence economic activity and employment. Extreme rainfall can cause natural disasters such as floods that can damage infrastructure and eliminate jobs. Changes in average temperature, which show an increase, can lead to low labor productivity and reduced working hours. The effects of climate change will be felt more severely in developing countries that still depend on climate-vulnerable sectors such as agriculture. According to research by Yunus et al (2024), climate change does not directly affect unemployment because the economy and workers can adapt quickly. Regional Domestic Product (RDP) has a greater impact on unemployment. Meanwhile, RDP is used as a control variable to capture the impact of economic growth on labor. A high RDP means that the economic sector is producing at a high level, leading to high labor demand (Tutupoho, 2019). Other studies show different results, with RDP having a positive impact on unemployment rates. When RDP grows but only in capital-intensive sectors, labor demand remains low, thereby increasing unemployment rates (Nuzulaili, 2022). The dependent variable used is the Open Unemployment Rate (OUR) as an indicator of unemployment not absorbed by the labor market across the six provinces on Java Island.

Empirical studies examining the impact of climate change on unemployment at the regional level in Indonesia are still limited, especially those that discuss short-term and long-term dynamics. Most previous studies are still national aggregates or only link climate to the productivity of certain sectors, without directly linking it to the labor market.

LITERATURE REVIEW AND HYPOTHESIS FORMULATION

According to Keynesian theory, unemployment occurs because aggregate demand is insufficient to absorb the available labor force. When demand for goods and services declines, companies reduce production capacity and the number of workers (Mankiw, 2012). The open unemployment rate measures the percentage of the labor force that is actively seeking work but has not yet found employment. The open unemployment rate reflects a region's ability to create jobs.

As a complex economic challenge, addressing climate change requires economic policies that incorporate climate dimensions into long-term development planning. Climate change, characterized by rising temperatures, will cause economic output to decline if global temperatures increase (Nordhaus, 2018). High temperatures will affect vulnerable sectors such as agriculture, construction, and other informal sectors through mechanisms of reduced productivity due to high temperatures (heat stress) (Cruz, 2024; Burke et al., 2015b). Hotter temperatures will reduce investment and well-being, thereby disrupting overall macroeconomic activity (Hsiang, 2016). Tropical and developing countries with low adaptive capacity, such as Indonesia, are relatively more severely affected by climate change (Nordhaus, 2018; T. Y. Liu & Lin, 2023; Cruz, 2024).

Rainfall is another indicator of climate change. While high rainfall is necessary for the agricultural sector at certain times, extremely high rainfall can reduce labor productivity, particularly in weather-sensitive sectors such as agriculture, mining, and construction. Climate change will ultimately displace labor (Huang et al., 2020). If labor displacement is not balanced, structural and frictional unemployment will increase (Marafa, 2024). The increase in unemployment is exacerbated by infrastructure that is not prepared to cope with high rainfall, thereby increasing the risk of disasters (Islam et al., 2021). Meanwhile, drought or low rainfall can reduce labor by up to 15% in just one year (Climate Council of Australia, 2016).

Climate change, characterized by rising temperatures and rainfall uncertainty, can reduce agricultural productivity and household food security, particularly through disruptions to food availability and access. Climate change that is not accompanied by adaptation causes agricultural productivity to decline because climate change disrupts planting patterns and reduces crop yields. This situation leads to a decline in farmers' income from both farming and other related sources (Barokatuminalloh et al., 2022). When agricultural income is unstable, the agricultural sector becomes unattractive and at risk of labor force decline, especially in rural areas that are highly dependent on the agricultural sector.

One effort to control this research uses GDP as a control indicator to capture the impact of economic growth on unemployment. Under ideal conditions, an increase in GDP indicates high production and labor absorption. In the context of climate change, low GDP often becomes an indirect pathway leading to increased unemployment (Yunus et al., 2024). Therefore, controlling the influence of GRDP is necessary to analyze the pure effects of climate change more accurately.

Structural transformation is a crucial foundation for understanding the relationship between GRDP growth, labor structure, and unemployment. Structural transformation refers to the long-term shift from the primary sector to the secondary or tertiary sector, accompanied by increased productivity and labor distribution. Chenery & Syrquin (1975) in their book state that structural transformation explains the systematic shift in output structure and factor utilization as per capita income increases. In this research context, GDP growth driven by labor-intensive sectors aligns with this theory and is expected to reduce unemployment rates.

Based on research conducted by Cruz (2024); Hsiang et al., (2017); (T. Y. Liu & Lin, (2023); and Marafa, (2024); which states that changes in temperature affect unemployment, the hypothesis proposed is that changes in temperature significantly affect the open unemployment rate on Java Island in both the short and long term. Based on research conducted by Marafa (2024); Islam et al. (2021); and the Climate Council of Australia (2016), which states that rainfall affects unemployment, the hypothesis proposed is that rainfall significantly affects the open unemployment rate in.

RESEARCH METHODS

This study uses a quantitative approach with secondary data obtained from the Central Statistics Agency (BPS). The data required are the Open Unemployment Rate (the percentage of unemployed people in the labor force), Rainfall (the height of rainwater collected in a rain gauge on flat ground and measured in millimeters), and Temperature Changes in Provinces on the Island of Java (a quantitative measure of temperature, heat, or cold expressed in degrees Celsius). Java Island was chosen as the research location because of its high contribution to the national GDP, yet three

out of six provinces on Java Island (Banten, Jakarta Special Region, and West Java) have relatively high unemployment rates. In this study, GDP at constant prices measured in rupiah was used to control the influence of economic growth on TPT. GDP was chosen as the control variable because it reflects the economic production capacity of each province, which can influence labor absorption both directly and indirectly. The selection of the period from 2015 to 2024 is based on the global implementation of the SDGs since 2015, allowing for an examination of dynamics within the framework of sustainable development.

The Panel ARDL approach with the Pooled Mean Group Model enables testing for cointegration and long-term relationships using bounds testing, as well as testing for short-term relationships through the Error Correction Model (ECM). Additionally, to confirm the existence of long-term relationships between variables in a panel context, cointegration tests are also employed. The following is the model used in this study:

$$TPT_{it} = a_i + \sum \beta_1 TEMP_{i,t-j} + \sum \beta_2 RAIN_{i,t-j} + \sum \beta_3 PDRB_{i,t-j} + \epsilon_{it}$$

Description:

TPT_{it}	= Open unemployment rate in province i in year t
$TEMP_{i,t-j}$	= Average annual temperature in province I at time t-j
$RAIN_{i,t-j}$	= Annual rainfall in province I at time t-j
a_i	= Constant specific to each province
β	= Estimated parameter coefficient
ϵ_{it}	= Error component

RESULTS AND DISCUSSION

Java Island is the region with the highest population concentration and largest economic activity in Indonesia, as evidenced by its significant contribution to the national GDP. However, the high unemployment rate in the provinces of Java Island indicates the existence of labor issues. On the other hand, Java Island has shown a significant trend of increasing average annual temperatures and changes in rainfall over the past decade. These conditions undoubtedly affect labor-intensive sectors such as agriculture, construction, and other informal services that are vulnerable to climate change.

According to Table 1, West Java has the largest population, followed by East Java and Central Java provinces. In terms of economic growth, Yogyakarta recorded the highest economic growth, but the highest per capita income was achieved by East Java Province. Jakarta is the national economic center, but its per capita income is low due to income disparities or the high burden of the urban population. Yogyakarta's per capita income is not very high, but it has the lowest open unemployment rate on the island of Java.

Table 1. Socio-economic data for provinces on the island of Java

Provinces in Java Island	Number of People	Economic Growth Rate	Per Capita Income	TPT
Jakarta	11140000	4.9	344350000	6.21
West Java	50490000	4.95	56080000	6.75
Banten	12630000	4.79	70276000	6.68
Central Java	38280000	4.95	47972000	5.3
Yogyakarta	3730000	5.03	51473000	3.48
East Java	41710000	4.93	75770000	4.19

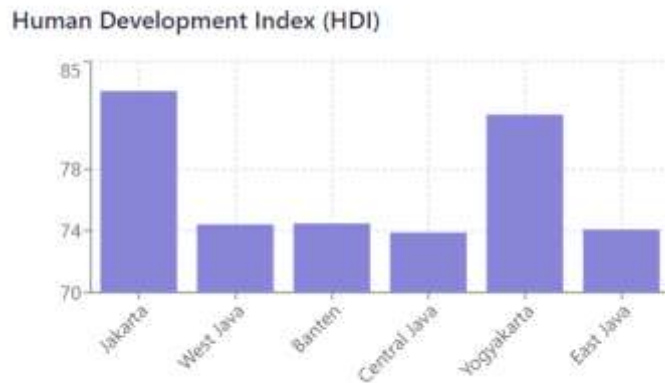
Source: BPS

Table 2. Climate Characteristics of Java Island

Provinces in Java Island	Average Rainfall	Average Temperature
Jakarta	2259.2	28.97
West Java	4857.9	26.7
Banten	2429.2	28.07
Central Java	2885.7	28.89
Yogyakarta	1293.64	26.6
East Java	2146.8	27.7

Source: BPS

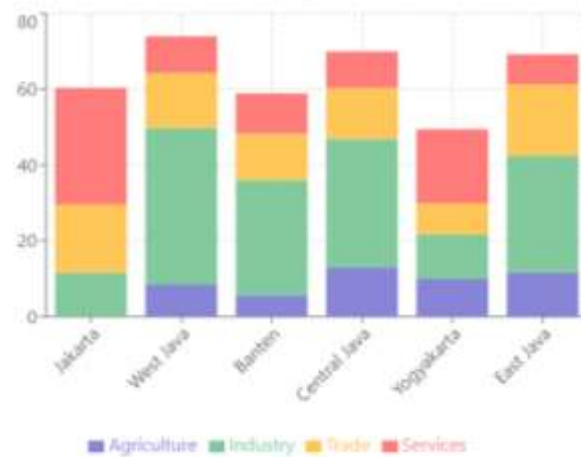
Based on Table 2, the province with the highest rainfall is West Java, while the highest average temperature is in the province of Jakarta. Provinces with high rainfall tend to have relatively low average temperatures, such as West Java Province, which is consistent with the wet tropical climate pattern in mountainous areas. Although Jakarta is located in a coastal area and has moderate rainfall, its relatively high average temperature indicates the presence of an urban heat island effect due to population density and intensive economic activity.



Source: BPS

Figure 1. Human Development Index

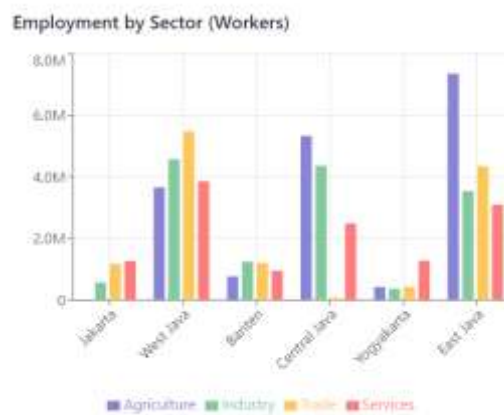
Figure 1 shows the highest Human Development Index in the Special Region of Jakarta, while the province with the lowest index is Central Java. The Human Development Index for Java Island is relatively high because the indices for all provinces on Java Island are above 70. Figure 1 shows a pattern where urban areas and administrative centers such as the Special Capital Region of Jakarta and the Special Region of Yogyakarta tend to have higher indices due to better access to education, health services, and economic opportunities compared to provinces with more rural or industrial characteristics.



Source: BPS

Figure 2. Contribution of Sectors to GRDP of each Province in Java Island

Figure 2 indicates that the industrial sector contributes the most to the RDP of Central Java, Banten, East Java, and even West Java, which contributes 40%. However, the Special Capital Region of Jakarta and the Special Region of Yogyakarta have different economic conditions, with the service sector dominating contributions to RDP. This indicates that these regions are undergoing economic transformation toward a service-based economy, a characteristic of regions experiencing more advanced economic development. Conversely, the agricultural sector is the lowest contributor to RDP in every province. The Special Capital Region of Jakarta is the province where the agricultural sector contributes the least to RDP, at around 5%. This situation indicates that the processes of urbanization and industrialization have shifted the economic base from the primary sector to the secondary and tertiary sectors.



Source: BPS

Figure 3. Labor Force by Sector in Java Island

Based on Figure 3, the agricultural sector dominates employment in Central Java and East Java, which employs 7.8 million workers. In contrast, the Special Region of Jakarta has almost no workers employed in the agricultural sector. The rapidly growing industrial sector also has the potential to absorb a large workforce. West Java Province is the province with the largest workforce employed in the industrial sector.

Figures 2 and 3 show that East Java Province is a province where employment is dominated by the agricultural sector, but the contribution of the agricultural sector to the RDP is very low. This

indicates low labor productivity in the agricultural sector, resulting in relatively small economic output. West Java and Central Java provinces have a large number of workers in the industrial sector, but the contribution of this sector to the RDP is also relatively large. This means that labor productivity in the industrial sector in these regions is high. The high contribution of the industrial sector to RDP also indicates high efficiency and added value. This situation indicates the existence of economic dualism, where traditional sectors such as agriculture absorb a large number of workers but have low productivity. Meanwhile, modern sectors such as industry and services absorb fewer workers but have high productivity.

Based on this phenomenon, this study examines the short-term and long-term relationships between climate change, economic growth, and unemployment in six provinces on the island of Java using the Panel ARDL (1,1,1,1) model based on the Akaike Information Criterion.

Tabel 3. Short Run Equation

Variable	Coefficient	Std. Error	t-Statistic	Prob.
COINTEQ01	-0.4170	0.1473	-2.8301	0.0087
D(GDP)	-24.5213	5.1181	-4.7911	0.0001
D(RAIN)	-0.1985	0.0663	-2.9950	0.0058
D(TEMP)	7.1468	2.735	2.6127	0.0145
C	48.8430	16.7340	2.9188	0.0070

Source:E-Views

Tabel 4. Long Run Equation

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(GDP)	-3.3416	0.4510	-7.4094	0.0000
D(RAIN)	0.7354	0.1338	5.4978	0.0000
D(TEMP)	-19.29511	2.4954	-7.7323	0.0000
C	48.8429	16.7337	2.9188	0.0070

Source:E-Views

Based on Table 3, there is an adjustment mechanism towards long-term equilibrium of 41.6% per year. In the short term, rapid increases in GRDP reduce unemployment. This situation shows that local economic strength greatly determines the resilience of the labor market to environmental changes.

In the short term, high rainfall actually reduces the open unemployment rate. High rainfall sufficiently supports agriculture optimally. High rainfall leads to increased agricultural productivity. Increased agricultural productivity will boost labor demand in the agricultural sector. As one of the sectors that absorbs the most labor on Java Island, rainfall has a significant effect on employment on Java Island, particularly in East Java Province, which has a high dependence on the agricultural sector of up to 30%. In line with Keynesian unemployment theory, when there is an increase in production capacity, there will be an increase in labor demand (Mankiw, 2012). Thus, the hypothesis that rainfall significantly affects unemployment on Java Island is accepted. The results of this study align with the research by Darisa et al. (2023), which states that agricultural production requires high rainfall. When rainfall is too low or drought occurs, the agricultural sector struggles to produce goods of good quality and quantity (Climate Council of Australia, 2016).

The long term has a different effect than the short term. In the long term, when rainfall is high or even extreme, it actually increases unemployment. With GDRP control variables, even though GDRP has a negative effect on unemployment, increased rainfall does not stimulate the agricultural sector, especially if economic growth is not yet strong enough to adapt to climate change. Extreme rainfall has the potential to increase the risk of natural disasters such as floods, soil erosion, and infrastructure damage, which ultimately disrupt economic activities structurally. Rainfall that causes

natural disasters increases the potential for crop failure in the agricultural sector, leading to a decline in agricultural output. The decline in agricultural productivity will also impact the demand for agricultural labor. This is certainly a significant blow to the labor market on Java Island. Not only the agricultural sector, but the industrial sector also has the potential to experience a decline in productivity due to difficulties in finding raw materials because of crop failures in the agricultural sector, as well as difficulties in distribution. Thus, the hypothesis that rainfall affects open unemployment on Java Island in the long term is accepted. The results of this study are in line with the research by Islam et al. (2021), who state that if infrastructure is not prepared to handle extreme rainfall, it will cause infrastructure damage that can hinder economic activities. Infrastructure damage impacts a decline in labor productivity and difficulties in distribution (Nugraha, 2024). Extreme rainfall that causes natural disasters will ultimately eliminate jobs, leading to an increase in unemployment rates (Marafa, 2024). Priyanto (2021) states that climate change can reduce agricultural sector output due to disrupted planting patterns and harvest yields. Low output in the agricultural sector reduces its ability to absorb labor, thereby triggering an increase in unemployment rates.

In terms of temperature change, Table 3 shows that rising temperatures have a significant impact on increasing unemployment rates. High temperatures tend to reduce labor productivity (heat stress), thereby increasing the risk of job loss, especially in the informal sector. In the context of developing countries located in tropical regions, Java relies on labor absorption in climate-vulnerable sectors and tends to carry out outdoor work activities. When temperatures are too high, labor productivity declines because workers are at risk of dehydration and heat stress, which reduces working hours and increases job losses. Rising temperatures directly contribute to a decline in agricultural productivity. Crops that experience stress due to high temperatures become more vulnerable to external disturbances such as pest and disease attacks. A warmer environment can accelerate pest life cycles, expand their spread, and increase the intensity of attacks. Based on these effects, agricultural yields will disrupt the income of agricultural workers, especially those on Java Island, where most are still employed in the agricultural sector. Thus, climate change can reduce agricultural productivity while also decreasing employment in the agricultural sector.

Although GDRP has been included as a control variable, the effect of temperature remains significant. This means that the economic capacity of provinces on the island of Java is not yet able to overcome the effects of temperature in the short term. Thus, the hypothesis that temperature change has a significant effect on open unemployment in the long term is accepted. This finding is consistent with the studies by Marafa (2024) and T. Y. Liu & Lin (2023) that temperature exerts greater labor market pressure in tropical countries, especially when the labor market depends on sectors sensitive to climate change. This finding is also in line with the research by Iqbal et al. (2016), which states that increased temperature will increase plant stress and enhance plant vulnerability to pest and disease attacks. Pest attacks lead to decreased agricultural productivity, followed by reduced labor absorption in the agricultural sector. Climate change significantly reduces agricultural sector productivity and food security, ultimately lowering income and interest in working in the agricultural sector (Barokatuminalloh et al., 2022). Declining income will drive agricultural workers to migrate to other sectors. The lack of preparedness of the formal sector targeted for migration triggers structural unemployment. This indicates that climate change not only reflects job losses but also the failure of adaptation processes in the sectors most vulnerable to climate change.

The long-term effects of temperature changes on unemployment provide a different direction. Estimation results show that rising temperatures actually reduce the open unemployment rate in the long term. This phenomenon indicates the presence of gradual structural adaptation processes, particularly in provinces with modern economic structures such as Jakarta, Banten, West Java, and Yogyakarta. In these regions, economic growth reflected in high GDRP allows for a shift of labor from the agricultural sector to the industrial and service sectors, which are relatively more resilient to temperature pressures. High GDRP also plays a role in increasing investment in more adaptive and robust work infrastructure and expanding the formal sector, enabling sustainable labor

absorption. Based on this phenomenon, high temperatures in the short term can increase unemployment rates, but in the long term, they drive the transformation of the labor sector to become more resilient, sustainable, and modern. This effect is likely to be dominated by provinces with modern economic structures and high adaptability, such as Jakarta and Banten, while East Java remains structurally vulnerable due to its continued reliance on the agricultural sector. Thus, the hypothesis that temperature changes affect the open unemployment rate in the long term is accepted. The results of this study are in line with Burke et al. (2015a) and Nordhaus (2018), who state that when a region has strong economic adaptation capacity, the negative impact of climate change on employment in the long term can be mitigated.

CONCLUSION

This study found that climate change, as represented by temperature and rainfall, has a significant effect on the open unemployment rate on the island of Java. In the short term, excessively high temperatures can increase unemployment, while high rainfall can reduce unemployment. In the long term, extreme or excessively high rainfall has the potential to cause natural disasters, thereby increasing unemployment rates, while temperature shows a negative correlation with the Open Unemployment Rate (OUR) due to shifts in the economic sector toward sectors more resilient to climate pressures. The Gross Regional Domestic Product (GRDP) variable has consistently been shown to play a role in reducing unemployment rates while also functioning as a buffer against climate impacts.

Based on the above explanation, climate change is not only an environmental issue but also an employment issue. Therefore, policy formulation in building a regional economy oriented toward community welfare, inclusivity, and sustainability requires the integration of climate data into regional labor planning and investment. Adaptation capacity also needs to be strengthened through climate-resilient labor infrastructure. Climate-resilient labor infrastructure can be supported by maintaining agricultural sector output through active climate adaptation strategies, not merely survival. Adaptation can be achieved through the use of heat-resistant crop varieties, changes in planting patterns based on technology-based weather forecasts, and improved access to water-efficient irrigation technology and modern agricultural tools. Adaptation and transition are not about replacing sectors but ensuring that the agricultural sector remains productive and sustainable under climate pressure, accompanied by job diversification.

GDRP plays a crucial role in reducing unemployment rates, so improving the quality of economic and social infrastructure is essential to drive inclusive economic growth that can absorb labor. These efforts may include strengthening road, irrigation, and logistics infrastructure in agricultural and industrial areas, developing digital infrastructure to create job opportunities in technology-based service sectors, revitalizing industrial zones with climate-friendly principles, and providing investment incentives for labor-intensive sectors and adaptive industries.

Additionally, policies can be established to facilitate labor transition from climate-vulnerable sectors to more adaptive sectors such as services and green industries. Thus, labor market resilience can be strengthened without compromising the sustainability of the agricultural sector.

This study has limitations in terms of climate data granularity. This study uses data at the provincial level, even though climate realities vary significantly between districts or cities within a province. As a result, significant microclimate fluctuations at the local level are not captured by this research model. In future studies, it is recommended to use data with higher spatial resolution to identify local vulnerabilities that are not visible at the provincial level.

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