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# Economic Openness and the Regional Output-Employment-Poverty Nexus in Indonesia: A Fixed-Effects IV Approach

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**Abstract**

This study examines the relationship between economic openness and the regional output-employment-poverty nexus in Indonesia. Economic openness is theoretically expected to stimulate regional economic performance through market expansion, productivity growth, and technology diffusion. However, in geographically fragmented developing economies such as Indonesia, the benefits of openness may not be evenly distributed across regions due to disparities in infrastructure, labor-market conditions, and human development. Despite sustained national economic growth, regional disparities, unemployment, and poverty remain persistent, particularly outside Java and Bali. This study therefore aims to analyze the causal effects of economic openness on regional output, unemployment, and poverty within an integrated analytical framework. This study employs balanced provincial panel data covering 34 provinces in Indonesia from 2017 to 2024. The analysis applies a Fixed-Effects Instrumental Variable (FE-IV). The results indicate that trade openness significantly increases regional output and modestly reduces unemployment, but does not directly reduce poverty. Unemployment negatively affects regional output and significantly increases poverty, indicating that labor-market absorption constitutes the primary transmission channel linking economic growth and welfare. Human development significantly reduces both unemployment and poverty, while ICT development and government expenditure positively contribute to regional output. In contrast, FDI only exhibits a limited poverty-reducing effect. Furthermore, the COVID-19 shock significantly worsened unemployment and poverty. The findings suggest that openness policies should be complemented by employment-oriented industrial strategies, human capital development, productive public expenditure, and stronger local economic linkages to promote more inclusive regional development outcomes.

**Keywords:** Employment, economic openness, fixed-effects iv, poverty nexus, regional output

# 1 Introduction

Economic openness has long been regarded as a catalyst for structural transformation in developing countries (Chakrabarti et al., 2025; Mujeri & Mujeri, 2021). By reducing trade barriers and facilitating capital flows, openness expands market access for domestic producers, drives productivity growth, and creates channels for technology diffusion. In Indonesia, as an archipelagic nation with a geographically fragmented landscape and significant inter-regional disparities (Dahlan et al., 2025), trade and investment liberalisation policies since the post-1998 reform era have reshaped provincial economies unevenly (Ramesh, 2025). Geographical conditions mean that the spillover effects of economic openness tend to be concentrated in regions with better infrastructure and connectivity, thereby widening inter-regional disparities (Bunde, 2025; Yin et al., 2024). The interrelationship between openness, regional output, employment and poverty—collectively referred to as the output-employment-poverty nexus—is key to understanding whether growth driven by openness is capable of generating equitable improvements in welfare at the regional level.

Although national GDP growth continues, Indonesia still exhibits persistent regional disparities and pockets of high poverty, particularly outside Java and Bali (Beurden, 2025). The latest data from the Central Statistics Agency (BPS) show that poverty rates in several eastern provinces remain more than double the national average, whilst the elasticity of employment to growth varies significantly across regions. On the other hand, global trade uncertainty and changes in global supply chains have heightened attention on how regional economies absorb external shocks through openness (Charoenwong et al., 2023; Baldwin & Freeman, 2022). If the benefits of openness fail to translate into job creation and poverty reduction at the regional level, the risk is a growth path that is inefficient and socially unsustainable (Mishra et al., 2024; Mbodj & Laye, 2025). This requires empirical evidence capable of isolating the causal impact of openness on this nexus whilst accounting for regional heterogeneity.

Empirical studies on openness and regional development in Indonesia have so far largely used panel regression models to estimate the direct effects of trade openness on provincial GRDP growth and labour market outcomes (Badriah, 2024; Muzzakar et al., 2023; Suparman, & Muzakir, 2023). This research notes a positive association between export orientation and output, as well as between FDI and job creation in manufacturing centres (Crescenzi et al., 2022; Tripathy et al., 2023). On the poverty front, studies using household survey data have found mixed results: openness reduces poverty through wage increases in the tradable sector, but can exacerbate inequality if the benefits are concentrated in urban centres. Methodologically, most analyses assume that openness is exogenous and use fixed-effects or system GMM to address unobserved heterogeneity and dynamic effects. However, the potential for endogeneity due to reverse causality—where higher output actually attracts more trade and investment—has not yet been adequately addressed in the Indonesian regional context.

There are two main gaps in the literature. Firstly, few studies explicitly model the simultaneous interaction between output, employment and poverty within a single analytical framework, as most analyse these outcomes separately. Second, although the issue of endogeneity has been recognised, the application of instrumental variable strategies utilising exogenous variations in openness at the provincial level is still rarely used for the case of Indonesia. Consequently, causal estimates regarding how economic openness propagates through the output-employment-poverty nexus remain limited,

thereby reducing the policy relevance of existing findings for region-specific interventions.

This study addresses this gap by employing a Fixed-Effects Instrumental Variable approach to estimate the causal pathways of economic openness on the output-employment-poverty nexus across Indonesian provinces for the period 2017–2024. Unlike previous research, this study constructs a simultaneous system that captures the feedback effects between output, employment, and poverty, and instruments economic openness using geographically and historically based trade cost variables that are plausibly exogenous to provincial economic conditions. This design makes it possible to isolate the direct and indirect effects of openness and to identify regional conditions in which openness contributes to inclusive growth. These findings contribute to the literature on regional economic development and provide evidence for designing regional policies that align trade liberalisation with the objectives of reducing unemployment and poverty.

# 2 Method

## 2.1. Data and Variables

This study uses provincial panel data from Indonesia. The dataset covers 34 provinces during 2017-2024. The unit of analysis is province-year. The study focuses on three development outcomes. The first is regional output, measured by the natural logarithm of real GRDP at constant 2010 prices ($LnGRDP$). The second is unemployment, measured by the open unemployment rate ($Un$). The third is poverty, measured by the poverty headcount rate ($Poverty$).

The main variable of interest is trade openness ($TO$). It is measured as the ratio of exports plus imports to GRDP. This variable captures how strongly a provincial economy is connected to external markets. Trade openness may raise output through market expansion, specialization, better access to imported inputs, and higher efficiency. However, the effect of trade openness is not always straightforward. Its impact depends on domestic capacity, labor-market adjustment, sectoral structure, and distributional mechanisms. This is why the trade-growth-poverty relationship remains debated in the literature (Dollar & Kraay, 2004; Rodríguez & Rodrik, 2000; Winters et al., 2004).

In the output equation, this study includes foreign direct investment ($LnFDI$), government expenditure ($LnGE$), infrastructure ($LnInfra$), and ICT development ($ICT$). Infrastructure is proxied by road density, measured as the length of roads per provincial area, expressed in meters per square kilometer (m/km²). These variables represent regional productive capacity. FDI may bring capital, technology, and production linkages. Government expenditure may support output through public spending and public services. Infrastructure helps connect production centers, markets, and logistics networks. ICT is also important because digital connectivity can reduce transaction costs and improve access to markets. These variables are commonly used in growth-related studies because output differences across regions are closely linked to capital, public spending, infrastructure, and technology (Aschauer, 1989; Mankiw et al., 1992; Romer, 1990).

In the unemployment equation, the study includes FDI, human development ($HDI$), inequality ($Gini$), labor force participation rate ($LFPR$), and provincial minimum wage ($LnPMW$). These variables represent several labor-market channels. HDI captures human capability and employability. LFPR reflects the pressure of labor supply. Minimum wage is included because wage policy can affect labor demand, especially when productivity differs

across regions. The literature shows that minimum wage effects are not uniform. They may differ depending on labor-market structure, firm adjustment, and institutional context (Blanchflower & Oswald, 1994; Card & Krueger, 1994).

In the poverty equation, the study includes FDI, HDI, Gini, and minimum wage. Poverty is not only affected by aggregate output. It is also shaped by investment transmission, human capability, income distribution, and labor income. Trade openness may affect poverty through many channels. It can work through growth, employment, wages, prices, or government revenue. For this reason, the model separates the direct association of trade openness from the indirect channels through output and unemployment (Dollar & Kraay, 2004; Winters et al., 2004).

A Covid-19 dummy is also included in all equations. It equals 1 for 2020 and 0 otherwise. This variable controls for the major common shock during the pandemic. The shock affected production, labor markets, and household welfare. Since the panel is relatively short, the Covid dummy is used to capture the most important time shock while keeping the model parsimonious.

## 2.2. Empirical Strategy

This study uses a fixed-effects instrumental-variable/two-stage least squares approach, since regional output, unemployment, and poverty are likely to influence each other. A standard fixed-effects model can control for time-invariant differences across provinces, but it may still be biased if some regressors are endogenous. This can happen because of simultaneity, reverse causality, or omitted shocks. Instrumental-variable estimation is useful in this situation because it separates the exogenous variation in the endogenous regressors from the part that is correlated with the error term (Angrist & Pischke, 2009; Wooldridge, 2010).

Province fixed effects are included to control for persistent provincial characteristics. These include geography, historical infrastructure, long-standing industrial structure, and other fixed regional characteristics. Such factors may affect both openness and development outcomes. Fixed effects are commonly used in panel-data models when unobserved unit-specific characteristics may be correlated with the explanatory variables (Baltagi, 2008; Wooldridge, 2010).

The IV part of the model is used because the three outcomes are jointly related. Output may affect unemployment and poverty. At the same time, unemployment and poverty may also affect output. Unemployment may increase poverty by reducing household income. Because of these feedback effects, the three outcomes should not be treated as fully independent.

## 2.3. Model specification

The first equation explains regional output:

$$\ln GRDP_{it} = \alpha_1 + \beta_{11} TO_{it} + \beta_{12} \ln FDI_{i,t-1} + \beta_{13} \ln GE_{i,t-1} + \beta_{14} \ln Infra_{i,t-1} + \beta_{15} ICT_{i,t-1} + \theta_{11} Un_{it} + \theta_{12} Poverty_{it} + \delta_1 COVID_t + \mu_i + \varepsilon_{1it}$$

In this equation, unemployment and poverty are treated as endogenous. The logic is that both variables can affect output in the same period. High unemployment means that part of the labor force is not being used productively. Poverty can also reduce productivity, weaken purchasing power, and limit participation in economic activities. Therefore, unemployment and poverty are instrumented in the output equation.

The second equation explains unemployment:

$$Un_{it} = \alpha_2 + \beta_{21} TO_{it} + \beta_{22} \ln FDI_{i,t-1} + \beta_{23} HDI_{i,t-1} + \beta_{24} Gini_{i,t-1} + \beta_{25} LFPR_{it} + \beta_{26} \ln PMW_{i,t-1} + \theta_{21} \ln GRDP_{it} + \delta_2 COVID_t + \mu_i + \varepsilon_{2it}$$

In the unemployment equation, regional output is treated as endogenous. Output can affect unemployment through labor demand. But unemployment can also affect output through labor utilization. For that reason, output is instrumented.

Poverty is not included as an endogenous regressor in the unemployment equation. This is a deliberate choice. In this study, the more direct short-run channel runs from unemployment to poverty, not the other way around. Poverty may still affect labor-market outcomes, but mostly through human development, labor participation, inequality, and wage conditions. These channels are already represented by HDI, LFPR, Gini, and minimum wage. Leaving poverty out of the unemployment equation also keeps the model more parsimonious.

The third equation explains poverty:

$$Poverty_{it} = \alpha_3 + \beta_{31} TO_{it} + \beta_{32} \ln FDI_{i,t-1} + \beta_{33} HDI_{i,t-1} + \beta_{34} Gini_{i,t-1} + \beta_{35} \ln PMW_{i,t-1} + \theta_{31} \ln GRDP_{it} + \theta_{32} Un_{it} + \delta_3 COVID_t + \mu_i + \varepsilon_{3it}$$

In three equations above, $i$ denotes province and $t$ denotes year. $\mu_i$ captures province fixed effects, while $\varepsilon_{1it}$, $\varepsilon_{2it}$, and $\varepsilon_{3it}$ are equation-specific error terms. The definitions and measurement of all variables are provided in Section 2.1. In the poverty equation, regional output and unemployment are treated as endogenous. Output may reduce poverty through income and economic opportunities. Unemployment can increase poverty by lowering household income. But these relationships may also work in reverse. Poverty may weaken regional output and labor-market adjustment. For this reason, output and unemployment are instrumented in the poverty equation.

Most exogenous regressors are included in one-period lagged form. This is done for two reasons. First, many explanatory variables do not affect development outcomes immediately. FDI needs time to enter production and employment. Government expenditure may affect output with a delay. Infrastructure and ICT also work through gradual improvements in connectivity and productivity. Human development, inequality, and minimum wage may influence unemployment and poverty with some time lag. Second, lagged regressors help reduce contemporaneous feedback. For example, current poverty may affect current government spending, or current unemployment may influence current policy responses. Using lagged values helps create a clearer time ordering. Nevertheless, Bellemare et al. (2017) warn that lagged explanatory variables do not automatically solve identification problems. Therefore, this study does not rely on lagged variables alone. The model combines lagged controls with IV/2SLS estimation for the endogenous development outcomes.

Trade openness is kept in contemporaneous form in the main model. This is because trade openness is the main variable of interest. The aim is to estimate how the current degree of trade integration is associated with current output, unemployment, and poverty, after controlling for lagged regional capacity and after instrumenting the endogenous outcomes. LFPR is also kept contemporaneous in the unemployment equation. This is because LFPR and open unemployment are both current labor-market indicators.

LFPR captures the current pressure of labor supply. At the same time, lagged LFPR is used as one of the excluded instruments because past labor-force participation can help predict current labor-market conditions with less contemporaneous feedback. The excluded instruments are chosen based on theory and diagnostic performance. The instrument set includes lagged values of the endogenous variables in each equation. It also includes lagged exogenous variables that are relevant to the endogenous regressors but excluded from the corresponding structural equation.

The IV approach requires two main conditions. The first is relevance. The instruments must be correlated with the endogenous regressors. The second is exogeneity. The instruments should affect the dependent variable only through the instrumented regressors, conditional on the controls and province fixed effects. Therefore, this study reports standard IV diagnostic tests. The Kleibergen-Paap rk LM statistic is used to test underidentification. The Kleibergen-Paap rk Wald F statistic is used to assess weak-identification concerns. The Hansen J statistic is used to test overidentifying restrictions. These diagnostics are important because weak instruments can bias IV estimates and make statistical inference unreliable (Kleibergen & Paap, 2006; Stock & Yogo, 2005). The equations are estimated using fixed-effects IV/2SLS with standard errors clustered at the provincial level. Clustered standard errors are used to account for heteroskedasticity and within-province serial correlation. The estimation is implemented using the xtivreg2 module in Stata (Baum et al., 2007).

# 3 Results

## 3.1 Descriptive Patterns of Trade Openness and Development Outcomes

Before presenting the IV estimates, this section provides a brief descriptive overview of the variables used in the model. Table 1 reports pooled descriptive statistics for the provincial panel. These statistics are calculated from province-year observations for 34 provinces during 2017-2024 and therefore summarize both cross-provincial and over-time variation. Several variables are transformed into natural logarithms in the estimation, but the descriptive statistics are reported in their original units to make the figures easier to interpret.

**Table 1** Descriptive statistics of variables used in the estimation

| Variable | Unit | Mean | Median | Std. Dev. | Min. | Max. |
|---|---|---|---|---|---|---|
| GRDP | Trillion IDR | 334.63 | 142.62 | 474.16 | 23.21 | 2151.20 |
| Un | % | 5.02 | 4.63 | 1.72 | 1.40 | 10.95 |
| Poverty | % | 10.34 | 8.65 | 5.34 | 3.42 | 27.76 |
| TO | % | 98.89 | 90.08 | 75.15 | 3.40 | 529.91 |
| FDI | Million USD | 1122.80 | 448.90 | 1676.52 | 2.20 | 9972.30 |
| GE | Trillion IDR | 25.73 | 14.68 | 38.73 | 3.57 | 258.60 |
| LFPR | % | 68.39 | 68.68 | 3.56 | 60.18 | 79.02 |
| Infra | road density, m/km² | 749.32 | 427.36 | 1625.41 | 42.18 | 10138.40 |
| ICT | Index | 5.58 | 5.68 | 0.82 | 3.22 | 7.88 |
| HDI | Index | 71.45 | 71.49 | 4.01 | 59.09 | 83.08 |
| Gini | Index | 0.35 | 0.34 | 0.04 | 0.24 | 0.46 |
| PMW | Thousand IDR / month | 2604.32 | 2586.01 | 613.41 | 1237.70 | 5067.38 |

The Table 1 shows substantial variation across provinces and years. Real GRDP has a mean of IDR 334.63 trillion, but its median is much lower at IDR 142.62 trillion. This indicates that regional output is highly concentrated in a few large provincial economies. Trade openness also varies widely, from 3.40% to 529.91%, showing large differences in provincial exposure to external markets. Poverty ranges from 3.42% to 27.76%, while unemployment ranges from 1.40% to 10.95%. These variations support the use of provincial panel data rather than national aggregate data.

Figures 1–3 show the raw association between trade openness and the three main development outcomes in 2017 and 2024. The scatterplots are descriptive only. They do not control for province fixed effects, simultaneity, or other covariates.

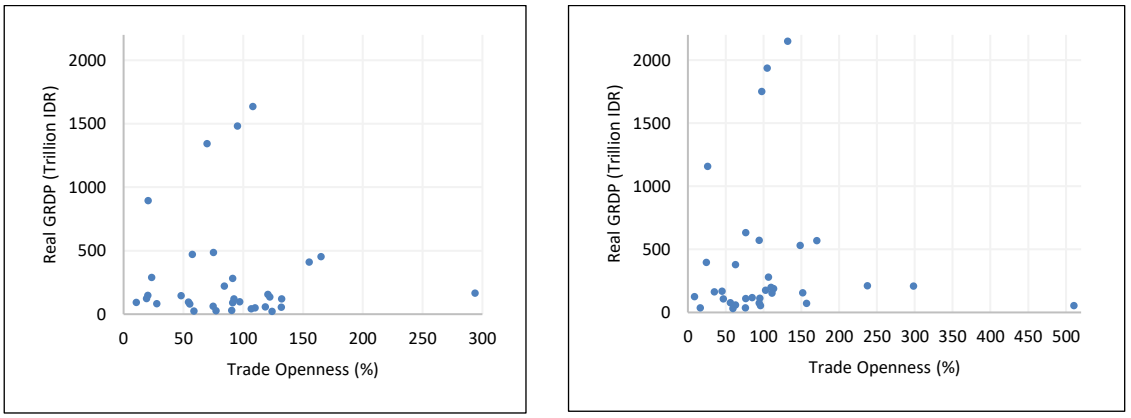



**Fig. 1** Scatterplot of provinces' trade openness and real GRDP in 2017 (left) and 2024 (right)

Figure 1 above shows the relationship between trade openness and real GRDP in 2017 and 2024. The pattern is quite scattered. Provinces with high trade openness are not always the provinces with the largest GRDP. This is understandable because trade openness is measured as a ratio to GRDP, so smaller economies can appear very open when their trade flows are large relative to their economic size. Still, the figure gives an early indication that openness and output are connected in a heterogeneous way across provinces.

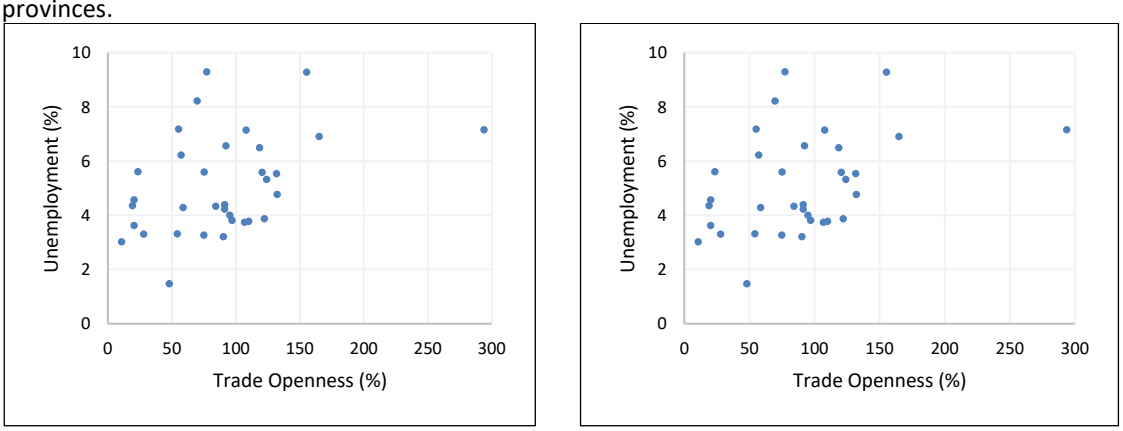



**Fig. 2** Scatterplot of provinces' trade openness and unemployment rate in 2017 (left) and 2024 (right)

Figure 2 presents the scatterplot between trade openness and unemployment. The raw pattern is not very strong in either 2017 or 2024. Some provinces with high trade openness still had relatively high unemployment, while others had lower unemployment. This suggests that openness alone does not directly explain labor-market outcomes. The employment effect of openness may depend on other factors, such as industrial structure, labor absorption, human development, and the type of sectors connected to trade.

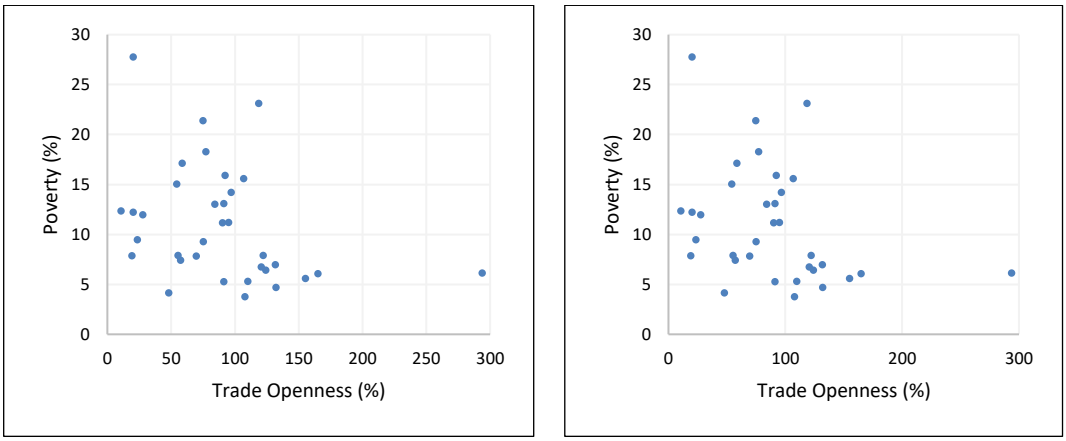



**Fig. 3** Scatterplot of provinces' trade openness and poverty rate in 2017 (left) and 2024 (right)

Figure 3 shows the relationship between trade openness and poverty. The pattern is also not clearly negative. Provinces with similar levels of trade openness can have very different poverty rates. This suggests that openness does not automatically translate into poverty reduction. Poverty is likely affected by deeper factors, including employment, human development, income distribution, and whether poor households can access the benefits of a more open economy.

Since these figures only show raw bivariate patterns, a more formal estimation strategy is needed. The next section therefore presents the fixed-effects IV results, which account for province-specific effects and the simultaneity among output, unemployment, and poverty.

## 3.2. Fixed-effects panel IV estimation results

This section presents the results of the fixed-effects IV estimation. The model is estimated in three equations. The first equation explains regional output, proxied by log real GRDP. The second equation explains unemployment. The third equation explains poverty. The compact results are reported in Table 2.

**Table 2** Fixed-effects panel IV estimation results

| Variable / Diagnostics | Output equation | Unemployment equation | Poverty equation |
|---|---|---|---|
| $Un_{it}$ | -0.0271*** (0.004) | — | 0.2684*** (0.006) |
| $Poverty_{it}$ | -0.0465*** (0.000) | — | — |
| $LnGRDP_{it}$ | — | 0.1642 (0.881) | -0.6736 (0.609) |
| $TO_{it}$ | 0.0012*** (0.000) | -0.0026* (0.090) | 0.0022 (0.336) |

| Variable / Diagnostics | Output equation | Unemployment equation | Poverty equation |
|---|---|---|---|
| $LnFDI_{it-1}$ | -0.0006 (0.924) | -0.0954 (0.255) | -0.1100* (0.075) |
| $LnGE_{it-1}$ | 0.2939*** (0.000) | — | — |
| $LnInfra_{it-1}$ | -0.0520 (0.380) | — | — |
| $ICT_{it-1}$ | 0.1044*** (0.000) | — | — |
| $HDI_{it-1}$ | — | -0.6747*** (0.000) | -0.4888** (0.034) |
| $Gini_{it-1}$ | — | -7.4110* (0.085) | 4.2701 (0.319) |
| $LFPR_{it}$ | — | -0.0498 (0.111) | — |
| $LnPMW_{it-1}$ | — | 4.9480*** (0.001) | 1.8599 (0.177) |
| $COVID_t$ | 0.0162 (0.155) | 1.1940*** (0.000) | 0.2750* (0.058) |
| Observations | 238 | 238 | 238 |
| Provinces | 34 | 34 | 34 |
| Clustered SE | Yes | Yes | Yes |
| Province fixed effects | Yes | Yes | Yes |
| Endogenous regressor | $Un_{it}$, $Poverty_{it}$ | $LnGRDP_{it}$ | $LnGRDP_{it}$, $Un_{it}$ |
| Excluded instruments | $Un_{it-1}$, $Poverty_{it-1}$, $LFPR_{it-1}$, $HDI_{it-1}$, $Gini_{it-1}$, $LnPMW_{it-1}$ | $LnGRDP_{it-1}$, $LnGE_{it-1}$, $LFPR_{it-1}$, $LnInfra_{it-1}$, $ICT_{it-1}$ | $LnGRDP_{it-1}$, $Un_{it-1}$, $LnGE_{it-1}$, $LFPR_{it-1}$, $LnInfra_{it-1}$, $ICT_{it-1}$ |
| Kleibergen-Paap rk LM statistic | 16.542*** (0.0055) | 10.312* (0.0669) | 14.367** (0.0134) |
| Kleibergen-Paap rk Wald F statistic | 14.731 | 66.503 | 42.760 |
| Hansen J statistic | 4.293 (0.3678) | 7.650 (0.1053) | 2.873 (0.5792) |

**Notes:** Values in parentheses are p-values. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. The estimation uses province fixed effects and cluster-robust standard errors at the provincial level to account for heteroskedasticity and within-province serial correlation.

Before discussing the coefficients, it is important to look at the IV diagnostics. First, the Kleibergen-Paap rk LM statistic rejects the null of underidentification in all three equations. The p-values are 0.0055 in the output equation, 0.0669 in the unemployment equation, and 0.0134 in the poverty equation. This means that the excluded instruments are sufficiently correlated with the endogenous regressors. The unemployment equation is weaker than the other two in terms of the LM test, but it still passes at the 10% level.

Second, the Kleibergen-Paap rk Wald F statistics are 14.731, 66.503, and 42.760 for the output, unemployment, and poverty equations, respectively. These values suggest that weak identification is not a major concern, especially in the unemployment and poverty equations. The output equation has a lower F statistic, but it is still reasonably acceptable for an applied panel setting. Third, the Hansen J statistics do not reject the overidentifying restrictions. The p-values are 0.3678, 0.1053, and 0.5792. This suggests that the instruments are not rejected by the overidentification test. Overall, these diagnostics support the use of the IV specification. The model is not underidentified, the instruments are reasonably strong, and the overidentifying restrictions are not rejected.

# 4 Discussion

The research findings indicate that economic openness does not have a uniform impact across all dimensions of regional development. Trade openness has been shown to be positively correlated with regional output, suggesting that increased trade integration can expand production activities, improve the efficiency of resource allocation, and enhance market access for regions. These findings are consistent with classical international trade theory and endogenous growth theory, which position trade openness as a key instrument in driving productivity and economic growth through technology transfer, production specialisation, and enhanced competitiveness. Furthermore, trade openness also exhibits a negative relationship with unemployment rates, although its significance is limited to the 10% level, suggesting that trade expansion has the potential to create new employment opportunities through increased industrial and trade activity. However, trade openness does not show a significant direct impact on poverty. This confirms that the increase in economic output resulting from openness has not automatically translated into improved welfare for low-income groups (Esmaeili et al., 2023; Nessa & Imai, 2023). In other words, the benefits of economic growth tend to be concentrated in specific sectors or groups, meaning that the trickle-down effect on poverty reduction remains relatively limited.

The research findings show that the reduction in poverty is largely explained by structural factors such as the unemployment rate, the lag in foreign direct investment (FDI), the Human Development Index (HDI), and the shocks caused by the COVID-19 pandemic. These findings suggest that poverty is more sensitive to labour market conditions and the quality of human development than to economic openness alone. Theoretically, this relationship can be explained through the capability development approach proposed by Amartya Sen, which emphasises that poverty reduction is highly dependent on people's ability to access education, healthcare, and decent economic opportunities. Furthermore, the significant influence of the FDI lag indicates that foreign investment takes time before it can generate a multiplier effect on job creation, productivity growth, and household income. On the other hand, the COVID-19 pandemic has exacerbated poverty through the contraction of economic activity and increased labour market vulnerability, particularly in the informal sector (Beccaria et al., 2024; Sumarto & Syarifah, 2022). Therefore, these findings underscore that poverty reduction strategies cannot rely solely on increasing openness, but must be accompanied by the enhancement of human capital quality, the creation of inclusive jobs, and investment policies capable of generating equitable long-term economic impacts.

## 4.1. Regional Output Equation

A positive and significant trade openness coefficient indicates that an increase in trade openness is associated with an increase in real regional output. As the dependent variable uses lnGRDP, the interpretation is in terms of semi-elasticity, whereby a 1 percentage point increase in trade openness is associated with an increase in real GRDP of approximately 0.117%. Economically, these results indicate that international trade integration is capable of expanding regional economic capacity through market expansion, access to imported inputs, increased scale of production, integration into global supply chains, and competitive pressures that drive production efficiency. Furthermore, trade openness also creates export opportunities for regional key sectors, thereby boosting regional economic activity (Chen et al., 2022; Jia et al., 2022).

These findings are consistent with international trade theory, which states that openness can improve the efficiency of resource allocation and expand market size. The provinces in Indonesia, regions that are more connected to international trade tend to gain greater access to external demand and production technology (Lihun, 2025; Jia et al., 2022). The relatively moderate magnitude of the effect suggests that trade openness is not the sole driver of regional growth, but rather works in conjunction with other domestic factors such as the quality of institutions, the labour force, and regional infrastructure capacity (Nchofoung & Asongu, 2022; Tan et al., 2023).

A negative and significant unemployment coefficient indicates that a 1 percentage point increase in the open unemployment rate is associated with a decline in real GRDP of approximately 2.71%. These results suggest that unemployment constitutes a form of labour underutilisation that reduces regional production capacity, as a portion of the labour force is not absorbed into productive economic activities. The higher the unemployment rate, the greater the potential output lost due to the low utilisation of the labour factor of production. These findings show that regional economic performance is heavily influenced by labour market conditions, with regions with high unemployment rates tending to experience a loss of production capacity and low economic dynamism. Furthermore, these results confirm that output growth cannot be separated from a region's economic capacity to create productive and inclusive employment opportunities (Ofori et al., 2026; Zhang et al., 2026). Consequently, increasing regional output requires policies that are not only oriented towards aggregate economic growth but also towards improving the quality of labour absorption.

A negative and statistically significant poverty coefficient indicates that a 1 percentage point increase in the poverty rate is associated with a decline in real GRDP of approximately 4.65%. This finding suggests that poverty is not merely a consequence of weak economic development, but also acts as a factor limiting regional production capacity. Poor households generally face restricted access to education, healthcare services, business capital, labour mobility, and productive economic opportunities, thereby reducing the community's economic productivity. These conditions reinforce the simultaneous relationship between poverty and regional output, whereby high levels of poverty can suppress household purchasing power, reduce the quality of human capital, and limit productive participation in economic activities. Consequently, these results support a methodological approach that treats poverty as an endogenous variable in output equations, as the relationship between the two is bidirectional and structurally interdependent (Awad & Warsame, 2022; Butkus et al., 2025).

The positive and significant coefficient for lagged government expenditure indicates that an increase in government spending in the previous period is associated with an increase in regional output in the current period. As the variables are measured on a logarithmic scale, these results suggest an elastic relationship between local government fiscal capacity and regional economic growth. Economically, government spending can stimulate output through infrastructure development, the provision of public services, the creation of a multiplier effect, and support for economic activities within the community and the business sector. These findings underscore the importance of local fiscal capacity in underpinning regional economic activity. However, as the variables used represent total government expenditure, these results cannot yet distinguish between the impacts of productive spending and routine spending. Consequently, the effectiveness of government spending is highly dependent on the quality, efficiency, and composition of public

expenditure. Expenditure that is more directed towards productive sectors such as infrastructure, education, and health tends to have a greater economic impact compared to administrative or consumptive expenditure (Dilla et al., 2025; Kumar & Shree, 2026).

The positive and significant lagged ICT coefficient indicates that a region's technological capacity and digitalisation contribute to an increase in regional output. These results suggest that digital readiness can enhance economic efficiency by accelerating the flow of information, reducing transaction costs, improving business connectivity, and expanding market access for economic actors. From the perspective of modern regional development, ICT forms a vital part of absorptive capacity, which determines a region's ability to capitalise on opportunities arising from economic openness and the development of global markets (Dao et al., 2024). Regions with higher levels of ICT readiness tend to be more adaptable to technological change and better able to integrate their economic activities into broader trade networks. Furthermore, ICT development also has the potential to strengthen the role of SMEs through access to digital platforms, online marketing, and more efficient supply chain integration. Thus, digital transformation is not only a factor supporting economic growth but also a strategic instrument in enhancing regional competitiveness.

The non-significant coefficients for lagged FDI and lagged infrastructure suggest that these two variables do not yet have a direct impact on regional output in the short term. This result does not necessarily imply that foreign investment and infrastructure are unimportant for regional economic development; rather, it indicates limitations in the transmission mechanism of their impact on aggregate output. In the case of FDI, it is likely that foreign investment remains concentrated in specific capital-intensive sectors, meaning that its impact on regional output is not yet directly apparent on a broader scale (Emako et al., 2024). Furthermore, the effects of FDI generally require a longer time horizon before generating spillover effects on productivity, job creation, and local economic activity. Meanwhile, the insignificance of the infrastructure variable may be influenced by the limitations of the proxy used—namely, road length per unit of area—which fails to represent road quality, logistical efficiency, inter-regional connectivity, or access to production centres and export ports. Physical infrastructure does not automatically generate economic productivity unless supported by robust economic activity and effective market integration. Interestingly, in the poverty equation, FDI actually exerts a significant influence, suggesting that the impact of foreign investment is felt more strongly through the welfare channel and the labour-market channel than through a direct effect on regional aggregate output.

## 4.2. Unemployment Equation

A negative and statistically significant trade openness coefficient at the 10% level indicates that an increase in trade openness is associated with a decrease in the unemployment rate. Quantitatively, a 1 percentage point increase in trade openness is associated with a decrease in unemployment of approximately 0.0026 percentage points. Although the magnitude of the effect is relatively small, the direction of the relationship is consistent with international trade theory, which states that economic openness can expand production and trade activities, thereby increasing labour demand. In the regions in Indonesia, increased openness can drive job creation through the expansion of the export sector, the growth of supporting industries, and increased distribution and trade services activities (Wu & Akram, 2026). However, the small magnitude of the coefficient indicates

that trade openness is not the sole solution to the problem of unemployment. The employment impact of economic openness depends heavily on the characteristics of the developing sector—whether it is labour-intensive or capital-intensive the capacity of the local labour force, the connectivity of SMEs to trade networks, and the level of formality in the labour market in each province.

The insignificant lnGRDP coefficient in the unemployment equation suggests that an increase in regional output is not automatically associated with a decline in the unemployment rate once the simultaneity issue has been corrected using instrumental variables. This finding indicates that output growth or an increase in regional economic capacity does not necessarily result in strong labour absorption. In many cases, output expansion may occur in capital-intensive sectors, such as mining, extractive industries, or high-productivity sectors that require relatively little labour (Azenui, 2024; Seyoum, 2024). Thus, regional economic growth is not always synonymous with labour-market inclusion. These results reinforce the argument that the quality of economic growth is more important than merely the magnitude of output growth, particularly in the context of a region's ability to create inclusive and sustainable employment opportunities.

The strong, significant negative coefficient of the lagged HDI indicates that improvements in human development in the previous period are associated with a decline in the unemployment rate in the current period. This finding is consistent with human capital theory, which identifies the quality of human resources as a key factor in enhancing the employability of the workforce. The Human Development Index reflects the dimensions of education, health and living standards, which directly influence an individual's ability to participate in the labour market (Grisolia et al, 2024; Putri et al., 2022). Workers with better education and health tend to adapt more easily to changing market needs and have a greater chance of securing productive employment. The HDI can also be viewed as an indicator of a region's capacity to capitalise on economic opportunities arising from trade liberalisation and investment flows. Thus, human development serves as a crucial channel for improving the performance of the regional labour market.

The negative but statistically insignificant coefficient for the labour force participation rate (LFPR) at the 10% level suggests that an increase in labour force participation tends to be associated with a decrease in unemployment, although the statistical evidence is not yet sufficiently robust. This situation can be explained by the presence of two mechanisms operating simultaneously in the labour market. On the one hand, an increase in labour force participation may reflect more active economic dynamics, leading to greater labour absorption and a fall in unemployment. On the other hand, if the increase in the labour force is not matched by the creation of sufficient jobs, the unemployment rate may actually rise due to the influx of new job seekers. The interaction between these two mechanisms makes the relationship between the LFPR and unemployment more complex and not always linear (Amin et al., 2024; Bhardwaj & Thory, 2025). Therefore, these results indicate that an increase in labour force participation needs to be accompanied by an expansion of employment opportunities in order to have a significant impact on reducing unemployment.

The positive and significant lagged minimum wage coefficient indicates that an increase in the minimum wage in the previous period is associated with a rise in the unemployment rate. These results must be interpreted with caution, as they do not imply that minimum wage policies are inherently negative. In regions with relatively low labour

productivity, an increase in the minimum wage may raise production costs for firms, thereby prompting adjustments through workforce reductions, delays in hiring new staff, or a shift towards more labour-saving technologies. Furthermore, some businesses may also respond by increasing the use of informal workers to alleviate the pressure of formal labour costs. Nevertheless, minimum wage policies continue to play a vital role in improving the welfare of workers who remain in employment and in maintaining a minimum income standard for the population (Bíró et al., 2022). Consequently, the effectiveness of minimum wage policies is highly dependent on a region's ability to boost labour productivity and expand the creation of formal jobs.

The positive and highly significant COVID-19 dummy coefficient indicates that the pandemic had a major impact on the rise in unemployment rates, with 2020 associated with an increase in unemployment of approximately 1.19 percentage points. This result is entirely reasonable given that the pandemic caused widespread disruption to economic activity, public mobility, industrial production, trade, and labour-intensive service sectors. Restrictions on social and economic activities during the pandemic led many companies to reduce operational capacity, make redundancies, or halt the recruitment of new staff. Consequently, the number of unemployed individuals increased significantly across various regions. These findings reinforce the importance of including the COVID-19 dummy variable as the primary temporal shock control variable, Borsati et al. (2023); Hamman et al., (2023) as the pandemic constitutes an external economic shock with systemic effects on regional labour markets.

A negative Gini coefficient that is statistically significant at the 10% level must be interpreted with caution, as this relationship does not directly align with general theoretical expectations. One possible explanation is that provinces with higher levels of inequality are generally more urbanised and have larger centres of economic growth, enabling them to absorb more labour despite a relatively skewed distribution of income. In other words, low unemployment in these areas does not necessarily reflect an equitable distribution of welfare. Furthermore, the relationship between inequality and unemployment is likely to be non-linear and influenced by varying regional economic structures. Hutter & Weber (2023); Marrero & Servén (2022) the inequality variable also tends to be more relevant in explaining the dynamics of poverty than the labour market directly. Therefore, this finding should not be treated as a primary result, but rather understood as an indication of structural heterogeneity among provinces in Indonesia.

## 4.3. Poverty Equation

The insignificant trade openness coefficient suggests that trade openness does not have a strong direct impact on reducing poverty levels. This finding is one of the key results of the study as it indicates that international trade integration does not automatically lead to improved welfare for the poor. This does not mean that openness is unimportant in the process of economic development, but rather shows that its impact on poverty operates indirectly through various transmission channels such as increased output, labour absorption, foreign investment, human development, the sectoral structure of the economy, and the quality of jobs created. Poverty is fundamentally a multidimensional issue linked to households' limited access to education, healthcare, decent work, productivity, and the distribution of the benefits of economic growth (Balasubramanian et al., 2023; Zulkifli & Abidin, 2023). Therefore, economic openness will only be an effective instrument for poverty reduction if the benefits of growth can be transmitted inclusively to

vulnerable groups through the creation of employment opportunities and the enhancement of human capacity.

A positive and significant unemployment coefficient indicates that a 1 percentage point increase in the unemployment rate is associated with an increase in the poverty rate of approximately 0.27 percentage points. These results are highly consistent both theoretically and empirically, as unemployment directly reduces household income sources and increases the economic vulnerability of the population. In regions with limited social protection and household savings capacity, job loss can rapidly push households into poverty. These findings confirm that the success of poverty reduction strategies depends heavily on a region's economic capacity to create productive and sustainable employment opportunities. Consequently, development policies focused solely on economic growth without addressing labour absorption risk producing growth that is less inclusive of the poor (Karani et al., 2023).

The negative and statistically significant lagged FDI coefficient at the 10% level indicates that foreign investment in the previous period is associated with a reduction in the poverty rate in the current period. Although the significance is relatively moderate, these results suggest that FDI can contribute to improvements in social welfare through various economic mechanisms. Foreign investment has the potential to create direct jobs, expand local supply chain activities, increase demand for domestic inputs, transfer skills and technology, and boost the income of communities around the investment location (Calabrese & Balchin, 2022; Viegelahn et al., 2023). Interestingly, the impact of FDI does not appear significantly in the output equation, but is evident in the poverty equation, suggesting that the impact of foreign investment is likely to be stronger through the welfare channel than through a direct increase in regional aggregate output. However, as the significance level remains at 10%, these results should be interpreted with caution and not overstated as a very strong causal relationship.

The negative and significant lagged HDI coefficient indicates that human development is one of the most important factors in reducing poverty levels. These results have very strong policy implications as they confirm that improvements in the quality of education, health, and living standards are capable of increasing households' capacity to escape poverty. From a human capital perspective, human development enhances labour productivity, increases employment opportunities, broadens economic access, and improves communities' ability to adapt to economic changes. Dao et al. (2023) these findings also suggest that economic openness will be more inclusive if supported by adequate human capital. In other words, poverty reduction cannot rely solely on trade integration or aggregate economic growth, but requires long-term investment in human development so that communities have the capacity to benefit from economic transformation.

A positive and statistically significant COVID-19 dummy coefficient at the 10% level indicates that the pandemic increased the poverty rate by approximately 0.275 percentage points in 2020. These results are consistent with economic conditions during the pandemic, which were characterised by a decline in production activity, disruption to the labour market, a fall in household income, and a weakening of the informal sector—which serves as the primary source of livelihood for many low-income households. Although the impact of COVID on poverty was relatively smaller compared to its effect on unemployment, these results nevertheless demonstrate that macroeconomic shocks can rapidly translate into a decline in household welfare. These findings underscore the

importance of social safety nets and adaptive social protection policies to prevent temporary economic shocks from developing into long-term poverty that is more difficult to reverse (Zhaou et al., 2025; Hayre, 2025).

The non-significant lnGRDP coefficient indicates that an increase in regional output is not automatically associated with a reduction in poverty levels after the simultaneity issue has been corrected using instrumental variables. This finding reinforces the argument that economic growth is not always inclusive of the poor. Poverty reduction will only occur if output expansion is able to create employment opportunities for the poor, increase labour wages, reach the informal sector, expand the income of vulnerable groups, and is supported by adequate basic services and social protection. Conversely, if economic growth is concentrated in capital-intensive sectors or enclave sectors with low linkages to the local economy, its impact on poverty reduction tends to be limited (Grewal, 2026; Sitepu et al., 2025). Therefore, these results indicate that the quality and distribution of economic growth are more important than merely an increase in regional aggregate output.

## 4.4. Sintesis Nexus: Output–Employment–Poverty

The estimation results indicate that trade openness has a multi-faceted effect on various dimensions of regional development. Trade openness has been found to have a positive and significant impact on regional output and a negative impact on unemployment, albeit with relatively weak significance. However, trade openness does not show a significant direct impact on poverty. This pattern indicates that economic openness works more effectively on macroeconomic dimensions and production capacity than directly on household welfare (Mezdour & Belkacem, 2025). International trade integration is capable of expanding production activities, improving economic efficiency, and partially improving the labour market, but these benefits have not automatically been transmitted into a reduction in poverty. In other words, openness requires additional transmission channels, such as the creation of productive jobs, improvements in the quality of the workforce, and a more inclusive distribution of the benefits of growth, so that its impact can be felt more widely by the poor.

The relationships between the equations indicate that the labour market is the primary transmission mechanism linking regional economic performance to social welfare. In the output equation, unemployment has a negative effect on regional output, whereas in the poverty equation, unemployment has a positive effect on poverty levels. These findings suggest that high unemployment not only reduces regional production capacity through the underutilisation of labour, but also exacerbates household welfare conditions due to the loss of income sources. Thus, the success of economic development is determined not only by an increase in aggregate output, but also by a region's ability to create inclusive and productive labour absorption (Sander, 2023). These results underscore that labour-market absorption is the key bridge in transforming economic growth into poverty reduction.

The significant role of the Human Development Index (HDI) in reducing unemployment and poverty demonstrates that human development is a fundamental factor in enhancing a region's ability to capitalise on the economic opportunities arising from openness. The HDI reflects the quality of education, health, and living standards of the population, which directly influence labour productivity and employability. Regions with better quality human resources tend to be better able to adapt to economic changes,

capitalise on investment opportunities, and participate in more competitive trade activities. Therefore, human capital can be understood as a form of absorptive capacity that determines the extent to which the benefits of openness can be translated into increased employment opportunities and community welfare (Isac et al., 2026). These findings suggest that economic openness will be more inclusive if supported by long-term investment in human development.

The research findings show that lagged FDI has no significant effect on output or unemployment, but has a negative effect on poverty at the 10% significance level. This pattern suggests that the impact of foreign investment is likely to be more evident in terms of social welfare than in a direct increase in regional aggregate output. One possible explanation is that foreign investment generates more localised and gradual effects through job creation around the investment site, increased demand for local inputs, skills transfer, and higher household income. Thus, the contribution of FDI to poverty reduction may occur through the mechanisms of employment and income effects rather than through an increase in aggregate production capacity in the short term (Amzil et al., 2026). However, as the level of significance remains relatively weak, the interpretation of these results must be approached with caution and should not be over-generalised.

The COVID-19 pandemic highlights the importance of controlling for temporary shocks in regional development analysis. In the estimation results, the COVID variable is not significant in the output equation, but it significantly increases unemployment and poverty. These findings suggest that the impact of the pandemic is felt more strongly in the labour market and household welfare than in regional aggregate output in this model. One possible cause is the varying resilience across economic sectors, where some key sectors were still able to sustain regional output despite the labour market and informal activities facing severe pressure (Aditya & Amri, 2021; Hartal et al., 2023). Consequently, although the contraction in aggregate output was not always significant across all provinces, many households still experienced job losses and a decline in income. These results confirm that economic crises can be transmitted more rapidly through labour-market and welfare channels than directly to aggregate output indicators; consequently, controlling for shocks such as the pandemic is crucial in empirical analyses of regional economic development.

## 4.5. Policy Implications

1. An openness policy must be complemented by an employment-oriented industrial policy

Research findings indicate that trade openness is capable of increasing regional output and, to a limited extent, reducing unemployment rates. These findings indicate that economic openness policies remain important for strengthening market integration and expanding regional economic activity. However, for the labour market to reap greater benefits from openness, trade policy needs to be integrated with an employment-oriented industrial policy. Expanding exports and imports alone is insufficient if the resulting sectoral growth is capital-intensive and has low labour absorption. Therefore, the government needs to encourage the development of the manufacturing sector, strengthen the integration of SMEs into export supply chains, provide support for productive labour-intensive sectors, enhance workforce training based on the needs of the export industry, and facilitate the certification and standardisation of local products so that they can compete in international markets. In this way, economic openness will not only increase

production capacity but also expand employment opportunities in a more inclusive manner.

2. Poverty reduction cannot rely solely on openness

The insignificance of the direct impact of trade openness on poverty indicates that trade policies cannot automatically be considered pro-poor. Although economic openness can boost output and trade activity, these benefits do not necessarily reach poor households directly in the absence of adequate distribution mechanisms. Therefore, openness policies need to be complemented by more targeted poverty reduction programmes. The government needs to strengthen social protection, improve the skills of the poor workforce, expand access for small MSMEs to markets and finance, promote the development of disadvantaged and rural areas, and improve the quality of education and basic health services. This approach is essential to ensure that the economic growth benefits of trade openness are transmitted more evenly to vulnerable groups in society and are not merely concentrated in specific sectors or economic groups.

3. Human development is key to ensuring that openness is inclusive

The significant role of the Human Development Index (HDI) in reducing unemployment and poverty demonstrates that human development is the cornerstone of inclusive economic development. The quality of education, healthcare and workforce capacity determines a society's ability to capitalise on the economic opportunities arising from trade and investment openness. Therefore, investment in human development must be a strategic priority for regional development. The government needs to strengthen vocational training programmes, improve the alignment between education and industry needs, expand digital training, enhance the quality of vocational schools, broaden access to healthcare services—particularly for informal workers—and develop reskilling programmes for workers affected by changes in trade structures and technology. With a higher-quality workforce, economic openness will be better able to translate into increased employment opportunities, productivity, and the well-being of the wider community.

4. FDI needs to be channelled to foster local linkages

Although lagged FDI has contributed to a reduction in poverty, its impact on output and unemployment has not yet been significant. This indicates that foreign investment has not yet fully generated widespread spillover effects on the regional economy. Therefore, FDI policy should not focus solely on increasing the volume of investment, but also on strengthening local linkages between foreign investors and the domestic economy. The government can encourage the use of local sourcing, strengthen linkages between foreign companies and local SMEs, enhance technology transfer, provide training for local workers, and offer incentives for investment in productive, labour-intensive sectors. Furthermore, the development of industrial zones connected to local economic activities is also crucial so that the benefits of investment can be more widely distributed to the surrounding community. With such a strategy, FDI will not only serve as a source of capital but also as an instrument for more inclusive economic development.

5. The minimum wage must be linked to productivity

The finding that the minimum wage has a positive correlation with unemployment highlights the importance of maintaining a balance between worker protection and the capacity of the business sector. This result does not imply that minimum wage policy should be curtailed, but rather indicates that increases in the minimum wage must be accompanied by improvements in labour productivity and support for the business sector,

particularly labour-intensive industries and SMEs. In conditions of low productivity, rising labour costs may prompt companies to reduce recruitment or increase the use of informal labour. Therefore, the government needs to strengthen policies to boost productivity through training and skills certification, the provision of incentives for labour-intensive industries, support for SME productivity, and wage-setting mechanisms that take into account the economic structure and productivity capacity of each region. With this approach, minimum wage policies can continue to safeguard workers' welfare without reducing the capacity for formal labour absorption.

6. ICT needs to be strengthened as enabling infrastructure

The significant impact of ICT on regional output demonstrates that digital infrastructure is a key factor in improving regional economic performance. Better digital capacity enables more efficient transactions, improved business connectivity, expanded market access, and the integration of regional economies into wider trade networks. Therefore, the development of ICT needs to be positioned as enabling infrastructure within regional development and economic openness strategies. The government needs to expand digital connectivity, particularly outside Java and in underdeveloped regions, promote the digitalisation of SMEs, develop digital export platforms, enhance e-commerce training, and strengthen the integration of regional trade data. With the strengthening of digital infrastructure, regions will have greater capacity to capitalise on economic opportunities arising from openness and to enhance regional economic competitiveness in a sustainable manner.

7. Government expenditure must be directed towards productive spending

The positive impact of government expenditure on regional output demonstrates that the government's fiscal capacity plays a vital role in supporting local economic activity. However, the effectiveness of government spending depends heavily on the quality and composition of public expenditure. Therefore, government spending must be directed towards productive and inclusive investment in order to strengthen local capacity to benefit from economic openness. Spending priorities should focus on the development of economic infrastructure, education, health, workforce training, support for SME productivity, improved logistics connectivity, and the strengthening of basic public services. With a more productive spending orientation, government expenditure will not only serve as a short-term stimulus but also as an instrument to enhance competitiveness, the quality of human resources, and the capacity for regional economic development in the long term.

# 5 Conclusion

Overall, this study demonstrates that trade openness has a positive effect on regional output and modestly reduces unemployment, but it does not yet exert a significant direct effect on poverty reduction. These findings indicate that economic openness is more effective in promoting production capacity and economic activity than in directly improving the welfare of poor households. Within the output–employment–poverty nexus, the labor market emerges as the primary transmission channel linking economic growth to poverty reduction, where rising unemployment not only suppresses regional output but also increases poverty levels.

Furthermore, human development plays a strategic role in enhancing regional capacity to benefit from economic openness. HDI is found to significantly reduce both

unemployment and poverty, suggesting that human development constitutes a crucial foundation for more inclusive development. Meanwhile, FDI shows some indication of contributing to poverty reduction through local income and welfare effects, although its impact on aggregate output remains limited. Therefore, openness policies should be integrated with stronger human development, productive job creation, ICT expansion, enhanced local investment linkages, and more productive public expenditure to ensure that the benefits of economic growth are distributed more evenly and inclusively across regions.

## Ethics Statement

Ethical approval was not required as the data did not involve direct interaction with human subjects or personal identification


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## Data Availability

Data from this study are available for sharing in raw format. The covariance matrix and analysis codes can be obtained by submitting a request to the first author.

## Consent to Publish Declaration

Not applicable.

## Consent to Participate Declaration

Yes.

## Author Contributions

Conceptualization, W.R. and F.S.A.; methodology, W.R. and F.S.A.; software, F.S.A; validation, W.R., F.S.A. and G.; formal analysis, W.R., F.S.A; investigation, W.R.; resources, W.R. and F.S.A.; data curation, W.R. and G.; writing—drafting the original manuscript, W.R., F.S.A. and G.; writing—revision and editing, W.R. and G.; visualization, W.R., F.S.A., and G.; supervision, W.R.; project administration, G.; funding acquisition, W.R. All authors have read and approved the published version of this manuscript.


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