

Dynamic Panel Data Analysis of Income Inequality in Indonesia

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ABSTRACT

Research Originality: This study examines the short-term and long-term relationships between macroeconomic variables and income inequality, adopting a broader approach than previous research, which has primarily focused on partial and simultaneous influences on income inequality.

Research Objectives: This study aims to analyze the dynamic variables that affect income inequality in Indonesia.

Research Methods: This study uses panel data from 34 provinces in Indonesia from 2015 to 2023 and employs the Generalized Method of Moments Arellano Bond (GMM-AB) approach. This method was selected to address endogeneity and heteroscedasticity issues commonly encountered in panel data analysis.

Empirical Results: The findings reveal that the Indonesian Democracy Index and the Gender Inequality Index significantly impact income inequality. Meanwhile, the ICT Development Index and the Human Development Index also exhibit significant influences. These results reinforce the argument that enhancing access to education and promoting gender equality are essential strategies for reducing income inequality.

Implications: The study provides valuable insights for policymakers, emphasizing the need to strengthen democratic institutions and empower women through improved access to education and economic opportunities as key measures to mitigate income inequality.

Keywords:

income inequality; ICT development index; Indonesia democracy index; human development index; gender inequality index

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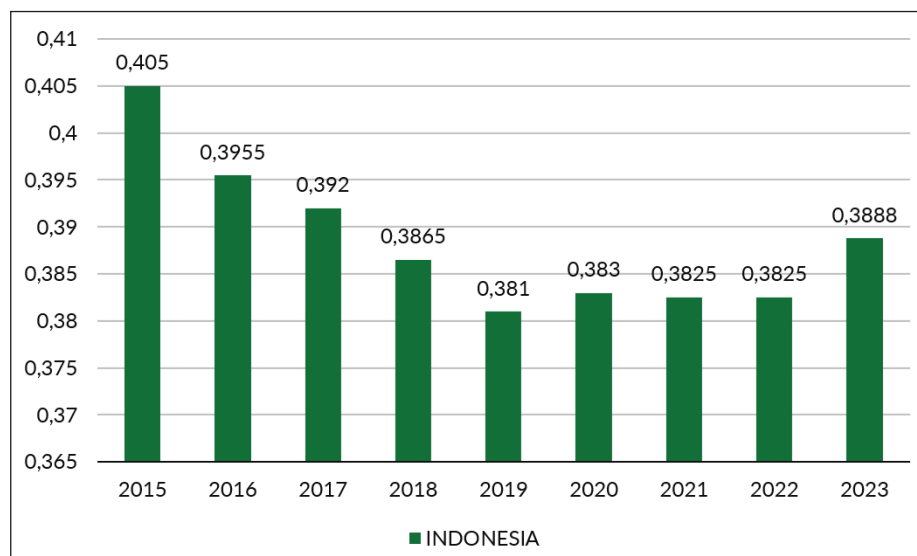
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INTRODUCTION

Income inequality is one of the global issues that attracts attention from academics, the government, and the public. Indonesia is a developing Asian country that has experienced increased income inequality in recent decades. Income inequality can be measured through the Gini ratio (Siththiyot & Holasut, 2020), reflecting the significant gap between rich and poor groups (Fahmi, 2019). Rising inequality leads to various social problems, such as increasing poverty rates, social instability, and slower economic growth (Peterson, 2017). The World Bank proves that human capital, particularly the average length of education, is one of the most important factors in reducing income inequality. In Indonesia, efforts to improve human resources are primarily focused on developing the education sector.

Data from Statistics Indonesia (BPS) for the period 2015-2023 highlights the trends in income inequality in Indonesia. The highest level of inequality was recorded in 2015, with a Gini ratio of 0.40, indicating a considerable income gap between the rich and disadvantaged groups. By 2023, the Gini ratio had declined slightly to 0.38, though it remained relatively high, reflecting persistent income inequality, as shown in Figure 1.

Figure 1. Indonesia's Income Inequality 2015-2023



Source: Data processed from the Statistics Indonesia (BPS)

High income inequality can hinder inclusive economic growth, increase the potential for social conflict, and widen the gap between the rich and the poor (Menyelim et al., 2021). Additionally, it can obstruct efforts to achieve the Sustainable Development Goals (SDGs), particularly in poverty reduction, inequality reduction, and improving community welfare. Income inequality also exacerbates gender inequality by creating barriers for women to access economic resources, education, and employment opportunities (Adeosun & Owolabi, 2021). Regions with a high Gini Ratio tend to experience greater levels of gender inequality (Fisher & Naidoo, 2016). In other words, disparities in income distribution result in inequalities in quality of life across communities.

Income inequality not only impacts economic growth but also affects various development indicators such as the ICT Development Index, the Indonesian Democracy Index (IDI), the Human Development Index (HDI), and the Gender Inequality Index (GII). Kartiasih et al. (2023) found that ICT adoption in Indonesia can help reduce income inequality, as ICT development enhances communication and social development. Inequality in society, both in the social and economic fields, can affect the implementation of democracy; if income inequality increases, it will change the condition of democracy in society (Anyanwu et al., 2016).

Setyadi et al. (2023) analyzed the development of digital technology and its impact on income inequality in Indonesia, emphasizing that as ICT expands, individuals must develop digital competencies to utilize technology across different sectors effectively. Study Yunga et al. (2023) found that technology plays a significant role in reducing income inequality. Equitable, efficient, and innovative development can expand information at a lower cost (Wanof, 2023). This condition creates opportunities for the poor and disadvantaged. ICT development can reduce income inequality by increasing worker productivity (Cheng et al., 2021). The rapid dissemination of information reduces transaction costs. Research by Ma et al. (2023) also found that adopting ICT improves the well-being of rural communities by providing farmers with market information to increase their bargaining power and boost income generation.

Study by Lyrra et al. (2025) suggests that a strong democracy is expected to encourage a more equitable distribution of income through political participation and government accountability mechanisms. Similarly, Stoetzer et al. (2023) emphasize that income inequality is a critical issue in both global social and political contexts, especially in democratic nations. However, Ramadhan (2023) argues that good democracy will increase income inequality. On the other hand, when the country is increasingly undemocratic, income inequality will decrease (Saputro & Najicha, 2022).

Low-income communities have limited access to education and information, reducing participation in democratic processes (Willeck & Mendelberg, 2025). Efforts must focus on improving the quality of the Human Development Index (HDI) to enhance economic well-being. Prioritizing human capital development is crucial for fostering long-term economic growth and sustainable development (Agustina et al., 2023). Research Janah (2022) found a positive correlation between the Human Development Index and income inequality. This result means regions with higher HDI values tend to experience greater income inequality (Susilo et al., 2020). Conversely, a low HDI reflects a region's inability to optimize resources, resulting in income disparities (Iddrisu & Bhattacharyya, 2015).

Limited access to education and information not only affects HDI but also contributes to gender inequality, as disadvantaged groups, particularly poor women, face unequal opportunities (Kling et al., 2022). Increasing gender equality is expected to reduce income inequality (Chung et al., 2021). Ensuring equal access for women in education and economic participation so that household productivity can increase (Jabeen et al., 2020). Conversely, when women lack access to education and employment, their income potential declines, further reinforcing income inequality (Yavorsky et al., 2019).

Kuznets' theory of economic growth and income inequality explains that technology affects income inequality. According to this theory, during the early stages of industrialization, inequality in developing countries increased and then decreased after reaching a certain level of income, forming what is known as the inverted U-curve (Tabash et al., 2024). The development of ICT can have both exogenous and endogenous effects on public goods and services. Research also shows that democracy influences income inequality, as higher democratic standards can contribute to fairer income distribution (Ramadhan, 2023).

The inconsistency in the findings of previous studies on income inequality is evident. Cheng et al. (2021) found that the Information and Communication Technology (ICT) Development Index had a negative effect on income, while (Wang et al., 2021) indicated that the ICT Development Index had a significant positive effect on income inequality. Similarly, Lyrre et al. (2025) found that the democracy index had a significant negative effect. Bahamonde and Trasberg (2021) stated that the positive influence was significant on income inequality. The Human Development Index (HDI) significantly negatively affects income inequality (Ghifara et al., 2022).

Meanwhile, in Sasmita et al. (2023), the Human Development Index significantly positively affects income inequality. Study Adeosun & Owolabi (2021) demonstrated that the Gender Inequality Index (GII) has a significant negative effect on income inequality, while Ali et al. (2021) show that the gender inequality index has a significant positive effect on income inequality. These discrepancies highlight ongoing debates regarding the relationship between the ICT Development Index, the Indonesian Democracy Index, the Human Development Index, and the Gender Inequality Index about income inequality.

A research gap persists due to data selection inconsistencies such as time periods, sample sizes, and data sources. Variations in observational areas across multiple linear regression analyses lead to conflicting findings on income inequality. Specifically, prior studies have not adequately distinguished between the short-term and long-term effects of macroeconomic variables, making it difficult to understand their impact comprehensively. Previous studies have not used analytical methods that can reveal short-term and long-term effects, thus creating a gap that needs to be filled. Previous studies have not examined the short-term and long-term relationships between the ICT Development Index (Adams & Akobeng, 2021), the Indonesian Democracy Index (Al-Majali, 2024), the Human Development Index (Sarkodie & Adams, 2020), and the Gender Inequality Index (Yip et al., 2015) about income inequality. This study seeks to fill this gap by empirically analyzing the dynamic relationship between these variables and their effects on income inequality over both short-term and long-term horizons.

Several prior studies have used the ICT development index (Yunga et al., 2023), democracy index (Rau et al., 2024), human development index (Iddrisu & Bhattacharyya, 2015), gender inequality index (Kling et al., 2022). However, these studies were limited

to static models, which did not account for dynamic relationships over time. This study employs panel data analysis to examine the short-term and long-term dynamics using the Generalized Method of Moments Arellano-Bond (GMM-AB) approach. Furthermore, this study incorporates observational data from 34 provinces in Indonesia for 2015–2023. This study also examines the relationship between dynamic macroeconomic variables, where other variables influence one variable, both simultaneous effects and past values.

The purpose of this study was to analyze the short-term and long-term relationship of the ICT Development Index, Indonesian Democracy Index, Human Development Index, and Gender Inequality Index variables to income inequality in 34 provinces in Indonesia using the Generalized Method of Moments Arellano-Bond (GMM-AB) First Difference analysis. The findings are expected to provide new insight into the factors of income inequality and can be used as recommendations in making policies. Additionally, these findings aim to support policymakers in formulating more effective strategies to address economic challenges.

This study applies dynamic panel data regression using the Generalized Method of Moments (GMM) developed by Arellano and Bond. This dynamic panel data model includes the lagged dependent variable as an explanatory variable to capture both short-term and long-term effects. This approach ensures that the resulting estimators are unbiased, consistent, and efficient. Consequently, this study aims to comprehensively analyze the short-term and long-term relationships between these key variables and income inequality in Indonesia.

METHODS

This study employs quantitative secondary data from the Central Statistics Agency of Indonesia. The estimation method used is the Generalized Method of Moments (GMM), which is applied to evaluate the parameters of the data the model provides. The dataset consists of 34 provinces in Indonesia, covering the observation period 2015–2023, making it panel data. The total sample size in this study is 306 observations. Data collection was conducted by searching, gathering, and downloading information from the official website of the Central Statistics Agency of Indonesia for the 2015–2023 period.

The dependent variable in this study is income inequality, measured using the Gini ratio index. The independent variables include the ICT Development Index, the Indonesian Democracy Index, the Human Development Index, and the Gender Inequality Index in Indonesia. A dynamic panel data regression method is employed to analyze the relationship between these independent variables and income inequality across 34 provinces in Indonesia.

In dynamic panel data regression, the Arellano-Bond GMM estimation method is used to obtain unbiased, consistent, and efficient parameter estimates. This method effectively addresses the issues of endogeneity and heteroscedasticity, which are common in panel data analysis. The estimation process is carried out using the two-step Arellano-Bond GMM estimator, which is formulated as follows:

$$\begin{pmatrix} \hat{\delta} \\ \hat{\beta} \end{pmatrix} = a \times b$$

$$a = [(N^{-1} \sum_{i=1}^N (\Delta y_{i,t-1} \Delta x_i)' Z_i) \hat{\Lambda}^{-1} (N^{-1} \sum_{i=1}^N Z_i' (\Delta y_{i,t-1} \Delta x_i))]^{-1}$$

$$b = [(N^{-1} \sum_{i=1}^N (\Delta y_{i,t-1} \Delta x_i)' Z_i) \hat{\Lambda}^{-1} (N^{-1} \sum_{i=1}^N Z_i' \Delta y_i)] \quad (1)$$

Value $(\hat{\delta})$ and $(\hat{\beta})$ to estimate parameters in the dynamic panel data regression model. This parameter calculates the influence of independent variables on dependent variable variables. Simultaneous significance testing to determine the presence or absence of variable relationships in the model was carried out by Arellano-Bond: 1991, using the Wald test. The goal is to find out the significance of variables simultaneously in the equation model (1). The hypothesis of simultaneous testing is as follows.

$H_0: \delta = \beta_1 = \beta_2 = \dots = \beta_k = 0$ (No variable coefficients have a significant effect on the model)

$$w = \hat{\beta}' \tilde{V}^{-1} \hat{\beta} \sim X_{(k)}^2 \quad (2)$$

Reject H_0 if the value statistic test $w > X_{(k)}^2$ or p-value $< \alpha$ ($\alpha = 0.05$). To find out the coefficient of variables that have a significant effect on the model, partial testing is conducted using the Z test.

$H_0: \delta \text{ or } \beta_j = 0$ (There are not response lag variables or independent variables that had a significant effect on the model)

$H_1: \delta \text{ or } \beta_j \neq 0, j = 1, 2, \dots, k$ (Response lag variables or independent variables that have a significant effect on the model)

$$Z_{test} = \frac{\hat{\beta}_j}{se(\hat{\beta}_j)} \text{ dan } Z_{test} = \frac{\hat{\delta}}{se(\hat{\delta})} \quad (3)$$

Reject H_0 if $|Z_{test}| > Z_{0.05/2} = 1.96$, or p-value $< \alpha$ ($\alpha = 0.05$). Furthermore, to evaluate the specification of parameters, tests were carried out using the Sargan test and the Arellano-Bond test. The sargan test is used to assess whether there is a problem with the validity of the instrument used, meaning that there is no correlation between the instrument and *the error* component. The Sargan test determines the validity of the use of variable instruments with *overidentifying restrictions*, which is more than the estimated number of parameters. The sargan test is also to determine homogeneity, i.e., the variation of *error* is constant. The hypothesis of the Sargan test is as follows

H_0 : *overidentifying restrictions* in the valid model estimation (variable instrument does not correlate with error)

H_1 : *overidentifying restrictions* invalid model estimates.

$$S = \hat{v}' Z (\sum_{i=1}^N Z_i' \Delta_{vi} \Delta_{vi}' Z_i)^{-1} Z' \hat{v} \sim X_{L-(k+1)}^2 \quad (4)$$

The Arellano-Bond test is proposed as a test for the absence of first-order serial correlation of *errors* in the *first Difference* equation, used to determine the consistency of the estimation results. The Arellano-Bond test is also used to determine the correlation of observation *errors* to-t (y_t) with previous observations (y_{t-1}).

The consistency of the method is indicated by statistical values m_1 significant ($p - value < \alpha$) and statistical values m_2 insignificant ($p - value < \alpha$). The statistics of the Arellano-Bond test for the serial correlation of first order components in *the first Differencing* can be written as follows.

$$m(2) = \frac{\Delta \hat{v}'_{i,t-1} \Delta \hat{v}'_*}{(\Delta \hat{v})^{1/2}} \sim N(0,1) \quad (5)$$

Where $\Delta \hat{v}'_{i,t-1}$ is a vector error in the 1st lag with the order $q = \sum_{i=t}^N T_i - 2$ and $\Delta \hat{v}'_*$ is a cropped error vector corresponding to $\Delta \hat{v}'_{i,t-1}$ sized $q \times 1$.

In order to analyze the influence of income distribution, this study uses the GINI index coefficient variable as a dependent variable and a number of influential variables such as ICT development index, Indonesian democracy index, human development index, and gender inequality index as independent variables. The econometric model used in this study to measure the influence of finance on income distribution is as follows:

$$\begin{aligned} \text{Income inequality } (Y)_{i,t} = & \beta_{1i} + \beta_{2i} \text{income inequality}_{2i,t-1} - \\ & \beta_{3i} \text{ICT development index}_{3i,t} - \beta_{4i} \text{Indonesian democracy index}_{4i,t} - \\ & \beta_{5i} \text{Human development index}_{5i,t} - \beta_{6i} \text{Gender inequality index}_{6i,t} - \epsilon_{i,t} \end{aligned}$$

The model is adapted from the model developed by Kus (2012) dan Asfar et.al (2014) which is estimated by panel data analysis. All variables used are estimated in the form of linear logs to get an overview of the elasticity.

RESULTS AND DISCUSSION

At this stage, the panel data regression model was estimated using the first-difference GMM (FD-GMM) two-step estimator approach. This model was chosen because it provides a valid instrument. Table 1 presents the intercept and slope values for each exogenous variable based on the FD-GMM approach model. The p-value indicates how much the independent variable influences the dependent variable.

Table 1. Parameter Estimation

Parameter	Coefficient	Standard Error	z	p-value
Income Inequality	.1658186	.1268791	1.31	0.191
ICT Development Index	-.0341413	.0410435	-0.83	0.406
Indonesian Democracy Index	-.4513132	.1253987	-3.60	0.000
Human Development Index	-.0628988	.2214747	-0.28	0.776
Gender Gap	-.1978232	.0376705	-5.25	0.000
cons	1.240963	.9465477	1.31	0.190

Source: data processing results using Stata application

The estimation used in this study uses the GMM Arellano-Bond two-step estimator. The signification test was conducted simultaneously using the Wald test with the following results in Table 2. From Table 2, it was decided to reject because the Wald value obtained was 46.22 or p-value (with $\alpha = 0.05$), thus it can be concluded that there is at least

one independent variable that affects the dependent variable. After the Wald test is met, then a partial parameter significance test will be carried out using the Z test, the results of the Z test can be seen as follows $H_0 < \alpha$

Table 2. Wald Test

Wald value(w)	P-value
46.22	0.0000

Source: Data Processing

From Table 3, it can be decided to reject H_0 the IDI and IKG variables because the p-value of the Indonesian democracy index and the gender inequality index respectively is 0.000 with a negative coefficient. This means that the increase in the variables of Indonesia's democracy index and the gender inequality index will reduce gender inequality. Meanwhile, the ICT and HDI variables failed to be rejected because the p-values were 0.327 and 0.777 respectively so that there was no significant influence on income inequality H_0

Table 3. Partial Parameter Significance Test

Parameter	Coefficient	Standard Error	z	p-value
Income Inequality	.1658186	.140192	1.18	0.237
ICT Development Index	-.0341413	.0349875	-0.98	0.329
Indonesian Democracy Index	-.4513132	.1099028	-4.11	0.000
Human Development Index	-.0628988	.2223908	-0.28	0.777
Gender Gap	-.1978232	.0454879	-4.35	0.000
cons	1.240963	1.090683	1.14	0.255

Source: Data Processing

Furthermore, a model specification test was carried out on all variables that significantly influenced the model. The best dynamic panel data model estimation can be seen from the criteria, namely, the variables of the instrument used are valid, and the estimates obtained are consistent. The test of the variable of the instrument uses the Sargan test, and the estimation consistency test uses the Arellano-Bond test. The results of the Sargan test can be seen as follows in Table 4.

Table 4. Sargan Test Result

Test	Statistics Value (S)	P-value
Sargan Test	33.6773	0.1756

Source: Data Processing

From Table 5, it can be concluded that the p-value (0.1756) is greater than the significance level (0.05), then it fails to reject. The sargan test is also used to look at

residues that undergo heteroskedasticity. So, it can be H_0 decided that it fails to reject, which means that there is no heteroskedasticity or residual from the estimate of GMM Arellano-Bond homogeneous H_0 . Next, the Arellano-Bond test will be carried out, the results of the Arellano-Bond test can be seen in Table 5.

Table 5. Arellano-Bond Test

Test	Statistics Value (S)	P-value
Arellano Bond	-.58366	0.5595

Source: Data Processing

From Table 6, it can be decided that the rejection failed because the p-value is much greater than the 5% significance level; this means that there is no autocorrelation in the error of the first difference of the first order, so the estimate has been consistent. The results of the analysis in Table 6 found that the information and communication technology development index has a p-value of 0.329, and the human development index has a p-value of 0.777; this study found that the information and communication technology development index and the human development index have no significant influence on income inequality. This means that changes in the variables of the information and communication technology development index and the human development index do not provide a change in income inequality. Meanwhile, the Indonesian democracy index and the gender inequality index have a p-value of 0.000. Thus, this study found that the Indonesian democracy index and the gender inequality index have a negative effect on income inequality. This result means that changes in the quality of Indonesia's democracy index and gender inequality index have an impact on reducing income inequality.

Table 6. Short-Term and Long-Term Parameters Test

Parameter	Short-Term Elasticity Coefficient	p-value	Long-Term Elasticity Coefficient	p-value
Income Inequality	-	-	-	-
ICT Development Index	-.0341413	0.329	-.0409279	0.344
Indonesian Democracy Index	-.4513132	0.000	-.5410253	0.000
Human Development Index	-.0628988	0.777	-.0754019	0.775
Gender Gap	-.1978232	0.000	-.2371465	0.001

Source: Data processing

Table 6 evaluates the short-term and long-term effects of income inequality on the variables of the ICT Development Index, the Indonesian Democracy Index, the Human Development Index, and the Gender Inequality Index. The short-term and long-term elasticity coefficients in the Indonesian Democracy Index variables are -.4513132 and -.5410253, respectively, with a probability value of 0.000; this shows that a 1% increase in the Indonesian democracy index will cause a statistically significant decrease in the dependent variables, both in the short and long term. The probability value of the gender

inequality index is negligible from a significance level of 0.05 in the short and long term of (0.000 and 0.001) with its elasticity (-.1978232 and -.2371465). This result means that every 1% increase in the gender inequality index will cause a partially significant decrease in the dependent variables in the short and long term. The main findings in this study show a significant negative influence both in the short and long term of the Indonesian democracy index and the gender inequality index on income inequality. These findings conclude that efforts to reduce income inequality can be made by improving the quality of Indonesia's democracy index and gender inequality index both in the short and long term.

The study finds that the Indonesian Democracy Index significantly negatively affects income inequality in the short term and long term. Research (Uzar, 2023) shows that the democracy index significantly affects income inequality through increased transparency and redistribution policies. A strong democracy enables a more equitable income distribution by promoting public participation in policymaking and increased government transparency (Hue & Tung-Wen Sun, 2022). In research by Acemoglu et al. (2015), It was explained that when income inequality decreases, it will improve the quality of democracy in society; on the contrary, if income inequality increases, the quality of democracy in society will decrease. Research by Trinugroho et al. (2023) found that democracy negatively impacts economic growth, although democracy can help reduce income inequality between provinces. Fadly and Chandra (2024) argue that democracy can contribute to reducing income inequality but may simultaneously slow economic growth if not accompanied by appropriate policies. Furthermore, income inequality in Indonesia does not directly affect the implementation of democracy, as human development interventions measuring the quality of human capital play a mediating role.

Furthermore, the results of this study found that the gender inequality index has a significant negative effect on income inequality in the short term and long term. The results of this study are supported by research by Badriah and Istiqomah (2022), which found that the gender inequality index was significantly negative regarding income inequality. Rofatunnisa and Usman's (2024) research explained that areas with high income inequality tend to have greater gender inequality. High gender inequality can create barriers for women to access economic resources, education, and decent work, exacerbating overall income inequality. Gender inequality often results in women having limited access to education and skills training.

The findings of this study emphasize that improvements in democracy and reductions in gender inequality play a critical role in reducing income inequality. The implications suggest that a well-functioning democracy can contribute to a fairer income distribution by increasing public participation in economic policy decisions and ensuring equitable resource allocation. Furthermore, reducing gender inequality can help lower income inequality by providing equal access to economic resources and employment opportunities. The government should focus on enhancing the quality of democracy through inclusive economic policies while ensuring equal educational access for both men and women. Greater community participation will enable the government to understand societal needs better, leading to more inclusive policymaking.

CONCLUSION

Based on the results of this study, the ICT Development Index and the Human Development Index do not significantly affect income inequality in the short or long term. This result indicates that, despite technological advancements and improvements in human resource quality being key focuses of various development policies, they have not directly contributed to reducing income inequality in Indonesia. Meanwhile, the Indonesian Democracy Index and the Gender Inequality Index significantly negatively impact income inequality in the short and long term. These findings highlight that governance and gender equality are crucial in determining income distribution within society. Gender inequality, for instance, can weaken economic growth by limiting access to jobs, education, and economic opportunities for women. Conversely, a stronger democracy enables fairer policy redistribution and increased public participation in decision-making.

Based on these findings, we recommend that relevant stakeholders, including both central and local governments, design effective policies grounded in factors that support income inequality reduction in Indonesia. These policies should prioritize improving democratic quality through enhanced transparency, accountability, and community empowerment in economic policymaking. Additionally, efforts to reduce gender inequality—such as expanding women's access to education, healthcare, and equal employment opportunities—should be a key priority in development strategies. For future research, we suggest expanding the scope of observational data and conducting comparative analyses to provide further insights into this issue.

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