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The Associations of Age at First Marriage, Poverty, and Total Fertility Rate with Infant Mortality in Indonesia

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Abstract

Infant mortality is an important indicator of population health and development outcomes. This study examines the associations between age at first marriage, poverty, total fertility rate (TFR), and provincial level infant mortality in Indonesia. Using an ecological cross-sectional design based on provincial level secondary data from 35 provinces, this study applies multiple linear regression to examine how demographic and socioeconomic indicators are associated with variations in infant mortality rate (IMR) across provinces.

The regression model explained 77.1% of the variation in provincial IMR ($R^2 = 0.771$). Poverty and total fertility rate showed positive and statistically significant associations with infant mortality, indicating that provinces with higher poverty rates and higher fertility levels tended to report higher IMR. In contrast, age at first marriage showed a negative but statistically non-significant association with IMR after controlling for poverty and fertility.

These findings indicate that socioeconomic and fertility-related conditions showed stronger statistical associations with provincial differences in infant mortality than age at first marriage within the present model. However, the findings should be interpreted cautiously because the study uses aggregated provincial level data and an ecological cross-sectional design, which does not permit causal or individual-level inference.

Keywords

infant mortality rate, age at first marriage, poverty, total fertility rate, Indonesia

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Introduction

The infant mortality rate (IMR) is a key indicator for assessing population health status, social welfare, and the effectiveness of development efforts. In demographic and public health research, IMR is widely recognised as a sensitive measure of maternal health conditions, the quality of healthcare services, and the broader socioeconomic environment in which infants are born [1, 2]. As such, IMR reflects not only health system performance but also broader social and economic development outcomes and remains one of the principal indicators used to monitor progress toward the Sustainable Development Goals (SDGs) [3].

Over recent decades, Indonesia has experienced a substantial decline in infant mortality alongside the expansion of maternal and child health services, improved immunisation coverage, and broader socioeconomic development. Despite these achievements, progress has not been uniform across provinces and population groups. Considerable regional disparities in infant mortality continue to exist, reflecting differences in maternal characteristics, socioeconomic conditions, healthcare accessibility, and the capacity of local health systems. Findings from the 2023 Indonesian Health Survey (Survei Kesehatan Indonesia/SKI) indicate that maternal and socioeconomic factors remain important determinants of infant survival and that reducing regional inequalities remains a major public health challenge in Indonesia [4]. These regional disparities underscore the importance of ecological analyses that examine demographic and socioeconomic characteristics at the provincial level [5].

One demographic factor frequently associated with infant mortality is women's age at first marriage. Early marriage is commonly followed by early childbearing, which has been associated with pregnancy complications, preterm birth, low birth weight, and other adverse maternal and neonatal outcomes that may increase the risk of infant mortality [6–8]. Recent studies in Indonesia further demonstrate that child marriage remains more prevalent among socially and economically disadvantaged populations and is closely associated with lower educational attainment, poverty, and limited access to maternal healthcare services, thereby increasing reproductive health vulnerabilities [9, 10].

The relationship between age at first marriage and infant mortality is closely intertwined with broader socioeconomic conditions, particularly poverty. Previous studies have consistently shown that poor households often experience limited access to adequate nutrition, sanitation, healthy living environments, education, and quality healthcare services, all of which are associated with poorer maternal and infant health outcomes [11, 12]. Recent evidence from Indonesia similarly identifies household socioeconomic status as one of the strongest determinants of infant mortality after accounting for maternal and healthcare-related characteristics [4]. These findings suggest that poverty remains an important contextual factor underlying regional differences in infant mortality across Indonesia.

In addition to marriage timing and poverty, fertility patterns, as reflected in the total fertility rate (TFR), have also been widely discussed in demographic research on infant mortality. High fertility is commonly associated with demographic conditions such as shorter birth intervals, higher parity, and increased demands on household and healthcare resources, all of which may adversely influence maternal and infant health outcomes [13, 14]. At the regional level, persistently high fertility may also place additional pressure on healthcare systems, particularly in resource-constrained settings, thereby contributing to variations in infant mortality across provinces.

Although previous studies have examined the relationships among age at first marriage, poverty, fertility, and infant mortality, most have investigated these factors separately or focused primarily on individual or household level determinants of infant mortality. In Indonesia, relatively few studies have simultaneously examined the provincial level associations among age at first marriage, poverty, total fertility rate, and infant mortality using aggregated ecological data. Consequently, evidence on how these demographic and socioeconomic indicators are jointly associated with regional variation in infant mortality remains limited. Considering that many population and public health policies in Indonesia are formulated, implemented, and evaluated at the provincial level, ecological analyses provide valuable complementary evidence for understanding regional demographic patterns and informing policy development, while recognising that such analyses do not permit individual level or causal inference [4, 5, 15].

Against this background, this study aims to examine the associations among age at first marriage, poverty, total fertility rate, and infant mortality across provinces in Indonesia using cross-sectional provincial level secondary data. Specifically, the study assesses whether provincial variations in age at first marriage, poverty, and fertility are associated with differences in provincial infant mortality. By integrating these demographic and socioeconomic indicators within a single ecological analytical framework, this study extends existing provincial level evidence on infant mortality in Indonesia and provides a more comprehensive understanding of regional demographic and socioeconomic disparities. The findings are expected to contribute to population health and demographic research while providing evidence to support integrated policy discussions on reproductive health, fertility, poverty reduction, and equitable health development across Indonesian provinces.

Theoretical Framework

In population and public health research, infant mortality is widely regarded as a sensitive indicator reflecting the interaction between socioeconomic conditions, reproductive behaviour, and health system performance. Demographic transition theory posits that declines in mortality, including infant mortality, occur alongside structural changes in fertility patterns, educational attainment, and economic development [16–18]. Within this framework, age at first marriage, poverty, and fertility levels are frequently discussed as demographic and socioeconomic factors associated with infant survival outcomes.

Age at first marriage is commonly linked to women's educational attainment, reproductive health knowledge, and social conditions related to childbearing. Previous studies suggest that later marriage is generally associated with more favourable maternal and child health outcomes, including

greater utilisation of maternal health services and improved reproductive health practices [17, 18]. Conversely, early marriage has often been associated with reproductive health challenges, including pregnancy complications, preterm birth, and low birth weight, which are themselves linked to infant mortality [6, 8]. Empirical studies in developing countries also report associations between lower age at first marriage and higher infant mortality levels [19, 20]. Nevertheless, these theoretical mechanisms primarily operate at the individual or household level, whereas the present study examines aggregated provincial level relationships.

Poverty is also widely recognised as an important socioeconomic factor associated with infant mortality. The Mosley and Chen framework conceptualises socioeconomic conditions such as poverty as distal determinants that may influence child survival through proximate factors related to nutrition, environmental conditions, and healthcare access [1]. Previous studies have shown that populations living in economically disadvantaged conditions are more likely to experience limited access to sanitation, nutrition, and healthcare services, conditions that are often associated with poorer infant health outcomes.

A substantial body of empirical evidence further indicates that areas with higher poverty levels tend to report higher infant mortality rates, even after accounting for demographic characteristics [21]. At the aggregate level, poverty may also reflect broader disparities in regional development capacity, including differences in public health infrastructure, sanitation systems, and access to essential healthcare services.

Total fertility rate (TFR), as an indicator of cumulative reproductive behaviour, has also been widely associated with infant mortality patterns. Within demographic transition theory, high fertility is generally characteristic of earlier stages of demographic transition, during which demographic pressure on households and healthcare systems tends to remain relatively high [16, 18]. Previous demographic research suggests that high fertility and short birth intervals are often associated with less favourable maternal and infant health outcomes [23–25].

From a demographic and socioeconomic perspective, fertility may also be associated with variations in household and regional resource allocation related to health and child welfare [26, 27]. However, these mechanisms are primarily conceptual and operate largely at the individual- or household-level, whereas the present study employs aggregated provincial level data.

In the Indonesian context, substantial interprovincial variation in age at first marriage, poverty levels, and fertility rates reflects heterogeneity in socioeconomic development, access to family planning services, healthcare availability, and reproductive norms. Drawing on demographic transition theory and population health frameworks, this study examines whether provincial variations in age at first marriage, poverty, and fertility are associated with provincial differences in infant mortality in Indonesia.

Although the theoretical literature identifies many additional determinants of infant mortality, including female education, healthcare access, water and sanitation, and maternal nutrition, not all relevant variables are available in the present analysis. Consequently, the findings should be interpreted as ecological statistical associations at the provincial level rather than causal explanations of infant mortality outcomes.

Recent public health literature also emphasises the importance of the social determinants of health framework in understanding regional disparities in infant mortality. This perspective argues that population health outcomes are shaped not only by biological and demographic factors but also by broader structural conditions such as poverty, inequality, healthcare access, sanitation, and social policy environments [28]. Within this framework, provincial variation in infant mortality may reflect differences in social and institutional capacity across regions.

Contemporary population health approaches further highlight the importance of contextual and ecological influences on maternal and child health outcomes [22]. Regional demographic characteristics, healthcare infrastructure, and socioeconomic inequality may interact simultaneously in shaping infant survival patterns. Consequently, ecological analyses using aggregated regional indicators remain relevant for identifying broad structural associations, although they cannot establish individual-level causal mechanisms.

Methods

Data and Study Design

This study employed an observational ecological cross-sectional design using aggregated provincial level secondary data to examine the associations among age at first marriage (AFM), poverty, total fertility rate (TFR), and infant mortality rate (IMR) in Indonesia. The province was used as the unit of analysis to assess interprovincial variation in demographic and socioeconomic characteristics associated with infant mortality.

The analysis included data from 35 of Indonesia's 38 provinces. Three newly established provinces South Papua (Papua Selatan), Central Papua (Papua Tengah), and Highland Papua (Papua Pegunungan) were excluded because they were created through administrative regional expansion and did not yet have complete and comparable official statistics for all study variables. Specifically, provincial level data on IMR, AFM, TFR, and poverty were not yet available for these provinces in the official publications used in this study. To ensure data completeness, consistency, and comparability across observations, the analytical sample was therefore restricted to provinces with complete information for all study variables. As a limitation, the exclusion of these provinces may have affected the estimated associations and cannot be ruled out as a potential source of systematic bias. Nevertheless, the findings should be interpreted as applying only to the provinces included in the analysis and should not be generalised to provinces for which complete data were unavailable.

Provincial level indicators were compiled from official government publications. Infant mortality rate (IMR), age at first marriage (AFM), and total fertility rate (TFR) were obtained from the 2023 Indonesia Demographic and Health Survey (Survei Demografi dan Kesehatan Indonesia/SDKI 2023), the results of which were officially published in 2024 through a collaborative publication by Statistics Indonesia (BPS), the National Population and Family Planning Board (BKKBN), and the Ministry of Health. Provincial poverty

Table 1: Operational Definitions and Data Sources of Study Variables

Variable	Operational Definition	Unit of Analysis	Official Publication	Institution	Survey/ Ref. Period	Data Processing
Infant Mortality Rate (IMR)	Number of deaths among infants under one year of age per 1000 live births	Province	Indonesia Demographic and Health Survey(SDKI) 2023, published 2024)	BPS, BKKBN, Ministry of Health	Survey conducted in 2023, published 2024	Provinsial indicator extracted without modification
Age at First Marriage (AFM)	Provincial median age at first marriage among ever-Married Women aged 15-49 years	Province	Indonesia Demographic and Health Survey(SDKI) 2023, published 2024)	BPS, BKKBN, Ministry of Health	Survey conducted in 2023, published 2024	Provinsial indicator extracted without modification
Poverty Rate	Percentage of the provincial population living below the official national poverty line	Province	Profil Kemiskinan di Indonesia Tahun 2024	Statistics Indonesia BPS	2024	Provinsial indicator extracted without modification
Total Fertility Rate (TFR)	Average number of children expected to be born to a woman during her reproductive years (15–49 years)	Province	Indonesia Demographic and Health Survey(SDKI) 2023, published 2024)	BPS, BKKBN, Ministry of Health	Survey conducted in 2023, published 2024	Provinsial indicator extracted without modification

rates were obtained from Profil Kemiskinan di Indonesia 2024, published by Statistics Indonesia (BPS). Accordingly, the demographic indicators were derived from the most recent nationally representative survey conducted in 2023 and officially released in 2024, whereas poverty data represented the official provincial estimates for 2024. All variables were extracted as aggregated provincial level indicators from these official publications and harmonised using the province as the common unit of analysis. No additional transformation, recalculation, or imputation was performed prior to statistical analysis.

Table 1 summarises the operational definitions, official data sources, responsible institutions, reference periods, and data processing procedures for each study variable, thereby facilitating the reproducibility of the analytical dataset.

The study relied exclusively on aggregated provincial level indicators and therefore did not include information on individual births, households, or maternal characteristics. Consequently, the analysis was not intended to estimate individual-level risk factors or causal pathways underlying infant mortality. Prior to regression analysis, exploratory data analysis was conducted to examine variable distributions, identify potential outliers, assess data completeness, and identify potentially influential observations. Descriptive statistics, histograms, scatter plots, residual plots, leverage values, and Cook's distance were examined to evaluate data characteristics and the suitability of the regression model.

Measures

The dependent variable was the infant mortality rate (IMR), defined as the number of deaths among infants younger than one year of age per 1,000 live births at the provincial level. Provincial IMR estimates were obtained from the 2023 Indonesia Demographic and Health Survey (Survei Demografi dan Kesehatan Indonesia/SDKI 2023), the results of which were officially published in 2024. The indicator represents the most recent nationally standardised provincial estimate available at the time of the study. The explanatory variables included age at first marriage (AFM), poverty rate, and total fertility rate (TFR).

Age at first marriage (AFM) was measured as the provincial median age at first marriage among ever-married women aged 15–49 years, as reported in the 2023 Indonesia Demographic and Health Survey (SDKI 2023), published in 2024. The indicator reflects the distribution of age at first marriage among ever-married women of reproductive age in each province and was used as an aggregated provincial measure for comparison across provinces. The reference period for the AFM estimates is the 2023 survey. Because AFM was measured at the provincial level, it should not be interpreted as representing the marital timing of individual women included in this ecological analysis.

The poverty rate was measured as the percentage of the provincial population living below the official national poverty

line, based on Profil Kemiskinan di Indonesia 2024, published by Statistics Indonesia (BPS).

The total fertility rate (TFR) was defined as the average number of children a woman would be expected to bear during her reproductive years (15–49 years) if current age-specific fertility rates remained constant throughout her lifetime. Provincial TFR estimates were obtained from the 2023 Indonesia Demographic and Health Survey (SDKI 2023), published in 2024.

All variables were measured as aggregated provincial level indicators, with the province serving as the unit of analysis. Consequently, the statistical analyses evaluated associations between provincial characteristics rather than relationships at the individual- or household-level. The findings should therefore be interpreted as ecological (province-level) associations and not as evidence of individual-level or causal relationships.

Statistical Analysis

The associations between infant mortality and the explanatory variables were examined using multiple linear regression analysis. Because the study employed an ecological cross-sectional design based on aggregated provincial level data, the objective of the analysis was to estimate provincial level associations between age at first marriage, poverty, total fertility rate, and infant mortality rather than to infer causal relationships or individual-level effects. The regression model was specified as follows:

$$\mathbf{IMR_i} = \boldsymbol{\beta_0} + \boldsymbol{\beta_1}\mathbf{AFM_i} + \boldsymbol{\beta_2}\mathbf{POV_i} + \boldsymbol{\beta_3}\mathbf{TFR_i} + \boldsymbol{\varepsilon_i}$$

where IMR_i denotes the infant mortality rate in province *i*; AFM_i denotes the median age at first marriage; POV_i denotes the provincial poverty rate; TFR_i denotes the total fertility rate; β_0 is the intercept; $\beta_1 - \beta_3$ are the unstandardised regression coefficients; and ε_i is the random error term.

Prior to model estimation, the assumptions of ordinary least squares (OLS) regression were evaluated. Multicollinearity was assessed using variance inflation factors (VIFs). Residual normality was evaluated using graphical inspection and the Shapiro–Wilk test, whereas heteroskedasticity was assessed using the Breusch–Pagan test. Potentially influential observations were examined using standardised residuals, leverage values, Cook's distance, and residual plots.

These diagnostic procedures were undertaken to evaluate the adequacy of the fitted regression model and to identify observations that might disproportionately influence the estimated coefficients. No variable transformation was applied because exploratory analyses indicated that the assumptions of linear regression were adequately satisfied and the original variable scales facilitated straightforward interpretation of the estimated regression coefficients.

Model performance was evaluated using the coefficient of determination (R^2), adjusted R^2, and the overall F-statistic. Regression coefficients are reported as unstandardised coefficients together with their corresponding standard errors, 95% confidence intervals, and p-values. Statistical significance was assessed using a two-sided significance level of $p < 0.05$. All statistical analyses were performed using IBM SPSS Statistics version 26.

Given the ecological study design and the use of aggregated provincial level data, all estimated regression coefficients should be interpreted as measures of association between provincial characteristics and infant mortality. Accordingly, the findings do not permit causal inference or interpretation at the individual- or household-level.

Ethics Statement

This study used aggregated secondary data at the provincial level obtained from publicly available sources. The dataset contained no personally identifiable information and did not involve direct contact with human participants. Therefore, formal ethical approval and informed consent were not required for this study.

Results

Descriptive Statistics

This study analysed provincial level data from 35 provinces in Indonesia to examine the associations of age at first marriage (AFM), poverty rate, and total fertility rate (TFR) with infant mortality rate (IMR). Table 2 presents the descriptive statistics of the variables included in the analysis.

The results show that the average infant mortality rate (IMR) across Indonesian provinces was 19.65, with a standard deviation of 7.03, indicating considerable variation in infant mortality outcomes among provinces. The mean age at first marriage (AFM) was 22.07 years, with relatively low variation across provinces ($SD = 1.03$).

The average provincial poverty rate was 10.07%, with a standard deviation of 5.11, indicating substantial differences in socioeconomic conditions among provinces. Meanwhile, the average total fertility rate (TFR) was 2.25 children per woman, with a standard deviation of 0.22, indicating moderate variation in fertility levels across Indonesian provinces.

Diagnostic Tests

Before estimating the multiple linear regression model, diagnostic tests were conducted to assess whether the model satisfied the assumptions required for regression analysis. The results of the diagnostic tests are presented in Table 3.

The Shapiro Wilk test indicated that the residuals were normally distributed ($p = 0.448$). The Breusch Pagan test showed no evidence of heteroskedasticity ($p = 0.314$). Furthermore, all VIF values were below the commonly accepted threshold, indicating no problematic multicollinearity among the explanatory variables. Overall, the diagnostic results indicated that the regression model met the assessed assumptions and was appropriate for further analysis.

Multiple Linear Regression Results

Multiple linear regression analysis was conducted to examine the associations of age at first marriage (AFM), poverty rate, and total fertility rate (TFR) with infant mortality rate (IMR)

Table 2: Descriptive Statistics of Study Variables

Variable	N	Mean	Std. Dev.
Infant Mortality Rate(IMR)	35	19.6546	7.03001
Age at First Marriage(AFM)	35	22.0689	1.02899
Poverty Rate	35	10.0683	5.10820
Total Fertility Rate(TFR)	35	2.2480	0.21719

Note: Descriptive statistics are calculated using province level data.Source: Statistics Indonesia (BPS, 2024). Processed by the authors using SPSS 26.

Table 3: Diagnostic Tests for Regression Assumptions

Diagnostic Test	Indicator	Value	Interpretation
Normality test	Shapiro-Wilk p-value	0.448	Residuals are normally distributed
Heteroskedasticity	Breusch–Pagan p-value	0.314	No evidence of heteroskedasticity
Multicollinearity	AFM VIF	1.021	No multicollinearity problem
Multicollinearity	Poverty Rate VIF	1.644	No multicollinearity problem
Multicollinearity	TFR VIF	1.621	No multicollinearity problem

across Indonesian provinces. The estimated regression model is expressed as follows:

$$\mathrm{IMR_i} = -8.269 - 0.804\mathrm{AFM_i} + 0.602\mathrm{POV_i} + 17.622\mathrm{TFR_i} + \acute{\varepsilon}_\mathrm{i}$$

Where *IMR* represents the infant mortality rate in province *i*; *AFM* represents the age at first marriage; *POV* represents the provincial poverty rate; *TFR* represents the total fertility rate; and ε represents the error term. The overall performance of the regression model is presented in Table 4.

The regression model demonstrated strong explanatory capacity. The coefficient of determination ($R^2 = 0.771$) indicates that AFM, poverty rate, and TFR jointly explained 77.1% of the variation in provincial infant mortality rates. After adjusting for the number of predictors and sample size, the adjusted R^2 remained high (0.749), indicating that the model retained substantial explanatory power. The overall regression model was statistically significant ($F(3,31) = 34.812$, $p < 0.001$), indicating that the three explanatory variables jointly provided significant statistical information for explaining variations in IMR across Indonesian provinces. The estimated regression coefficients are presented in Table 5.

Among the explanatory variables, poverty rate exhibited a positive and statistically significant association with IMR ($B = 0.602$; $\beta = 0.437$; $p < 0.001$). A one-percentage-point increase in the provincial poverty rate was associated with an estimated increase of approximately 0.60 infant deaths per 1,000 live births, holding the other variables constant.

Similarly, TFR showed a positive and statistically significant association with IMR ($B = 17.622$; $\beta = 0.544$; $p < 0.001$). Provinces with higher fertility levels tended to report higher infant mortality rates. Among the predictors included in the model, TFR had the largest standardised coefficient, indicating the strongest statistical association with provincial variation in IMR. In contrast, AFM showed a negative association with IMR ($B = -0.804$; $\beta = -0.118$), although this relationship was not statistically significant ($p = 0.185$). While the direction of the association suggests that a higher age at first marriage may be associated with lower infant mortality, this relationship was not statistically significant after adjustment for poverty rate and TFR.

Overall, the findings indicate that poverty rate and TFR exhibited stronger statistical associations with provincial differences in infant mortality than AFM within the present model specification. These results suggest that socioeconomic disadvantage and fertility patterns remain the principal factors associated with provincial variation in infant mortality in Indonesia.

Discussion

The findings of this study highlight the importance of socioeconomic and reproductive factors in explaining provincial variation in infant mortality in Indonesia. The regression model showed that poverty and total fertility rate (TFR) were significantly associated with infant mortality rate (IMR), whereas age at first marriage (AFM) showed a negative but statistically non-significant association after controlling for other factors.

The non-significant association between AFM and IMR suggests that differences in marriage timing alone may not sufficiently explain variations in infant mortality at the provincial level. Although AFM showed a negative coefficient, indicating a direction consistent with improved maternal and reproductive outcomes, the relationship was not statistically significant after accounting for poverty and fertility conditions. Previous studies have reported that the association between maternal age, age at first marriage, and infant mortality may become weaker after adjusting for socioeconomic and reproductive characteristics [6, 7, 19].

This finding suggests that provincial variation in infant mortality is likely to reflect a broader combination of demographic, socioeconomic, and health system characteristics that were not fully captured in the present ecological analysis. Because mediation was not formally examined, no inference

Table 4: Model Summary and Overall Significance of the Regression Model

R	R-Square	Adjusted R-Square	Std.Error of the Estimate	F-Statistic	P-value
0.878	0.771	0.749	3.52234	34.812	<0.001

Table 5: Multiple Linear Regression Coefficients for Infant Mortality Rate

Predictor	B	Stand.Error	Standardised β	t-value	p-value	95% CI Lower	95% CI Upper
Constant	-8.269	14.826	—	-0.558	0.581	-38.507	21.969
AFM	-0.804	0.593	-0.118	-1.356	0.185	-2.014	0.405
Poverty	0.602	0.152	0.437	3.968	<0.001	0.292	0.911
TFR	17.622	3.542	0.544	4.975	<0.001	10.398	24.845

regarding indirect pathways can be drawn from the present findings.

The positive and statistically significant association between poverty and IMR observed in this study is consistent with the social determinants of health framework. Provinces with higher poverty rates tended to experience higher infant mortality rates, reflecting potential disadvantages in nutrition, sanitation, housing conditions, maternal education, and healthcare access. Previous studies have demonstrated that socioeconomic inequality is closely associated with differences in child survival outcomes [11, 12, 29, 30]. Recent evidence from Indonesia also indicates that socioeconomic disadvantage is associated with child marriage, lower maternal healthcare utilisation, and poorer maternal and child health outcomes [10]. Therefore, socioeconomic disparities remain an important context for understanding regional differences in infant mortality.

The regression results also showed a strong positive association between TFR and IMR. Among the predictors included in the model, TFR had the largest standardised coefficient ($\beta = 0.544$), indicating the strongest statistical association with provincial variations in IMR. This finding is consistent with demographic and reproductive health literature suggesting that higher fertility levels and shorter birth intervals may be associated with less favourable maternal and infant health conditions [13, 14, 25]. Previous research has also shown that reproductive patterns characterised by high fertility and younger maternal age are associated with increased risks of adverse neonatal outcomes in low- and middle-income countries [7]. From a demographic transition perspective, declining fertility is often accompanied by improvements in child survival as societies experience broader socioeconomic development and improvements in health systems [16–18].

Although AFM was not statistically significant in the multivariable model, the negative direction of the coefficient remains theoretically consistent with previous research suggesting that later marriage may be associated with improved reproductive preparedness, educational attainment, and maternal healthcare utilisation [19, 20]. However, the present ecological analysis indicates that provincial differences in infant mortality appear to be more strongly associated with socioeconomic and fertility conditions than with differences in AFM among ever-married women aged 15–49 years. Because AFM was measured as a provincial aggregate based on the 2023 survey, the finding should be interpreted as a province-level association rather than as evidence of an individual-level relationship between age at first marriage and infant mortality.

Taken together, these findings suggest that reducing disparities in infant mortality in Indonesia requires integrated approaches addressing socioeconomic vulnerability and reproductive health conditions. Strategies that improve economic opportunities, maternal and child healthcare access, and family planning services may contribute to improving infant survival outcomes, particularly in provinces experiencing higher levels of mortality.

Several limitations should be acknowledged. First, this study used aggregated provincial level data; therefore, the observed associations should not be interpreted as individual level relationships because of the possibility of ecological fallacy. A further limitation is the exclusion of South Papua, Central Papua, and Highland Papua because complete data were unavailable for all variables included in the analysis. The absence of these provinces may have affected the estimated associations and cannot be ruled out as a potential source of systematic bias. Therefore, the findings apply only to the provinces included in the analysis and should not be generalised to provinces for which complete data were unavailable.

Second, the cross-sectional design limits the ability to establish temporal or causal relationships among variables. Third, several potentially important determinants, including female education, healthcare accessibility, sanitation conditions, and maternal nutritional status, could not be included because of data limitations. Furthermore, the analysis did not consider possible spatial dependence among provinces, where neighbouring regions may share similar socioeconomic and healthcare characteristics. Future research using longitudinal designs, spatial econometric approaches, or individual-level data could provide deeper insights into the mechanisms underlying variations in infant mortality.

In the Indonesian context, where substantial interprovincial disparities in infant mortality persist, this study provides evidence that poverty and fertility patterns are more strongly associated with provincial variations in IMR than AFM. These findings contribute to the literature on population health and provide empirical evidence that may support the development of more targeted demographic and public health policies in Indonesia.

Conclusion

This study provides empirical evidence on the associations between age at first marriage, poverty, total fertility rate, and infant mortality rate (IMR) across Indonesian provinces using an ecological cross-sectional design based on aggregated provincial level data.

The findings indicate that poverty and total fertility rate (TFR) are positively and significantly associated with provincial variation in IMR, while age at first marriage (AFM) shows a negative but statistically non-significant association after controlling for poverty and TFR. These results suggest that socioeconomic conditions and fertility patterns are important factors associated with differences in infant mortality across Indonesian provinces.

From a population health perspective, the findings highlight the importance of considering demographic and socioeconomic contexts together when examining variations in infant mortality. Strategies that address socioeconomic disadvantage, strengthen reproductive health services, and improve maternal and child healthcare access may contribute to reducing regional disparities in infant mortality.

However, the findings should be interpreted within the limitations of an ecological cross-sectional study, and they should not be considered as evidence of individual-level causal relationships. Future research using longitudinal, spatial, or individual-level data, incorporating additional contextual factors such as healthcare access, female education, sanitation, and maternal health conditions, would provide a more comprehensive understanding of the factors associated with infant mortality in Indonesia.

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Statement on Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

Ethics Statement

This study uses secondary data obtained from publicly available sources. The data are aggregated and do not contain any personal identifiers. Therefore, ethical approval and informed consent were not required for this study.

Data Availability Statement

The data used in this study are publicly available from the Badan Pusat Statistik (BPS), the National Population and Family Planning Board (BKKBN), and the Ministry of Health of the Republic of Indonesia (MoH). The data sources are cited in the manuscript.

AI Statement

Artificial intelligence (AI)-based tools were used solely to assist with language editing and proofreading. The author takes full responsibility for the content, interpretation, analysis, and conclusions of the manuscript.

References

1. Mosley, W. H., & Chen, L. C. (1984). An analytical framework for the study of child survival in developing countries. Population and Development Review, 10(Suppl.), 25–45. https://doi.org/10.2307/2807954

2. Cutler, D., Deaton, A., & Lleras-Muney, A. (2006). The determinants of mortality. Journal of Economic Perspectives, 20(3), 97–120. https://doi.org/10.1257/jep.20.3.97

3. United Nations. (2015). Transforming our world: The 2030 Agenda for Sustainable Development. United Nations. https://sdgs.un.org/2030agenda.

4. Badan Kebijakan Pembangunan Kesehatan. (2024). Laporan Tematik Survei Kesehatan Indonesia (SKI) 2023. Jakarta: Kementerian Kesehatan Republik Indonesia.

5. Morgenstern, H. (1998). Ecologic studies. In K. J. Rothman & S. Greenland (Eds.), Modern epidemiology (2nd ed., pp. 459–480). Lippincott-Raven.

6. Raj, A., Saggurti, N., Winter, M., Labonte, A., Decker, M. R., Balaiah, D., & Silverman, J. G. (2010). The effect of maternal child marriage on morbidity and mortality of children under 5 in India: Cross-sectional study of a nationally representative sample. BMJ, 340, b4258. https://doi.org/10.1136/bmj.b4258

7. Neal, S., Channon, A. A., Chintsanya, J., Crampin, A. C., Madise, N. J., & Nyirenda, M. (2018). The impact of young maternal age at birth on neonatal mortality: Evidence from 45 low- and middle-income countries. PLOS ONE, 13(5), e0195731. https://doi.org/10.1371/journal.pone.0195731

8. Ganchimeg, T., Ota, E., Morisaki, N., Laopaiboon, M., Lumbiganon, P., Zhang, J., Yamdamsuren, B., Temmerman, M., Say, L., Tunçalp, Ö., Vogel, J. P., Souza, J. P., & Mori, R. (2014). Pregnancy and childbirth outcomes among adolescent mothers: A World Health Organization multicountry study. BJOG: An International Journal of Obstetrics & Gynaecology, 121(Suppl. 1), 40–48. https://doi.org/10.1111/1471- 0528.12630

9. Cameron, L., Contreras Suarez, D., & Wieczkiewicz, S. (2023). Child marriage: using the Indonesian family life survey to examine the lives of women and men

who married at an early age. Review of Economics of the Household, 21, 725–756. https://doi.org/10.1007/s11150-022-09616-8

10. Suryaningrum, N., Samosir, O. B., & Djutaharta, T. (2023). Child marriage and infant mortality in Indonesia: A spatial analysis approach. Al-Sihah: The Public Health Science Journal, 15(2), 175–185. https://doi.org/10.24252/al- sihah.v15i2.38833

11. Sastry, N. (1996). Community characteristics, individual and household attributes, and child survival in Brazil. Demography, 33(2), 211–229. https://doi.org/10.2307/2061873

12. Houweling, T. A. J., & Kunst, A. E. (2010). Socio-economic inequalities in childhood mortality in low- and middle-income countries: A review of the international evidence. British Medical Bulletin, 93(1), 7–26. https://doi.org/10.1093/bmb/ldp048

13. Cleland, J., & Sathar, Z. A. (1984). The effect of birth spacing on childhood mortality in Pakistan. Population Studies, 38(3), 401–418. https://doi.org/10.1080/00324728.1984.10410289

14. Hobcraft, J., McDonald, J. W., & Rutstein, S. (1985). Demographic determinants of infant and early child mortality: A comparative analysis. Population Studies, 39(3), 363–385. https://doi.org/10.1080/00324728.1985.10410172

15. Victora, C. G., Requejo, J. H., Barros, A. J. D., Berman, P., Bhutta, Z., Boerma, T., & Bryce, J. (2011). Countdown to 2015: Tracking progress in maternal, newborn, and child survival. The Lancet, 377(9772), 1469–1487. https://doi.org/10.1016/S0140-6736(11)60138-5

16. Notestein, F. W. (1945). Population—The long view. In T. W. Schultz (Ed.), Food for the world (pp. 36–57). University of Chicago Press.

17. Caldwell, J. C. (1986). Routes to low mortality in poor countries. Population and Development Review, 12(2), 171–220. https://doi.org/10.2307/1973109

18. Bongaarts, J. (2015). Modeling the fertility impact of the proximate determinants: Time for a tune-up. Demographic Research, 33, 535–560. https://doi.org/10.4054/DemRes.2015.33.19

19. Finlay, J. E., Özaltin, E., & Canning, D. (2011). The association of maternal age with infant mortality, child anthropometric failure, diarrhea, and anemia for first births: Evidence from 55 low- and middle-income countries. BMJ Open, 1(2), e000226. https://doi.org/10.1136/bmjopen-2011-000226

20. Efevbera, Y., Bhabha, J., Farmer, P. E., & Fink, G. (2019). Girl child marriage as a risk factor for early childhood development and stunting. Social Science & Medicine, 235, 112384. https://doi.org/10.1016/j.socscimed.2019.112384

21. Wagstaff, A. (2002). Poverty and health sector inequalities. Bulletin of the World Health Organization, 80(2), 97–105. https://doi.org/10.1590/S0042-96862002000200004

22. Victora, C. G. (2010). Commentary: LiST: Using epidemiology to guide child survival policymaking and programming. International Journal of Epidemiology, 39(Suppl. 1), i1–i2. https://doi.org/10.1093/ije/dyq044

23. Cleland, J., & van Ginneken, J. K. (1988). Maternal education and child survival in developing countries: The search for pathways of influence. Social Science & Medicine, 27(12), 1357–1368. https://doi.org/10.1016/0277-9536(88)90201-8

24. Rutstein, S. O. (2005). Effects of preceding birth intervals on neonatal, infant, and under-five years mortality and nutritional status in developing countries: Evidence from the demographic and health surveys. International Journal of Gynecology & Obstetrics, 89(Suppl. 1), S7–S24. https://doi.org/10.1016/j.ijgo.2004.11.012

25. Conde-Agudelo, A., Rosas-Bermúdez, A., Castaño, F., & Norton, M. H. (2012). Effects of birth spacing on maternal, perinatal, infant, and child health: A systematic review of causal mechanisms. Studies in Family Planning, 43(2), 93–114. https://doi.org/10.1111/j.1728-4465.2012.00308.x

26. Becker, G. S., & Lewis, H. G. (1973). On the interaction between the quantity and quality of children. Journal of Political Economy, 81(2), S279–S288. https://doi.org/10.1086/260166

27. Becker, G. S. (1991). A treatise on the family (2nd ed.). Harvard University Press. https://doi.org/10.4159/9780674020665

28. World Health Organization. (2022). Social determinants of health. World Health Organization. https://www.who.int/health-topics/social-determinants-of-health.

29. Badan Pusat Statistik. (2024). *Profil kemiskinan di Indonesia Maret 2024*. Badan Pusat Statistik. https://www.bps.go.id/id/pressrelease/2024/07/01/2307/profil-kemiskinan-di-indonesia-maret-2024.html.

30. Wagstaff, A. (2000). Socioeconomic inequalities in child mortality: Comparisons across nine developing countries. Bulletin of the World Health Organization, 78(1), 19–29. https://doi.org/10.1590/S0042-96862000000100003