

PROMOTING ECONOMIC TRANSFORMATION THROUGH STRENGTHENING HUMAN CAPITAL: EMPIRICAL EVIDENCE FROM DISTRICTS/CITIES IN RIAU PROVINCE

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Abstract:

Purpose:

This study examines the effects of Mean Years of Schooling (MYS), Expected Years of Schooling (EYS), and Life Expectancy at Birth (LEB) on the share of manufacturing sector GRDP in total GRDP at current prices across 12 regencies/cities in Riau Province during 2011–2024.

Methodology:

A balanced panel dataset comprising 168 observations, sourced from official publications of Statistics Indonesia (BPS) Riau Province, was analyzed using panel data regression in EViews. Model selection using the Chow, Hausman, and Lagrange Multiplier tests identified the Random Effects Model (REM) as the most appropriate specification.

Findings:

MYS has a positive and significant effect on the manufacturing share (coefficient = 3.189; $p = 0.0018$), while EYS ($p = 0.3178$) and LEB ($p = 0.6750$) are not statistically significant. The model explains 36.45 percent of the variation in manufacturing share (weighted R^2) and is jointly significant ($F = 31.351$; $p < 0.001$).

Implication:

The findings suggest that Riau's industrial structure remains heavily shaped by capital-intensive natural-resource sectors, so longer-term human capital accumulation and population health have not yet been fully translated into manufacturing development at the regency/city level. The study recommends integrating vocational education policies with resource-based downstream industrial development to strengthen regional structural transformation.

INTRODUCTION

Economic transformation from a natural-resource-based economy toward high-value-added manufacturing is a long-term development agenda in Indonesia. Human capital theory argues that education and health investment increase productivity and support the transition from primary to more productive sectors (Schultz, 1961; Becker, 1993). Structural transformation theory similarly emphasizes human capital in shifting economic activity from agriculture and mining toward manufacturing (Clark, 1940; Kuznets, 1966; Chenery and Syrquin, 1975).

Riau Province provides an important context because, despite relatively high human capital, its economy remains resource-dependent. In 2024, RLS reached 9.43 years, above the national 8.85 years, while national UHH and HLS reached 74.15 and 13.21 years, respectively (BPS, 2024). In the first quarter of 2026, Manufacturing Industry contributed 29.44 percent and Mining and Quarrying 17.07 percent of Riau's GRDP (BertuahPos, 2026). The provincial government has therefore promoted downstream industrialization based on palm oil and other non-oil-and-gas commodities (Kompas, 2022).

Evidence across Riau's 12 regencies/cities during 2011–2024 also challenges a straightforward relationship between human capital and manufacturing. Pekanbaru had the highest human capital indicators but only a 20.20 percent average manufacturing share, whereas Dumai had the highest share at 56.10 percent. Bengkalis recorded the highest manufacturing-share growth at 112.94 percent despite moderate human capital. These patterns suggest that natural resources and capital-intensive industries may influence the relationship.

National and regional evidence is similarly mixed. Ryandiansyah (2024) found no significant effect of mineral-resource dependence and human capital on Indonesia's structural productivity. Huda (2018) found that RLS and per capita expenditure were insignificant, while UHH significantly affected economic growth in East Java. Conversely, another study found RLS significant but UHH insignificant for GRDP per capita in Central Kalimantan. These inconsistencies indicate the need for context-specific evidence in resource-rich Riau.

Therefore, this study examines the effects of RLS, HLS, and UHH on the Manufacturing Industry GRDP share across 12 regencies/cities in Riau Province during 2011–2024 using panel data regression. It contributes by testing human capital and structural transformation theories in a resource-rich regional context and informing downstream industrialization policies.

Philosophical Study. This study adopts a positivist perspective, assuming that relationships between human capital and economic structure can be measured and empirically tested using quantitative data. Knowledge is developed through hypothesis testing using systematic panel data, enabling objective and replicable conclusions. The study also seeks to provide practical evidence for human development and regional industrialization policies.

The capability approach developed by Sen (1999) provides an additional foundation by emphasizing development through expanded substantive freedoms, particularly education and health. Accordingly, RLS, HLS, and UHH represent fundamental human capabilities that may contribute to productivity and structural transformation.

Grand Theory. Human Capital Theory, Human capital theory was formalized by Schultz (1961), who viewed education, training, and health expenditure as investments that increase productive capacity. Mincer (1958) linked educational investment to income, while Becker (1993) explained returns through higher productivity and income. Lucas (1988) emphasized human capital accumulation as a source of long-term productivity growth, while Mankiw, Romer, and Weil (1992) demonstrated that human capital improves the explanatory power of the Solow growth model.

In this study, RLS represents realized educational attainment, HLS expected educational attainment, and UHH health and longevity. These dimensions are expected to increase productivity and support the transition toward higher-skilled sectors, including manufacturing.

Structural Transformation Theory. Structural transformation theory explains the shift from primary activities, particularly agriculture and mining, toward secondary and tertiary sectors. Clark (1940) argued that rising income reduces the relative role of the primary sector while increasing industry and services. Kuznets (1966) conceptualized structural transformation through changes in aggregate demand, trade, and supply, while Chenery and Syrquin (1975) emphasized capital accumulation, including human and physical capital.

Together, these theories suggest that stronger human capital through RLS, HLS, and UHH should increase manufacturing's share by raising productivity and supporting the transition toward higher-value-added industries. However, capital-intensive natural-resource exploitation may weaken this relationship in resource-rich economies (Ryandiansyah, 2024). Testing this relationship in Riau is therefore relevant.

Previous Research. Previous studies report mixed relationships between human capital indicators and economic outcomes depending on regional context, period, and dependent variable. The relevant studies are summarized below.

Table 1. Summary of Previous Research

Researchers	Focus and Method	Key Findings
Huda (2018)	The influence of RLS, UHH, and per capita expenditure on economic growth in East Java Province 2014–2018 (panel data, REM)	UHH has a significant positive effect; RLS and per capita expenditure are not significant on economic growth
Elasticity Study of Journal of Development Economics (2025)	The influence of RLS, UHH, and open unemployment rate on the poor population of districts/cities in East Java 2017–2023 (panel data)	UHH has a significant negative effect on poverty; RLS has no significant effect
Ryandiansyah (2024)	Structural transformation, productivity, and the shift to the services sector in Indonesia 1998–2014	Dependence on mineral resources and the level of human capital does not have a significant impact on the low structural productivity of the Indonesian economy.
Study of the Human Development Index (HDI) of East Nusa Tenggara	The influence of UHH, HLS, and RLS on HDI through real expenditure per capita	UHH, HLS, and RLS have a positive effect on HDI, but HLS and per capita expenditure show a relatively low progressive contribution.
Study of Central Kalimantan's GRDP per capita	The influence of UHH and RLS on GRDP per capita and economic growth (path analysis)	RLS has a significant positive effect on GRDP per capita; UHH has a positive but insignificant effect

Overall, previous findings indicate that the effects of RLS, HLS, and UHH vary across economic outcomes. None of the five studies specifically examines the simultaneous effects of the three human capital indicators on the manufacturing industry's share at the regency/city level in a resource-rich province such as Riau. Thus, this study's novelty lies in its specific regional unit of analysis, the 2011–2024 observation period, and its focus on the manufacturing industry's share as a direct indicator of regional structural transformation.

Hypothesis Development. Mean Years of Schooling (RLS) reflects the existing educational stock of the workforce. Human capital theory suggests that workers with higher educational attainment possess better cognitive and technical skills and are more likely to enter skill-intensive sectors such as manufacturing. Therefore, RLS is expected to positively affect the manufacturing industry's share of GRDP.

Expected Years of Schooling (HLS) represents the expected educational attainment of the younger population. A higher HLS indicates greater potential for future human capital accumulation and may support the transition toward more skill-intensive industries. Therefore, HLS is expected to positively affect the manufacturing industry's share of GRDP.

Life Expectancy (UHH) reflects population health and longevity, which support productivity over the working life cycle. A healthier population may contribute to longer productive periods and stronger high-value-added sectors, including manufacturing. Therefore, UHH is expected to positively affect the manufacturing industry's share of GRDP.

Conceptual Framework. Based on the grand theories and previous research, this study examines the relationship between three human capital indicators—RLS, HLS, and UHH—and the share of Manufacturing Industry GRDP in the regional economic structure.

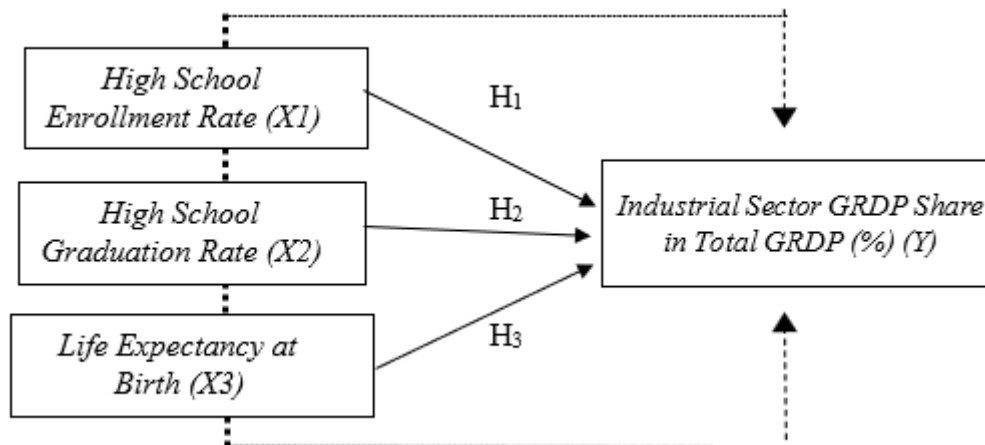


Figure 1. Conceptual Framework of the Research

Research Paradigm. This study adopts a causal-associative quantitative research paradigm to examine the causal relationships established through grand theory and previous research. Secondary panel data are used to empirically test the proposed relationships. The research process consists of grand theory, previous research, conceptual framework, hypothesis formulation, data collection, model estimation, and discussion.

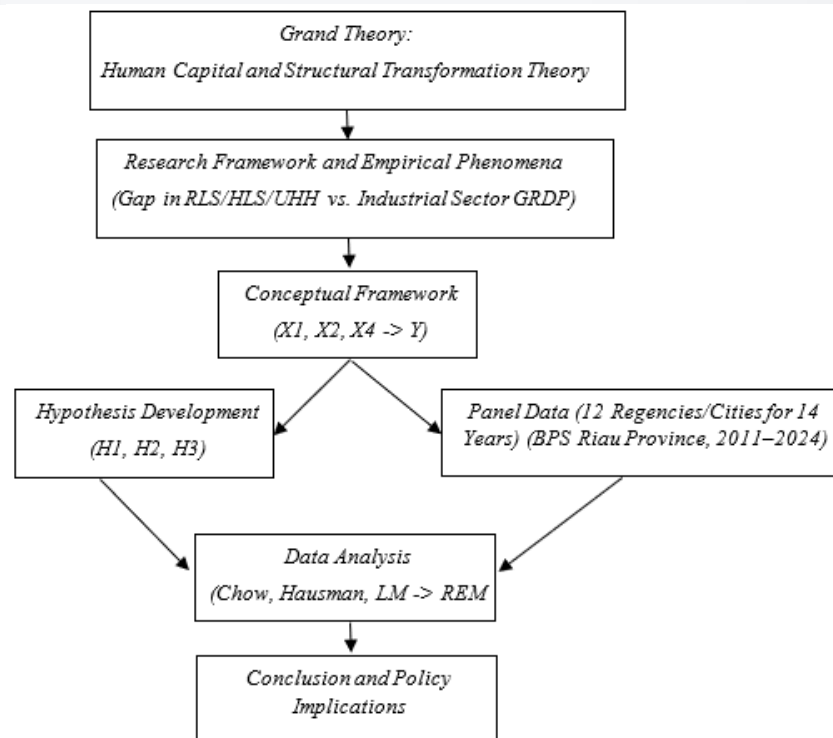


Figure 2. Research Paradigm

Research Hypothesis. Based on the conceptual framework and hypothesis development, the hypotheses are formulated as follows:

H1: Mean Years of Schooling (RLS) has a positive and significant effect on the share of Manufacturing Industry GRDP in total GRDP at current market prices (ADHB) in regencies/cities in Riau Province.

H2: Expected Years of Schooling (HLS) has a positive and significant effect on the share of Manufacturing Industry GRDP in total GRDP at current market prices (ADHB) in regencies/cities in Riau Province.

H3: Life Expectancy (UHH) has a positive and significant effect on the share of Manufacturing Industry GRDP in total GRDP at current market prices (ADHB) in regencies/cities in Riau Province.

H4: Mean Years of Schooling (RLS), Expected Years of Schooling (HLS), and Life Expectancy (UHH) simultaneously have a significant effect on the share of Manufacturing Industry GRDP in total GRDP at current market prices (ADHB) in regencies/cities in Riau Province.

METHODS

Types and Approaches of Research. This research is a quantitative study using a causal associative approach (ex post facto), which aims to examine causal relationships between variables that have already occurred without manipulating the treatment of the research subjects. This approach was chosen because the data used are historical secondary data that are given and cannot be controlled by the researcher.

Population and Sample. The population of this study is all regencies/cities in Riau Province, totaling 12 regencies/cities, namely Bengkalis, Indragiri Hilir, Indragiri Hulu, Kampar, Meranti Islands, Kuantan Singingi, Pelalawan, Rokan Hilir, Rokan Hulu, and Siak, as well as Dumai City and Pekanbaru City. The sampling technique uses saturated sampling (census), namely all members of the population are used as research samples, so that the cross-section unit of the study is 12 regencies/cities with a time series span of 14 years (2011–2024), resulting in balanced panel data of $12 \times 14 = 168$ observations.

Types and Sources of Data. The data used in this study are secondary time series and cross-site (panel) data sourced from official publications of the Central Statistics Agency (BPS) of Riau Province and districts/cities, including the publication of the Human Development Index (HDI) for RLS, HLS, and UHH data, as well as the publication of Gross Regional Domestic Product (GRDP) of Districts/Cities by Business Field for the share of GRDP of the Manufacturing Industry to the Total GRDP of ADHB. The dependent variable Y is calculated from

the ratio of GRDP of Business Field C (Processing Industry) at current prices to the Total GRDP of ADHB, multiplied by 100 percent, for each district/city in each observation year. Considering that the GRDP publications of districts/cities are published in series with overlapping year coverage, the compilation of the final data follows the rule of selecting the latest series of publications that still cover the relevant observation year in order to obtain the most up-to-date and methodologically consistent values.

Table 2. Operational Definitions of Variables

Variables	Name	Operational Definition	Unit	Data source
Y	Share of the Manufacturing Industry's GRDP to the Total GRDP of ADHB	(ADHB Processing Industry GRDP ÷ Total ADHB GRDP) × 100%	Percentage (%)	BPS Riau Province – Publication of Regency/City GRDP by Business Sector
X1	Average Years of Schooling (RLS)	The average number of years spent by people aged 25 years and over in formal education	Year	BPS Riau Province – Human Development Index Publication
X2	Expected Years of Schooling (HLS)	The expected length of schooling that children aged 7 years and above will experience in the future	Year	BPS Riau Province – Human Development Index Publication
X3	Life Expectancy (UHH)	The estimated average length of life from birth that a population will attain assuming a constant mortality pattern	Year	BPS Riau Province – Human Development Index Publication

Data Analysis Techniques. The data were analyzed using a panel data regression model with the help of EViews software. The general panel data regression model in this study is formulated as follows:

$$Y_{it} = \beta_0 + \beta_1 X_{1it} + \beta_2 X_{2it} + \beta_3 X_{3it} + e_{it}$$

Information.

	Y_{it}	= Regency/City Processing Industry GRDP
X_1	= RLS	
X_2	= HLS	
X_3	= UHH	
β_0	= Intercept	
$\beta_1, \beta_2, \beta_3, \beta_4$	= Coefficient regression at a time coefficient elasticity	
e	= Error term	
i	= Indicator country	
t	= Year indicator	

Panel data estimation can be performed using three approaches: the Common Effects Model (CEM), the Fixed Effects Model (FEM), and the Random Effects Model (REM). The selection of the best model is carried out through the following three testing stages.

- Chow test, to determine the best model between CEM and FEM. If the Cross-section F/Chi-square probability value is <0.05, then H₀ is rejected and the model chosen is FEM; conversely, if ≥ 0.05 then the model chosen is CEM.
- Hausman Test, to determine the best model between FEM and REM if the Chow Test results choose FEM. If the Chi-square probability value is <0.05, then H₀ is rejected and the model chosen is FEM; conversely, if ≥ 0.05 then the model chosen is REM.
- Lagrange Multiplier (LM) Test, to determine the best model between CEM and REM when the Hausman Test selects REM. If the Breusch–Pagan probability value is < 0.05, H₀ is rejected and REM is selected; otherwise, if the probability value is ≥ 0.05, CEM is selected.

In addition to the model selection test, this study also conducted a multicollinearity test using the Variance Inflation Factor (VIF) value to ensure there was no excessive correlation between independent variables that could interfere with the interpretation of partial coefficients, with the criteria of a VIF value <10 indicating no serious multicollinearity. Hypothesis testing was carried out through a t-test (partial) to test H₁–H₃, an F-test (simultaneous) to test H₄, and a coefficient of determination (R²) to measure the extent of the independent variable's ability to explain variations in the dependent variable. The testing criteria used a significance level (alpha) of 5 percent, namely H₀ was rejected if the probability value <0.05.

RESULT AND DISCUSSION

General Description of Research Object. Riau Province is one of the provinces with the largest contribution to GRDP outside Java, and its economy has historically been supported by the oil and gas mining sector. In recent years, the role of the oil and gas sector has gradually declined due to the natural decline in production from mature wells, while the processing industry sector, which includes oil refining, palm oil and its derivatives, and the pulp and paper industry, has grown to become one of the main pillars of the regional economic structure, alongside the agriculture, forestry, and fisheries sectors.

Descriptive Statistics. Descriptive statistics of research variables during the period 2011–2024 (168 observations) are presented in Table 3.

Table 3. Descriptive Statistics of Research Variables (N = 168)

Statistic	Y	X1	X2	X3
Mean	28,25676	8,658155	12,60738	69,84304
Median	24,81287	8,525	12,68	70,175
Maximum	61,79405	11,96	15,84	73,21
Minimum	6,785108	6,27	10,49	66,17
Std. Dev.	12,51706	1,202588	1,014769	1,57518
Skewness	1,0847	0,710463	0,733335	-0,55226
Kurtosis	3,426418	3,2649	4,563945	2,67055
Jarque-Bera	34,21693	14,62441	32,17932	9,299475
Probability	0	0,000667	0	0,009564
Sum	4747,136	1454,57	2118,04	11733,63
Sum Sq. Dev.	26165,03	241,5183	171,9692	414,3592
Observations	168	168	168	168

Source: EVIEWS 12 Output Results (2026)

The average share of GRDP of the processing industry in 12 regencies/cities in Riau during 2011–2024 was 28.26 percent with quite large inter-regional variations (standard deviation 12.52), ranging from 6.79 percent to 61.79 percent. This wide variation indicates the heterogeneity of the economic structure between regencies/cities, from regions that are highly dependent on oil and gas and commodity-based processing industries (such as Dumai and Pelalawan) to regions whose economic structure is more dominated by the service and trade sectors (such as Pekanbaru City). Meanwhile, the three human capital variables showed a relatively stable upward trend with much smaller inter-regional variations compared to variations in the share of the processing industry, indicating that the convergence of human capital between regencies/cities in Riau is progressing faster than the convergence of their economic structures. Development of the Share of GRDP of the Processing Industry to the Total GRDP of ADHB, 12 Regencies/Cities in Riau, 2011–2024.

Table 4. Development of Average Share of GRDP of the Manufacturing Industry in 12 Regencies/Cities in Riau, 2011–2024

Regency/City	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Bengkalis	7.28	6.79	6.99	7.64	10.4	11.7	12.9	11.8	13.2	17.2	16.2	14.8	15.7	15.5
Indragiri Hilir	24.6	25.1	25.4	24.5	24.8	24.5	23.7	24.1	23.6	24.1	24.6	25.1	24.1	25.6
Indragiri Hulu	24.4	24.6	25.4	26.1	28.1	28.5	28.5	27.7	27.4	28.3	28.2	27.4	27	27.5

Regency/City	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Kampar	21.8	21	20.4	19.7	22	22.4	23	22	23.5	25.9	25.4	24.2	24.1	24.6
Meranti Islands	22.2	20.7	21.3	21.3	23.8	24.2	24.8	23.6	24.6	26.2	25.7	24.5	23.7	23.5
Dumai City	51.4	49.3	51.4	52.9	53.2	54	54.8	56.4	57.7	60	60.8	61.8	61.3	60.4
Pekanbaru City	20.9	20.6	20.3	19	20	20	19.9	19.5	19.1	20.8	21.1	21.1	20.1	20.6
Kuantan Singingi	24.3	25.3	26.3	25.8	26.9	27.5	27.8	28.2	28	27.7	27.9	27.7	25.7	26
Pelalawan	51.5	50.1	48.6	48.7	48.8	48.9	48.9	49	49.1	48.7	48.4	49.1	48.8	48.9
Rokan Hilir	13.4	13.9	14.1	13.4	15.5	16.2	17.4	16.7	18	21.5	21.2	20.4	19.8	19.9
Rokan Hulu	21.4	21.5	22.2	22.2	23.9	24.7	25.6	25.2	25.1	25.3	25.1	26.4	26	25.7
Siak	30.7	26.4	27.5	29.4	34.8	35.4	35.7	34.7	37	42.2	40.5	38.7	40	41.1

Source: BPS 12 Districts/Cities, 2011-2024

Table 4 shows that based on data from 2011–2024, the highest overall share of the manufacturing industry is found in Dumai City, amounting to 61.79% in 2022. This high contribution indicates the strong industrial-based economic structure in Dumai City. In 2024, the manufacturing industry was also recorded as one of the main sectors in the economic structure of Dumai City (BPS Dumai City, 2025). Conversely, the lowest overall value is found in Bengkalis Regency, amounting to 6.79% in 2012. The low share of the manufacturing industry can be attributed to the Bengkalis economic structure which has strong links with the mining and quarrying sector, including oil and gas activities. The dominance of this sector causes the relative contribution of the manufacturing industry sector to the total GRDP to be smaller (BPS Bengkalis Regency, 2025). In Indragiri Hilir Regency, the share of the processing industry ranged from 23.63% in 2019 to 25.55% in 2024. This condition indicates that the processing industry has a significant role in the regional economic structure. The potential of plantation resources and the primary sector in Indragiri Hilir is one of the bases that can support the development of a processing industry based on local resources (BPS Indragiri Hilir Regency, 2025). Meanwhile, the high share of the processing industry in Pelalawan Regency, which reached 51.50% in 2011, indicates the strong role of the industrial sector in the regional economic structure. Pelalawan Regency has large-scale processing industry activities that make a significant contribution to the formation of regional GRDP (BPS Pelalawan Regency, 2025). Siak Regency showed an increase from the lowest value of 26.42% in 2012 to 42.20% in 2020. The high contribution of the processing industry shows the increasing importance of this sector in the economic structure of Siak Regency and reflects the development of industrial activity in the area (BPS Siak Regency, 2024).

In general, differences in the share of the manufacturing industry between districts/cities in Riau Province primarily reflect differences in regional economic structures. Regions with large and growing manufacturing activity tend to have higher industry shares, while regions whose economic structures are more dominated by the primary sector or mining have relatively lower processing industry shares (BPS Riau Province, 2025).

Multicollinearity Test. Before estimating the panel model, a multicollinearity test was conducted between independent variables using a correlation matrix, as presented in Table 4.

Table 5. Descriptive Statistics of Research Variables (N = 168)

Correlation			
	X1	X2	X3
X1	1.000000	0.834732	0.818699
X2	0.834732	1.000000	0.580668
X3	0.818699	0.580668	1.000000

Source: Eviews 12 Output Results (2026)

The correlation matrix in Table 4 shows a fairly high correlation between X1 and X2 ($r = 0.835$) and between X1 and X3 ($r = 0.819$), which is a logical consequence because all three are components that form the Human Development Index which naturally move in the same direction over time in a region. so that formally there is no serious multicollinearity according to general criteria because all correlation values between independent variables are still below 0.90, it can be concluded that the research model does not experience serious multicollinearity problems. Thus, the variables Average Years of Schooling (X1), Expected Years of Schooling (X2), and Life Expectancy (X3) can be used together in a panel data regression model.

Estimation Model Selection Test. Chow Test.

Table 6. Chow Test Results

Redundant Fixed Effects Tests			
Equation: Untitled			
Cross-section fixed effects test			
Effects Test	Statistics	df	Prob.
Cross-section F	454.335783	(11,153)	0.0000
Cross-section Chi-square	590.763389	11	0.0000

Source: EViews 12 Output Results (2026)

The Cross-section F and Chi-square probability values of 0.0000 (< 0.05) indicate that H_0 is rejected, so the Fixed Effect Model (FEM) is a better model than the Common Effect Model (CEM). The test is continued with the Hausman Test to determine the choice between FEM and REM.

Hausman Test.

Table 7. Hausman Test Results

Correlated Random Effects - Hausman Test			
Equation: Untitled			
Cross-section random effects test			
Test Summary	Chi-Sq. Statistic	Chi-Sq. df	Prob.
Random cross-section	7.000192	3	0.0719

Source: EViews 12 Output Results (2026)

The Hausman Test probability value of 0.0719 (> 0.05) indicates that H_0 is not rejected, so the chosen model is the Random Effect Model (REM) compared to FEM. The test is continued with the Lagrange Multiplier Test to ensure that REM is better than CEM.

Lagrange Multiplier (LM) Test.

Table 8. Lagrange Multiplier (LM) Test Results

Lagrange Multiplier Tests for Random Effects			
Null hypotheses: No effects			
Alternative hypotheses: Two-sided (Breusch-Pagan) and one-sided			
(All others) alternatives			
	Test Hypothesis		
	Cross-section	Time	Both
Breusch-Pagan	767.7371 (0.0000)	0.867003 (0.3518)	768.6041 (0.0000)
Honda	27.70807 (0.0000)	0.931130 (0.1759)	20.25097 (0.0000)

Lagrange Multiplier Tests for Random Effects

King-Wu	27.70807 (0.0000)	0.931130 (0.1759)	21.02296 (0.0000)
Standardized Honda	32.97665 (0.0000)	1.241833 (0.1071)	19.33201 (0.0000)
Standardized King Wu	32.97665 (0.0000)	1.241833 (0.1071)	20.31414 (0.0000)
Gourieroux, et al.	--	--	768.6041 (0.0000)

Source: EVIEWS 12 Output Results (2026)

The Breusch-Pagan cross-section probability value of 0.0000 (<0.05) indicates that H_0 is rejected, so the chosen model is REM over CEM. Based on the series of three tests above (Chow, Hausman, and LM), the best estimation model used in this study is the Random Effect Model (REM).

Results of Selected Model Estimation (Random Effect Model)

Table 9. Random Effect Model (REM) Estimation Results

Dependent Variable: Y				
Method: Panel EGLS (Cross-section random effects)				
Date: 09/06/26 Time: 21:35				
Sample: 2011 2024				
Periods included: 14				
Cross-sections included: 12				
Total panel (balanced) observations: 168				
Swamy and Arora estimator of component variances				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	9.348736	32.32974	0.289168	0.7728
X1	3.189089	1.007013	3.166880	0.0018
X2	0.594134	0.592965	1.001972	0.3178
X3	-0.231864	0.552062	-0.419996	0.6750
Effects Specification			S.D.	Rho
Cross-section random			11.20933	0.9677
Idiosyncratic random			2.047704	0.0323
Weighted Statistics				
Root MSE	2.047705	R-squared	0.364472	
Mean dependent var	1.377935	Adjusted R-squared	0.352846	
S.D. dependent var	2.576299	S.E. of regression	2.072526	
Sum squared resid	704.4399	F-statistic	31.35100	
Durbin-Watson stat	0.414206	Prob(F-statistic)	0.000000	

Dependent Variable: Y

	Unweighted Statistics		
R-squared	-0.033095	Mean dependent variable	28.25676
Sum squared residual	27030.97	Durbin-Watson stat	0.010794

Source: EVIEWS 12 Output Results (2026)

Based on Table 8, the panel data regression equation of the REM model formed is as follows:

$$Y = 9.3487 + 3.1891 X1 + 0.5941 X2 - 0.2319 X3 + \epsilon it$$

The constant value of 9.3487 indicates that if RLS, HLS, and UHH are zero, the share of GRDP of the manufacturing industry is estimated at 9.35 percent (this value has no practical substantive meaning because empirically the value of the three independent variables never approaches zero, but is mathematically required as a model cutoff point). The X1 (RLS) coefficient of 3.1891 indicates that every additional 1 year of RLS is estimated to increase the share of the manufacturing industry by 3.19 percentage points, *ceteris paribus*. The X2 (HLS) coefficient of 0.5941 and the X3 (UHH) coefficient of -0.2319 indicate a statistically insignificant direction of influence as will be discussed further in the hypothesis testing section.

Hypothesis Testing. Partial Test (t-Test)

- Variable X1 (RLS) has a probability value of $0.0018 < 0.05$ with a positive coefficient (3.189), so H1 is accepted: RLS has a positive and significant effect on the share of GRDP in the processing industry.
- Variable X2 (HLS) has a probability value of $0.3178 > 0.05$, so H2 is rejected: HLS does not have a significant effect on the share of GRDP in the processing industry.
- Variable X3 (UHH) has a probability value of $0.6750 > 0.05$, so H3 is rejected: UHH does not have a significant effect on the share of GRDP in the processing industry.

Simultaneous Test (F Test). The F-statistic value of 31.351 with a probability of $0.000000 < 0.05$ shows that simultaneously RLS, HLS, and UHH have a significant effect on the share of GRDP in the processing industry, so H4 is accepted.

Coefficient of Determination (R^2). The weighted R-squared value of 0.364472 indicates that 36.45 percent of the variation in the share of GRDP of the processing industry in 12 districts/cities in Riau can be explained jointly by variations in RLS, HLS, and UHH, while the remaining 63.55 percent is explained by other factors outside the model, such as the existence of natural resources, investment, infrastructure, and industrial downstream policies in each district/city.

The Effect of Average Years of Schooling (ADL) on the Share of the Manufacturing Industry. The estimation results show that RLS has a positive and significant effect on the GRDP share of the manufacturing industry (coefficient 3.189; $p=0.0018$), thus H1 is accepted. This finding is consistent with the human capital theory proposed by Schultz (1961) and Becker (1993), which states that the realized stock of labor education increases the productivity and adaptability of the workforce to the needs of the industrial sector, which is more complex than the primary sector. Empirically, this finding is also in line with research in the context of Central Kalimantan, which found RLS to have a significant positive effect on GRDP per capita. In the context of Riau, districts/cities with relatively high RLS, such as Dumai City and Siak Regency, also show a relatively high share of the manufacturing industry, in line with the need for skilled labor in the oil refining and palm oil-based industries operating in both regions. With a relatively large coefficient magnitude (each additional year of RLS is associated with a 3.19 percentage point increase in industrial share), the RLS variable is proven to be the most substantive determinant of human capital in encouraging the strengthening of the regional processing industry structure compared to HLS and UHH.

The Effect of Expected Years of Schooling (HLS) on the Share of the Processing Industry. In contrast to RLS, HLS was not shown to have a significant effect on the share of GRDP in the manufacturing industry (coefficient 0.594; $p=0.3178$), thus H2 was rejected. There are several theoretical and empirical reasons that can explain this finding. First, conceptually, HLS measures the projected length of education of 7-year-olds who have just entered formal education and have not yet participated in the labor market. Thus, the effect of HLS on economic structure is forward-looking and involves a substantial time lag (tens of years), making its effect on the contemporary economic structure, particularly the manufacturing industry's share in the current year, difficult to detect statistically using the 14-year observation period in this study. Second, the results of the multicollinearity

test in Table 4 show a high correlation between HLS and RLS ($r=0.835$), which indicates the possibility of overlapping information (shared variance) between the two. When RLS has absorbed most of the relevant variation in Y, the additional (marginal) contribution of HLS to the explanation of Y becomes statistically insignificant even though the coefficient remains positive in the theoretical direction. Third, this finding is consistent with Huda's (2018) research in East Java Province which also found that education indicators (in this case RLS) did not have a significant effect on economic growth, indicating that education indicators based on projections or macro-aggregate stocks tend to provide a weaker signal to short- to medium-term economic performance compared to realized education indicators. Fourth, in terms of labor market structure, most of Riau's mainstay processing industries (oil refining, basic palm oil processing, pulp and paper) are capital-intensive and machine-intensive technology-intensive so that the absorption of new educated workers (higher education graduates resulting from the increase in HLS) is relatively limited compared to its absorption in the modern service sector in large cities such as Pekanbaru City, so that the increase in HLS in a region is not automatically absorbed into the processing industry sector of the same region.

The Effect of Life Expectancy (UHH) on the Share of the Processing Industry. The UHH variable did not have a significant effect on the share of the processing industry's GRDP (coefficient = -0.232 ; $p = 0.6750$); therefore, H3 was rejected. The coefficient was negative, contrary to the hypothesized direction. Based on the data and literature, several factors may explain this insignificant effect. First, the variation in UHH across Riau's regencies/cities is relatively narrow, with a standard deviation of only 1.58 years from an average of 69.84 years, or a coefficient of variation of approximately 2.3 percent, compared with approximately 44 percent for Y. This limited variation makes it statistically difficult to detect a significant effect on the more varied dependent variable and represents a data-driven limitation rather than simply a rejection of the theory. Second, UHH is highly correlated with RLS and HLS ($r = 0.819$ and $r = 0.581$, respectively), as all three indicators are influenced by improvements in regional welfare, including income, health infrastructure, and access to education. When RLS explains much of the variation in Y associated with human development, the partial contribution of UHH may become insignificant and produce a coefficient sign reversal, a common issue when predictors are highly correlated. Third, Riau's main processing industries, including oil refining, upstream palm oil processing, and pulp and paper, are capital-intensive, with productivity determined more by machinery, production scale, and natural-resource availability than by workforce health or life expectancy. This is consistent with Ryandiansyah (2024), who found that mineral-resource dependence and overall human capital did not significantly affect Indonesia's structural productivity, suggesting that in resource-dependent economies, the transmission from population health to industrial development tends to be weak and indirect. Fourth, Pekanbaru, which has the highest UHH in Riau (average 72.07 years), has a relatively low processing-industry share because its economy is dominated by trade, financial services, and government activities rather than manufacturing. This urban service-oriented structure may therefore be negatively associated with the processing industry's share in the panel data.

Simultaneous Discussion and Model Limitations. Simultaneously, the F test results show that RLS, HLS, and UHH together have a significant effect on the share of GRDP in the processing industry ($F=31.351$; $p=0.000$), which means that the overall human capital dimension remains relevant as a factor explaining variations in the economic structure of districts/cities in Riau, although partially the significant contribution is driven more by RLS. The weighted R^2 value of 0.3645 is classified as moderate for cross-regional panel data, indicating that in addition to human capital, there are other structural factors that are more dominant in explaining the share of the processing industry in Riau, especially the existence of natural resource endowments (oil and gas reserves, oil palm plantation land, and wood raw materials for pulp), physical capital investment in processing facilities (refineries, palm oil mills, pulp and paper mills), infrastructure accessibility (ports and roads), and policies promoting downstream industrial development in each region, which are not included as explicit variables in this model.

It should also be noted that the Durbin-Watson statistic value in the weighted REM model is relatively low (0.414), indicating autocorrelation in the panel data, a common phenomenon in time-series cross-sectional data with a 14-year observation period, because regional economic structures tend to persist from year to year. This autocorrelation does not cause bias in the REM estimator but may affect the efficiency of the standard errors. Therefore, caution is needed when generalizing the significance of the findings, and future research may consider Driscoll-Kraay standard error correction or dynamic panel specifications.

CONCLUSION

Based on the results of the Random Effect Model panel data regression analysis in 12 districts/cities in Riau Province for the period 2011–2024, several conclusions can be drawn. First, Average Years of Schooling (RLS) has a positive and significant effect on the share of GRDP in the manufacturing industry, indicating that the realized stock of workforce education is the strongest determinant of human capital in driving the strengthening of the regional manufacturing industry structure. Second, Expected Years of Schooling (HLS) and Life Expectancy (UHH) are not proven to have a significant effect, indicating that long-term education investment and population health have not been fully transmitted to strengthen the manufacturing sector at the district/city level, possibly due to the characteristics of Riau's mainstay processing industry which is capital-intensive and relies on natural resources, as well as the high correlation between human capital indicators that makes it difficult to detect the partial influence of each variable. Third, simultaneously, RLS, HLS, and UHH have a significant effect on the share of GRDP in the manufacturing industry with a model explanatory power of 36.45 percent, confirming that human capital remains a relevant factor although not the sole determinant of Riau's economic structural transformation.

Theoretical Implications. This study provides empirical evidence that the relevance of human capital theory to the structural transformation of regional economies is conditional (context-dependent), not uniformly applicable to all components of human capital. In natural resource-rich regions such as Riau, the influence of human capital on strengthening the manufacturing industry sector is driven more by the realized stock of education (RLS) than by projections of future education (HLS) or the health dimension (UHH). Therefore, this study enriches the literature by demonstrating the need to moderate human capital theory with the structural characteristics of regional economies (resource-based economies) when applied at the subnational level.

Practical and Policy Implications. Practically, these findings imply that the regional government's strategy to drive economic transformation through strengthening human capital needs to be focused not only on expanding access to education (as reflected in HLS), but also on improving the quality and relevance of education that has been taken by the current workforce (RLS), especially through vocational education and technical skills training that are aligned with the needs of the local resource-based processing industry (palm oil, oil and gas, and pulp and paper). The Riau Provincial Government and district/city governments need to synergize education policies with the industrial downstreaming agenda, so that the increase in human capital achievements is truly absorbed by expanding employment in the manufacturing sector, not simply increasing the human development index without being followed by real structural transformation. Suggestions and recommendations:

a. For the Riau Provincial Government and district/city governments, it is recommended to strengthen vocational and polytechnic education that is oriented towards the needs of the region's leading natural resource processing industry (palm oil, oil and gas, pulp and paper), while simultaneously encouraging industrial downstreaming so that the absorption of educated workers increases in line with the increase in RLS and HLS.

b. Health development policies still need to be continued as a long-term investment in human resource quality, although their direct impact on the share of the processing industry has not been seen to be significant in the short-to-medium term in this study; the benefits of UHH on productivity are likely more cross-generational and require a longer observation period to be statistically detected.

c. For further researchers, it is recommended to expand the model by adding other structural variables such as investment realization (PMDN/PMA), infrastructure, and natural resource endowment dummy variables (oil and gas/non-oil and gas) to increase the model's explanatory power, as well as considering a dynamic model (dynamic panel/GMM) or robust standard error correction (Driscoll-Kraay) to address the indications of autocorrelation found in this study.

d. For industry players, the results of this study can be considered in designing education-industry partnership programs (link and match) in districts/cities with relatively low RLS, so that the availability of local skilled labor can support the sustainability of processing industry operations in the region.

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