

IMPACT OF TOLL ROAD ENTRY POINTS ON THE GROSS REGIONAL DOMESTIC PRODUCT (GRDP) OF REGENCIES AND CITIES IN JAVA ISLAND

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Abstract

This study aims to evaluate the impact of toll road access on the Gross Regional Domestic Product (GRDP) of regencies/municipalities in Java in 2024 by employing the Propensity Score Matching (PSM) method to address selection bias. Transportation infrastructure development, particularly toll roads, constitutes a strategic instrument in promoting regional economic development in Indonesia, especially in reducing relatively high logistics costs. This study uses secondary data obtained from the Central Statistics Agency (BPS), covering a total of 119 observations. The variables include GRDP at constant prices in 2024 as the dependent variable, as well as population density and industrial share in 2015 as control variables. The analysis is conducted through propensity score estimation using a probit model, a matching process, and impact evaluation using the Average Treatment Effect (ATE) and Average Treatment Effect on the Treated (ATT). The results indicate that population density and industrial structure have a positive and significant effect on the probability of a region having toll road access. The PSM estimation shows that toll road development has a positive and significant impact on increasing GRDP. The Average Treatment Effect (ATE) value of 0.4982 indicates that, on average, toll road development increases GRDP by 49.82% across all regions. Meanwhile, the Average Treatment Effect on the Treated (ATT) value of 0.6990 indicates that regions with toll road access experience a higher increase in GRDP, reaching 69.90%. The difference between ATT and ATE suggests that the impact of toll road development is more optimal in regions with stronger structural readiness, such as high population density and a strong industrial base. Therefore, toll road development is proven to be effective in driving regional economic growth, but it also has the potential to widen interregional inequality if not accompanied by more equitable development policies.

Keywords: Toll Roads, GRDP, Propensity Score Matching, ATE, ATT, Economic Growth

INTRODUCTION

The development of transportation infrastructure serves as one of the main pillars of Indonesia's regional economic development strategy. As the island with the largest economic contribution, Java faces challenges from high logistics costs, which account for 24% of the national Gross Domestic Product (GDP). The government has responded to this situation by accelerating the construction of inter-regency and inter-city toll roads to enhance distribution efficiency and connectivity. Theoretically, this improved accessibility is expected to stimulate regional economic output, as reflected in the 2024 Gross Regional Domestic Product (GRDP). This aligns with the findings of Maryaningsih, Hermansyah, and Savitri (2014), published in the Buletin Ekonomi Moneter dan Perbankan, which state that the availability of road infrastructure has a positive and

significant correlation with regional economic growth through increased productivity of production factors.

However, the impact of toll roads on GRDP is heterogeneous and highly dependent on the intrinsic characteristics of the region. This study deepens the analysis by incorporating two main control variables (covariates): Population Density and Industrial Share. Population density represents market scale and labor availability, while industrial share reflects the regional economic structure in absorbing logistics benefits. Prasetyo and Firdaus (2015), in their study published in *Jurnal Ekonomi dan Kebijakan Pembangunan*, affirm that regions with a strong manufacturing industrial base tend to respond more quickly to transportation infrastructure compared to agrarian areas due to the industrial sector's reliance on supply chain efficiency. Therefore, without considering these characteristics, the analysis of the infrastructure's impact on the regional economy becomes less accurate.

One of the main challenges in assessing the impact of toll roads is the presence of selection bias. Toll road development does not occur randomly but is typically prioritized in established, densely populated areas with strong economies. If the impact is analyzed simply by comparing regions with toll roads to those without, the results may be biased. As stated in the academic literature on infrastructure impact evaluation, traditional approaches cannot separate the true effects of toll road construction from the region's natural growth.

To address this issue, this study applies the Propensity Score Matching (PSM) method. PSM is used to create a quasi-experimental setting by pairing (matching) regencies/cities with toll roads to control areas (without tolls) that have similar characteristics in population density and industrial structure. This strategy allows for an apples-to-apples comparison across regions. Drawing on Sakti and Thohari (2020), published in *Jurnal Ekonomi dan Pembangunan Indonesia*, the matching approach constructs an objective counterfactual group, enabling estimation of the Average Treatment Effect (ATE) the net impact of toll road development on 2024 GRDP. This method is expected to yield evidence-based policy recommendations for future infrastructure development.

LITERATURE REVIEW AND HYPOTHESIS FORMULATION

2. 1 Theory of Economic Growth and Infrastructure

The development of toll roads on Java Island, particularly between regencies/cities, aims to enhance inter-regional connectivity, reduce transportation costs, and promote efficiency in the distribution of goods and services. Regional economic growth and improved accessibility can boost productivity, investment, and local economic activities, as reflected in increases in Gross Regional Domestic Product (GRDP) (Todaro & Smith, 2015). Furthermore, from a regional economics perspective, transportation infrastructure serves as an enabling factor that enhances regional productivity and competitiveness by reducing logistics costs.

The New Economic Geography theory, proposed by Paul Krugman (1991), explains that improved connectivity from transportation infrastructure development can drive economic agglomeration, where economic activities tend to concentrate in certain areas with better accessibility. This can increase production efficiency through economies of scale but may also lead to inter-regional disparities. Additionally, according to David Aschauer (1989), investments in public infrastructure such as toll roads have a positive impact on private sector productivity, as such infrastructure acts as public capital supporting various economic activities.

2.2 Evaluation of Impacts and Selection Bias

Areas with toll road development typically have characteristics such as high population density and developed industrial structures, which can lead to selection bias (Wooldridge, 2016). Therefore, Propensity Score Matching (PSM) research aims to compare areas with and without toll roads that have similar initial characteristics. This method enables a more causal

estimation of the impact of toll road development on GRDP through the calculation of the Average Treatment Effect on the Treated (ATT) (Rosenbaum & Rubin, 1983).

Additionally, the concept of spillover effects is relevant in this context, where toll road development not only impacts the directly traversed areas but also surrounding regions through improved accessibility and inter-regional economic interactions. This aligns with the theory that infrastructure can create multiplier effects on local economic activities. Thus, the analysis of toll road development impacts must consider not only direct effects but also indirect effects on regional economic growth.

RESEARCH METHODS

This study utilizes secondary data sourced from the Central Bureau of Statistics (BPS). The population comprises 119 regencies/cities on the island of Java, while the sample includes regencies/cities on Java with and without access to toll gate exits as the control variable. Log-transformed 2024 GRP-ADHK (Gross Regional Domestic Product at Constant Prices) serves as the dependent variable (outcome), with population density in 2015 and industrial share in 2015 as independent variables (covariates).

GRP-ADHK (Gross Regional Domestic Product at Constant Prices) represents the total value of goods and services produced in a regency/city within a year, calculated using prices from a specific reference year. Population density indicates the average number of inhabitants per unit area of the regency/city territory. Industrial share (contribution of the industrial sector) is the percentage reflecting the role of the manufacturing industrial sector in forming the total economic value (GRP) of the regency/city.

The obtained data are analyzed using the Propensity Score Matching (PSM) method. This approach is based on distinct groups within the sample: the treatment group and the control group (those not receiving treatment). PSM was selected to estimate the causal impact of toll gate access on GRP and to address potential selection bias in analyzing the effect of a treatment.

Classification of Groups

Treatment Group (T=1): Regencies/cities on Java with operational toll gate access

Control Group (T=0): Regencies/cities on Java without toll gate access but possessing socio-economic characteristics similar to the treatment group

Mean Difference Test

The analysis begins by comparing the mean Log GRP between the treatment and control groups. This test examines initial aggregate economic differences before controlling for regency/city characteristics.

Propensity Score Estimation

A Probit model is employed to calculate the probability of a regency/city gaining toll road access based on its regional characteristics.

Matching

Matching is performed between treatment units and control units with the most similar propensity scores.

Average Treatment Effect on the Treated (ATT) and Average Treatment Effect (ATE)

ATT measures the actual impact experienced by regencies/cities with toll access. ATE measures the average impact if all regencies/cities received the treatment.

Weighted Regression

This study employs Weighted Regression, utilizing weights generated from the prior matching process to ensure the consistency of the toll access effect on GRP after controlling for population density and industrial share variables.

Formula

$$Y_i = a + bPSM_i + cX_i + \epsilon_i$$

Description:

Y_i (Dependent Variable)	:	The outcome variable to be measured
a	:	The mean value of Y when all independent variables are zero
b	:	The parameter indicating the magnitude of the treatment effect on Y
PSM_i (Treatment Dummy)	:	$T = 1$ if receiving treatment, and $T = 0$ if not receiving treatment
c	:	The magnitude of the effect of control variables on Y
X_i (Covariate)	:	Variables influencing Y
e_i (Error Term)	:	The error capturing the influence of external factors that affect Y

RESULTS AND DISCUSSION

5.1 Distribution of Sample Locations

The research data cover a total of 119 districts/cities on Java Island. The table below details the regional distribution according to whether a district/city has access to a toll-road entrance.

Table 1. Composition of Sample Groups (Treatment vs Control)

Group	Category	Frequency	Percentage (%)	Cumulative (%)
Control (0)	Without toll-road access	45	37.82	37.82
Treatment (1)	With toll-road access	74	62.18	100.00
Total		119	100.00	

Source: Processed Secondary Data, 2026

Based on toll-road-entrance access on Java Island, the total sample consists of 119 observations divided into two groups: value 0 represents the control group, and value 1 represents the treatment group. The frequency column shows that the majority of the sample 74 districts (62.18%) already have access to a toll-road entrance, whereas the remaining 45 districts (37.82%) are not yet integrated into the toll-road network. The relationship between Percentage and Cumulative Percentage confirms that all data have been entered without any missing values, thereby providing a robust and balanced basis for examining economic impacts in the subsequent analysis.

5.2 Descriptive Analysis and Initial Difference Test (T-Test)

The first step in the analysis is to compare the mean PDRB (GDP) between regions with toll-road access (Group 1) and those without (Group 0).

Table 2. Comparison of Mean Log PDRB (T-test)

Group	Obs	Mean (Log PDRB)	Std. Dev	[95% Conf. Interval]
Control (0)	45	10.01974	0.707041	9.807319 - 10.23216
Treatment (1)	74	10.70494	1.101075	10.44984 - 10.96004
Difference		0.6852056		p-value = 0.0003

Source: Processed Secondary Data, 2026

The analysis in the table shows a statistically significant difference in economic conditions between districts/cities on Java Island with and without toll-road access. The mean Log PDRB in regions with toll-road access (10.705) exceeds that in regions without access (10.020). This difference of 0.685 indicates that, on average, districts connected to the toll-road network have an economic output level approximately 68.5% higher than districts without toll-road entrances. The significance of this finding is reinforced by a p-value of 0.0003 (significant at $\alpha = 5\%$), confirming that this difference is not attributable to chance but reflects

a strong association between toll-road infrastructure and regional economic advancement. However, this difference of 0.685 is still biased because the location of toll-road entrances is not randomly assigned. Therefore, the probability of treatment assignment must be estimated using a Probit model.

5.3 Estimating the Propensity Score (Probit Model)

The results of the propensity score estimation using the Probit model are presented below.

Table 3. Estimation of the Propensity Score Using the Probit Model

Variable	Coefficient	Std. Error	z-stat	p-value
Population density (2015)	0.000131	0.0000406	3.22	0.001
Share of industry (2015)	0.0230924	0.0079974	2.89	0.004
Constant	-0.5474729	0.232518	-2.35	0.019

Source: Processed Secondary Data, 2026

The Probit results show that the population density in 2015 has a coefficient of 0.000131 and a p-value of 0.001 (significant at $\alpha = 5\%$). This indicates that population density in 2015 has a positive and statistically significant effect on the probability that a district/city will obtain toll-road access or a toll-road entrance. In other words, the higher the population density in a region, the greater the probability that the region will receive a toll-road entrance.

The share of industry in 2015 has a coefficient of 0.0230924 and a p-value of 0.004 (significant at $\alpha = 5\%$). This indicates that the industrial share in 2015 positively and significantly affects the probability of having a toll-road entrance. The larger the proportion of the industrial sector in a region's economic structure, the higher the probability that the region will have a toll-road entrance. This reflects that toll-road infrastructure tends to be concentrated in areas with relatively more intensive economic activity.

The estimated coefficients indicate that demographic and economic-structure characteristics play an important role in determining the probability that a district/city will receive a toll-road entrance. Regions with higher population density are likely to have greater mobility needs and therefore receive priority in infrastructure development. In contrast, regions with a larger industrial share reflect higher economic activity, and large-scale industrial activity requires smooth transportation access to support economic operations, making toll-road access particularly important.

Table 4. Summary of the Model

Statistic	Value
Number of observations	119
LR Chi-square (2)	22.73
Prob > Chi-square	0.0000
Pseudo R ²	0.1440
Log likelihood	-67.5508

Source: Processed Secondary Data, 2026

The model is estimated using 119 observations. The LR Chi-square statistic of 22.73 with a Prob > Chi-square of 0.0000 indicates that the model is jointly significant, meaning that the independent variables together significantly affect the probability of having a toll-road entrance. Furthermore, the pseudo-R² of 0.1440 indicates that the model explains approximately 14.4% of the variation in this probability. This suggests that although the model is significant, other factors outside the model also influence the likelihood of obtaining a toll-road entrance.

5.4 Frequency Distribution of Matched Control Units (Matched Controls)

Table 5. Distribution of Control-Unit Weights (Matched Controls)

Matched Controls	Freq.	Percent (%)	Cum. (%)
1	13	50.00	50.00
2	4	15.38	65.38
3	3	11.54	76.92
4	2	7.69	84.62
5	1	3.85	88.46
9	1	3.85	92.31
10	1	3.85	96.15
12	1	3.85	100.00
Total	26	100.00	

Source: Processed Secondary Data, 2026

The table shows that, out of a total of 26 matched uses of control units, most control units are used infrequently once to three times. Thirteen control units (50%) are used once, four units (15.38%) are used twice, and three units (11.54%) are used three times. By contrast, as the frequency of use increases, the number of control units becomes increasingly limited: only two units (7.69%) are used four times, and one unit each (3.85% each) are used five, nine, ten, and twelve times. This indicates that certain control units have characteristics that are closest to several treatment units and are therefore matched repeatedly in the matching process.

5.5 Estimating the Impact of Toll-Road Entrances on Log PDRB Using PSM

The impact analysis in this study proceeds in two stages to ensure result accuracy. The first stage examines the change in the PDRB difference before and after rebalancing regional characteristics. The preliminary estimates are presented in table below.

Table 6. Estimating the Impact of Toll-Road Entrances on Log PDRB Using PSM

Sampel	Treated	Control	Selisi	Std. Error	t-stat
Unmatched	10.7049343	10.0197378	0.6852056	0.18371175	3.73
ATT	10.7049343	9.9899865	0.714956876	0.260218742	2.75
ATU	10.0197378	10.1451612	0.125423431	–	–
ATE	–	–	0.492024061	–	–

Source: Processed Secondary Data, 2026

The table shows that the preliminary estimates before matching indicate that the mean Log PDRB in 2024 in the treatment group (10.705) is considerably higher than in the control group (10.020). The difference of 0.685 is statistically significant, with a t-statistic of 3.73, indicating an initial imbalance between the two groups prior to matching.

After matching using the Propensity Score Matching (PSM) method, the Average Treatment Effect on the Treated (ATT) is estimated at 0.7149569 with a t-statistic of 2.75. Since the t-statistic exceeds 1.96, it can be concluded that the presence of a toll-road entrance has a positive and statistically significant effect on regional PDRB. This result indicates that districts/cities with toll-road access have higher PDRB levels than those without, after accounting for comparable baseline characteristics. The Average Treatment Effect (ATE) of 0.4920241 indicates that, on average, the construction of toll-road entrances also has a positive effect on PDRB across the entire sample.

To validate these findings more rigorously, a second stage is conducted using a Logit-based estimation algorithm that corrects the variance via robust standard errors. The validation results are presented in Table 5.7 below.

Table 7. Estimation of ATE and ATT Effects on Log PDRB

Impact Indicator	Obs	Coefficient	Robust Std. Error	Std. Dev	p-value
ATE (Average Treatment Effect)	119	0.4982701	0.2062915	1.11299	0.016
ATT (Average Treatment Effect on the Treated)	74	0.6990528	-	1.190129	-

Source: Processed Secondary Data, 2026

The table shows that the ATE coefficient of 0.4982701 indicates that, on average, toll-road access increases regional PDRB by approximately 49.83% for the entire population of districts/cities in the sample, regardless of whether each district currently has toll-road access. This estimate is statistically significant, with a p-value of 0.016 ($\alpha = 5\%$). This figure provides an indication of the general economic impact if toll-road access infrastructure were more evenly distributed.

Meanwhile, the ATT coefficient captures the average effect experienced only by districts/cities that actually have toll-road access. The ATT value of 0.6990528 indicates that, for currently treated districts, PDRB increases by approximately 69.91%. This indicator is particularly important because it reflects the tangible benefits received by the treatment group compared to what they would have experienced in the absence of toll-road access.

Finally, the fact that ATT (0.699) is higher than ATE (0.498) indicates that the economic impact of the toll road is more pronounced in regions that already have access. This pattern is closely related to the selection bias indicated by the earlier Probit results, in which toll-road entrance locations are not randomly assigned but are instead directed toward regions with high population density and a large industrial share. Consequently, the districts that currently have toll-road entrances are structurally better positioned to respond to the arrival of this infrastructure with considerably higher increases in economic output.

5.6 Weighted Regression Analysis as a Robustness Test

To test the consistency of the estimates obtained through Propensity Score Matching (PSM), an additional analysis is conducted using weighted linear regression. This regression uses the weights generated from the matching process, so the comparison remains between units with comparable characteristics. The purpose of this test is to examine whether the previous results are stable when evaluated using a different approach. The estimation results are presented in Table 8 below.

Table 8. Weighted Regression Results

Variable	Coefficient	Std. Error	t-stat	p-value
Population density	0.0000732	0.00001368	5.35	0.000
Share of industry	0.0300759	0.00355811	8.45	0.000
Treatment (Toll entrance)	0.5637327	0.12899947	4.37	0.000
Constant	9.02192	0.14065567	64.14	0.000

Source: Processed Secondary Data, 2026

The weighted regression results show that the toll-road-entrance variable (T) has a positive and statistically significant effect on district/city PDRB in Java. The t-statistic of 4.37 exceeds the critical value of 1.96, and the p-value is 0.000 (significant at $\alpha = 5\%$). The coefficient of 0.564 indicates that districts with toll-road entrances tend to have higher PDRB than those without, after controlling for population density and industrial share.

In addition, population density (2015) and industrial share (2015) are both statistically significant, with p-values of 0.000. This suggests that initial regional conditions also play an important role in determining PDRB levels. Compared across variables, the effects of population density and industrial share appear stronger and more consistent in explaining PDRB differences than the toll-entrance variable. Beyond the individual effects, the model's

overall explanatory power can be assessed using the coefficient of determination, as shown in the following table.

Table 9. R-squared and Model Statistics

Indicator	Value
R-squared	0.4456
Adjusted R-squared	0.4341
Root MSE	0.77246
Number of observations	148

Source: Processed Secondary Data, 2026

The R-squared value of 0.4456 indicates that the model explains approximately 44.56% of the variation in district/city PDRB. The variables of toll-road access, population density, and industrial share collectively play an important role in capturing PDRB differences across regions, although factors outside the model still contribute. The adjusted R-squared of 0.4341, which is close to the R-squared, suggests that the model is relatively stable.

5.7 The Contribution of Toll-Road Entrances in Driving PDRB Differentiation Across Districts/Cities

The existence of toll-road entrances not only raises average PDRB but also reveals heterogeneous impacts across regions on Java Island. The fact that ATT is higher than ATE indicates that the economic benefits of toll-road infrastructure are more strongly felt by regions that already have access. This suggests that infrastructure impacts are not standalone but depend on the readiness and internal characteristics of each region.

From a regional-economic perspective, this pattern reflects a tendency toward agglomeration, whereby economic activities become increasingly concentrated in areas with better accessibility. Regions with high population density and a strong industrial base tend to exploit the presence of toll-road connections more quickly to enhance their economic activities. In contrast, regions without direct access are relatively more constrained in capturing these benefits. Consequently, the presence of toll-road entrances can stimulate growth but also has the potential to widen disparities in economic development across regions.

CONCLUSION

1. **Impact of Toll Road Development on GRP**
Toll road development demonstrates a positive and significant effect on increasing GRP in regencies/cities on Java after controlling for regional characteristic biases using the Propensity Score Matching (PSM) method. This indicates that toll road infrastructure plays a crucial role in enhancing regional economic connectivity and efficiency.
2. **Regional Characteristics as Determinants of Toll Road Access**
The probability of a region gaining toll road access is not random but significantly influenced by its initial characteristics, particularly population density and industrial share. Regions with high density and a strong industrial base tend to be prioritized for infrastructure development due to greater demand for mobility and economic activity.
3. **Magnitude of Economic Impact Based on ATT (Average Treatment Effect on the Treated)**
The Average Treatment Effect on the Treated (ATT) value of 0.6990 indicates that regions with toll gate access experienced a 69.90% increase in GRP. This represents the actual impact received by areas directly benefiting from toll road development.
4. **Magnitude of Economic Impact Based on ATE (Average Treatment Effect)**
The Average Treatment Effect (ATE) value of 0.4982 indicates that, on average, toll road development can increase GRP by 49.82% across all regions. This value reflects the potential policy impact if infrastructure is implemented more broadly.

5. Regional Economic and Policy Implications.

The higher ATT value compared to ATE suggests that toll road development impacts are more optimal in regions that are structurally economically prepared. This indicates a tendency toward economic agglomeration, where economic activity concentrates in highly accessible areas. While promoting growth, this condition may widen inter-regional disparities.

The findings of this study are confirmed as consistent through weighted regression testing, which shows that the toll access variable remains positively and significantly associated with GRP even after controlling for population density and industrial share variables. This research affirms that toll road development is an effective policy instrument for driving regional economic growth. However, to achieve balanced development, more inclusive and integrated policy strategies are required to ensure infrastructure benefits are distributed more evenly across all regions.

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