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DOES TOLL ROAD OPERATION IMPACT WAGES AND UNEMPLOYMENT? EVIDENCE FROM JAVA ISLAND

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ABSTRACT

Research Originality – To address the empirical gap left by previous studies that focused primarily on regional growth and industrial productivity, this study evaluates the impact of toll roads on average wages and open unemployment rates. The analysis utilizes Labor Force Survey microdata and focuses specifically on Java Island, where the majority of the toll road in Indonesia operates.

Research objectives – This study uses difference-in-differences with variation in the treatment timing with data from regencies/cities in Java Island from 2010 to 2023.

Research methods – This study using difference in differences with variation in the treatment timing with data from regencies/cities in Java Island from year 2010 to 2023.

Empirical result – This study implies that construction of toll roads has positive and significant impacts to wages. Then, the construction of toll roads doesn't have an impact on unemployment but shows a positive correlation in which the operation of toll road increases the unemployment in the area with toll.

Implications – The findings of the research suggest that the toll road can be maintained, and the government must anticipate the potential crowding out of workers shifting from the primary to the secondary sector due to wage increases in the latter.

Keywords: Difference in Differences; Infrastructure; Toll Road; Unemployment; Wage.

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INTRODUCTION

Toll road development in the Republic of Indonesia is a top priority within the strategy to move forward with transportation infrastructure. This is targeted at enhancing national connectivity and promoting equitable economic growth across various regions. As part of the National Strategic Projects (PSN) initiative, toll road construction aims to accelerate infrastructure development with the objective of strengthening connectivity and improving the competitiveness of the national economy. The Indonesian government has determined the acceleration of toll road construction through Presidential Regulation No. 16 of 2016, which was then updated by Presidential Regulation No. 109 of 2020 on National Strategic Projects. The National Strategic Projects underscore infrastructure, including toll road development, as a critical national priority that has the greatest economic and labor impact (Khoirunurrofik & Anas, 2023).

By the end of 2022, the operational length of toll roads reached 2,599.12 kilometers and was distributed across several islands, such as 1,691.87 km in Java Island, 738.461 km in Sumatra Island, 97.27 km in Kalimantan Island, 61.455 km in Sulawesi Island, and 10.072 km in Bali Island (Badan Pengatur Jalan Tol Kementerian Pekerjaan Umum dan Perumahan Rakyat, 2023). The expansion of the toll roads has generated a lot of benefits, notably in enhancing transportation efficiency and supporting economic activities across regions.

Furthermore, toll road construction policies intend to address interregional infrastructure disparities, improving accessibility and logistics efficiency. This can foster economic growth. The primary impact of the

accelerated toll road development is the increased accessibility of regions, which results in boosting investment opportunities. Withal, the reduction in travel times facilitated by toll roads contributes to accelerating regional economic development (Nanda, 2023).

From the perspective of economic theory, investment in transportation infrastructure is recognized as having a positive impact on economic growth (Zhang et al., 2020). Zhang further states that regional economic growth can be achieved by expanding market potential through the attraction of investment and the facilitation of consumption. Furthermore, transportation infrastructure development elevates economic efficiency by broadening market access and reducing logistics costs.

A key advantage of transportation infrastructure development is the efficiency of transportation and logistics distribution. Hayakawa & Tsubota (2022) assert that reductions in travel time can decrease transportation costs and improve the speed of movement, thus contributing to increased economic productivity. Toll roads, for instance, have been shown to reduce travel time by up to thirty-five percent (Ardiyono et al., 2018), thus significantly improving transportation efficiency, the distribution of goods, and public access to labor markets.

In addition, transportation infrastructure plays a vital role in the allocation of economic resources. Binswanger et al. (1993) and Fan et al. (2004) emphasize that the availability of quality transportation infrastructure determines the efficiency of economic activity allocation and influences the distribution of household resources, ultimately contributing to improvements in societal welfare.

In addition to its effects on connectivity and transportation efficiency, toll road development also exerts an influence on labor market dynamics and the economic welfare of communities (Abdullah, 2014). Nanda (2023) asserts that the presence of toll roads can expand employment opportunities and stimulate economic growth in the regions through which they pass. Consistent with this assertion, the data we have gathered indicate that the average wage in Indonesia experienced an upward trend between 2015 and 2023. According to Badan Pusat Statistik (2025), this wage growth was generally accompanied by a decline in the Open Unemployment Rate (OUR), except in 2020, when the unemployment rate rose because of the COVID-19 pandemic.

Several studies have examined the impact of toll road development. Several of them have reported positive economic effects at the regional level. Ahmad (2022), for instance, found that the operation of toll roads contributed to an increase in economic growth in the areas traversed by these roads. Moreover, toll road operations have been shown to have a positive effect on regional government revenues (PAD), increasing them by 10.96% (Arumadani, 2022). Toll road development has also positively impacted Indonesia's retail sector, with the number of minimarkets in villages intersected by toll roads rising by an average of 0.53 units compared to villages not affected by the toll network (Putra, 2023).

Nevertheless, despite the theoretical expectation that infrastructure development, such as toll roads, would yield positive economic outcomes, some studies have identified adverse effects. For instance, a decline in East Java's economic growth rate was observed two years after the commencement of toll road operations. Factors such as limited accessibility, high toll fees, and inadequate supporting infrastructure are believed to contribute to this negative outcome (Nouri et al., 2024). Similarly, Djumantara & Wisana (2025) found that the Trans-Java Toll Road exerted an insignificant negative impact on the number and growth of micro and small enterprises, with a significant negative effect particularly observed in the food and beverage industry sector.

The macroeconomic advantages of toll road development are well established, but the specific impact on labor remains under-studied. Existing studies on Indonesian infrastructure have focused greatly on regional growth and industrial productivity. This leaves a notable empirical gap regarding labor market outcomes such as wages and unemployment. Therefore, this study addresses this gap while also resolving methodological limitations in the literature.

This study contributes to the literature in three aspects. First, it analyzes regencies/cities-level labor market consequences of toll road operation in Java Island using average wages constructed from repeated cross sections of Sakernas. Second, this study applies a staggered difference-in-differences estimator that

APPLICATIONS FOR PRACTICE

- The construction of toll roads has positive and significant impacts to wages.
- Most significant impacts happened to wages in secondary sector (manufacturing, gas, water, electricity, and construction).
- Toll road impact on reducing the unemployment rate remains insignificant, even tends to increase unemployment. This is due to the rising labor force participation and migration flows that are not matched by job creation, job mismatch, etc.
- The government must anticipate the potential crowding out of workers shifting from the primary to the secondary sector due to wage increases in the latter.

adjusts for heterogeneous/various treatment timing based on the Callaway & Sant'Anna (2021) framework and avoids the weighting problems associated with conventional two-way fixed-effects models. Third, this study examines heterogeneous wage effects across primary, secondary, and tertiary sectors while separately evaluating whether higher wages are accompanied by improvements in local employment conditions. Hence, this study is directed by the following research question: "Does the operation of toll roads significantly impact average wages and open unemployment rates in regencies/cities where they traverse?" In addressing this question, the research provides critical empirical evidence from Java Island, including the Jabodetabek Toll, Trans Java Toll, and non-Trans Java tolls, to analyze how toll road operation shapes wages and open unemployment rates.

LITERATURE REVIEW

Massive infrastructure plays a vital role in boosting economic growth and reducing poverty through policy channels, while also serving as a precondition for the functioning of market mechanisms that influence the structure and quality of growth (GRIPS Development Forum, 2003). Infrastructure elevates economic development by boosting the productivity of firms and individuals and by improving overall living standards. Particularly, it induces significant structural transformations within national and regional economies. To evaluate the linkage effects of large-scale infrastructure, it is essential to distinguish between first-round impacts and broader, long-term outcomes.

Massive infrastructure acts as a primary catalyst for development through three integrated channels: supply-side efficiency, demand-side stimulus, and socio-fiscal integration. From the supply-side perspective, the betterment of infrastructure, measured precisely in terms of cost efficiency, availability, and reliability, generates two transformative outcomes. The first is the investment-inducement effect, which incentivizes industrial expansion and the entry of new firms, thus fostering job creation and income generation within both primary and auxiliary industries. Complementing this is the regional economic activation effect, wherein improved connectivity unlocks latent economic opportunities and enhances the marginal productivity of existing local activities.

On the other hand, the demand-side impact is most pronounced during the initial construction phase of a project. This period generates an effective demand effect, where the massive capital outflow for materials and labor provides immediate employment and direct income to the local workforce. While these demand-driven benefits are often concentrated in the short term, the long-term social perspective of infrastructure development serves as a bridge to basic public services, improving the well-being of disadvantaged or isolated communities. Eventually, these integrated effects expand the local fiscal capacity and trigger multiplier effects, boosting systemic economic advantages across the framework.

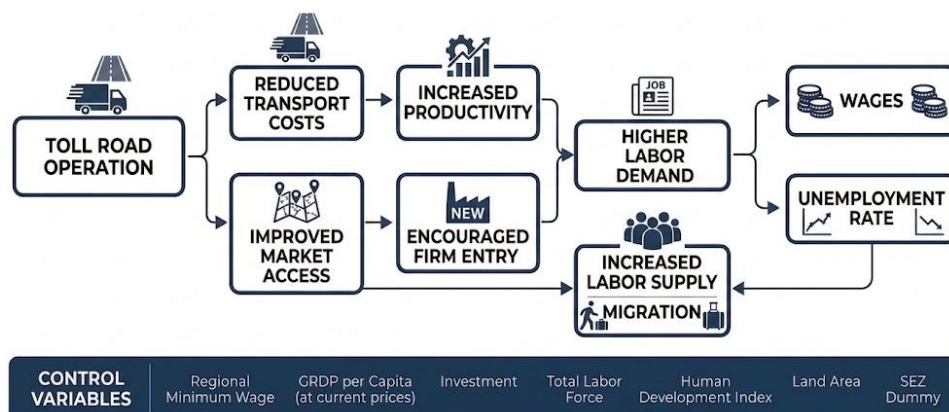
From previous studies, transportation infrastructure contributes directly to improving Gross Domestic Product (GDP). Zhang et al. (2020) stated that transport infrastructure boosts market potential, thus promising investment inflows and facilitating consumption. Lindgren et al. (2021) point out the significant economic aspects resulting from improved transport systems. In the Indonesian context, toll road infrastructure has been positively correlated with regional economic growth (Ahmad, 2022; Zhang et al., 2020). Arumandani (2022) finds that toll road operations increase local government revenue by 10.96%, though the relationship is weakly significant. Furthermore, toll road development has been associated with positive spillover effects on the retail sector (Putra, 2023). Regarding labor market outcomes, Lindgren et al. (2021) report that transport infrastructure investment enhances local industrial productivity and employment generation across sectors. Nawaz et al. (2021) estimate that a 10% increase in road infrastructure results in a 4.3% rise in employment, while Lin (2017) notes that improved transport speed correlates with a 7% increase in employment. Yamauchi (2016) further confirms that improved transportation reduces agricultural labor hours and increases wages in both agricultural and non-agricultural sectors.

Nevertheless, toll road development also entails adverse effects. Djumantara & Wisana (2025) highlight a significant negative impact on the growth of micro and small enterprises, particularly within the food and beverage industry. Additionally, toll roads have contributed to a 24% decrease in agricultural land area and a 7% increase in urban built-up land, compared to districts not traversed by toll roads (Fakhruddin & Gultom, 2021). Doerr & Gaebler (2022) find that highway proximity reduces employment by 9% within a 10 km radius. While infrastructure investments are generally effective in reducing unemployment in the short term, Montolio (2018) concludes that such benefits are not significant in the long run.

Based on Figure 1, toll road operation is positioned as the primary variable that triggers specific microeconomic mechanisms. The operation directly leads to reduced transport costs and improved market access. Reduced transport costs can lead to increased productivity, while improved market access leads to new firm entry. Reduced transport costs and improved market access result in higher labor demand. At the same time, improved market access facilitates migration, leading to an increased labor supply. Then the

interaction between this higher labor demand and increased labor supply may affect the labor market, impacting wages and the unemployment rate.

Figure 1 The Conceptual Framework



Source: Processed by the authors

In this study, several economic indicators are also used as control variables, as they are considered to influence the average wages and the unemployment rate. These control variables include Regional Minimum Wage (RMW), Gross Regional Domestic Product (GRDP) per capita at current prices, Investment (the total of Foreign Direct Investment (FDI) and Domestic Direct Investment (DDI)), Human Development Index (HDI), total labor force, land area, and the SEZ (Special Economic Zone) dummy for each regency or city annually.

METHODS

The scope of this study is focused on Java Island, as more than 65% of Indonesia's operational toll roads are located on this island. This study also focused on the operational impact of the toll road. In addition to that, Java offers a more proportional balance between regencies/cities traversed by toll roads and those that are not, compared to other islands. Java Island also provides a more robust basis for accurately capturing the impact of toll road construction because toll roads in Java have a longer operational history than the others.

Next, the data source regarding toll road segments and the opening of each toll road segment was obtained from the Toll Road Regulatory Agency. Then, data on average wages at the regencies/cities levels was obtained from microdata processing of the National Labor Force Survey (Survei Angkatan Kerja Nasional), conducted annually in August from 2010 to 2023 by BPS-Statistics Indonesia. Annual data on the OUR at regencies/cities levels were also gathered from BPS-Statistics Indonesia.

Sakernas is specifically designed to collect employment data on a continuous basis. The August iteration of Sakernas is conducted across all provinces and regencies/cities throughout the Republic of Indonesia, encompassing a sample size of approximately 300,000 households. Individual-level data from August Sakernas are afterwards aggregated at the regencies/cities level. To perform this aggregation, the individual monthly wage is multiplied by its respective survey weight and summed across all individuals within a given regency/city. This sum is then divided by the total survey weights of all individuals in the corresponding regencies/cities to derive the aggregate weighted average wage per regency/city.

This study also uses control variables that may affect the relationship between toll road construction, wages, and unemployment. The first control variable is labor force size, which is included because labor size constitutes a primary factor of production within the analyzed economy. Furthermore, previous studies indicate that road infrastructure development has a positive impact on employment (Lin, 2017; Nawaz et al., 2021; Yamauchi, 2016).

Gross Regional Domestic Product (GRDP) per capita at current prices is also included as a control variable, as it reflects the regional economic conditions and the overall level of societal welfare. GRDP at current prices also contains GDP deflators, so it can also address the inflation control. Previous studies by Arumandani (2022) and Zhang (2020) demonstrate that infrastructure development stimulates regional economic growth by escalating economic activities (Lindgren et al., 2021). So it is essential to include GRDP as a control variable.

In addition to representing human capital, the Human Development Index (HDI) is included as a control variable. This is because wage levels and employment opportunities are contingent upon workforce quality. As Barro (2001) states, higher levels of education improve labor productivity and also increase wages. A high HDI is correlated with a more robust labor market, higher employment rates, and improved

wage levels (United Nations Development Programme, 2016). The data about GRDP per capita at current prices and HDI are also obtained from BPS-Statistics Indonesia.

Regional Minimum Wage (RMW) is also included as a control variable. Card & Krueger (1993) demonstrate that an increase in the minimum wage in the United States raises average wages without significantly reducing total employment. (2010)Dube et al. (2010) also note that minimum wage hikes elevate earnings in the retail sector. The data of RMW sourced from various agencies, such as BPS-Statistics Indonesia, Local Government Law, and Local Government authorities.

Investment variables are also included in the control variable because investment attracts new firms and thus attracts employment opportunities. In this study, the investment variables consist of Domestic Direct Investment (DDI) and Foreign Direct Investment (FDI). Feenstra & Hanson (1997) reveal that FDI contributes to wage growth driven by heightened productivity and labor demand. Dabla-Norris et al. (2015) also state that investment fosters inclusive growth by generating broader employment opportunities and elevating household incomes. These investment data is obtained from the Ministry of Investment of the Republic of Indonesia.

Industrial area often distracts labor sector, so in order to isolate the effects of toll road operations and ensure they are not conflated with other industrial policies, a Special Economic Zones (SEZ) control variable is introduced. The dummy variable for SEZ is 1 if there is SEZ in that city at that year and 0 otherwise. SEZ data are obtained from the SEZ Council Report up to 2023. These variables provide a robust framework for analyzing the impacts of toll road operation on wages and unemployment.

A logarithmic transformation then applied to most of the data after all the data for each regency/city from 2010 to 2023 has been compiled. But the transformation is not done to OUR, Toll, and SEZ. This transformation was conducted exactly prior to the Difference-in-Differences (DID) estimation to normalize the distribution, mitigate potential biases arising from differing units of measurement, and simplify the interpretation of the results.

Since the operation of toll roads was carried out gradually and not simultaneously across all regencies/cities, this study employs the Difference-in-Differences (DID) method with variation in treatment timing, as there is variation in the timing of toll road operations, such an approach was applied by Goodman-Bacon (2021) and Callaway & Sant'Anna (2021). In this study, regencies/cities traversed by toll roads are classified as treatment areas, while those not traversed by toll roads are classified as control areas.

The basic empirical model of this study is specified as follows,

$$WAGE_{ip} = \beta_0 + \beta_1 TOLL_{ip} + \beta_2 X_{ip} + \delta_i + \delta_p + \varepsilon_{ip} \quad (1)$$

$$UNEMPLOYMENT_{ip} = \beta_0 + \beta_1 TOLL_{ip} + \beta_2 X_{ip} + \delta_i + \delta_p + \varepsilon_{ip} \quad (2)$$

$$\text{with } \beta_1 = ATT_X(g, t) = E[(Y_t(g) - Y_t(0)|X, G_g = 1)] \quad (3)$$

In Equation (1), $WAGE_{ip}$ represents the average wage level in city i during year p , whereas Equation (2) employs $UNEMPLOYMENT_{ip}$ as the dependent variable, representing the open unemployment rate in city i during year p . The parameter β_0 denotes the constant term, while β_1 represents the estimated treatment coefficient associated with toll road operation. The treatment variable $TOLL_{ip}$ is specified as a dummy variable that equals one when a toll road is operational in city i during year p and equals zero when the toll road has not yet operated or no toll road available during the observed period.

The vector X_{ip} represents a set of control variables consisting of regional characteristics that are assumed to influence labor market outcomes. These variables include the Regional Minimum Wage (UMR), Gross Regional Domestic Product (GRDP) per capita at current prices, investment measured by Domestic Direct Investment (DDI) and Foreign Direct Investment (FDI), Human Development Index (HDI), labor force size, Special Economic Zone (SEZ) dummy variable, and land area of each regency or city. The inclusion of these variables aims to control for observable differences across regions that may affect variations in wages and unemployment rates.

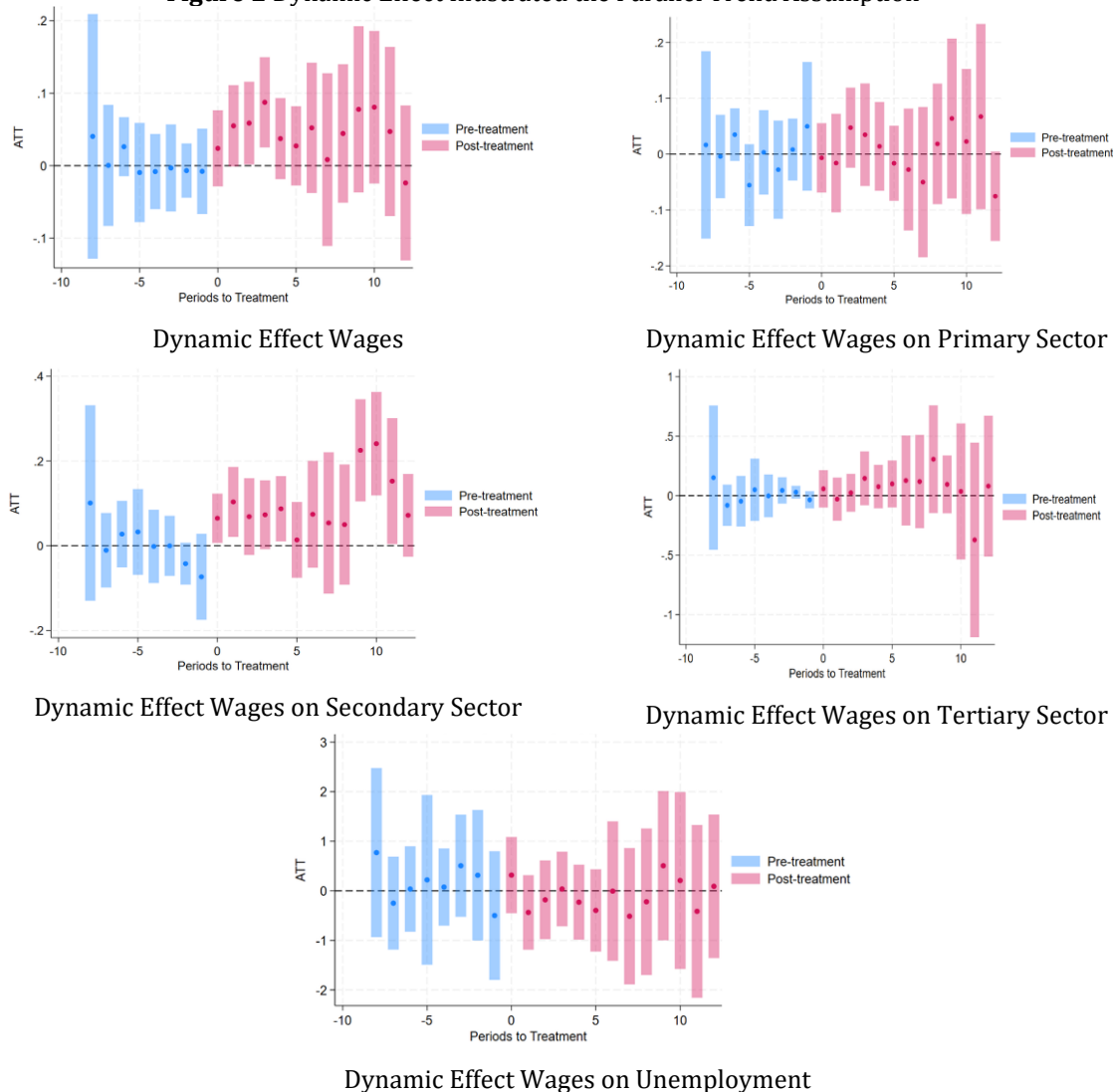
The terms δ_i and δ_p denote city fixed effects and year fixed effects, respectively. City fixed effects control for unobserved time-invariant characteristics specific to each city or regency, while year fixed effects capture common temporal shocks affecting all regions during a particular year. Finally, ε_{ip} represents the error term, capturing other unobserved factors that may influence the dependent variables.

This study employs the Difference-in-Differences (DID) approach with variation in treatment timing, following the framework proposed by Callaway & Sant'Anna (2021), which requires several key assumptions to be met. First, the Irreversibility of Treatment assumption states that no unit receives treatment at time $t = 1$, and once treated, a unit remains treated in all subsequent periods. In line with this, units classified as always treated are excluded from the analysis, as they do not contribute to the estimation of the Average Treatment Effect on the Treated (ATT). Afterward, 28 cities traversed by the Jagorawi, Cipularang, Jakarta-Cikampek, Jakarta-Merak, Semarang ABC, Surabaya-Gempol, and Kanci-Pejagan toll roads are excluded following the framework proposed by Callaway & Sant'Anna (2021) that state always

treated unit needed to be excluded. Additionally, the regencies of Kepulauan Seribu, Sumenep, Pamekasan, Sampang, and Bangkalan are omitted due to their location outside of Java Island. Demak, Lebak, and Sumedang regencies are also excluded as outliers. These outliers are caused by their industrial characteristics, proximity to major urban centers, and the fact that the toll road projects in these three regencies only reached the operational stage at the end of the observation period, during which the wage and labor variables remained distorted. Because of that, Demak, Lebak, and Sumedang Regencies were excluded from the research sample to mitigate estimation bias arising from temporary construction shocks. After these exclusions, the final dataset consists of 1,162 observations, covering 83 cities over a 14-year period from 2010 to 2023.

The second assumption, Random Sampling is satisfied as the study utilizes a longitudinal panel dataset of 83 cities in Java for 14 years, capturing the entire population of regencies/cities on the island of Java, without sample but then filtered with certain conditions. To account for the non-independence of repeated observations within these same administrative units over time, standard errors are clustered at the regency/city level, ensuring that the unobserved error terms are appropriately treated. The third assumption, Limited Treatment Anticipation, holds as well pre-treatment test in the dynamic effect on Figure 2 is statistically not significant. The fourth and fifth assumptions concern the Conditional Parallel Trends requirement, based on comparisons with both Never-Treated and Not-Yet-Treated groups. Both groups are present in the dataset, which allows for robust estimation of the ATT. Lastly, the assumption of No Overlap is also fulfilled, ensuring the validity of the identification strategy employed in this analysis.

Figure 2 Dynamic Effect Illustrated the Parallel Trend Assumption



Source: Processed by the authors

The parallel trends assumption in this study can also be illustrated through the dynamic effect on Figure 2. The point estimates show the yearly impact of toll road operation at the 95% confidence interval.

The interval is represented by the bars stemming from the point estimates. The point estimate is statistically different from 0 if the bar does not pass the dotted horizontal line at 0. This interaction term captures any potential anticipatory effects and is expected to be statistically insignificant in the pre-treatment. All Dynamic Effect on Figure 1 also meaning that there is no anticipatory behavior as the pre-treatment always insignificant bar. Meanwhile, the post-treatment effects provide insights into the dynamic impacts of toll road operations. From the Dynamic Effect Wages Chart above, we can see that the operation of the new toll road significantly affects wages in the third year after the toll road is operational. Then from Dynamic Effect Wages on Secondary Sector Chart, we can conclude that the new toll road significantly affects wages on secondary sector from the first year of the operation of the toll road.

RESULT AND DISCUSSION

Before conducting inferential analysis, a descriptive analysis is first carried out to sharpen economic interpretation. This descriptive analysis provides an initial overview of the data or variables before proceeding to further analysis. To better understand the differences between areas traversed by toll roads and those that are not, an analysis is conducted through Table 1.

Table 1 Descriptive Statistics

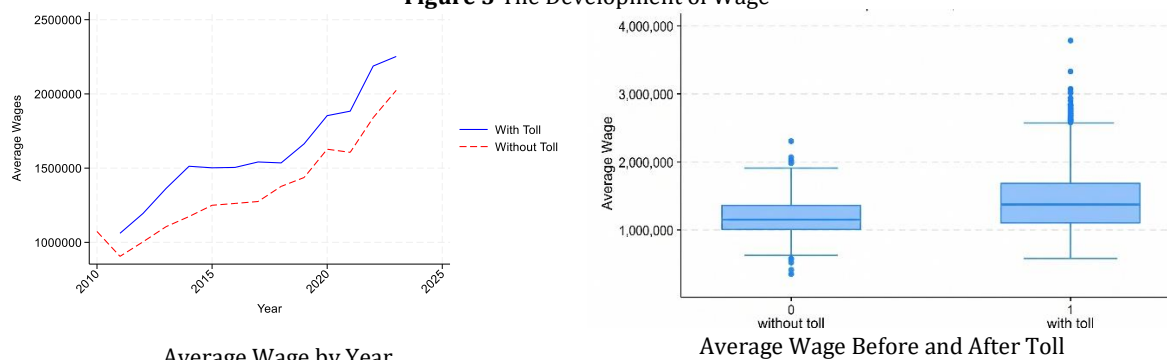
Year 2010 : Before Toll					
Variable	N	Mean	Std. Dev.	Min	Max
Average Wage (Rp)	83	1073334	184635.97	657292.38	1532054.9
OUR (%)	83	6.12	3.03	0.87	15.65
Average Wage on Primary Sector (Rp)	83	913673.9	842966.36	312210.59	5290951.5
Average Wage on Secondary Sector (Rp)	83	852576.79	195792.77	525627.88	1437833.5
Average Wage on Tertiary Sector	83	1210292.2	169429.74	850099	1631089.1
Year 2023 : City Not Traversed by Toll Road					
Variable	N	Mean	Std. Dev.	Min	Max
Average Wage (Rp)	55	2024147.1	407935.86	1441781.1	3027947.5
OUR (%)	55	4.78	1.78	1.52	9.49
Average Wage on Primary Sector (Rp)	55	1601749.1	508746.04	932989.38	3147253.8
Average Wage on Secondary Sector (Rp)	55	2034800.1	383771.75	1374687.9	2979602.8
Average Wage on Tertiary Sector (Rp)	55	2211522.2	369963.55	1658609.8	3189840.5
Year 2023 : City Traversed by Toll Road					
Variable	N	Mean	Std. Dev.	Min	Max
Average Wage (Rp)	28	2252339.7	418791.72	1695437.1	3331893.3
OUR (%)	28	5.28	1.61	2.41	8.60
Average Wage on Primary Sector (Rp)	28	1754465.3	585390.79	1090431.5	4177683.3
Average Wage on Secondary Sector (Rp)	28	2429656.3	489393.91	1788592.3	3550438.3
Average Wage on Tertiary Sector (Rp)	28	2350048.5	360509.72	1866693.9	3278812.3

Source: Statistics Indonesia (Processed by the authors)

Based on Table 1, the average wage experienced a significant increase, doubling in 2023 compared to 2010, with the average wage in areas traversed by toll roads being higher than in areas not traversed by toll roads. The Standard Deviation reveals the level of inequality or disparity between cities; notably, the Primary Sector (especially in 2010) shows extremely high variation relative to its mean, indicating that wages in this sector differ drastically from one city to another compared to the more stable Secondary and Tertiary sectors. The Minimum and Maximum show the full range of the data and highlight extreme outliers, in which the average wage in the primary sector has a wider range than the other sectors.

Next, looking at the data collected, the HDI also rose from 66.21 to 73.88 in areas not traversed by toll roads and was slightly higher in areas traversed by toll roads, at 74.36. Furthermore, the GRDP saw a significant increase, more than doubling in 2023 compared to 2010, with GRDP in areas not traversed by toll roads being higher than in areas traversed by toll roads. In terms of investment, cities traversed by toll also higher than cities not traversed by toll roads. The unemployment rate in 2023 decreased compared to 2010, although unemployment in areas traversed by toll roads was higher than in those not traversed by toll roads. Interestingly, in terms of labor force numbers, areas traversed by toll roads had a larger labor force than those not traversed by toll roads.

As seen from Figure 3, it is evident that both the average and median wages increased following the construction of toll roads. The wage dispersion also widened, indicating that more individuals are earning higher wages. Initial mean comparison tests were conducted to assess pre-treatment differences, revealing no statistically significant difference. Afterwards, a two-sample t-test was performed to compare average wages in toll-traversed regencies/cities versus non-toll-traversed regencies/cities. The result indicates a significant difference, in which cities traversed by toll roads have higher average wages than those without. This result also suggest that toll road operation has a positive impact on increasing wages for workers.

Figure 3 The Development of Wage

Source: Statistics Indonesia (Processed by the authors)

The differences in the average OUR between areas traversed by toll roads and those not traversed can be seen in Figure 4. In 2010, the average OUR in regencies /cities across Java Island was 6.12%. Then, 2011 to 2014, the average OUR in regencies/cities with toll roads was lower than in those without toll roads. However, the trend reversed between 2015 to 2023, the regencies/cities that are traversed by toll roads has higher OUR than in those not traversed. This trend could imply that toll road operation may initially contribute to employment opportunities, but its long-term impact on local labor markets is ambiguous. The rising unemployment in toll-connected areas may reflect structural mismatches, such as the gap between labor supply and the specific skills demanded in new industries emerging along toll corridors.

Figure 4 Average Unemployment Rate by Year

Source: Statistics Indonesia (Processed by the authors)

The descriptive statistics presented above serve to provide contextual background and do not imply causality. Therefore, we must conduct a causal Difference-in-Differences (DID) analysis. Meanwhile, the empirical results of the DID analysis on the impact of toll road operation on average wages in Java Island can be seen in Table 2.

Table 2 shows that toll road operation has a positive and statistically significant effect on the average wage of workers, with a significance level of 5%. The average wages of worker in the cities traversed by the toll road is 5.97% higher than the cities that are not traversed. In practical terms, this implies that if Kota Magelang (a non-toll city) has an RMW of Rp 2066000,- in 2023, then RMW in Kota Surakarta (a toll-traversed city) is 5.97% higher than Kota Magelang, equivalent to an increase of approximately Rp 123340,-. This projection aligns with actual data from 2023, where Kota Surakarta's RMW of Rp 2174196,- was indeed approximately 5-6% higher than that of Kota Magelang. The event study analysis can also be seen in the Dynamic Effect Wages Chart above. It concludes that the operation of a new toll road begins to have a significant impact on the average wage of workers in the third year after it becomes operational.

The impact of toll roads on wages can be explained as follows. Improvements in road quality enhance both firm and labor productivity (Foster et al., 2025; Gertler et al., 2024; Gibbons et al., 2019). Better roads allow firms to increase their utilization of intermediate inputs (goods and services) and reduce logistics transport costs (Gibbons et al., 2019). Afterwards, enhanced road quality leads to a rise in nominal labor income. The elasticity of labor income with respect to road quality is 0.24, indicating that road improvements significantly raise worker earnings (Gertler et al., 2024). Increased accessibility attracts establishment entry and triggers the opening of new factories, with an estimated elasticity of new firm entry with respect to road quality of 1.2 (Gertler et al., 2024; Gibbons et al., 2019). These new firms are usually

transport intensive firms that gain benefits from improved accessibility. These new firms also tend to bid up local wages to attract labor, which could increase the regional average wage (Gibbons et al., 2019). Furthermore, highway construction has been shown to reduce the monopsony power of manufacturing firms over labor, compelling them to compete more intensely for workers. This results in an increase in labor's share of income ranging from 1.8 to 2.3 percent for workers in firms located near new highways compared to those situated further away (Foster et al., 2025).

Table 2 Empirical Results on Wage

	Control Variable						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ATT	0.0946***	0.0896***	0.0530*	0.0703**	0.082***	0.0621*	0.0597**
Str. Error	0.0311	0.0299	0.0275	0.0316	0.0313	0.0329	0.0297
Z	3.04	2.99	1.93	2.23	2.62	1.89	2.01
P > z	0.002	0.003	0.054	0.026	0.009	0.059	0.044
Chi ²	3920.44	2329.51	1199.18	1439.63	1154.91	1774.88	4332.67
GRDP	yes	yes	yes	yes	yes	yes	yes
HDI		yes	yes	yes	yes	yes	yes
RMW			yes	yes	yes	yes	yes
Investment				yes	yes	yes	yes
Labor Force					yes	yes	yes
Size							
Land Area						yes	yes
SEZ							yes

*** p<0.01, ** p<0.05, * p<0.1

Source: Processed by the authors

Subsequently, a subsample analysis that also served as sensitive analysis was conducted on the average wages of workers in the primary sector, secondary sector, and tertiary sector. The primary sector in this study includes economic activities in Agriculture, Forestry & Fisheries, and Mining & Quarrying. Meanwhile, the secondary sector includes economic activities in Manufacturing, Gas, Water, Electricity, and Construction. The tertiary sector comprises economic activities in Services and other economic sectors.

Table 3 Empirical Results on Wage per Sector

Sector	Primary Sector	Secondary Sector	Tertiary Sector
ATT	0.0268	0.0745***	0.0004
Str. Error	0.1205	0.2417	0.0388
Z	0.22	3.08	0.01
P > z	0.824	0.002	0.991
Chi ²	268.8411	226.3983	4230.0282

*** p<0.01, ** p<0.05, * p<0.1

Source: Processed by the authors

The empirical results on Table 3 show the operation of toll roads has not yet had an impact on the average wages of workers in the primary sector. A non-significant impact means that although there is an increase, statistically the relationship is not strong or consistent enough to be considered a definite effect.

Toll roads have not yet impacted wages in the primary sector can be explained by several structural causes. Employment in the primary sector, like agriculture, forestry, and mining, tends to be localized and tied to natural resources. Afterwards, improved connectivity through toll roads does not directly elevate worker mobility or income (Sakamoto & Chen, 1991; Wauthy & Zenou, 1997). In addition to that, the labor market in the primary sector is generally segmented and informal, that did not guarantee wage protection or social security. This makes it difficult for workers in the primary sector to secure wage increases, even when the economy is growing (Dickens & Lang, 1988). Moreover, the primary sector workforce often possesses low levels of education and skills, which troubles them from wage increase (Strauss & Thomas, 1991). Finally, without legal protections or formal employment contracts, income increases in the surrounding region often fail to translate into real wage gains for primary sector workers (Khamis, 2013; Negi & Akhter, 2022).

The analysis of the average wages of workers in the secondary sector shows that toll road operation has a positive and statistically significant impact on the average wages of workers in the secondary sector, with a 1% significance level. The operation of toll roads increases wages by 7.45% for secondary sector workers in regencies or cities through which the toll roads traverse. This indicates that toll road operation has a greater impact on increasing wages in the secondary sector, which includes Manufacturing, Gas, Water, Electricity, and Construction, compared to other sectors. Furthermore, through the event study

analysis, toll road operation has a significant effect on the average wages of secondary sector workers in the first year after operation. The toll road operation again shows a significant effect in the long term period (beyond nine years of operation).

These findings consistent with previous studies indicating that the most significantly positive highway effects occur in the manufacturing industry (Holl, 2016). From the firm's perspective, improved road infrastructure enhances labor productivity, particularly in terms of gross output (Gibbons et al., 2019), while also reducing production and transportation costs (Holl, 2016). Afterwards, this leads to an increase in average workers' wages (Gibbons et al., 2019; Yamauchi, 2016). This also aligns with other studies in Indonesia that demonstrate the interaction between infrastructure expansion and the manufacturing sector. Octaviano & Yudhistira (2024) stated that the development of the Trans Java Toll Road has a significant positive impact on the productivity of the manufacturing industry. The positive effect on company revenue reflects increased efficiency and market access. Khoirunurrofik & Anas (2023) also show that National Strategic Project in infrastructure had the most substantial economic and employment impact. Furthermore, Verico & Qibthiyyah (2023) stated that the expansion of infrastructure in Indonesia is instrumental in improving logistics efficiency and supply chain connectivity, which are essential prerequisites for elevating the manufacturing sector's competitiveness and stimulating foreign direct investment to spur economic growth.

The results for the average wages of workers in the tertiary sector, which included service and other sectors, indicate that toll road operation has not yet had an impact, although it does show a positive relationship. The event study analysis also can be seen on Dynamic Effect Wages on Tertiary Sector Chart above. It shows that toll road operation does not have a significant impact on the average wages of tertiary sector workers, even after 13 years of operation.

This lack of significance can be explained as follows. First, the tertiary sector is heavily influenced by non-physical factors such as workforce educational attainment, the structure of service demand, and labor market policies. Afterwards, physical infrastructure like toll roads does not automatically increase productivity or wages in this sector (Petek & Jagric, 2017; H. Strauss & de la Maisonneuve, 2009). Although toll roads may improve accessibility to tourist areas or trade centers, an increase in the number of customers or tourists does not necessarily raise service workers' wages, particularly where the labor market remains saturated, and competition is high (Boarnet, 1997; Sahli & Hazari, 2005). Moreover, many jobs in the tertiary sector are informal, not fixed salaries, and depend on daily demand volumes that are not directly influenced by road infrastructure (Mazar, 2014).

From the above analysis, it can also be concluded that toll road construction has the greatest impact on the average wages of workers in the secondary sector (Manufacturing, Gas, Water, Electricity, and Construction). The operation of the toll road increases the average wage by 7.45% for workers in the secondary sector in the regencies or cities it traverses. This is consistent with the data processed by the author, which shows that the difference in average wages between areas traversed by the toll road and those not traversed is greatest in the secondary sector. Hence, it can be concluded that the secondary sector is more sensitive to improving accessibility caused by toll road operation.

The 7.45% higher average wage in the city traversed by the toll road at the secondary sector highlights a structural transformation driven by improving infrastructure. This aligns with New Economic Geography theories, where toll roads facilitate the agglomeration of industrial capital in specific nodes, often at the expense of the resource dependent area (Fujita et al., 1999). This sectoral imbalance creates a polarization risk as rising industrial wages widen the gap between factory workers and those in the primary sector, leading to a crowding out of the traditional agricultural class (Autor & Dorn, 2013). Ultimately, this wage premium acts as a powerful pull factor that accelerates the migration of labor from rural-agricultural roles into urban-industrial ones. However, without targeted policy support, this transition may leave remaining primary workers vulnerable or push displaced labor into low-productivity, informal roles within the tertiary sector.

Lastly, a DID analysis was conducted to assess the impact of toll road operation on the OUR in Java Island. The results on Table 4 indicate that toll road operation has not yet had an impact on the unemployment rate. Although the descriptive statistics, it is show that the OUR is higher in areas that are traversed by toll roads than in those without. This finding also supports Doerr & Gaebler's (2022) conclusion that infrastructure expansion may lead to a decline in local employment opportunities.

The research results show that toll road operations have not significantly reduced unemployment by complex factors that influence unemployment. Massive infrastructure development often stimulates greater labor force participation and migration, resulting in a surge in job seekers that can outpace job creation (Cloos, 1977). This is consistent with evidence from Special Economic Zones (SEZs), where population inflows into SEZ regions often exceed the number of available job opportunities (Sa'diah & Khoirunurrofik, 2025). In addition to that, jobs generated by toll road projects are typically temporary and

concentrated in the construction phase, offering only short term impact on employment (Anghel et al., 2017; Hornstein et al., 2011). Furthermore, a mismatch between the skills of local workers and the demands of industrial jobs constrains local employment opportunities. In Indonesia, the job mismatch is prevalent among graduates of Vocational High Schools (SMK) and Diploma programs, where educational curricula are often misaligned with industrial needs (Paramitasari et al., 2024; Wihardja & Cunningham, 2021). However, in contrast to these findings, Gertler et al. (2024) state that improving major national and provincial highways can enhance local economic development by increasing opportunities within the formal labor market.

Table 4 Empirical Results on Unemployment

	Control Variable						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ATT	-0.4359	-0.2044	-0.1884	-0.1619	-0.1519	0.3834	0.4596
Str. Error	0.3767	0.0330	0.3804	0.3762	0.4501	0.5805	0.6597
Z	-1.16	-0.62	-0.50	-0.43	-0.34	0.66	0.70
P > z	0.247	0.536	0.620	0.667	0.736	0.509	0.486
Chi ²	4615.746	2712.285	4287.643	832.386	1136.988	415.959	235.19
GRDP	yes	yes	yes	yes	yes	yes	yes
HDI		yes	yes	yes	yes	yes	yes
RMW			yes	yes	yes	yes	yes
Land Area				yes	yes	yes	yes
Labor Force Size					yes	yes	yes
Investment						yes	yes
SEZ							yes

*** p<0.01, ** p<0.05, * p<0.1

Source: Processed by the authors

To ensure the robustness of the research findings, the author conducted a robustness check through regression analysis by gradually including independent and control variables into the model. The results show that the effect of these variables on average wages remains stable and consistent, thus confirming the reliability and stability of the model used. The same results were also found for the dependent variable, OUR.

Another sensitivity analysis also conducted by addressing the COVID-19 pandemic, that can be seen on Appendix 1. First, a DID analysis using a year fixed effect for 2020 produced the same results as the earlier model. Then, a sensitivity analysis was conducted by excluding the 2020 data. The impact of toll roads on the OUR remained insignificant, but the impact on average wages fell to 4.4%, and its significance changed. The results were similar when excluding both 2020 and 2021. This shows that the COVID-19 pandemic altered how toll roads affect average wages and the OUR. Therefore, the faster mobility enabled by toll roads helped minimize the pandemic's negative effects on these two variables.

CONCLUSION

The operation of toll roads has a positive and significant effect on average wages. Specifically, toll road operations increase the average wage by 5.97% for workers in the traversed regencies/cities. This impact is most pronounced in the secondary sector (Manufacturing, Gas, Water, Electricity, and Construction), where wages rise by 7.45% compared to the city that is not traversed by toll road. This evidence confirms that toll road construction successfully enhances cost efficiency, resource availability, and logistical reliability, thus boosting overall economic productivity (Gibbons et al., 2019; Holl, 2016) thus subsequently elevating worker compensation (Gibbons et al., 2019; Yamauchi, 2016).

Conversely, the toll road operation does not have a significant impact to unemployment rate, although the descriptive statistics suggest that cities traversed by toll road has higher OUR than cities that are not traversed.

However, this study has a few limitations. Based on sensitivity analysis excluding the COVID-19 year, the causal relationship between toll operation and average wages is heavily influenced. Additionally, because of national budget cuts in 2016, the August 2016 National Labor Force Survey (Sakernas) only provided data at the provincial level. Afterwards, the 2016 data for average wages, the open unemployment rate (TPT), and the labor force size were approximated using imputation methods by calculating the average trends or proportions of provincial-level indicators.

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Appendix 1 COVID-19 Sensitivity Analysis

1. Year Fixed Effect (with usual fixed effect method)

The Impact Toll Road Operation to Average

Fixed-effects (within) regression			Number of obs			=	1,162			
Group variable: Kodebab			Number of groups			=	83			
R-squared:			Obs per groups:							
Whitin	=	0.8552		min	=		14			
Between	=	0.0173		avg	=		14			
Overall	=	0.3550		max	=		14			
corr(u_i), Xb)			=	-0.4543	F(4,4)			=	.	
						Prob > F			=	.
(Std. err. adjusted for 5 clusters in kodeprov)										
ln_UPAH	Coefficient	Robust std. err.	t	P> t	[95% conf. interval]					
OPERASI	.05333	.0224529	2.38	0.076	-.0090093			.1156693		
COVID	-.0401645	.0394115	-1.02	0.366	-.1495883			.0692593		
ln_UMR	.3151607	.0568682	5.54	0.005	.1572692			.4730522		
ln_PDRB	.049763	.0905445	0.55	0.612	-.2016287			.3011547		
IPM	.0178182	.0081949	2.17	0.095	-.0049345			.0405709		
ln_investasi	.0045269	.0040098	1.10	0.331	-.0068509			.0159046		
ln_JANGKER	-.0119527	.0262971	-0.45	0.673	-.0849651			.0610596		
DummyKEK	0	(omitted)								
ln_luas	.1561663	.0722535	2.16	0.097	-.0444416			.3567742		

Source: Processed by the authors

The Impact Toll Road Operation to Open Unemployment Rate

Fixed-effects (within) regression				Number of obs		=	1,162
Group variable: Kodebab				Number of groups		=	83
R-squared:				Obs per groups:			
Whitin	=	0.2497			min	=	14
Between	=	0.0028			avg	=	14
Overall	=	0.0119			max	=	14
corr(u_i), Xb				=	-0.4543		
				F(4,4)		=	.
				Prob > F		=	.
(Std. err. adjusted for 5 clusters in kodeprov)							
TPT	Coefficient	Robust std. err.	t	P> t	95% CI lower		
OPERASI	-.1256067	.2539553	-0.49	0.647	-.8306997	.5794862	
COVID	-2.301541	2.362508	-0.97	0.385	-8.860913	4.257832	
ln_UMR	1.986739	.4559037	4.36	0.012	.7209473	3.252531	
ln_PDRB	1.628661	1.729707	0.94	0.400	-3.173774	6.431097	
IPM	-.1109865	.2574129	-0.43	0.689	-.8256792	.6037062	
ln_investasi	.0183157	.0358865	0.51	0.637	-.0813213	.1179527	
ln_JANGKER	-.3462617	.3459619	-1.00	0.374	-1.306806	.6142825	
DummyKEK	0	(omitted)					
ln_luas	.8161456	.6236446	1.31	0.261	-.9153695	2.547661	

Source: Processed by the authors

Impact of Toll Operation to Average Wage on Unemployment

Pretrend Test. H0 All Pre-treatment are equal to 0							
chi2(26)	=	235.1922					
p-value	=	0.0000					
Average Treatment Effect on Treated							
	Coefficient	Std. err.	z	P> z	[95% conf. interval]		
ATT	0.44595613	.6596686	0.70	0.486	-.8333654	1.752488	
ATT by Periods Before and After treatment							
Event Study: Dynamic effects							
	Coefficient	Std. err.	z	P> z	95% CI lower		
Pre_avg	.1018301	.1190889	0.86	0.393	-.1315798	.3352399	
Post_avg	.3847133	.621503	0.62	0.536	-.8334101	1.602837	
Tm8	1.154499	.6296372	1.83	0.067	-.0795676	2.388565	
Tm7	-.2495217	.4974302	-0.50	0.616	-1.224467	.7254236	

Impact of Toll Operation to Average Wage on Unemployment (Continued)

ATT by Periods Before and After treatment

Event Study: Dynamic effects

	Coefficient	Std. err.	z	P> z	95% CI lower	
Tm6	.2945234	.4237489	0.70	0.487	-.5360092	1.125056
Tm5	-1.026019	.5525181	-1.86	0.063	-2.108229	.0561905
Tm4	.287789	.554142	0.52	0.604	-.7983095	1.373887
Tm3	.5107845	.5831475	0.88	0.381	-.6321636	1.653733
Tm2	.3021797	.6457664	0.47	0.640	-.9634991	1.567859
Tm1	-.4595937	.7797742	-0.59	0.556	-1.987923	1.068736
Tp0	1.058613	.7533376	1.41	0.160	-.4179012	2.535128
Tp1	.4617468	.6883911	0.67	0.502	-.8874751	1.810969
Tp2	.4873063	.6193339	0.79	0.431	-.7265659	1.701178
Tp3	.4130302	.6395833	0.65	0.518	-.8405299	1.66659
Tp4	.2391323	.6673228	0.36	0.720	-1.068796	1.547061
Tp5	.255672	.6297214	0.41	0.685	-.9785592	1.489903
Tp6	1.326741	1.327483	1.00	0.318	-1.275077	3.928559
Tp7	.6502614	1.394288	0.47	0.641	-2.082492	3.383015
Tp8	.5905418	1.452636	0.41	0.684	-2.256573	3.437657
Tp9	.3254754	.6524954	0.50	0.618	-.9533921	1.604343
Tp10	-.1137981	.7321785	-0.16	0.876	-1.548842	1.321245
Tp11	-.675578	.7726642	-0.87	0.382	-2.189972	.8388159
Tp12	-.0178714	.6704157	-0.03	0.979	-1.331862	1.296119

Source: Processed by the authors

2. Year fix effect (with CSDID method)

Impact of Toll Operation to Average Wage

Pretrend Test. H0 All Pre-treatment are equal to 0

chi2(26) = 433.6746

p-value = 0.0000

Average Treatment Effect on Treated

	Coefficient	Std. Err.	Z	P> z	[95% conf. Interval]	
ATT	.0596909	.0296705	2.01	0.044	.0015378	.1178439

ATT by Periods Before and After treatment

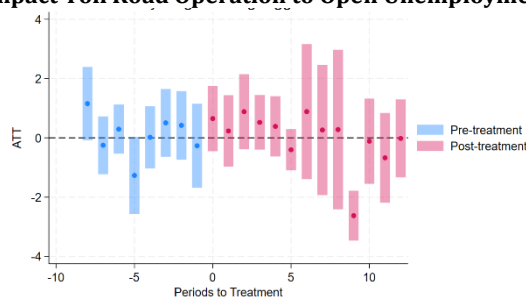
Event Study: Dynamic effects

	Coefficient	Std. Err.	Z	P> z	95% CI lower	
Pre_avg	.0127886	.0142002	0.90	0.368	-.0150432	.0406205
Post_avg	.0582406	.0295503	1.97	0.049	.000323	.1161582
Tm8	.0777539	.1033685	0.75	0.452	-.1248445	.2803524
Tm7	.0274155	.0455775	0.60	0.547	-.0619148	.1167458
Tm6	.0305269	.0226833	1.35	0.178	-.0139316	.0749854
Tm5	-.0271811	.0353567	-0.77	0.442	-.0964788	.0421167
Tm4	-.0133939	.0310778	-0.43	0.666	-.0743052	.0475174
Tm3	-.0236974	.0344658	-0.69	0.492	-.0912491	.0438542
Tm2	.0067773	.0183066	0.37	0.711	-.029103	.0426576
Tm1	.0241076	.0397603	0.61	0.544	-.053821	.1020363
Tp0	.0227404	.0282005	0.81	0.420	-.0325316	.0780124
Tp1	.0445181	.030615	1.45	0.146	-.0154862	.1045224
Tp2	.0526609	.0387839	1.36	0.175	-.0233541	.128676
Tp3	.0913409	.0405647	2.25	0.024	.0118355	.1708463
Tp4	.1030992	.0393747	2.62	0.009	.0259261	.1802722
Tp5	.0453928	.0316223	1.44	0.151	-.0165857	.1073714
Tp6	.0776828	.0556212	1.40	0.163	-.0313329	.1866984
Tp7	.0678892	.083821	0.81	0.418	-.096397	.2321754
Tp8	.0612703	.0568227	1.08	0.281	-.0501001	.1726407
Tp9	.1048389	.043244	2.42	0.015	.0200822	.1895956
Tp10	.1014224	.038583	2.63	0.009	.025801	.1770438
Tp11	.0188304	.0395426	0.48	0.634	-.0586717	.0963325
Tp12	-.0345584	.0413945	-0.83	0.404	-.1156901	.0465732

Source: Processed by the authors

3. Without 2020 data

The Impact Toll Road Operation to Open Unemployment Rate



Pretrend Test. H0 All Pre-treatment are equal to 0

chi2(26) = 641.8441

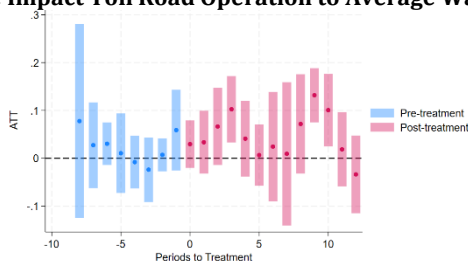
p-value = 0.0000

Average Treatment Effect on Treated

	Coefficient	Std. err.	z	P> z	[95% conf. interval]	
ATT	.3314106	.5348323	0.62	0.535	-.7168415	1.379663

Source: Processed by the authors

The Impact Toll Road Operation to Average Wages



Pretrend Test. H0 All Pre-treatment are equal to 0

chi2(26) = 3498.9468

p-value = 0.0000

Average Treatment Effect on Treated

	Coefficient	Std. Err.	Z	P> z	[95% conf. Interval]	
ATT	.0439948	.0280711	1.57	0.117	-.0110236	.0990132

Source: Processed by the authors

4. Without 2020 and 2021 data

Impact Toll Road Operation on Average Wage

Pretrend Test. H0 All Pre-treatment are equal to 0

chi2(26) = 3498.9468

p-value = 0.0000

Average Treatment Effect on Treated

	Coefficient	Std. err.	z	P> z	[95% conf. interval]	
ATT	.0421862	.029441	1.43	0.152	-.015517	.0998895

ATT by Periods Before and After treatment

Event Study: Dynamic effects

	Coefficient	Std. err.	z	P> z	95% CI lower	
Pre_avg	.0225941	.0154727	1.46	0.144	-.0077319	.0529201
Post_avg	.0422452	.0291411	1.45	0.147	-.0148704	.0993607
Tm8	.0777539	.1033685	0.75	0.452	-.1248445	.2803524
Tm7	.0274155	.0455775	0.60	0.547	-.0619148	.1167458
Tm6	.0305269	.0226833	1.35	0.178	-.0139316	.0749854
Tm5	.0106735	.042391	0.25	0.801	-.0724113	.0937584
Tm4	-.0079452	.0281034	-0.28	0.777	-.0630269	.0471365
Tm3	-.0237683	.0344173	-0.69	0.490	-.091225	.0436885
Tm2	.0072054	.0174884	0.41	0.680	-.0270712	.041482
Tm1	.0588912	.0430078	1.37	0.171	-.0254025	.1431849
Tp0	.0296442	.0252315	1.17	0.240	-.0198086	.0790969
Tp1	.0335474	.0334962	1.00	0.317	-.0321039	.0991987
Tp2	.0619084	.052184	1.19	0.235	-.0403703	.1641871
Tp3	.1344055	.0448864	2.99	0.003	.0464298	.2223811
Tp4	.0410061	.040428	1.01	0.310	-.0382313	.1202435
Tp5	.0333596	.0298226	1.12	0.263	-.0250916	.0918109

Impact Toll Road Operation on Average Wage (Continued)

ATT by Periods Before and After treatment

Event Study: Dynamic effects

	Coefficient	Std. err.	z	P> z	95% CI lower	
Tp6	-.0211061	.0737732	-0.29	0.775	-.1656989	.1234866
Tp7	.0053451	.0821569	0.07	0.948	-.1556795	.1663698
Tp8	.071771	.0529803	1.35	0.176	-.0320684	.1756105
Tp9	.1317922	.0288749	4.56	0.000	.0751985	.1883859
Tp11	.0188769	.0395426	0.48	0.633	-.0586251	.096379
Tp12	-.0336082	.0413945	-0.81	0.417	-.1147398	.0475235

Source: Processed by the authors

Impact Toll Road Operation on OUR

Pretrend Test. H0 All Pre-treatment are equal to 0

chi2(26) = 641.8441

p-value = 0.0000

Average Treatment Effect on Treated

	Coefficient	Std. err.	z	P> z	[95% conf. interval]	
ATT	.2706581	.5387084	0.50	0.615	-.785191	1.326507

Source: Processed by the authors

ATT by Periods Before and After treatment

Event Study: Dynamic effects

Period	Coefficient	Std. err.	z	P> z	95% CI lower	
Pre_avg	.0760912	.127896	0.59	0.552	-.1745804	.3267627
Post_avg	-.05442	.4788533	-0.11	0.910	-.9929553	.8841152
Tm8	1.154499	.6296372	1.83	0.067	-.0795676	2.388565
Tm7	-.2495217	.4974302	-0.50	0.616	-1.224467	.7254236
Tm6	.2945234	.4237489	0.70	0.487	-.5360092	1.125056
Tm5	-1.267334	.663205	-1.91	0.056	-2.567192	.0325236
Tm4	.0197498	.5356601	0.04	0.971	-1.030125	1.069624
Tm3	.5047894	.5830237	0.87	0.387	-.637916	1.647495
Tm2	.420047	.58937	0.71	0.476	-.735097	1.575191
Tm1	-.2680227	.7230819	-0.37	0.711	-1.685237	1.149192
Tp0	.6492773	.5620344	1.16	0.248	-.4522898	1.750844
Tp1	.2319438	.6147461	0.38	0.706	-.9729364	1.436824
Tp2	.6288832	.862743	0.73	0.466	-1.062062	2.319829
Tp3	.655096	.6775755	0.97	0.334	-.6729276	1.98312
Tp4	.3864849	.518667	0.75	0.456	-.6300837	1.403053
Tp5	-.316609	.3867431	-0.82	0.413	-1.074612	.4413935
Tp6	-.0983302	.641475	-0.15	0.878	-1.355598	1.158938
Tp7	.2465018	1.210908	0.20	0.839	-2.126834	2.619838
Tp8	.2794936	1.372315	0.20	0.839	-2.410194	2.969181
Tp9	-2.623485	.4286407	-6.12	0.000	-3.463605	-1.783365
Tp11	-.6725942	.7726642	-0.87	0.384	-2.186988	.8417998
Tp12	-.0197026	.6704157	-0.03	0.977	-1.333693	1.294288

Source: Processed by the authors