Assessing the Impact of Road Infrastructure and Density on the Local Welfare

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Abstract. The ultimate goal of economic development is a better change in people's welfare. Researchers and policymakers have conducted many discussions, studies, and policies to improve people's welfare. Welfare can be measured using changes in per capita income. This study aims to examine the impact of road infrastructure, population density, and control variables on people's income. The researcher used the GLS fixed effect regression model with secondary data. Secondary data was from the publication of the Central Statistics Agency, and the sample size was 13 sub-districts (individuals) from 2016 – 2020. The results show that road infrastructure is not a significant determinant of increasing people's income. Meanwhile, population density significantly affects people's income. In other words, increasing population density can determine changes in people's welfare non-linearly. The more significant the increase in the number of people who have productivity, skills, and education, naturally and urbanization at a certain threshold can increase income. The findings of this study can contribute to the literature and the population management policies in Tangerang City.

Keywords: Infrastructure · Road · Density · Income · Welfare

1 Introduction

One of the crucial indicators in measuring the success of a region's economic development is an increase in the population's welfare. Better welfare will reduce the problem of income inequality and poverty. Many researchers have previously studied economic development at the local level, including [1], who argue that the concept of local development economics is related to institutions, income, wealth, social capital, and labor. Local economic development is the process of creating wealth using available resources in the government [2]. More recently, [1] defined economic development as "a means of achieving sustainable improvements in prosperity and quality of life through innovation, reducing transaction costs, and leveraging capabilities towards responsible production, and diffusion of goods and services."

The indicators used to measure local economic development by previous research are quality of life [1, 3], tax base [4], per capita income [5, 6], and job vacancy and growth [7, 8]. Other proxies for local economic development are the number of business incentives offered [8], the growth rate of gross domestic product [9], and the level of per capita

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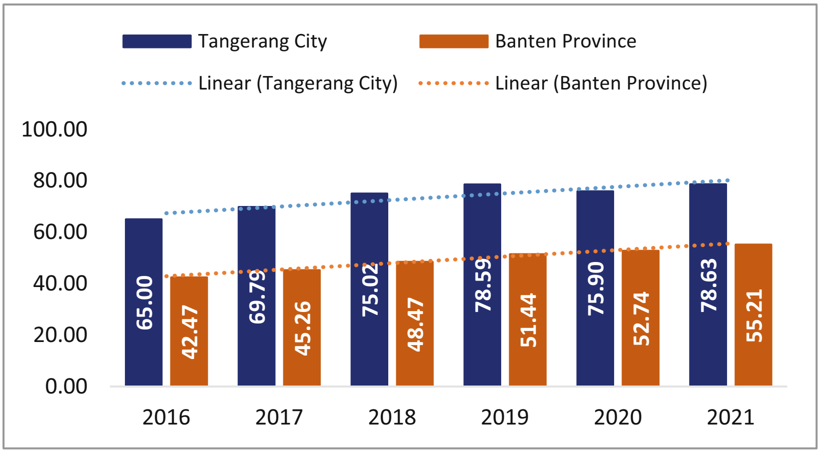

Fig. 1. Comparison of Tangerang City's Per Capita Income with Banten Province (According to Current Prices), 2016 – 2021. Source: BPS Banten Province (2022)

income and expenditure [5, 10, 11]. This study uses a measure of income per capita as a variable of local people's income because the higher the income per capita, the welfare will also increase. The income per capita measure of economic development is generally assessed at the global, regional, inter-country, national, provincial, and district/city levels. Studies at the local or sub-district level are still rarely conducted.

The condition or development of Tangerang City's per capita income in 2016–2021 shows a better condition and the trend of per capita income in Banten Province (see Fig. 1). Figure 1 shows that the per capita income of Tangerang City is higher than Banten Province. The average income per capita in Tangerang City during this period was IDR. 73.82 million per year, while Banten Province was IDR. 49.27 million per year. The highest achievement of per capita income in Tangerang City occurred in 2019 and 2021; IDR. 78.59 million per year and 78.63 million per year [12]. In other words, the prosperity or welfare of the people of Tangerang City improved that year, while the worst was in 2016. Figure 1 presents the details.

The development or availability of road infrastructure determines the level of prosperity or welfare of the community. Road infrastructure development ease to reach the location of economic facilities and community services by creating accessibility [11]. Road construction is a form of land transportation infrastructure [13] which benefits in encouraging the regional economy to increase connectivity or networks between regions [14]. The better the condition of the road network system in an area, the better the level of connectivity, which means the more accessible the relationship between regions. The higher level of connectivity can be seen from the shorter distance traveled and the increasing number of routes that become the choice of destination. Thus, it allows direct travel to the destination area and makes it accessible [15].

Road infrastructure investments directly affect users by reducing travel time and transportation costs [16]. In addition, investment in the transportation sector provides economic benefits for the production sector in the region (direct economic benefits).

These benefits include reduced costs of transportation of goods, a more extensive scale of operation, and economic accessibility [17]. The construction of road infrastructure and facilities directly impacts the community's welfare by creating jobs to reduce poverty levels [18]. Quality road infrastructure affects the accessibility and mobility of a region's development [19]and the improvement of the regional economy [11, 20]. Another study also proves that it is necessary to strengthen the road infrastructure in quality and quantity to increase people's income in one area [5]. However, another study found that the relationship between transportation and economic growth is indirect because it is through infrastructure capital stock, not transportation and private capital [21]. A recent study by Hidayati & Permana (2022) found that road infrastructure did not affect increasing per capita income. Therefore, the findings of previous studies regarding the linkages between road infrastructures are still inconsistent, and further research is needed to improve the consistency of the findings [22].

Another factor that affects local people's income is the population density of an area. Population density is the ratio between the total population and the area of a specific area. The high population growth will lead to an increase in population density. Population density between regions has different variances because it depends on the population and the area. Increasing population density depends on birth rates and urbanization flows [5, 23]. The relationship between population density and people's income as measured by per capita income has been carried out by previous researchers. For example Amri (2014) found a negative correlation between population density and per capita income [5]. Meanwhile, Gielen et al. (2021) test the relationship between population density and per capita expenditure, and the results show a significant negative relationship [24]. Meanwhile, other empirical results found that a low-density development pattern resulted in cost inefficiency in the provision of local public services [25]. Only a few researchers find the opposite: a positive correlation exists between population density and income per capita in aggregate [26]. This finding illustrates a pattern of positive and negative relationships, so testing innovations using a non-linear model is needed by adapting the Kuznets inequality hypothesis (Kuznets, 1967).

Previous studies examined the impact of road infrastructure, population density, and control variables on people's incomes at the global, inter-country, regional, national, provincial, and district/city levels. However, only a few examined the sub-district or village level. Therefore, this research was conducted using secondary data at the sub-district or village level. In addition, the authors find that the relationship between road infrastructure and community income is still inconsistent. Meanwhile, the relationship between population density and community income is linear. This study proposes a non-linear relationship for these two variables and evaluates the Kuznets' inequality curve at the sub-district level of Tangerang City. The research findings are expected to contribute to the literature on transportation and population economics and determine local government policies in improving the quality and quantity of sub-district roads and population problems.

2 Methods

The authors use panel data regression to examine the effect of road infrastructure and density on local people's income. The scope of this research is Tangerang City. Panel data is a combination of cross-sectional data and time series data. The data in this study is secondary data sourced from the Central Statistics Agency of Banten Province and the Central Statistics Agency of Tangerang City. The time range for the time series data is 2016–2020, and the number of individuals is 13 sub-districts in Tangerang City, resulting in a sample size of $t \times i = 5 \times 13 = 65$ units.

The dependent variable in this study is the community's income as measured by the income per capita of the sub-district. The author sets the independent variables consisting of road infrastructure and population density. Meanwhile, the control variables in this study are health and education infrastructure. For more details, the Table 1 presents the operationalization of the research variables.

The authors set specifications for the panel data empirical model to facilitate the testing of the variables used in this study as follows:

$$pic_{it} = \alpha_1 + \alpha_2 inf\_road_{it} + \alpha_3 lden_{it} + \alpha_j Z_{it} + u_{it} \tag{1}$$

where pic_{it} = local community income in sub-district i period t, inf_road_{it} = road infrastructure in sub-district i period t, $lden_{it}$ = population density in sub-district i period t, zit = control variable, which includes health and education infrastructure in sub-district i period t. α_0 = intercept, α_i = coefficient 1, 2,…, 4, and u_{it} = error term in estimation.

The use of Eq. (1) should meet the assumptions as a requirement of the analysis. These assumptions include that the data are typically distributed and free from multicollinearity, heteroscedasticity, and autocorrelation problems. Furthermore, it can be

Table 1. Operationalization of the variables

Variable name	Type of variable	Description	Scale
Local people's income [5, 11, 20, 28]	Dependent variable	Sub-district per capita income by working population aged above 15 years old	Ratio
Road infrastructure [5, 11, 20]	Independent Variable	Availability of road infrastructure as measured by road length per resident per sub-district area	Ratio
Population density [5, 26]	Independent variable	The total population of the sub-district is divided by the area of the sub-district.	Ratio
Health infrastructure [29]	Control variables	The number of hospitals, health centers, and posyandu in each sub-district is divided by the total population.	Ratio
Educational infrastructure [29, 31]	Control variable	The number of school infrastructures (junior, senior, and vocational high schools) in each sub-district is divided by the total population.	Ratio

done by selecting the best model by first conducting the Chow test to select the Common Effect (*CE*) or Fixed Effect (*FE*) model. The criteria set are if the probability value is < 0.05, then the model chosen is the fixed effect model. Next is choosing between Fixed Effect and Random Effect (*RE*) models with Hausman's test (Hausman, 1978). Both models are potentially valid in estimating the panel model with unobserved sub-district heterogeneity. Therefore, the *FE* or *RE* model can be a valid model based on the results of the Hausman specification test. To make the right decision between the *FE* and *RE* models, the Hausman formal specification test is estimated with the criteria that if the probability value is < 0.05, the model chosen is the fixed effect model. To produce the best model, if there is a heteroscedasticity problem, it is necessary to use the generalized least square (*GLS*) method.

3 Result

The author presents a statistical data description, including the mean, standard deviation, minimum, and maximum values. The presentation of the general statistical description of the data aims to control the data to be analyzed. The average value of the sub-district income per capita is 7.8710, and the standard deviation is 0.0812. This figure can be interpreted as the average income per capita of the sub-district in Tangerang City is IDR. 74,251,629.37 (see Table 2). Table 2 presents the description of statistical data.

The road infrastructure variable shows an average value of 0.00246 and a standard deviation of 0.0008, which means that the average length of sub-district roads is 0.00246 km per area per resident. Meanwhile, the average value of the population density variable is 4.09216, and the standard deviation is 0.1481, which means that the average sub-district population density is 13,016.06 people per kilometer during the study period (see Table 2).

A normality test is intended to test whether the data is typically distributed or not. The Jarque-Bera test has the criteria that if the significance probability value is >0.05, then the data is normally distributed. The results of the residual normality test resulted in the Jarque-Bera value = 3.7183 and the probability value = 0.1557 > 0.05. Therefore, it concludes that the data is typically distributed. The next assumption test is a multicollinearity test using the correlation between variables with r value criteria < 0.80. The

Table 2. Statistical description

Variables n = 65	Mean	Std. Deviation	Maximum	Minimum
pic	7.87101	0.08122	8.1022	7.5631
inf_road	0.00246	0.00088	0.0050	0.0009
lden	4.09216	0.14815	3.3546	3.8502
lden2	16.7674	1.2097	18.9625	14.8240
hinf	0.00058	0.00013	0.0012	0.0002
edinf	0.00067	0.00016	0.0013	0.0003

Table 3. Model selection test

Types	Effect test	Stat.	df	Prob.	Conclusion
Chow Test	Cross-section chi-square	108.956	12	0.000	Fixed effect model
Hausman Test	Cross-section random	149.9910	4	0.000	Fixed effect model

multicollinearity results produce a correlation value between -0.5439–0.0029 $<$ 0.80, concluding that the panel data regression model is free from multicollinearity problems.

The next classic assumption test is the heteroscedasticity test using the Panel Cross Section Heteroskedasticity LR test. The test results show that the LR test value = 24,667, and the probability value is sig. = 0.0025 $>$ 0.05. These results show that in the regression model, there is a problem of heteroscedasticity. Furthermore, the autocorrelation test aims to determine the error relationship between times. The author used the Durbin-Watson (DW) test to detect this problem. The test results show the value of DW = 1.8927. This value is compared with 4-du, 4-dl, du, and dl with k = 4. Values dl = 1.5034, du = 1.6960, 4-du = 4–1.5034 = 2.4965, 4-du = 4–1.6960 = 2.3039. Because the value of DW = 1.8927 is between 1.6960–2.3039, the panel data regression model is free from autocorrelation problems.

Before examining the impact of road infrastructure, population density, and control variables on the welfare of local communities in Tangerang City, the authors conduct a model selection test. There are three approaches in the model-selection test of panel data: the *LM* test, the Chow test, and the Hausman test. The following table presents the results of the model selection test:

Table 3 shows that the selection of the best panel data regression model only uses the Chow test and Hausman test because the results of the Chow test produce a probability value = 0.000 $<$ 0.05, which means that the proper regression model is the fixed effect model. Likewise, the Hausman test results show that the probability value = 0.000 $<$ 0.05, so the most common panel data regression model is the fixed effect model. Therefore, the *LM* test is no longer needed in this case.

As previously explained, the results of testing the heteroscedasticity problem are unavoidable, so the authors set a *GLS* fixed effect model to predict the welfare of local communities. Using the fixed effect *GLS* model is better than other regression models because it can overcome the problem of heteroscedasticity. The following table shows the estimation results of the regression model to test the effect of road infrastructure, population density, and control variables.

Table 4 explains that the selected model is the fixed effect model, and the fixed effect *GLS* shows relatively consistent results. The difference lies in the *GLS* fixed effect model that accommodates heteroscedasticity disorders. Therefore, the interpretation of the research results refers to the prediction results with the *GLS* 1 fixed effect model. R-square value = 0.9532 and adjusted *R*-square = 0.9364, *F*-Stat value = 59.881, and probability value = 0.000. It means that at least variables of road infrastructure, population density, and education infrastructure have a simultaneous effect on increasing the income of local people in Tangerang City. The predictive ability of these three

Table 4. Regression results (dependent variable = local per capita income)

Variables	Fixed effect model		*GLS* fixed effect model 1		GLS fixed effect model 2	
	Coefficient/Std. error	Prob.	Coefficient/ Std. error	Prob.	Coefficient/Std. error	Prob.
inf_road	-0.23.237 (13.437)	0.090	-28.639 (9.336)	0.004	-28.323 (9.037)	0.000
lden	-1.4637 (0.117)	0.000	-1.453 (0.086)	0.000	-6.477 (2.587)	0.015
lden2	-	-	-	-	0.606 (0.311)	0.058
hinf	34.804 (45.308)	0.446	9.833 (41.307)	0.813	41.643 (45.168)	0.361
edinf	-376.346 (42.643)	0.000	-389.252 (22.090)	0.000	-399.116 (22.057)	0.000
constant	14.152 (0.493)	0.000	14.145 (0.370)	0.000	24.529 (5.369)	0.000
Obs.	65		65		65	
R-square	0.8599		0.9523		0.9566	
Adjusted R-square	0.8133		0.9364		0.9408	
F-stat.	18.423		59.881		60.905	
Prob(*F*-stat.)	0.0000		0.0000		0.0000	

variables in determining people's income is 93.64%, and other variables determine the remainder.

The coefficient value of the road infrastructure variable is negative 28.639, and the probability value is $0.003 < 0.05$; therefore, for every 1 percent increase in new roads, it reduces the income of local communities by 28.63%. In other words, road infrastructure does not contribute to increasing people's income or welfare. Furthermore, the coefficient value of the population density variable is negative 1.452, and the probability value $= 0.000 < 0.05$. The interpretation is that for every 1% decrease in population density, local people's income will increase by 1.45%. In other words, the lower the population density, the higher the community's average income for all sub-districts in Tangerang City. Meanwhile, the control variable for the availability of health and education infrastructure does not determine the increase in community income for all sub-districts in Tangerang City, even though education infrastructure has a probability value $= 0.000 < 0.05$, but the coefficient value is negative.

The author also presents the estimation results using the *GLS* 2 fixed effect model by including the quadratic population density variable to determine whether the relationship between population density and community income forms a quadratic pattern (forming a

U curve) with the control variable. This model adapts from Kuznets' income inequality curve. The test results show that the relationship between population density and local people's income forms a *U* pattern. The coefficient values of population density and population density squared are -6,477 and 0.606, respectively, and the probability values are $0.015 < 0.05$ and $0.057 < 0.1$, respectively. Thus, the increase in population density initially negatively affects up to a certain threshold. Furthermore, increasing population density increases the average income of local people for all sub-districts in Tangerang City.

4 Discussion

The availability of road infrastructure in every sub-district of Tangerang City is expected to support the growth of the local economy because it will increase the mobility of goods and people in meeting their needs and economic activities. In addition, improved transportation flows and people's access to economic resources can increase goods and services. However, this study's results cannot prove that the sub-district road infrastructure variable per resident significantly affects increasing people's income. The author failed to prove that the availability of road infrastructure in increasing income is caused by the measurement of the variable length of roads per sub-district population. Moreover, the use of sub-district road length data is not disaggregated according to road conditions and types in each sub-district. As a result, road construction cannot be a significant determinant in increasing people's income.

This study's results certainly do not confirm previous research [5], which found that the increase in per capita income was determined by adding road length and road repairs. Likewise, other studies have found that quality road construction can increase access and reduce costs because it can save on production activities and increase people's income [11, 20]. However, this study is consistent with research findings that conclude that the availability of road infrastructure is not a significant determinant in increasing per capita income.

Meanwhile, the level of population density, as measured by the number of residents per region, has been shown to increase the income of local communities significantly. Population density is related to population growth in an area which means an increase in the number of the workforce so that it can encourage increased economic growth. The test results show that researchers can prove that population density significantly affects people's income. The higher population growth will impact increasing density in an area, so it can cause various problems that can hinder development. However, if this population density is appropriately handled, it can stimulate rapid economic development and increase people's income. This condition illustrates that the relationship between population density and community income (measured by sub-district per capita income) shows a parabolic relationship pattern, not linear.

For this reason, the researcher also examines the non-linear relationship between population density and people's income. The test results show that the relationship between the two variables forms a "U" relationship pattern, which means that the higher the population density, the income of the community will decrease (negative relationship) to a certain threshold. The addition of population can increase people's income. The population growth is an increase in productive age, adequate skills, and education to create jobs and support the success of local economic development. On the other hand, the increase in the population with no skills, low productivity, and uneducatedness can hinder local economic development. These findings are consistent with Kuznets's theory of income inequality (Kuznets, 1967) but do not form an inverted U pattern. Previous studies that are consistent with the findings of this study include [5, 23]. Recent studies in Indonesia also show that cities' urbanization encourages regions' existence and even increases population density, which impacts economic agglomeration (Tri & Angga, 2021).

In fact Mattson (2021) concludes that density is negatively correlated with per capita expenditure for the following cost categories: operational costs for fire protection, roads and highways, parks and recreation, sewerage, solid waste management, and water; construction costs for roads and highways, parks and recreation, sewers, and water; and the cost of land and existing facilities for police, sewers, and water. In other words, the more densely populated an area is, the lower the cost of spending, which means there is savings in income or an increase in welfare. Likewise, several previous studies that confirmed the findings of this study include a Spanish city study which also showed a negative relationship between population density or sprawl and per capita expenditure (Gielen et al., 2021). Meanwhile, Hortas-Rico & Solé-Ollé (2010) conducted an empirical analysis of 2500 Spanish municipalities and found that low-density development patterns lead to higher costs for local public services. However, other studies find that specialization in the production of capital goods is a source of increased yields in the aggregate economy, and population density is positively correlated with per capita income [26].

The researcher realizes that this research still has variable measurement limitations and findings. The limitation of this research is that the study of measuring the sub-district income per capita variable uses a proxy for the population aged 15 years and over who works in determining the Gross Regional Domestic Product at the sub-district level divided by the total population of the sub-district. The use of working people aged over 15 years; and people over 65 years are still counted even though they are no longer working. Likewise, the use of the length of sub-district roads and ignoring good road conditions, lightly damaged, moderately damaged, and heavily damaged, as well as the number of vehicles in Tangerang City in the analysis model. As a result, researchers cannot prove the role of road infrastructure as a determinant of increasing people's income. In contrast, good road infrastructure can increase the accessibility and mobility of economic resources to encourage the success of local economic development.

5 Conclusion

This study examines the impact of road infrastructure and population density on local people's income. Using the GLS fixed effect regression model, the researcher concludes that road infrastructure does not affect local people's income. In other words, improving road infrastructure quality and quantity is not a significant determinant in increasing the income of the sub-district community in Tangerang City. Meanwhile, population density has been shown to affect people's income significantly. Even the researchers were able to show that the pattern of the relationship between population density and people's income was a non-linear relationship with the addition of a control variable. It means that the higher the population density, the income level of the community will experience a decrease in income to a certain threshold. Furthermore, the increase in population density impacts increasing people's income.

The research findings implicate road infrastructure development to stimulate local economic development, but these study results cannot prove it. Therefore, the government continues to build road infrastructure for the success of local economic development. The government can improve road maintenance to ease the community in accessing essential public services such as population, education, and health services. The increasing population density due to natural population growth and urbanization has become a vital capital for the government to encourage the success of local economic development. The study results have shown that the existence of a population with skills, productivity, and education benefits the development of Tangerang City. Therefore, the government should continue to maintain optimal population density conditions.

Meanwhile, the implications of the findings of this study for future research should re-examine the road infrastructure variable by expanding or disaggregating road characteristics into separate variables. It aims to obtain information on the contribution of roads based on specific characteristics. Another significant thing from future research is the measurement of population density by including pure land use indicators in addition to the sub-district area to obtain information on the area after deducting land use for roads, housing, markets, and other economic activities. In addition, the use of time series for research data is more extended, thus increasing the size of the data. Decision-making generalization of research results becomes more manageable and better.

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