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Automobile and Motorcycle Traffic on Indonesian National Roads: Is It Local or Beyond the City Boundary?

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Abstract

This paper investigates the dimensions of private vehicles' trips on national roads between neighboring cities in Indonesia using the spatial lag model and the spatial error model approach to reveal the spatial correlations among cities. Private vehicles are defined as privately owned automobiles and motorcycles, and vehicle trips or usage levels are defined in terms of vehicle kilometers traveled (VKT) for both types of private vehicles. The paper finds that motorcycle trips are characteristically local because there is no sign of a spatial correlation with neighboring cities for those trips; by contrast, automobile trips often cross city boundaries, although the models constructed in this study demonstrate only weak spatial correlations among neighboring cities for automobile trips. The models also indicate that the road capacity, gasoline prices, gross domestic regional product per capita, population density, city size, number of public buses, and worker resident density have a significant effect on VKT for both cars and motorcycles. Therefore, these findings suggest that in general, the design of urban transportation policies on national roads could be less complex in Indonesian cities because local solutions may be effective for solving traffic problems in individual cities.

Keywords: auto transport, Indonesia road traffic, spatial autocorrelation

JEL codes: R41, R49, R53

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1 Introduction

Traffic demands on private vehicle usage for automobiles and motorcycles in one city can be affected by neighboring cities, as the residents of one city often make routine trips to neighboring cities for work, study, business, or other pursuits. In indonesia for example, national road networks are designed to facilitate not only intracity trips but also intercity trips. There, as in many neighboring developing countries with rising road transport demand, traffic counting surveys on national roads are conducted nearly every year; however, given the absence of origin-destination (OD) surveys for national roads, the true nature of trips on national roads cannot be precisely determined. Therefore, this study uses traffic counting data and spatial econometrics methods, specifically the spatial lag model (SLM) and the spatial error model (SEM), to examine the types of trips that are taken on national roads in Indonesia. The vehicle trips in this study are represented by the vehicle kilometers traveled (VKT) of automobiles and motorcycles; the VKT values are derived from traffic counting data.

This study hypothesizes that there is a positive spatial correlation for trips on national roads between neighboring cities and that this correlation should be stronger for automobiles than for motorcycles, reflecting our conjecture that automobile trips are intercity while motorcycle trips are more local. Results show that the spatial correlation for trips on national roads between cities in Indonesia is relatively weak such that motorcycle trips are not spatially correlated with neighboring cities and automobile trips demonstrate weak but statistically significant spatial correlations for intercity trips.

Furthermore, an analysis of the explanatory variables reveals that Gross Domestic Regional Product (GDRP) has a different impact for automobile trips than for motorcycle trips but that various other variables, such as the roughness of roads, national road capacity, city size, and population density, produce similar effects on both automobile and motorcycle trips.

This study uses cross-section data because many variables in the transportation sector do not change significantly in the short term, although a number of these variables, such as road length, city size, public transportation services, and capacity, among others, can change significantly in the long run. Qing (2010) used 20 years of panel data for 85 urban areas to find the variation across time, but it is very difficult to find a continuous set of transportation data in many developing countries, including Indonesia. Qing (2010) used dynamic panel data but was not aware of the possibility of spatial dependence. Thus, instead of focusing on the time variability of Indonesian transportation data, this study focuses on the spatial interdependencies among geographical units and explores the possibility of determining the use levels of automobiles and motorcycles by assessing the relationships between cities with the SLM and the SEM. Le Sage and Pace (2009) described the SLM as a model that uses dependent variables from neighboring cities as independent variables for other cities. These researchers also defined the SEM as a model that examines dependencies in disturbance; these dependencies imply that there is a spatial dependence in an unobserved variable.

VKT is the variable that is probably the most reliable data available in Indonesia to represent the country-wide usage levels of vehicles. VKT has been used in this context in studies conducted by Senbil, Zhang, and Fujiwara (2006), Tanner (1978), Qing (2010), Wen, Chiou, and Huang (2011), Huo et al. (2012), Duranton and Turner (2009), and Mulley and Tanner (2009). Tanner (2011) attempted to use GDP, income, demographic characteristics, and the price of fuel to predict VKT; Qing (2010) used urban spatial characteristics to predict VKT per capita, with the results showing that road density and city size have a positive impact on VKT per capita. Wen, Chiou, and Huang (2011) subsequently obtained the following conclusions: income had a negative relationship with VKT, males used motorcycles more often than females, a greater number of commuting and recreational days increased VKT, and the frequency of motorcycle usage was positively correlated with motorcycle engine size. In addition, Duranton and Turner (2009) used road infrastructure (measured in terms of the number of kilometers of lanes) to measure the effect on VKT. In Indonesia, two institutions use VKT for establishing policies, namely, the Ministry of Public Works and the Ministry of Transportation. These two institutions have different goals and use different approaches to measure VKT. The Ministry of Public Works applies the traffic count method to generate VKT and considers VKT to be one important performance metric to indicate the utilization level of a particular road (PK Ditjen Bina Marga, 2010). By contrast, the Ministry of Transport uses VKT as a tool for measuring CO2 emissions from various transportation sectors and derives VKT from JICA household trip survey data (SUTIP, 2010).

Senbil, Zhang, and Fujiwara (2006) studied motorcycle usage in Indonesia by utilizing a 2003 survey of household trips that was conducted by JICA. However, the area of study for this survey was limited to the Jakarta metropolitan area, and household trip surveys are infrequently conducted in Indonesia due to their high implementation costs. Thus, analyzing the existing household trip survey data from Indonesia would be highly limited in time and place and would not be representative of other Indonesian cities because Jakarta is a primate city with no domestic equal in terms of population or economy. This study attempts to create a model that can represent vehicle usage in various Indonesian cities by capturing the characteristics of a larger number of cities and observing the spatial correlations among cities.

Studies tracking the usage of private automobiles and motorcycles could become an important input for urban transportation policy because the rapid motorization of urban areas is a common situation that is being addressed in many modern Indonesian cities. In contrast to the motorization of developed countries, both cars and motorcycles play important roles in the motorization process in many developing countries. For this reason, many large Asian cities, such as Bangkok, Jakarta, and Hanoi, have become motorcycle cities and are referred to by certain transportation experts as "traffic disaster cities" (Kenworthy, 2011). As Kenworthy's study discussed, there is typically only 1 meter of road space per capita in developing countries compared with 5-8 meters per capita in developed countries; because of this extremely low ratio of road availability per capita in developing nations, the motorization of these developing nations creates severe traffic congestion. Kenworthy (2011) also observed that many individuals who had previously walked, operated non-motorized vehicles, or used low-cost public transportation have migrated to the use of motorcycles in developing countries and argued that this migration was not only a result of individual decisions but also an outcome that was promoted by governmental policies that encouraged road building, vehicle ownership, urbanization, and suburbanization. Moreover, as Dimitrou (2011) demonstrated, the rapid rates of motorization in Asia are closely related to the economic growth rates of the region.

The rapid motorization of Indonesia's cities can be observed by examining the average speed of vehicles in large, medium-sized and small cities. The average vehicular speed in large cities has dropped significantly from 2007 to 2010; in Surabaya, the average vehicular speed has fallen from 24 km/h to 21 km/h, and in Medan, the average vehicular speed has decreased from 39.4 km/h to 23.4 km/h. This decrease in speed can also be observed in medium and small cities such as Padang, where the average vehicular speed has been dramatically reduced from 40.9 km/h in 2007 to 30.9 km/h in 2010, and in Padang Panjang, where the average vehicular speed has declined from 38.8 km/h in 2007 to 25.62 km/h in 2010.

The number of private vehicles in Indonesia has increased significantly, as this number has more than doubled from 5,133,746 in 2003 to 11,828,529 in 2009. The number of motorcycles has increased even more rapidly during the same period, growing from 23,312,945 to 59,447,626 in just seven years. Conversely, during the same period, the total road length in Indonesia has only increased by approximately 35% from 328,314 km to 446,278 km. The increase in the number of private vehicles has been associated with a rise in the number of accidents, especially with respect to accidents that involve motorcycles, which increased from 9,386 to 164,431. Information regarding the demand for travel by car and motorcycle and the correlations among cities in terms of travel would provide better input to craft policies that could more effectively manage the motorization process.

2 Road Conditions and Traffic in Indonesian Cities

This study utilizes the database of the Indonesia Road Management System (IRMS). IRMS is a system that is managed by the Ministry of Public Works' Directorate General of Highways and is used for the planning, programming, and budgeting of national roads in all Indonesian provinces. Several different surveys and inventories collect data for input into the IRMS, all of which are used in this study: data from traffic surveys are utilized to measure the VKT values for cars and motorcycles, roughness data are used to compute the International Roughness Index (IRI) variables, and inventory data are used to determine the national road capacity and the number of kilometers of lanes.

Prior to an analysis of the model and the regression results, the separate assessment of each of the variables of the model, particularly the variables derived from road data, can provide a great deal of information about the conditions of road transportation in urban areas of Indonesia. More than 50% of both Indonesia's national economic activity and the Indonesian population is concentrated on the island of Java; for this reason, it is common to discuss and analyze Indonesia in terms of Java and "outer Java", a term that refers to the other Indonesian islands. Another term that is frequently used is "large cities", which are defined as cities with a population of at least 500,000 people. Cities with populations of less than 500,000 people are categorized as medium-sized and small cities.

As shown in Tables 1 and 2, the mean VKT value for motorcycles is almost three times greater in Java than in outer Java; however, this difference is statistically insignificant.

// insert Table 1 here //

// insert Table 2 here //

The mean VKT value for motorcycles is five times greater in large cities than in small and medium-sized cities, but this difference is also statistically insignificant. Similarly, for cars, the difference in the mean VKT values between Java and outer Java is not statistically significant, despite the fact that this difference is higher than the difference in the mean VKT values for motorcycles between these regions;

the differences in the mean VKT values for cars for different city sizes is statistically significant in 10%.

The difference in IRI between Java and outer Java is also not statistically significant; in particular, the condition of national roads in urban areas in both Java and outer Java is fair because the mean value remains stable at approximately 5 (see Table 3).

// *insert Table* 3 *here* //

However, we must recall that this value is only meaningful within the city limits. Large cities do not differ in a statistically significant way from small and medium-sized cities with respect to IRI. Thus, the IRI values in Indonesian cities do not vary significantly across cities.

Table 4 shows that the mean national road capacity in Java is almost twice the mean national road capacity of outer Java, but this difference is not statistically significant.

// *insert Table* 4 *here* //

The mean national road capacity of large cities is approximately three times greater than the mean national road capacities of small and medium-sized cities, a difference that is also statistically insignificant.

Motorcycles dominate city roads in many Asian countries, and the same phenomenon occurs in Indonesian cities, as indicated by data regarding the proportion of motorcycles in daily traffic on national roads (see Table 5).

// *insert Table* 5 *here* //

Furthermore, the mean proportion of motorcycles in outer Java is 50% of the daily traffic, a figure that is much higher than the 39% found in Java; at 10%, this difference in the proportion of motorcycles is statistically significant. The mean proportion of motorcycles in daily traffic is approximately 6% lower in large cities than in small and medium cities, and this difference is significant at the 5% confidence level.

As shown in Table 6, the proportion of private cars in daily traffic on national roads is less than that of private motorcycles.

// *insert Table* 6 *here* //

In Java, the mean of proportion of private cars is around 20%, which is 3% higher than that in outer Java and the difference is significant in 10%. For big cities, the mean of proportion of cars is around 21%, and for small and medium cities it is around 18%. The difference between big cities and small and medium cities is significant in 5% level of confidence.

3 Data

This section will explain the dependent and independent variables that are used in this study. The dependent variables are the VKT values for automobiles and motorcycles, and the explanatory variables are the road roughness, Gross Domestic Regional Product (GDRP) per capita, population density, city size, national road capacity, volume capacity ratio, price of gasoline, the number of working residents per area, number of public buses, and sex ratio for each city. These data are summarized in Table 7.

// insert Table 7 *here //*

The data for this study were obtained from two sources: the Ministry of Public Works and the Local Statistics Bureau. The study uses cross-section data from 77 cities across Indonesia that vary in size from small to medium-sized cities with populations of approximately 50,000 individuals to large cities with populations of approximately 9,000,000 residents. Geographically, the city sample is representative of all of the major Indonesian islands because there are only 93 administrative cities in the entirety of Indonesia.

3.1 Dependent variables

The dependent variable in this study is vehicle kilometers traveled for private cars and motorcycles. The VKT values are obtained from traffic data for national roads in 77 Indonesian cities. The traffic count survey is conducted annually by the Ministry of Public Works and characterizes vehicles into 12 different types: motorcycles, private cars, utility passenger vehicles, utility freight vehicles, small buses, large buses, trucks with two axles and four wheels, trucks with two axles and six wheels, trucks with three axles, tow trucks, semi-trailers, and non-motorized vehicles. The traffic count survey is conducted using both an automatic and manual traffic count over a period of approximately 40 hours.

The VKT values for cars and motorcycles are obtained as the summation of the average number of traffic per day in each road segment multiplied by its lengths over all the segments within the city for the 77 cities. The VKT is limited to national road segments in this study, meaning that the VKT gives information regarding the movement of vehicles on national roads for one year; this metric can also be interpreted as a measurement of the level of utilization of national roads. The units for VKT values are vehicle kilometers, and in the regression, this measurement is denoted by *vktcar* for private car VKT values and by *vktmtc* for motorcycle VKT values.

VKT values measure the amount of movement in a defined area; for the purposes of this study, the defined areas are the cities that are examined. Because traffic movement can be either restricted to the inner city or expanded to include intercity movement, the VKT in one city may be influenced by neighboring cities. Thus, there is a possibility of spatial dependence in the VKT variable; to overcome problems of spatial dependence, this study employs a spatial econometrics model.

3.2 Independent variables

The explanatory variables are proxies for road characteristics, economic factors, demographics, and urban factors. The independent variables that represent road characteristics are the International Roughness Index (IRI), the capacity of national roads, and the volume capacity ratio. The price of gasoline and the GDRP per capita are proxies for economic factors, and the sex ratio is a proxy for demographic factors. The population density, the number of working residents per km^2, and the city size are the variables that represent urban factors. Public transportation considerations are incorporated by considering the number of public buses that exist within a city. The IRI is an index that measures the roughness of pavement. This index was created by the World Bank in the 1980s as a tool for measuring road quality and user cost and is a continuous metric that begins at 0 mm/m.[1] A higher IRI value indicates that the road pavement is increasing in roughness. In the regression, the variable for IRI is denoted by *iri*.

The capacity of national roads is measured by totaling the total capacity of national roads for each road segment and multiplying this capacity by the length of the road segment in question. The unit for this variable is $km - PCE$ (passenger car equivalents) per hour. The road capacity is obtained from the road inventories survey, which assesses the carriage width, shoulders, type, and terrain for each road. The data from the inventories survey were used as an input for measuring road capacity in PCE per hour. The inventories survey is conducted by manual observation and is not performed every

[1] A roughness survey is conducted annually by Indonesia's Ministry of Public Works using various car-based tools, such as ROMDAS or NAASRA; the tool records the bumps on the road, and its results can later be converted to an IRI value.

year; rather, it is dependent on changes in road inventories. Duranton and Turner (2009) used road characteristics as the independent variable in their travel demand study. The symbol for this variable is capnroad.

The Volume Capacity Ratio (VCR) is used by traffic engineers and transport planners to indicate travel time and traffic flow or congestion. A VCR value of 1 indicates that traffic volume is equal to road capacity, If this ratio is greater than 1, the traffic flow may be heavy and the traffic speed may decrease to inconvenient levels; conversely, a decrease in the ratio can indicate that traffic is flowing more freely and that travel time may be decreasing (and/or traffic speed may be increasing) to more convenient levels. In the regression, this variable is represented by *vcr*. Because not all of the cities represented in this study collect data on average speeds, speed cannot be used as an explanatory variable in this study due to a lack of adequate data about speeds in particular cities or urban areas; however, speed levels can be predicted using the VCR data.

The price of gasoline is obtained from household gasoline expenditures, which is a statistic that is collected by Indonesia's National Bureau of Statistics; in the regression, the variable is represented by *pgasoline*, with the rupiah being the price unit. The price of gasoline represents one of the costs of using any type of private vehicle, and Qing (2010) and Tanner (1978) also use the price of gasoline as an explanatory variable for VKT values. The quantity of GDRP per km can represent the relative level of wealth and can also substitute for income data because income data are more difficult to obtain. In the regression, the variable of GDRP per km is represented by *gdrpcap* and is expressed in rupiahs. In addition, the sex ratio is a demographic characteristic that indicates the ratio of males to females. Previous studies, such as the investigation by Wen, Chiou, and Huang (2011), have demonstrated that gender can influence the demand for travel; this variable is represented by *sexratio* in the model.

Population density, which is represented by *popdens* in the regression, is an important variable for travel demand because low population densities can cause automobile dependence (Kenworthy, 2011); the population per km^2 can also describe the urban density and the level of sprawl of a region. The road density is the ratio of national and local road length to city size in km/km^2 and is represented by *roddens* in the model. The number of working residents per km^2, *rworkerperkm*, can be an indicator of the trips that result from work activity, and the value of this variable is obtained by dividing the number of working residents of a city by the city's area.

Public transportation variables could be very useful for explaining private vehicle usage behaviors for both cars and motorcycles. The variable for public transportation in this paper is *numpubbus*, the number of public bus vehicles that are available.

4 The Spatial Lag and Spatial Error Models

This study tests the hypothesis that there is a strong correlation of spatial lags for trips on national roads between neighboring cities where a stronger correlation is expected for automobile usage than for motorcycle usage because automobiles are more commonly employed for trips of longer distances.

Analyses of cross-section data typically use the ordinary least squares (OLS) method, and in our paper it becomes as follows (see, for example, Le Sage and Pacey, 2009):

$$\begin{aligned} y_i &= x_i\beta + \varepsilon_i \\ \varepsilon_i &\sim N\left[0, \sigma^2\right] \end{aligned}$$

where y_i is the VKT for car/motorcycle in city i while x_i is the vector of independent variables in the city i. In cross-section OLS analysis, the dependent variable values for one city are assumed to be independent of the values in other cities. Moreover, the expected value of errors between regions $E\left[\varepsilon_i \varepsilon_j\right]$ is zero.

However, cross-section observations often represent or relate to a spatial unit such as a geographic region; and in such a case the variable values that are observed in one region can be dependent on observations in other regions. Thus, the conventional OLS approach on cross-section data may be biased. Specifically, when there is spatial correlation among y_i the ordinary least squares is not consistent; thus, to solve this endogeneity problem, a model that can perform simultaneous calculations is required. The spatial autoregressive model can resolve the endogeneity due to spatial dependence of dependent variables across regions. In turn, if the relevant independent variables that are correlated with those in other regions are not included in the model, these omitted variables cause spatial correlation in the error term. When the errors are spatially correlated the simple OLS cannot be consistent either, and spatial error model (SEM) is appropriate. In this study, we therefore employ the spatial lag and spatial error models to solve the spatial dependence problems.

The spatial lag model (SLM) assumes that the dependent variables in one region are dependent on the dependent variables in other regions. Equation below provides the model for spatial lag:

$$y = \lambda W y + X\beta + \varepsilon$$

where y is a VKT vector, λ represents spatial lag coefficient, W is the spatial weight matrices, and X is a matrix of independent variables. Furthermore, the spatial error model (SEM), expressed as follows, will solve this problem of spatial error dependence:

$$\begin{aligned} y &= X\beta + u \\ u &= \rho W u + \varepsilon \end{aligned}$$

where a scaler ρ represents the spatial correlation among the error terms.

We define the spatial weight matrix W so as to indicate the proximity between cities in a way that the matrix values is one (before row normalization) for cities whose centers are not more than 100 km apart; and a pair of cities that does not meet this definition is given a value of zero in the matrix. A common alternative will be such that the matrix values is one when two cities share a common border and zero otherwise, however, this study does not use a contiguity matrix because there are many small and medium-sized cities in Indonesia who are close but do not share borders.

The use of the least squares method for calculating the spatial dependence model creates the problem of inconsistencies in the estimated parameters and standard errors; this problem can be mitigated through the use of maximum likelihood method (MLE) for spatial dependence problems (Le Sage and Pacey, 2009). In order to attain consistency in SLM and SEM estimation above we use the maximum likelihood method instead of the least squares approach. The generalized spatial two-stage least squares (GS2SLS) method also generates a consistent estimates in the models with spatial dependence. Thus, this study will evaluate both the maximum likelihood and the GS2SLS methods to determine which of these approaches produces more accurate results.

For each of two dependent variables namely VKT of cars and VKT of motorcycles, five regression models are hence estimated: OLS, SLM via MLE, SLM via GS2SLS, SEM via MLE, and SEM via GS2SLS. The maximum likelihood model assumes that errors are normally distributed. If the model fails the normality test, then the maximum likelihood approach cannot be used, and the problem can only be solved by the GS2SLS method. Therefore, we first estimate the OLS model and conduct the normality test of the error distribution in preparation for the MLE.

In our settings, if there are omitted variables that are spatially correlated then the spatial error model (SEM) will, and if there is no spatial dependence at all then the plain OLS model will attain. However, in our context we expect car travel have more inter-city trips and thus, the best model to explain the usage of cars is expected to be the spatial lag model (SLM). All of the explanatory variables for cars and motorcycles are the same and as listed in the previous section.

5 Results of the Regression Models

In the preliminary tests for spatial correlation, Moran's I, LM, and LM Robust tests, we found that the VKT of motorcycles had no indication of spatial correlation both in spatial error and spatial lag. In contrary, there was a weak indication, significant in 10%, of spatial correlation in spatial lag model of VKT for car.

// insert Table 8 here //

// insert Table 9 here //

In the Jarque-Berra normality test, the null hypothesis assumes that the model has a normal distribution, meaning that if the null hypothesis is rejected, the maximum likelihood approach cannot be used for solving the spatial correlation in this study. In our results, the normality test result for cars is only weakly (at 10%) significant and for motorcycles it is insignificant; therefore, this study uses both the MLE and the GS2SLS method. The estimation results from both methods produce almost identical results.

// insert Table 10 here //

// insert Table 11 here //

With respect to the automobiles, spatial lag coefficient λ in both SLM models via MLE and the GS2SLS are significant at the 5% level, implying that the spatial dependence of the VKT values for automobiles that supports our initial hypothesis that auto travel on national roads in Indonesia is beyond the city boundary. Yet, the coefficient of lambda is quite low (0.2); this result can be interpreted to mean that cross-boundary trips between cities are present, but does not necessarily consist a major part of the traffic. For motorcycle VKT, there is no evidence of spatial dependence between neighboring cities in terms of dependent variables; for both the MLE and GS2SLS regressions the values of λ are not statistically significant. This postulates that, unlike auto travel, motorcycle trips are limited within the city boundary.

As for SEM, the spatial error correlation parameter ρ is statistically insignificant for both cars and motorcycles, providing no evidence of spatial dependence in the error terms of the models. The values of the ρ exceeds unity, however it is statistically insignificant for both MLE and GS2SLS models.

Estimated coefficients for independent variables obtained from the SLM and the SEM do not provide different results from the findings of the OLS approach, but the significance of some independent variables in SLM and SEM are improved compared to the OLS approach. For automobiles, significance levels for the price of gasoline and VCR are greater for the OLS approach than for the results of either the SEM or the SLM.

The IRI values, which are typically used to evaluate the results of road maintenance, have only an insignificant influence on the VKT values for automobiles, but the capacity of national roads has a significant positive effect for automobile VKT values. This result implies that capacity expansion and new roads induce significantly greater car usage, although this effect is not guaranteed; only a large increase in capacity could significantly increase car usage. The GDRP per capita, city size, resident worker density, and VCR could also positively increase car usage. By contrast, gasoline prices and population density negatively influence the VKT values for cars. In addition, the number of public buses has a significant negative impact. The negative effect of the number of public buses on automobile VKT is statistically significant at the 10% confidence level, and on the usage of motorcycles it is at the 5% significance level. Another difference between the VKT results for motorcycles and cars is that in the OLS regression, the GDRP per capita is not significant for motorcycles.

6 Policy Implications and Concluding Remarks

This study investigated the correlations of private automobile and motorcycle usage on national roads among neighboring Indonesian cities. The investigation results demonstrated that on national roads, motorcycle trips exhibit the characteristics of local trips and do not show a significant spatial interdependencies with neighboring cities. Conversely, automobile trips evinced cross-city-boundary characteristics but with weak spatial correlations. For automobiles, the results of the SLM provide evidence that the spatial correlation of traffic between neighboring cities exists; however, the small number of spatial lag coefficients indicates that this correlation is rather weak. That is, in automobile travel the spatial correlation coefficient lambda is positive with 5% significance, although the magnitude of lambda is only 0.199 or 0.20. In other words, while some significant portion of it passes beyond city boundaries, the automobile excursions on a city's national roads are dominated by intracity trips. The results from the SEM indicate that there appears to be no other omitted variable that is spatially correlated. For motorcycles, there are no signs of spatial interdependencies of VKT values or omitted variables that are spatially related between neighboring cities. Thus, a motorcycle trips made on the national road in Indonesia is most likely to be a local trip within the city boundary.

Basing on this fact that private vehicles' trips on a city's national roads continue to be dominated by local trips, advocates increasing the local municipalities' responsibility of national road development and maintenance, and a local solution to the traffic problems on national roads could still be effective enough for solving traffic problems in the city. However, the weak relation of vehicle trips between neighboring cities could be a sign of low interaction between cities, such as interaction of economy activity between neighboring cities.

Concerning other socio-economics variables, the study found that the roughness of roads and the sex ratio had no significant impact on the VKT values of automobiles and motorcycles. The gross GDRP had no significant influence on motorcycle trips but was a significant influence on automobile trips. Moreover, the capacity of national roads, the city size, and the worker resident density had a positive impact on vehicle usage. By contrast, the price of gasoline, population density, and the number of public buses negatively impacted the VKT values for both automobiles and motorcycles.

This study does not include buses, trucks, and other heavier vehicles that are typically used for public or commercial purposes and for a longer distance, however, they make up only a small portion of national road traffic. In general, the traffic on national roads in Indonesian is still dominated by local trips of private vehicles and therefore, this paper concludes that required policy solution is less complex than it would be if traffic patterns evinced strong intercity tendencies.

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Table 1. Testing Two Means for VKT for Motorcycles in 77 Cities in 2010

by Islands	Mean (thousand VKT)	by City Sizes	Mean (thousand VKT)
Cities in Outer-Java	122,000	Small and Medium Cities	80,700
Cities in Java	337,000	Big and Metropolitan Cities	435,000
Total	193,000	Total	193,000
t-stat	0.954	t-stat	1.536
df	25.390	df	24.158
critical value	1.707	critical value	1.710
p-value	0.349	p-value	0.138

Table 2. Testing Two Means for VKT for Cars in 77 Cities in 2010

by Islands	Mean (thousand VKT)	by City Sizes	Mean (thousand VKT)
Cities in Outer-Java	42,700	Small and Medium Cities	24,800
Cities in Java	150,000	Big and Metropolitan Cities	193,000
Total	77,900	Total	77,900
t-stat	1.170	t-stat	1.7915
df	25.401	df	24.077
critical value	1.707	critical value	1.711
p-value	0.253	p-value	0.086

Table 3. Testing Two Means for IRI in 77 Cities

by Islands	Mean	by City Sizes	Mean
Cities in Outer-Java	4.6570	Small and Medium Cities	4.7363
Cities in Java	4.6098	Big and Metropolitan Cities	4.4368
Total	4.6415	Total	4.6415
t-stat	-0.1563	t-stat	-0.9784
df	56.564	df	51.668
critical value	1.672	critical value	1.675
p-value	0.876	p-value	0.332

Table 4. Testing Two Means for National Road Capacity in 77 Cities in 2010

by Islands	Mean	by City Sizes	Mean
Cities in Outer-Java	89,034	Small and Medium Cities	65,829
Cities in Java	147,474	Big and Metropolitan Cities	199,933
Total	108,267	Total	108,267
t-stat	1.270	t-stat	2.890
df	28.264	df	24.912
critical value	1.701	critical value	1.708
p-value	0.214	p-value	0.008

Table 5. Testing Two Means for Proportion of Motorcycles in National Road Daily Traffic in 77

by Islands	Mean	by City Sizes	Mean
Cities in Outer-Java	0.50	Small and Medium Cities	0.48
Cities in Java	0.39	Big and Metropolitan Cities	0.42
Total	0.46	Total	0.46
t-stat	-2.556	t-stat	-1,561
df	48.317	df	46.515
critical value	1.677	critical value	1.678
p-value	0.014	p-value	0.125

Table 6. Testing Two Means for Proportion of Cars in National Road Daily Traffic on National Roads in 77 Cities in 2010

by Islands	Mean	by City Sizes	Mean
Cities in Outer-Java	0.17	Small and Medium Cities	0.16
Cities in Java	0.20	Big and Metropolitan Cities	0.21
Total	0.18	Total	0.18
t-stat	1.861	t-stat	3.658
df	72.834	df	64.298
critical value	1.666	critical value	1.669
p-value	0.067	p-value	0.001

Table 7. Summary of Variables

Variable	Variables Description	Mean	Std. Dev.	Min	Max
vktmtc	Vehicle Kilometre Travelled for motorcycle on national roads (vehicle km	197,000,000	661,000,000	4,111,711	5,810,000,000
vktcar	Vehicle Kilometre Travelled for automobile on national roads (vehicle km	79,500,000	271,000,000	879,662.40	2,370,000,000
iri	Average international roughness index on national roads (m/km)	4.5951	1.2572	2.7476	7.7364
capnroad	Total capacity of national roads in the city (pce km)	109,927.50	146,081.30	9,703.45	1,148,825
vcr	Average volume capacity ratio	0.5229	0.363	0.0369	2.2441
pgasoline	Price of gasoline (Rp./Lt)	5,773.81	1,185	3,450.71	11,643.03
gdrpcap	Gross domestic regional product per-capita the city (Rp)	13.2269	16.321	3.232	135.2922
sexratio	Sex ratio of the city	101.0859	4.1882	93.6972	113.1609
popdens	Population density of the city (population per Km)	3,979.65	3,878.33	92.0866	14,469.34
rworkerpkm	Number of worker residence per km	1,601.84	1,616.47	36.2254	6,489.75
citsize	City size (km2)	274.8278	370.2814	10.77	2,399.50
numpubbus	Number of public buses (vehicles)	2,256.75	5,517.84	0	39,208

Table 8. Moran's I, LM, and Robust LM for VKT Car

Test	Statistic	p-value
Moran's I	0.483	0.629
Spatial error model:		
- Lagrange multiplier	0.151	0.698
- Robust Lagrange multiplier	0.087	0.768
Spatial lag model:		
- Lagrange multiplier	3.789	0.052
- Robust Lagrange multiplier	3.725	0.054

Table 9. Moran I, LM, and LM Robust for VKT Motorcycles

Test	**Statistic**	**df**	**p-value**
Spatial error:			
- Moran's I	0.677	1	0.498
- Lagrange multiplier	1.793	1	0.181
- Robust Lagrange multiplier	1.917	1	0.166
Spatial lag:			
- Lagrange multiplier	1.052	1	0.305
- Robust Lagrange multiplier	1.176	1	0.278

Table 10. The Results of Models for Car VKT as Dependent Variable

	OLS	SLM (ML)	SLM (GS2SLS)	SEM (ML)	SEM (GS2SLS)
VARIABLES	Lvktcar	lvktcar	lvktcar	lvktcar	lvktcar
Iri	0.0628	0.0546	0.0544	0.0664	0.064
	[0.0939]	[0.0722]	[0.0722]	[0.0746]	[0.0743]
Capnroad	3.76e-06***	3.89e-06***	3.89e-06***	3.79e-06***	3.77e-06***
	[1.12e-06]	[1.23e-06]	[1.23e-06]	[1.22e-06]	[1.23e-06]
Pgasoline	-0.0002*	-0.0003***	-0.0003***	-0.0002***	-0.0002***
	[0.000121]	[7.47e-05]	[7.47e-05]	[7.63e-05]	[7.56e-05]
Lgdrpcap	0.408**	0.415***	0.415***	0.377**	0.399**
	[0.158]	[0.154]	[0.154]	[0.168]	[0.160]
Sexratio	-0.016	-0.0093	-0.0091	-0.0108	-0.0144
	[0.0329]	[0.0271]	[0.0271]	[0.0296]	[0.0279]
Popdens	-9.25E-05	-0.0001**	-0.0001**	-8.81E-05	-9.13e-05*
	[5.80e-05]	[5.34e-05]	[5.34e-05]	[5.46e-05]	[5.34e-05]
Lcitsize	0.562***	0.579***	0.580***	0.599***	0.574***
	[0.161]	[0.137]	[0.137]	[0.152]	[0.140]
lrworkerpkm	1.041***	1.079***	1.080***	1.061***	1.048***
	[0.272]	[0.189]	[0.189]	[0.194]	[0.192]
numpubbus	-4.33e-05*	-5.16e-05*	-5.19e-05*	-4.86e-05*	-4.51E-05
	[2.50e-05]	[2.83e-05]	[2.83e-05]	[2.95e-05]	[2.86e-05]
Vcr	1.000**	1.005***	1.005***	0.986***	0.995***
	[0.417]	[0.276]	[0.276]	[0.280]	[0.281]
Constant	8.492**	7.575**	7.551**	7.629**	8.220**
	[4.214]	[3.092]	[3.092]	[3.545]	[3.208]
Lambda		0.199**	0.204**		
		[0.0993]	[0.0994]		
Rho			1.596		1.082
			[2.544]		[2.857]
sigma2		0.521***	0.544***		
		[0.0840]	[0.0880]		
R-squared	0.728**				
Jarque-Bera LM test	5.304*				

Table 11. The Results of Models for Motorcycle VKT as Dependent Variable

	OLS	SLM (ML)	SLM (GS2SLS)	SEM (ML)	SEM (GS2SLS)
VARIABLES	lvktmtc	lvktmtc	Lvktmtc	lvktmtc	lvktmtc
Iri	-0.0656	-0.061	-0.0612	-0.0761	-0.0693
	[0.0744]	[0.0692]	[0.0692]	[0.0697]	[0.0697]
Capnroad	6.19e-06***	6.13e-06***	6.13e-06***	6.06e-06***	6.14e-06***
	[1.25e-06]	[1.18e-06]	[1.18e-06]	[1.10e-06]	[1.12e-06]
Pgasoline	-0.0004***	-0.0004***	-0.0004***	-0.0004***	-0.0004***
	[0.000113]	[7.16e-05]	[7.16e-05]	[7.15e-05]	[7.04e-05]
Lgdrpcap	0.258	0.256*	0.256*	0.207	0.245
	[0.191]	[0.148]	[0.148]	[0.156]	[0.151]
Sexratio	-0.0356	-0.0392	-0.0391	-0.0317	-0.0347
	[0.0231]	[0.0261]	[0.0261]	[0.0269]	[0.0266]
Popdens	-0.0001*	-0.0001**	-0.0001**	-8.57E-05	-0.0001**
	[6.78e-05]	[5.10e-05]	[5.10e-05]	[6.01e-05]	[5.17e-05]
Lcitsize	0.239*	0.229*	0.230*	0.269**	0.244*
	[0.135]	[0.131]	[0.131]	[0.134]	[0.132]
lrworkerpkm	0.588**	0.569***	0.570***	0.529***	0.564***
	[0.222]	[0.181]	[0.181]	[0.179]	[0.179]
numpubbus	-5.99e-05**	-5.57e-05**	-5.59e-05**	-6.59e-05**	-6.20e-05**
	[2.79e-05]	[2.72e-05]	[2.72e-05]	[2.60e-05]	[2.64e-05]
Vcr	1.625***	1.623***	1.624***	1.598***	1.620***
	[0.281]	[0.264]	[0.264]	[0.258]	[0.259]
Constant	17.53***	18.02***	18.00***	17.32***	17.56***
	[2.953]	[2.970]	[2.970]	[3.144]	[3.103]
Lambda		-0.0969	-0.0934		
		[0.0925]	[0.0926]		
Rho				3.221*	2.433
				[1.825]	[1.881]
sigma2		0.479***		0.463***	
		[0.0773]		[0.0756]	
R-squared	0.709				
Jarque-Bera LM test	3.8293				