An Aggregate Analysis of Motorcycle and Car Ownership in South-East Asian Countries

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Abstract: This paper selects eight South-East Asian countries with similar economic development trend to examines a common saturation level of motorcycle and car, which in accordance with the assumption of identical behavior in these countries. The results from ordinary least squares (OLS) regression showed that per capita income, gender, age, and road construction to be strongly related to a country's motorcycle ownership but only income and the expand of road infrastructure should be certain to predict a country's car ownership rate. In the meanwhile, the Gompertz estimation provided a result of a joint saturation level of 332 motorcycles per 1000 inhabitants and 424 cars per 1000 inhabitants in sample while the current rates of motorcycle and car are 186 and 71 respectively. These mean the vehicle ownership per 1000 inhabitants will continually increase, especially the fast growth rate of car ownership that cause rapid growth in energy demand and emission.

Keywords: Motorcycle Ownership, Car Ownership, Transport Modelling, Saturation Rate

1. INTRODUCTION

Conventional approach to vehicle ownership has primarily considered four dimensions: socio-economic condition like income, gender, age, occupation, household composition (Anne Nolan, 2010; Creemers et al., 2012; Dargay et al., 2007; Hess and Ong, 2002; Prillwitz et al., 2006; Quin Shen, 2016, Schimek, 1996; Van Acker and Witlox, 2010) or characteristics of trip makers like trip purpose, trip length (Creemers et al., 2012; Wu et al., 2016), infrastructure like road development (Dunphy, 1998; Hansen and Huang, 1997) and psychological factor like attitudes, habit and perception (Handy et al., 2005; Lei Zang et al., 2012, Jinhyun Hong et al., 2014, Olaru et al., 2011). These studies have been mostly concerned the development of private cars. The empirical results of these studies show that car ownership was correlated with high income (Dargay et al., 2007; Quin Shen, 2016). There was different perception between males and females in car ownership and usage (Oakil et al., 2016). Levels of car ownership were examined to correlate to both household size and composition (Anne Nolan, 2019). Also, the level of education indirect influence the level of car ownership. For example, higher levels of education made people more concern on environment and therefore change their perception on conventional car ownership (Flamm, 2009). Belgiawan et al. (2014) summarized from recently researches that psychological factors like convenience, prestige and social orderliness might create "anti-car" trends in new young generation. In addition, recent studies on transportation and environment reveal interesting insights in environmental concerns of car owners. It revealed that there has been a shift towards electric cars or other friendliness vehicles, including public transportation (Lieven et al., 2011; Beirão, 2007)

In South-East Asian countries, where motorcycles are the major transportation modes, there have been a number of stated preference studies on motorcycle ownership such as a

study on household car and motorcycle ownership conducted by Dissanayake and Morikawa (2002) in Bangkok Metropolitan region or a research on modeling the household motorcycle ownership behavior conducted by Tuan and Shimizu (2005) in Hanoi. The results obtained revealed that household composition (like having school children), distance travel, household income, age significantly influence vehicle ownership. Leong et al., (2007) applied a disaggregate choice model to predict the trend of motorcycle ownership in Malaysia and found that motorcycles depended on income and had negative with the number of cars. Motorcycle ownership was also depended on the number of car and motorcycle license holder. Wen et al., (2011) conducted a dynamic analysis of motorcycle ownership and usage in Taiwan by using disaggregate choice models including the multinomial, nested, and mixed logit, their findings contributed in the side of state dependence effect in motorcycle ownership decision. It is noted that there was a research conducted by Hsu et al. (2005) that using aggregate data to forecast motorcycle ownership in three countries including Taiwan, Malaysia and Vietnam. The results revealed that population density, cultural background, economy, weather and GDP growth have significant impacts on motorcycle ownership.

Although a number of studies of motorcycle ownership is observed above, there is little research that analyze motorcycle ownership rates concurrently in several countries, except Hsu et al. (2005) conducting a sample analysis of Malaysia, Taiwan and Vietnam. Part of the reason for these is that the data can hardly be available at the same time period for many countries. Our understanding about determinants of motorcycle ownership, therefore, comes from stated preference studies. However, the stated preference choice technique normally depends on respondents' decision over hypothetical scenarios and sometime exist of bias between hypothetical decision and actual action. Conversely, aggregate information provides observations on actual choices made by people to measure preferences and therefore, this technique is a complement to stated preference studies and contributes to a comprehensive literature. Several previous researches have used secondary data to identify the vehicle ownership but emphasized automobile. From global perspective, Dargay et al. (2007) have published a study that analyzes income growth related to car ownership in 45 countries. That approach is invited in this study towards motorcycle ownership in several South-East Asian countries.

2. RESEARCH METHOD

In order to understand vehicle ownership rates across a series of countries, this research start by mentioning data collection based on a set of literature variables and data availability through South-East Asian countries. This will be described in section 2.1. Section 2.2 outlines the final model specification and section 2.3 provides the approach to understand this study.

3.1 Data Collection

Data from eight countries: Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Thailand and Vietnam were used in this statistical analysis. With the exception of Malaysia and Thailand whose per capita incomes are slightly higher, the rest of South-East Asian countries have GDP per capita below USD 4000. In these countries, motorcycles are realized as the main transportation mode and account for highest proportion. Utilizing a set of literature variables but considering given data availability, our study was limited to the influence of socio-economic factor like income, gender and age structure and infrastructure factor like road length. A higher of income would encourage people purchase more modern branch of vehicle, and could reduce the need of old vehicles. A higher proportion of female in

total population would encourage the shift to public transportation and could have a lower need for motorcycles. In addition, investment in a road network is more likely to promote driving demand and thus increase vehicle ownership. In this study we attempt to examine country socio-economic differences to vehicle saturation rate throughout a regression model that depict the relationship between country-specific saturation level and its gender structure, age structure and road length. These determinants, of course, may not be enough to account for all deference in saturation level among countries. It may have other reasons such as existence of reliable public transportation alternatives that may reduce reliance on private vehicles and increase dependence on public transport. In the other hand, a lack of parking system will most impact on the use of motorcycles and cars in urban areas, cause a lower need for these vehicles. Such factors, however, are difficult to take into account, as they would require detailed country-specific data and cannot be obtained without the support of host countries' regulatory authorities.

Based on the factors identified above, data were collected for the following variables for each country: motorcycle and car stock, income, gender, age structure and road length. Description of variables and their sources are mentioned in Table 1.

Table 1. Description of variable and sources

Variable	Data	Source
Motorcycle stock	National registered E-motorcycle per 1,000 inhabitants	Asean Statistics Data Portal; Statista website
Car stock	National registered E-motorcycle per 1,000 inhabitants	Asean Statistics Data Portal; Statista website
Income	National income per capita (100 USD)	World Bank database
Gender	The number of females per 1,000 inhabitants	World Bank database
Age structure	The number of people between 15-64 age per 1,000 inhabitants	World Bank database
Road length	1000 kilometer of road construction	Asean Statistics Data Portal

3.2 Models

3.2.1 OLS regression

Ordinary least squares (OLS) regression has been widely accepted to ascertain scalar response (or dependent variable) to one or more explanatory variables (Andriy Blokhin, 2019). Apart from regression techniques, OLS is one of the most common estimation methods. A key assumption underpinning its use is that the dependent variable is measured on a continuous, interval scale to avoid the problems of the model (Aldrich and Nelson, 1984, Judge et al., 1985).

To eliminate exhibit autocorrelation, heteroscedasticity and non-normality, diagnostic checking is used including the Lagrange Multiplier test for serial correlation (Breusch, 1978, Godfrey, 1978), and the White test for heteroscedasticity (White, 1980).

The variables were put into an ordinary least squares (OLS) regression. Letting V represents the level of vehicle ownership (vehicles per 1000 inhabitant), the model specification is defined as:

$$V_t = \alpha + \beta_1 * X_{1t} + \beta_2 * X_{2t} + \beta_3 * X_{3t} + \beta_4 * X_{4t} + \varepsilon \quad (1)$$

where,

X_{1t} : per-capita income (GDP, expressed in current 100 US dollar),

X_{2t} : Gender structure (number of females per 1000 inhabitants),
X_{3t} : Age structure (number of people age 15-64 per 1000 inhabitants),
X_{4t} : Road length (expressed in 1000 km), and
$\alpha, \beta_1, \beta_2, \beta_3, \beta_4$: coefficients.

3.2.1 Gompertz model

This study applied Gompertz model to understand the saturation rate of vehicle ownership by most influence factor across the country. The Gompertz model is named after one of its originator (Gompertz B., 1825), and serves as a measuring instrument for growth. Researchers have fitted the Gompertz model to everything including transportation (Dargay 2007, Wu et al., 2014, Winsor CP, 1932, Ricker WE, 1979, Proscott, R.B., 1922).

Gompertz model features the description of the relationship between the dependent variable and the independent variable by a S- shape curve. It is used for analysis of long and short-term prediction (Franses, 1994). The Gompertz diagram in Figure 1 explains the common shape of Gompert 3-parameter that represents the upper asymptote, the growth-rate coefficient (impact to the slope) and value of independent variable at inflection.

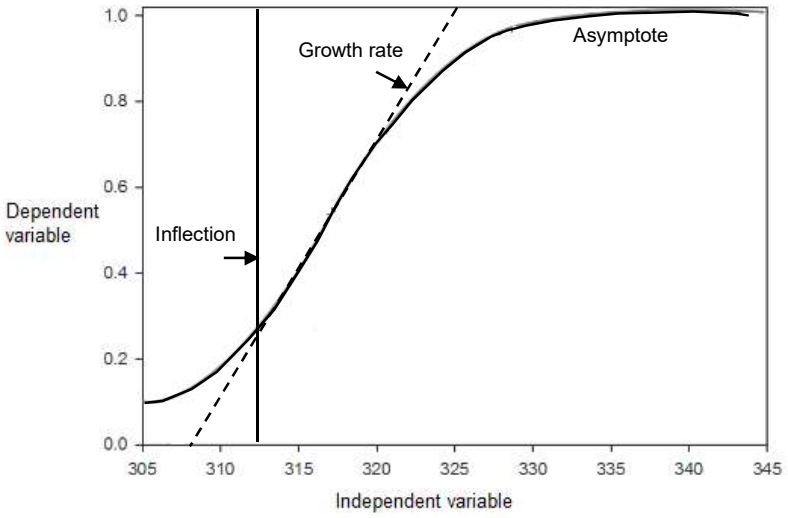

Figure. 1. Gompertz 3 parameter diagram

In this study, the Gompertz function above mention the influence of income on vehicle ownership and income. The relationship between vehicle ownership and income is represented by an S-shaped curve. It implies that vehicle ownership may increase slowly at the begining, and then more rapidly as income rises, and eventually slows down as saturation is reached. The Gompertz mode here is utilized from literature and can be written as:

$$Vt = \beta_1 * \exp(-\exp(-\beta_2 * (\text{income}-\beta_3))) \quad (2)$$

where,
β_1 : saturation level (measured in vehicle per 1000 inhabitants), and
β_2, β_3 : parameters defining the shape, or curvature, of the model.

Although, theoretically, the vehicle saturation level can be predicted separately for each country using formula (2), but due to the relatively small range of data in each country, the short collection period of samples from each country do not allow us to make a separate

analysis. However, differences between countries will be reflected in the growth-rate coefficient, which determines how much income each country achieves in its common saturation state.

Here the coefficients β_1 was assumed for country-specific saturation level. Countries with difference of gender structure, age structure and road length would have different saturation levels. The country-specific's saturation level is denoted as:

$$\beta_{1i} = \beta_1 + \alpha * (\text{average gender} - \text{gender}) + \gamma * (\text{average age} - \text{age}) + \varphi * (\text{average length} - \text{length}) \quad (3)$$

Substituting (3) into (2), the model to be estimated econometrically from the aggregate data sample becomes:

$$V_t = (\beta_1 + \alpha * (\text{average gender} - \text{gender}_i) + \gamma * (\text{average age} - \text{age}_i) + \varphi * (\text{average length} - \text{length}_i) * \exp(-\exp(-\beta_{2i} * (\text{income}-\beta_{3i}))) + \varepsilon \quad (4)$$

Where the subscript i represents country i and ε is random error term. The parameters β_1, α, γ, φ and β_3 are constrained to be the same for all countries, as is each country's saturation level from equation (3)

The implied elasticity of the vehicle ownership with respect to income is not constant, due to the nature of the functional form, but instead varies with income. The income elasticity is calculated as

$$E = \beta_2 * \exp(-\beta_2*(\text{income}-\beta 3) * \text{income} \quad (5)$$

3.2.1 Procedures

After gaining data series from eight countries, a descriptive analysis of motorcycle and car – specific factors will be explored. Factors including income, gender structure, age structure and road length are added in the model. The description analysis of these variables provided identifies how significant correlation between these factors on vehicle ownership. These analyses are basis of a more comprehensive study at a specific country. Next step, a linear regression model is analyzed to examine the effect of all independent variables on vehicle ownership. According to full model, insignificant factors will be removed and a reduced model will be run again.

For calibrate the saturation level at country-specific, firstly we run data from eight countries by using the common saturation rate. Secondly, we apply the formular (4) to predict the number of vehicle ownership rate and saturation rate at country-specific.

3. RESULTS AND DISCUSSIONS

3.1 Descriptive Analysis

3.1.1 General statistics

As mentioned in Table 2, motorcycle ownership (per 1000 inhabitants) ranged from 2 to 570 with an average 184. There was an improvement in numbers each year and was varied by country. Car ownership ranged from 0.19 to 437 with an average of 71, following a steady rise of vehicle stock each year. Income ranged from $218 to $11,101 with an average of $ 2,913 showed a significant increase over the year. The number of female (per 1000 inhabitant)

ranged from 484 to 518 with an average of 503. There has been a slight change in gender structure over the year. The number of people between 15-64 age (per 1000 inhabitant) ranged from 553 to 719 with an average of 654, with a slight climed number each year. Road length ranged from 4000 km to 620 000 km with an average of 189 000 km show a steadily increase over the year.

Table 2. Descriptive statistics

Distribution	MC ownership	Car ownership	Income	Gender	Age	Road length
Maximum	570	437	11101	518	719	620
Minimum	2	0.19	218	484	553	4.16
Mean	184	71	2913	503	654	189
Range	570	437	11101	34	166	616

3.1.2 Income

Considering the relationship between income and vehicle ownership at each country can help to find out the characteristics of each country instead of overall country in sample.

Per capita income (GDP) and motorcycle ownership in Figure 2 show a positive and significant relationship (P-value is significant). However, there is certain gap in the data series by country. There is distinguished by the countries with lower income and greater discrepancy in their vehicle ownership. Some representatives like Indonesia, Lao PDR and Vietnam matched low income with increase motorcycle ownership. However, this relationship was not observed as similar as other countries, like Cambodia and Philippine, offered low income but had relative low motorcycle ownership. Figure 2 suggests that there are factors other than income that drive motorcycle ownership.

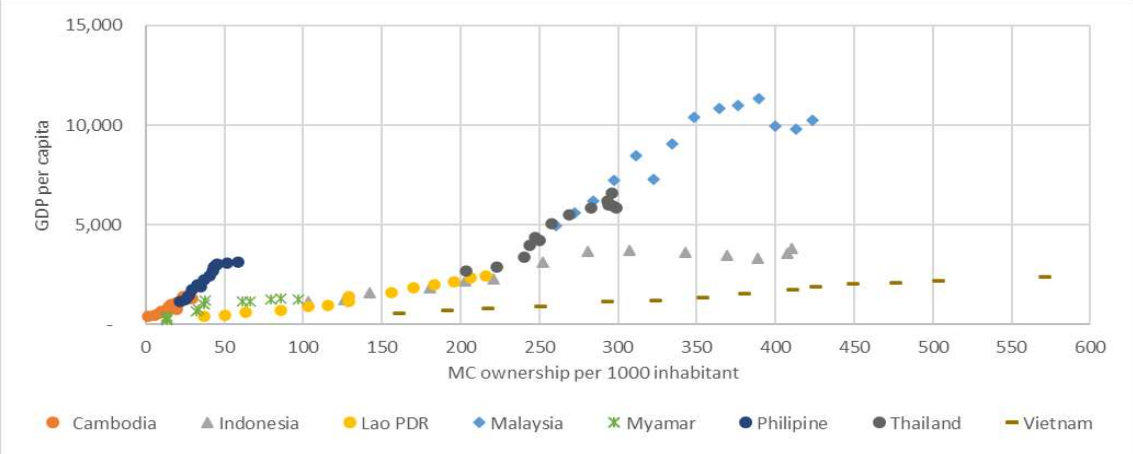

Figure 2. GDP per capita by country and corresponding motorcycle ownership

Figure 3 indicates a correlation (P-value of .000) between car ownership and per capita income. Despite an overall correlation, there were example of wide variation in the data as examined in case of Malaysia and Thailand. Lao PDR and Phillipine showed the special cases, while per capita income increased through periods, car ownership kept the constant.

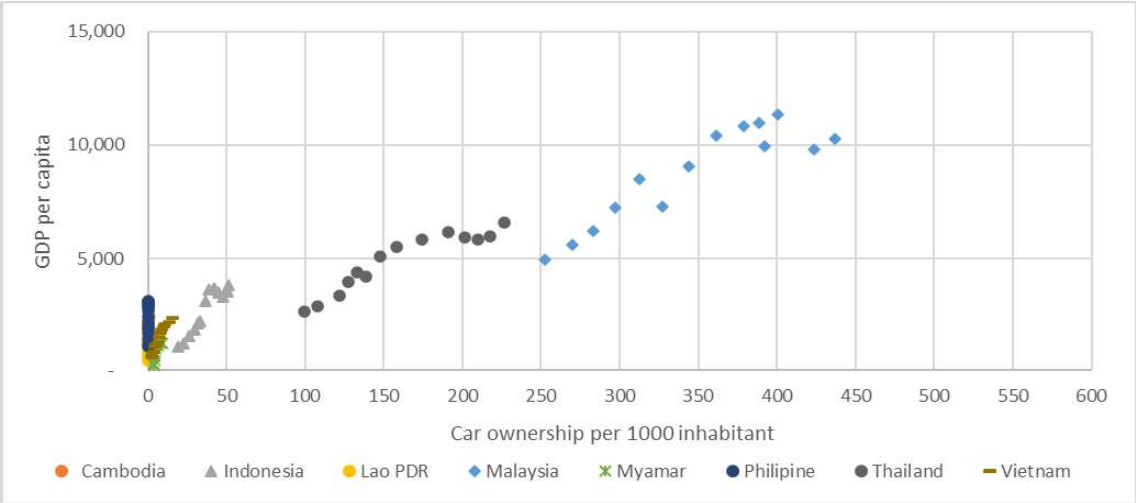

Figure 3. GDP per capita by country and corresponding car ownership

3.1.3 Road length

Analyzing Figure 4 and Figure 5, Philippine showed very little activity during road infrastructure development. Among the countries focusing on road expanding, Malaysia and Thailand represented a fast growth of both motorcycles and cars when building more roads. Indonesia, Myanmar and Vietnam are in the stage of slow growth of car ownership but they are in the stage of fast growth of motorcycle.

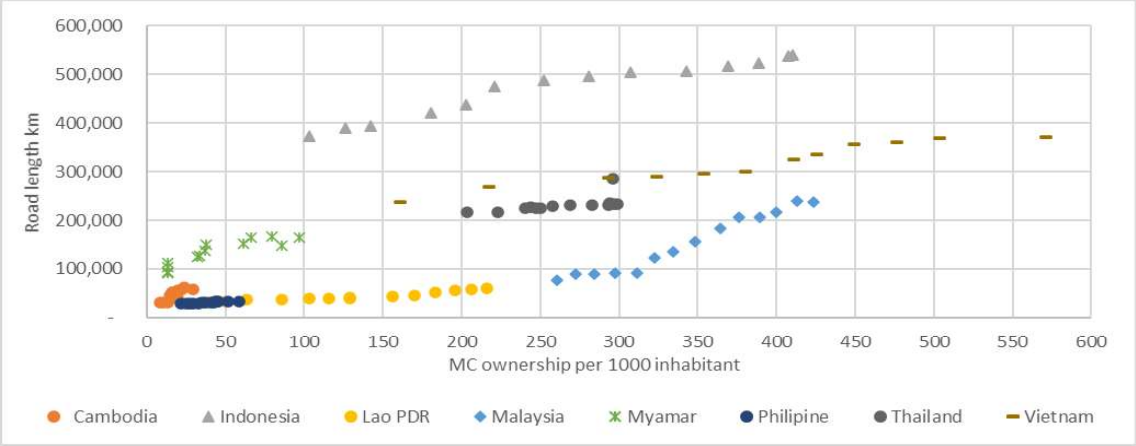

Figure 4. Road length by country and corresponding motorcycle ownership

3.2 Model Results and Implications

3.2.1 OLS model

Table 3 illustrates results from eight countries in our study for period 2004-2017. We regressed the vehicle ownership on per capita income (GDP), gender, age structure and road length.

In terms of regression model of motorcycle ownership, the adjusted R^2 was 0.8 meaning that more than 3/4 of the variation in motorcycle ownership could be explained by the tested variables. The coefficients for per capita income, age and road length were positive and statistically significant while gender was negative and significant with P-values of less than 0.05. Of those four variables, gender had higher Beta values, proving that it was stronger at predicting vehicle ownership.

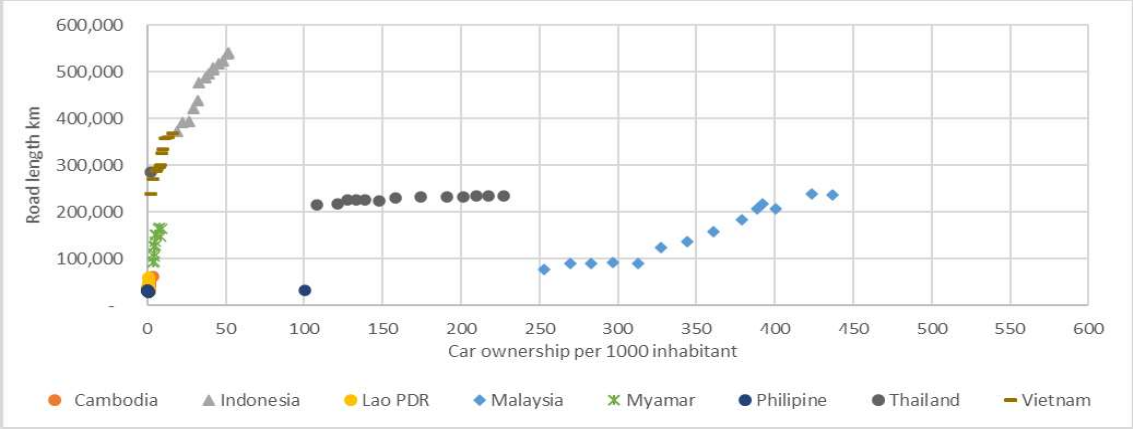

Figure 5. Road length by country and corresponding car ownership

Information from Table 3 reveals the relationship of income, gender, age and road length to motorcycle ownership. Keeping others constant, an increase in female rate (per 1000 inhabitants) would cause a country's motorcycle ownership per 1000 inhabitants to decrease by 4.19%. For income, keeping all other factors constant, each additional $100 that a country supplemented would increase its motorcycle ownership by 1.18%. In additional, increase of one person in age from 15-64 while others keep constant would increase motorcycle ownership by 1.12%. Finally, impact of road length was recognized that additional 1000 km constructed road would increase motorcycle ownership by 0.41%. This suggests that $ 100 in income could have approximate three times the impact on a country's motorcycle than 1000 km constructed road.

Table 3. Regression results for motorcycle ownership

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Constant	1,447.129	431.974	3.350	0.001	590.605	2,303.653
Income	1.175	0.424	2.772	0.007	0.335	2.016
Gender	- 4.193	1.037	- 4.042	0.000	- 6.250	- 2.136
Age structure	1.122	0.295	3.800	0.000	0.537	1.708
Road length	0.411	0.056	7.321	0.000	0.300	0.523
N	110					
R^2	0.834					
Adjusted R^2	0.827					

Table 4. Regression results for car ownership

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Constant	-530.245	242.355	-2.188	0.031	-1010.79	-49.69
Income	4.349	0.238	18.288	0.000	3.88	4.82
Gender	0.815	0.582	1.400	0.164	-0.34	1.97
Age structure	0.116	0.166	0.702	0.484	-0.21	0.44
Road length	-0.064	0.032	-2.037	0.044	-0.13	-0.00
N	108					
R^2	0.922					
Adjusted R^2	0.919					

The situation is a little different with car ownership, it reveals that gender and age structure do not impact on car ownership and the relationship between income and road length to car ownership is tighter than that to motorcycle ownership. More than 91% of the variation in car ownership was explained by the tested variables. Both explanatory variables were statistically significant with P-values of less than 0.05 but only income had a strong positive relationship to car ownership. Holding other factors constant, each $100 increase in income would cause a country's car ownership to increase by 4.35%, nearly four times higher to motorcycle ownership raising. In addition, every $100 in income could have about 68 times the impact on a country's car ownership compared to 1000 road length construction.

However, while our model has determined that income and road length were correlated to national vehicle ownership levels, it was not cover for all countries, as depicted in Table 3. For example, countries increased motorcycle ownership with the change of gender structure and age structure. Thus, income and road infrastructure should be seen as capable but uncertain to predict a country's vehicle ownership rate. In addition, a kind of specific vehicle fleet cannot increase forever, it will reach the saturation rate at some points, as examined by Dargay (2007). Therefore, it is important to know vehicle saturation rates even income increase accordingly.

These results could return to make a comparison with stated preference surveys. Income, gender and age were correlated to motorcycle ownership, they were the case with socio-economic variables that the literature had examined to be influential (Dissanayake and Morikawa, 2002; Hsu et al., 2005; Lee et al., 2007; Tuan and Shimizu, 2005; and Wen et al., 2011). Conversely, while road length was (as expected) significant in predicting vehicle ownership in South-East Asian country, this was not the case of previous studies. Gender and age were examined to be determinants of car ownership in literature (Oakil et al., 20160, they were not covered in this car ownership model. However, several difference in approaches between previous researches and this study could explain these conflicting results. First, the several previous studies examined a single nation for a single year whereas this study considered several countries over several years. Second, gender and age structure data in those earlier studies shown much difference than was found in our data. More research is necessary to consolidate impacts of gender, age to motorcycle or car ownership, specifically studies that span multiple years and look at several countries.

3.2.2 Gompertz model

The saturation level of motorcycle and car were evaluated by two steps. In the first step, the common saturation rate was estimated by applying equation (2) in section 2 with the

assumption that countries share the same behavior. The following step we estimated a number of motorcycles and car per 1000 inhabitants and country-specific saturation rate, inheriting the upper asymptote coefficient.

The model described in equation (2) was estimated for the aggregate timeseries data on vehicle ownership. The period of estimation is generally from 2004 to 2017. In all, we have 110 observations.

For the first model, the resulting estimates are shown in Figure 6, Figure 7 and Table 5. All regression coefficients are positive and significant. From the adjusted R^2, it can be observed that car-based Gompertz model allowed more accurate prediction of vehicle ownership in income (adjusted R^2 of 0.97 indicated that 97% of the total variation was explained by the model).

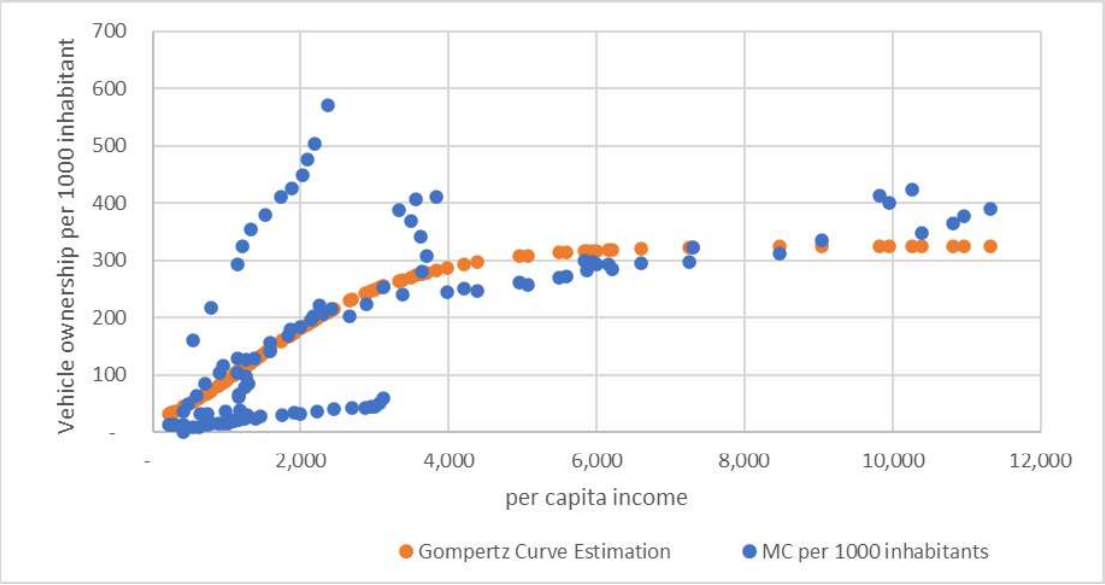

Figure 6. Comparison of real data and model

The results of the estimation provided a common saturation level of 332 motorcycles per 1000 inhabitants and 424 cars per 1000 inhabitants in sample. Currently, the average rates were 186 motorcycles and 71 cars, respectively. The results exhibit that motorcycle and car ownership will drastically increase, especially the growth of car ownership as income increase. Some lower-income countries such as Cambodia, Lao PDR, Myanmar, Philippine and Vietnam will have a higher growth in car ownership. Meanwhile, higher income countries like Malaysia and Thailand have lower growth rate of car ownership.

The results of the model sensitivity were obtained that the highest peak sensitivity was at USD 1287 GDP per capita with a sensitivity value of 1.04 for motorcycle and at USD 2.451 with a sensitivity value of 2.692. The results of total sensitivity can be seen in Figure 8.

However, from information in Figure 6, it is possible to observe the dispersion between actual data and predicted data in modelling motorcycle ownership. It proves that there may exist other explanatory variables, except income, not including in this study. Besides, above descriptive analysis also showed the difference in behavior among countries with the same level of economic development. It, therefore, should be more appropriate to estimate a country specific level of both motorcycle and car saturation.

The saturation level of motorcycle varies across countries — from a maximum of 734 motorcycles per 1000 inhabitants for Vietnam to a minimum of 156 for Cambodia. Lao PDR

has reached the saturation level with car ownership per 1000 inhabitant of approximately 175 units and Philippine can reach at 168 cars per 1000 inhabitants.

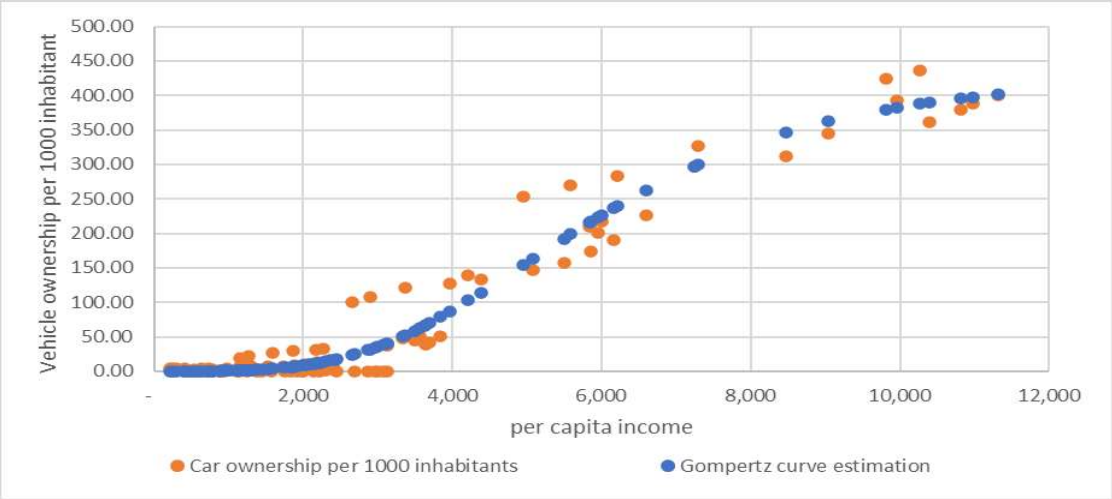

Figure 7. Gompertz curve for car ownership

Table 5. Parameters estimation and relevant statistical data of regression analysis

		Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Adjusted R^2
MC	β_1	332.22	28.86	11.51	0.000	275.00	389.44	0.7776
	β_2	.067	.02	3.56	0.001	.023	.105	
	β_3	12.81	2.25	5.67	0.000	8.33	17.28	
Car	β_1	424.39	15.28	27.76	0.000	394.08	454.69	0.968
	β_2	.045	.003	13.40	0.000	.039	.052	
	β_3	49.84	1.34	37.05	0.000	47.17	52.50	

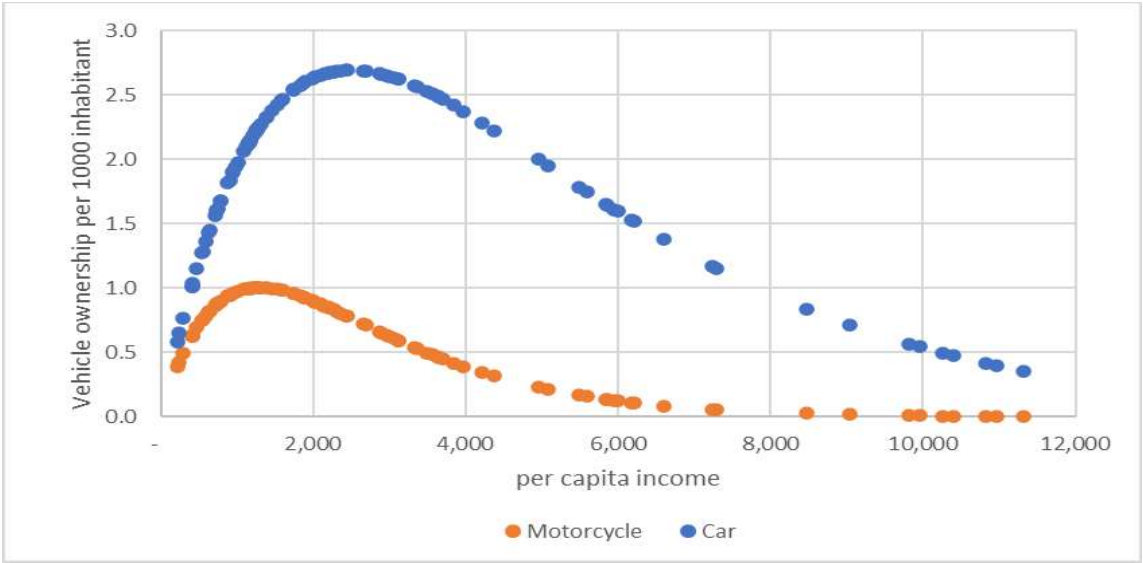

Figure. 8. Sensitivity of vehicle ownership to per capita income

Table 6. Vehicle ownership saturation level at country-specific

	Saturation level of motorcycle (per 1000 inhabitants	Saturation level of car (per 1000 inhabitants)
Cambodia	156	460
Indonesia	628	387
Lao PDR	175	454
Malaysia	486	446
Myanmar	280	443
Philippine	168	456
Thailand	478	419
Vietnam	734	418

The results reveal that vehicle stocks in South-East Asian countries continue to increase until they reach the saturation rate, it suggests that roadway fuel consumption and emission may also increase significantly. However, the rate of increase in roadway fuel demand and emission relies on the changes over time in vehicle technology and fuel types.

4. CONCLUSIONS

The aim of this research was to examine the impact of socio-economic factors and infrastructure development to vehicle ownership across several countries. We found that income, gender structure, age structure and road length were positive and significant in predicting motorcycle ownership rates for the countries in our study. In terms of car ownership, gender and age structure were not related to vehicle growth. Of two variables, per capita income was the most determinant of a country's car ownership. Overall, this analysis provides expected corroboration of income as a way to growth vehicle fleet. Furthermore, socio-economic factors like gender and age were found to be significant to motorcycle ownership but they were not good predictors of car ownership rate. Thus, income and road expanding are likely to be more correct for estimating a country's vehicle ownership.

Saturation calculation returned a common saturation levels of motorcycle and car were 332 motorcycles per 1000 inhabitants and 424 cars per 1000 inhabitants in sample while the current rates of motorcycle and car are 186 and 71 respectively. Based on these results, it is no doubt that motorcycle and automobile sale market will continue to rise in South-East Asian countries, causing concerns arising from pollution and congestion. Alternatively, the future dramatic growth in the vehicle fleet in South-East Asian countries will lead a high demand of fuel consumption. However, these consequences can be avoided if policymakers could learn lessons from developed countries. They may be able to slow vehicle expansion even by predicting that vehicle ownership will increase as the economy grows through some advance measures such as adopting tax policies, restructuring public transportation systems as well as low-emission vehicle-oriented urban planning.

Our model found income and road expanding to be powerful predictors of both motorcycle and car ownership rate for the countries in our sample. However, there may still exist a number of important variables that influence vehicle ownership but they not included in our model due to the unavailability of the data. Therefore, further analysis is necessary to discover the importance of alternative determinants.

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