MOTORIZATION IN ASIA

– 14 Countries and Three Metropolitan Areas –

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Motorization in terms of passenger cars in 14 Asian countries and passenger cars and motorcycles in three metropolitan areas are analyzed in this study. Using country-based data which cover 20 years (1980-2000), a linear regression is conducted by panel estimation with random and fixed effects. As a result from the model, fixed income elasticity for the region was found to be 1.75. Fixed effect estimated separately for each country characterizes the motorization pace in the countries. Two groups of countries were detected with a significant difference in motorization paces—Sri Lanka, India, Nepal, Philippines, Pakistan, Indonesia and Thailand have motorization paces higher than the rest of the countries. Additionally, using a cross-sectional data household car and motorcycle ownerships were analyzed for three metropolitan areas characterizing South-East Asia that are Jabotabek (Indonesia), Kuala Lumpur (Malaysia) and Manila (Philippines) metropolitan areas. Results indicate that ownership of cars and motorcycles are independent of each other in Jabotabek and Manila, but negatively correlated in Kuala Lumpur; and generally, income is more influential on car ownership than motorcycle ownership.

Key Words: Asia, Motorization, Bivariate ordered probit model, Car ownership, Motorcycle ownership, Jabotabek, Kuala Lumpur, Manila

1. INTRODUCTION

Sperling & Claussen[1] eloquently epitomizes the inherent dilemma of motorization in developing countries as: "…for many, vehicles are desirable as a secure and private means of travel, and as status symbols…but personal motorization also imposes enormous costs, especially in cities. The well-known litany includes air and noise pollution, neighborhood fragmentation, and high energy use". A recent study reports that increase in oil consumption in developing countries will be two thirds of the global increase between 2002-2030; surpassing total energy consumption of developed countries around 2030[2]. A significant part of the energy consumption is expected to be consumed by the transport sector, in which private transport is estimated to constitute a significant part[2].

In this line, a recent study expects sharp increases in passenger car ownership levels when per capita income level reaches a level between US$3,000 and US$5,000[3]. Similarly, Ingram and Liu[4] estimate that in developing countries passenger car ownership is expected to increase at a rate more than income growth. A possible explanation to this is social determinism— a sociological explanation— which associates car ownership in developing countries exclusively with middle class life styles, and stresses the social forces on the middle class to sustain a mobility level tied to car ownership[5].

Within the set of developing countries, in this matter, countries in Asia deserve a special touch due to, at least, two lines of macro-level development ongoing in the region, that constitute the backdrop of motorization momentum, both today and tomorrow. Firstly, Asia carries more than half of the world population along with the top two most populous countries worldwide, i.e., China and India. However, the region is the least urbanized worldwide— 37% according to UN Population Division statistics— though, notably, none of the other regions worldwide exceeds Asia in terms of urban population. Given this potential population thrust, motorization prospects in the region are promising, and the whole process will be likely to loom in line with two processes that are interdependent: the increasing urbanization rates (and/or increasing urban population shares within total population) and the increasing income per capita. Secondly, the rise of Asian economies has dominated the second half of the 20th century, with Japan the first and the others as followers, extending to the 21st century. As an illustration, from 1993 to 2003, the GDP per capita has increased the most in the Asian region, i.e., 1.44 times, exceeding all other regions worldwide. Especially, the last two decades have witnessed Asian giants integrating with the world economy and ensuing enormous changes in the economies of these countries — GDP per capita increased 2.13 and 1.52 times from 1993 to 2003 in China (2003: US$ 4,803) and India respectively (2003: US$ 2,729) — as well as countries surrounding them.

Having noted the above, this study concentrates on the motorization in Asian developing cities. Our aim is to identify the ongoing motorization trends and unearth the causes of vehicle ownership in the region. To do so, we used a panel data (1980-2000) of 14 Asian countries and a cross-sectional data of three metropolitan areas characterizing the South-East Asian sub-region: Jabotabek metropolitan area of Indonesia, Kuala Lumpur metropolitan area of Malaysia, and Manila metropolitan area of Philippines. The first data set was obtained from UNEP GeoData Portal — http://geodata.grid.unep.ch/ — and the data related to metropolitan areas were obtained from the household person-trip surveys administered by Japan International Cooperation Agency (JICA) within the past 10 years. Two separate models were applied in the analyses: a linear regression model and a bivariate ordered probit model. The first model, the linear regression model addresses the aggregate — country based — motorization (in terms of passenger cars) in Asia. In this model, we only used GDP per capita (Constant 2000 US$) as the sole explanatory variable. The second model, the bivariate ordered probit model addresses household car and motorcycle ownership levels simultaneously. This second model is applied separately to the three metropolitan areas by controlling for the household socio-economic and demographic attributes — the basic model. Among the three metropolitan areas, land use and transportation infrastructure data were available only for Jabotabek metropolitan area. Thus, to derive inferences regarding the land use information, the basic model was enhanced with the land use and transportation data in addition to household socio-economic and demographic attributes for Jabotabek metropolitan area only — the enhanced model. This also allows us to evaluate the contribution of land use and transportation attributes to the basic model.

The study is outlined as follows. In the second section, our focus is on motorization in Asia. In this section, we conducted regression analysis on the panel data of Asian countries as mentioned above. Where applicable, we supported our inferences and conclusions with results from other similar studies. Also in the same section, cross-country comparisons were conducted for both car and motorcycle ownership levels. In the third section, we present the empirical analyses of three metropolitan areas by first devising an econometrical model, i.e., the bivariate ordered probit model, which is followed by the model specification considering the pertinent variables used in the models and their summary statistics. The fourth section presents the estimation results with a discussion highlighting the inter-metropolitan differences and the contribution of land use and transportation variables to the basic model in the case of Jabotabek metropolitan area. The sixth section concludes the study.

2. MOTORIZATION IN ASIA

A survey conducted on a number of cities worldwide[6] tells us that the number of passenger cars per thousand population (as of 1995) is the lowest in developing cities of Asia, while motorcycle per thousand population enjoys the highest average values in the world (Table 1). When we use road supply, instead of population as denominator, the number of passenger cars per road kilometer increases to a relatively high score, while the number of motorcycles per road kilometer attains even a bigger value vs. the rest of the world.

Especially noteworthy at this point, the number of passenger cars in China and India show trends with sharp increases during the last two decades. China has already achieved a level half of the non-Asian developed world average, i.e., North America and Europe (Fig. 1), and it will not take long for China and India surpass the developed world averages given the trend and the impetus of their domestic automobile production capacities increasing year-by-year. However, with respect to the numbers of passenger cars per thousand population, China and India are well below other Asian countries, i.e., Philippines, Malaysia and Indonesia, not to mention the developed world (Fig. 1).

In this section, our focus is on two types of motor vehicles: passenger cars and motorcycles. For the passenger cars, we use country-based panel data of 14 Asian countries of various economies, and conducted linear regression analysis.

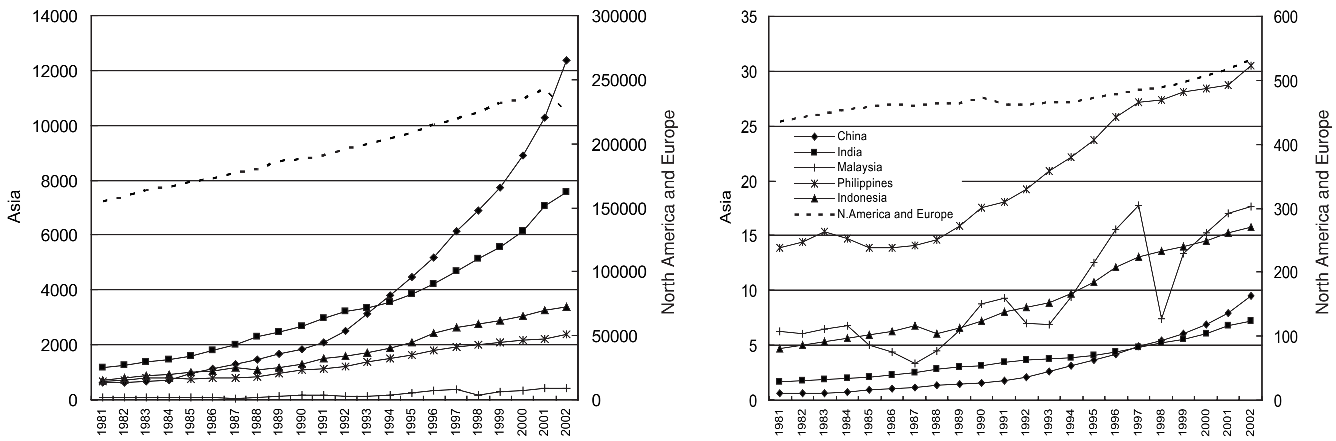
2.1 Regression analysis of passenger cars in Asia

An earlier study by Dargay & Gately[3] has successfully showed the close relationship between passenger cars per unit population and the GDP per capita in a country. By using a historical database from a number of countries, both developed and developing, they found a

Table 1 Passenger cars and motorcycles per thousand population and per kilometer of road (1995)

	Passenger cars per 1000 people	Motor cycles per 1000 people	Passenger cars per road kilometer	Motor cycles per road kilometer
AFRICA	102.12	6.92	117.44	12.99
MIDDLE EAST	185.26	23.38	151.06	47.53
LATIN AMERICA	188.53	11.81	176.96	10.14
ASIAN AFFLUENT CITIES[1]	217.33	65.79	110.15	26.52
OTHER ASIAN CITIES	88.30	117.21	135.71	246.66
EASTERN EUROPE	279.23	13.49	230.59	9.39
WESTERN EUROPE	411.86	33.30	175.66	14.81
NORTH AMERICA	567.95	11.90	100.46	2.12
OCEANIA	575.36	13.42	72.57	1.65

1: Hong Kong, Sapporo, Singapore, Osaka, Tokyo
Source: UITP (2001)



a. Number of passenger cars (millions)

b. Number of passenger cars per thousand population

Fig. 1 Passenger cars: Asian countries vs. (non-weighted average of) North America and Europe

significant positive relationship between them. According to Table 2, which presents both the gross change and average annual change in passenger cars per thousand population and GDP per capita between 1980 and 2000 in these countries, motorization in Asia has also evolved in a similar pattern.

In all countries, except Singapore, passenger cars, on the average, grew more than GDP per capita. In Singapore, partly because of limited land area available for transportation, ownership of passenger cars is strictly controlled under state supervision with various integrated policies imposed[7], hence the less growth in passenger cars than the GDP per capita. The Republic of Korea and China are the two countries that have achieved the highest increases in the twenty year period, showing characteristics of rapid development. However, with regard to passenger cars, even the Philippines, which stayed almost stable economically between 1980-2000, passenger cars per thousand population have increased slightly more than two times.

Having observed a non-linear S-curve type development in the world motorization patterns, Dargay & Gately[3] have applied the Gompertz equation resembling an *S*-curve of initial motorization (slow)–full motorization (fast)–post-motorization (slow) pattern. However, when the analysis is reduced to the Asian region, where most of the countries show similar development trends, the Gompertz equation does not fit to the phenomenal increase depicted in Table 2. A simpler and more refined non-linear relationship between income and motorization in Asian countries might better fit to explain the phenomenal increase in motorization. Thus, in this study, we propose a non-linear equation that can be given as follows:

Table 2 Change in passenger cars per thousand and GDP per capita in 14 Asian countries between 1980 and 2000

		Year 2000		Average annual % change		% change from 1980 to 2000	
		Passenger cars per thousand population	GDP per capita[a]	Passenger cars per thousand population	GDP per capita	Passenger cars per thousand population	GDP per capita
1	Bangladesh	0.52	$353	8.91[1]	1.93	246.67	46.47
2	Cambodia	0.63	$287	6.32[2]	4.96[5]	36.96	40.00
3	China	6.94	$1,065	13.91	7.79	1,209.43	345.61
4	India	6.02	$448	7.08	3.59	290.91	101.80
5	Indonesia	14.48	$788	6.43	3.70	240.71	102.05
6	Japan	415.15	$37,361	3.81	2.25	110.83	55.52
7	Malaysia	15.22	$3,927	7.43	3.93	63.66	112.50
8	Nepal	1.96	$225	6.87	2.43	269.81	60.71
9	Pakistan	7.47	$514	5.73	2.07	198.80	50.29
10	Philippines	28.46	$1,002	3.93[3]	0.10	104.60	1.31
11	Republic of Korea	172.81	$10,938	18.27	6.37	2,546.40	239.58
12	Singapore	103.05	$22,770	2.13	4.86	50.79	155.15
13	Sri Lanka	16.88	$823	3.89	3.33	112.59	92.29
14	Thailand	43.38	$1,998	7.67[4]	6.50	197.12	148.51

a: Constant 2000 US$, 1: 1980-1998, 2: 1990-2000, 3: 1981-2000, 4: 1980-1995, 5: 1993-2000.

$$PC_{ct} = \alpha_c GDP_t^{\theta} \qquad (1)$$

where PC_{ct} represents passenger cars per thousand population in country c and year t. After transforming equation (1) by taking its natural logarithm, i.e., $\log PC_{ct} = \log\alpha_c + \theta \log GDP_t$, the parameters can be estimated separately by linear regression. In this line, the panel data available for the twenty year period between 1980 and 2000 allows us to estimate the linear regression with fixed and random effects—fixed effects are assumed to be country-specific constant terms, i.e, $\log\alpha_c$ in the log-transformed regression equation, which determines the slope of motorization (in terms of passenger cars) in the Asian countries. Thus, two error terms are inserted into the log-transformed regression equation, ε_{ct} and u_c to represent random and fixed effects respectively. The parameters in equation (1) are estimated by using LIMDEP econometric software[8]. The results are presented in Table 3.

According to the model results, all parameter values are statistically significant and the overall goodness-of-fit of the model is very good. The parameter θ represents the fixed income elasticity, which is estimated to be 1.75, for the Asian whole region—one percent increase in income level causes a 1.75 percent increase in passenger cars per thousand population. However, the $\ln\alpha$ parameter in Table 3 is not directly interpretable—$\alpha = \exp(\ln(\alpha))$. The meaning of α parameter is the heterogeneous increase of mo-

Table 3 Estimation results of regression analysis of passenger cars per thousand population

			Parameter	t-score
	θ		1.75	29.0842
	$ln\alpha_c$			
1	Bangladesh		-10.94	-31.87
2	Cambodia		-10.04	-29.37
3	China		-10.35	-27.29
4	India		-8.95	-25.55
5	Indonesia		-9.14	-23.50
6	Japan		-12.49	-19.94
7	Malaysia		-11.76	-24.58
8	Nepal		-8.99	-28.35
9	Pakistan		-9.13	-24.63
10	Philippines		-9.03	-21.75
11	Republic of Korea		-11.62	-21.92
12	Singapore		-12.28	-21.17
13	Sri Lanka		-8.80	-22.73
14	Thailand		-9.17	-21.21
	Log-likelihood (restricted models)	Constant term only		-558.49
		Fixed effects only		-201.10
		Random effects only		-340.28
	Log-likelihood (the model)	Fixed and random effects		-2.68
	R^2			0.98

torization in the countries after controlling for income growth. High scores of α parameter are found for countries: Sri Lanka, India, Nepal, Philippines, Pakistan, Indonesia and Thailand (Fig. 2).

For these countries, apart from income effect, other reasons have also played important roles in the development of motorization in these countries. Another interpretation can be given as that the motorization trends in these countries have steeper slopes than the rest of the countries. Moderate values of α parameter are found for Cambodia and China. Except the special case of restrained motorization (Singapore), the remaining countries in the data set are experiencing either the initial motorization (Bangladesh) or post-motorization (Republic of Korea, Malaysia, and Japan).

2.2 Motorcycles

As regards the motorization in terms of motorcycles, Asia leads the world. In a number of Asian countries, motorcycle ownerships have already been enjoying high levels long before significant increases in per capita incomes were realized, as it is simply, much cheaper to buy a motorcycle than to buy a car. Thus, it might be said that the income effect is maximum for motorcycle ownership much earlier than passenger car ownership—according to Dargay & Gately[1], it is between US$ 3000~5000 GDP per capita for cars—considering the purchasing price of motorcycles, which is in the range between US$500~6000, in the region (this is based on personal communications with a small sample of students from the South East Asian sub-region in Hiroshima University).

However, income effect—although it might be the prime reason—can not alone justify the high levels of ownership that is special to Asia. Mostly, there might be three main reasons for motorcycle ownership in Asia. Firstly, most Asian cities are in the tropical or sub-tropical regions; thus the climate in these regions is suitable for motorcycle engines and rides all around the year. Secondly, favorable economic and institutional infrastructure together with sufficient industrial capacity foster motorcycle ownerships. Almost all of the Asian countries have motorcycle factories established within their borders, thus there are no import levies on motorcycles compared to most cars with a substantial amount of import levies hidden in the price tags—remember that major car producers are in developed countries. Lastly, high density urban forms prevailing in Asia and inadequate road space for cars, especially in the center of cities, is conducive to motorcycle ownership and its use as a last resort.

Consequently, in a number of Asian countries, motorcycle ownership has risen to high levels, e.g., Vietnam, Indonesia, Malaysia, compared to the rest of the world. A recent database[4] reveals supportive information in this respect. According to the database, the number of motorcycles per thousand people averaged over a number of Asian cities is approximately 196.45, which is 7.11 times the average of cities in the rest of the world; more importantly, the number of motorcycles per road kilometers supplied is 452.51 which is 18.51 times the average of

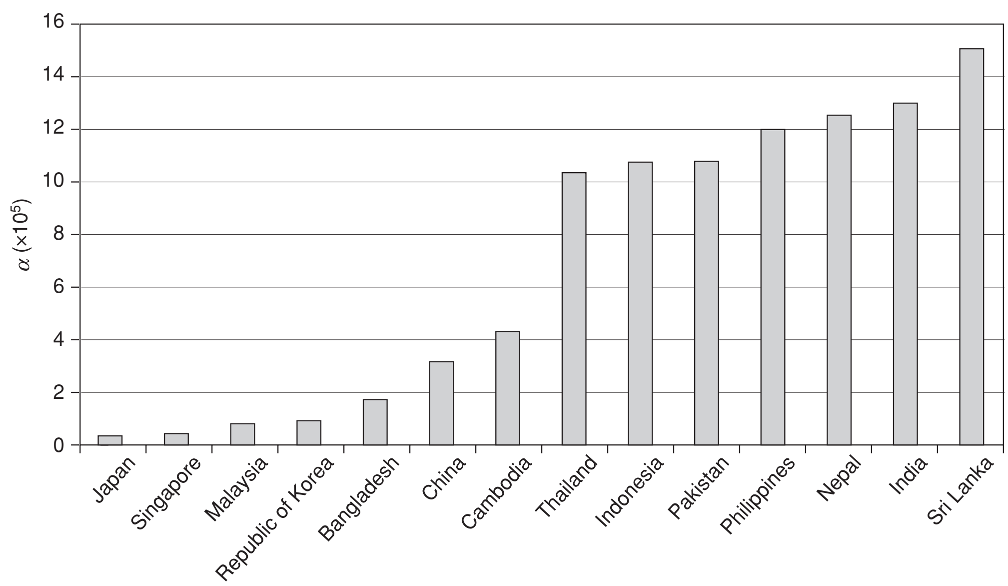


Fig. 2 Parameters α of fixed effects across countries

the rest of the world. Among these cities, notably, Ho Chi Minh City, the largest city in Vietnam, displays outlier properties as this city exceeds average values by 4 and 7 standard deviations for motorcycle ownership per thousand population and motorcycle ownership per road kilometer respectively.

3. JABOTABEK, KUALA LUMPUR AND MANILA METROPOILTAN AREAS

In the rest of this study, our focus switches to the analysis of ownership of passenger cars and motorcycles in three metropolitan areas in the South-East Asian subregion (Fig. 3), i.e., Jabotabek metropolitan area (Indonesia), Kuala Lumpur metropolitan area (Malaysia), and Manila metropolitan area (Philippines).

As mentioned above, the data used for three metropolitan were retrieved from household person-trip surveys conducted in the past decade. These surveys include types of information concerning household and individual attributes, vehicles owned, types of residences, etc. Household person-trip database of Jabotabek (the survey was conducted in 2000) includes information for 100,864 households (423,237 individuals). Databases for Kuala Lumpur (1995) and Manila (1996) include information from 27,331 and 60,752 households respectively.

A comparison in motorization levels in these three metropolitan areas can be made by looking at Figure 4. Consistent with the information given above, Kuala Lumpur is highly motorized, partially due to the aggressive marketing to support the domestic motor vehicle industry. Both car and motorcycle ownerships in Jabotabek constitute an in-between position among the three metropolitan areas. As opposed to others, Manila metropolitan area stays well below the others in terms of motorcycle ownership.

Considering trip times—trip time is the time duration that has passed between two locations, in all metropolitan areas, average trip times were close to each other: 29 minutes in Kuala Lumpur, 31 minutes in Jabotabek and 36 minutes in Manila. According to the trip modes, private trip modes constituted the biggest share in all metropolitan areas; on the other hand, public transit use was 9% in Jabotabek, 11% in Kuala Lumpur, and 10% in

Fig. 3 Jabotabek, Kuala Lumpur and Manila metropolitan areas

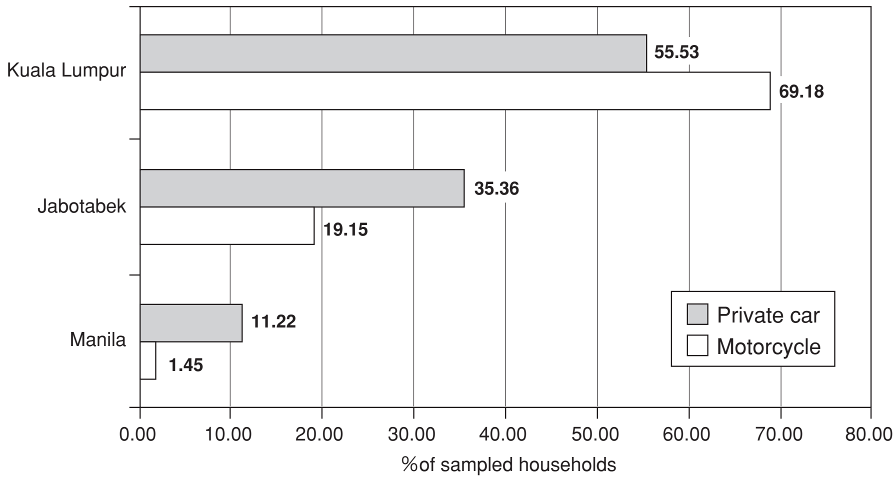


Fig. 4 Car and motorcycle ownership levels in three metropolitan areas

Manila. The non-motorized trip modes, predominantly walking, was found to be highest in Jabotabek among the three metropolitan areas, i.e,. 41%. The other two metropolitan areas are approximately same around 25 % for non-motorized trip mode shares. The high shares of non-motorized trips can partially be explained by the high share of intra-zonal trip destinations. In the rest of this section, we present brief introductions to these metropolitan areas.

3.1 Jabotabek metropolitan area

Jabotabek metropolitan area is located on the northern seaboard of Java Island of the Indonesian archipelago, and covers an area of, approximately 6800 km^2. The metropolitan area includes the province of DKI Jakarta—the capital city of Indonesia—and the surrounding regencies of Bogor, Bekasi and Tangerang in the provinces of West Java and Banten respectively. The core of the metropolitan area, DKI Jakarta encompasses five municipal jurisdictions called Jakarta Barat, Jakarta Pusat, Jakarta Selatan, Jakarta Timur, and Jakarta Utara.

The whole Jabotabek area has a population of around 21.5 million, which constitutes 10% of the population of Indonesia. The metropolitan population is concentrated on the axes defined by the DKI Jakarta and surrounding city centers. Between 1990 and 2000 the number of households has decreased in some of the center areas in DKI Jakarta and Tangerang while significantly increasing in the rest of Jabotabek. The extreme cases concentrate in the areas on the fringe of DKI Jakarta, i.e., the arc defined by the central cities of Kota Bekasi, Kota Depok and Kota Tangerang. This urban sprawl encroaching upon the immediate vicinity of DKI Jakarta is mostly the product of private housing development projects[9,10]. This is part of a long-lasting process that started during the early 1970s—decreasing population density in 0-5 km of the city center, increasing population densities in the rest of the metropolitan area with drastic increases in the 5-15 km ring[11].

The transport sector in Indonesia is almost entirely dominated by road transport[10]. This is partly because of the strong government support for motor vehicle users through intensive road construction projects and subsidies, such as under-priced fuel supply, to road users accompanied by underinvestment in public transport and rail systems[12]. The hotbed of motorization in Indonesia is Jabotabek metropolitan area. With 75 percent of all vehicles owned in Indonesia, Jabotabek houses a car population of 2.5 million (as of 2005), and about 140 new cars are sold every day[13].

3.2 Kuala Lumpur metropolitan area

Kuala Lumpur metropolitan area is located on the Malay peninsular, and covers an area of approximately 243 km^2 with a population of 4.5 million, significantly smaller than Jabotabek and Manila metropolitan areas.

One of the important developments in terms of motorization in Malaysia, consequently in Kuala Lumpur, is the establishment of a domestic car manufacturing company, Proton by the Malaysian government in 1985. Since then motorization has taken significant steps in the country, mostly in Kuala Lumpur. This is also supported by the increased affluence and the out-migration experienced from Kuala Lumpur to the outlying dormitory towns in the Klang Valley Region in which Kuala Lumpur is located. Thus, congestion has emerged during peak hours to and from the city centre of Kuala Lumpur to the rest of the Klang Valley region.

3.3 Manila metropolitan area

Manila metropolitan area is located on the eastern side of Manila Bay of Luzon island, the largest in the Philippine archipelago. Manila metropolitan area, commonly referred to as Metro Manila, encompasses 15 municipalities—around 636 km^2— and homes approximately 15 million people.

From the 1970s through the 1990s, the center of Metro Manila (i.e., 0 - 5 km area around the city center) has increased in population density – from nearly 350 persons per hectare to more than 400 persons per hectare in the highest populated center; up to a 5 kilometer radius from the city center, the densities gradually fall to, nearly 200 persons per hectare, and levels to around 100 persons per hectare in the ring from 13 - 14 km to 25 kilometers from the city center[9]. Probably, this kind of urban sprawl, contrary to other Asian cities, is due to the legacy of investments on the radial-circumferential road structure that started before the 1960s. However, the city has suffered from congestion continuously since then even after completion of most of radial-circumferential roads.

4. CAR AND MOTORCYCLE OWNERSHIPS IN JABOTABEK, KUALA LUMPUR AND MANILA

Choice related to different dimensions of travel behavior is a context-dependent phenomenon. Zhang et al.[12] classified different contexts effective on travel behavior choice into household and individual-specific, alternative-specific, and circumstantial contexts. Using these different contexts, we develop pertinent variables in the models for vehicle ownership levels in three metropolitan areas in this study. The first group of variables accounts for household and individual-specific context by drawing from socio-economic and demographic attributes of individuals and households. We use this group of variables for vehicle ownership in three metropolitan areas. Heterogeneity in individual and household decision-making processes are considered as an outcome of this context. Socio-economic and demographic variables of households and individuals include gender, age, occupation, household income, and household size and composition. The models devised only by using this group of variables are devised as the basic models. Table 4 presents the variables used in the basic models.

The variables that characterize residential location, land use and transportation system falls to the circumstantial context devised by Zhang et al.[14] In addition to the individual-specific context used for all metropolitan areas, we use the circumstantial context in the enhanced model, which is estimated for Jabotabek metropolitan area only. Regarding residential location, we use relative location of the residential neighborhood within the metropolitan area which is measured by Euclidian distance from a land mark in the center of DKI Jakarta, i.e., Istiqlal Mescid. Under land use and transportation system, we collect the observed variables related to the residential neighborhood and transportation system characteristics. Residential neighborhood is characterized by density and diversity. Population and jobs per developed land are the sole density variables used in the study. For diversity, average land use diversity is computed by averaging diversity in residential zone over all hectare grid cells of developed land. Diversity of a grid cell is computed by counting the number of different land uses of hectare grid cells immediately neighboring the grid cell on all sides. Other diversity variables are considered to be ratios of residential, commercial land uses and undeveloped lands in the neighborhood. Transportation system is represented by variables related to the transportation network, e.g., road supply, rail and bus routes passing through traffic zones. Among these, road supply is summarized by the length of all streets as well as all major roads passing through the residential zones. For public transit supply, bus system is summarized with the median of total bus lines on street segments; rail system is characterized with ratios of land within 1 km of a railway station in residential zones. Descriptive statistics of variables used in the enhanced model are presented in Table 5.

The variables used in the models are obtained from random samples extracted from original databases—10% of households in the Jabotabek database, 50% of the Kuala Lumpur database, and 15% from the Manila database. The variables in the samples are not different from the original samples at $p = 0.05$ significance level.

4.1 Econometric model: bivariate ordered probit model

For simultaneous ownership of passenger cars and motorcycles, we used the bivariate ordered probit model. The model is originally developed by McKelvey & Zavoina[15], and lately appeared in the transportation literature as an application to the number of cars, season tickets a household owns and other ordered categorical data[16]. The advantage of this model over its univariate version is that tradeoffs that might exist between two

Table 4 Descriptive statistics of variables used in the basic models for Jabotabek, Kuala Lumpur and Manila metropolitan areas (household)

Metropolitan area	Variable	Min.	Max.	Mean	Std. Dev.
Jabotabek	Cars owned	0	3	0.25	0.56
	Motorcycles owned	0	3	0.42	0.61
	Household income[1]	1	9	3.39	1.96
	Household size	1	9	3.65	1.54
	Average age of household members	5	80	31.81	11.42
	Number of male household members	0	7	1.48	0.93
	Number of employed household members	0	6	1.24	0.82
	# of cases 14,545				
Kuala Lumpur	Cars owned	0	3	0.87	0.75
	Motorcycles owned	0	3	0.62	0.67
	Household income[2]	1	10	4.52	1.94
	Household size	1	20	4.61	1.63
	Average age of household members	7	89	28.76	8.86
	Number of male household members	0	10	2.32	1.15
	Number of employed household members	0	16	2.86	1.54
	# of cases 15,654				
Manila	Cars owned	0	3	0.13	0.42
	Motorcycles owned	0	1	0.01	0.12
	Household income[3]	0	15	3.15	1.57
	Household size	1	15	4.16	1.57
	Average age of household members	6	85	29.36	9.55
	Number of male household members	0	9	1.81	1.07
	Number of employed household members	0	7	1.52	0.91
	# of cases 15,024				

1: 1 = less than Rp. 600,000; 2 = Rp.600000-Rp.999999; 3 = Rp.1,000,000-Rp.1,499,999; 4 = Rp.1,500,000-Rp.1,999,999; 5 = Rp.2000000-Rp.2999999; 6 = Rp.3000000-Rp.3999999; 7 = Rp.4000000-Rp.4999999; 8 = Rp.5000000-Rp.7499999; 9 = more than Rp.7500000; 1 US $ = approx. 9000 Indonesian Rupiahs (Rp.).
2: 1 = Less than RM 500; 2 = RM 501-RM 1000; 3 = RM1001-RM1500; 4 = RM1501-RM2000; 5 = RM2001-RM3000; 6 = RM3001-RM4000; 7 = RM4001-RM5000; 8 = RM5001-RM10000; 9 = RM10001-RM15000; 10 = more than RM15000; 1 US $ = approx. 2.50 Malaysian RInggits (RM)
3: 1 = under P3,000; 2 = P3,000 - P5,999; 3 = P6,000 - P9,999; 4 = P10,000 - P14,999; 5 = P15,000 - P19,999; 6 = P20,000 - P29,999; 7 = P30,000 - P39,999; 8 = P40,000 - P59,999; 9 = P60,000 - P99,999; 10 = P100,000 - P149,999; 11 = P150,000 - P199,999; 12 = more than P200,000; 1 US $ = approx. 27 Philippines Peso (P)

similar purpose travel behavior decisions are incorporated into the model structure. This fits very well to the modeling of ownership of passenger cars and motorcycles. Both trip modes might equally serve similar mobility purposes; thus, for example, ownership of multiple cars might alleviate the need—though not the desire!—to own another motorcycle, hence the negative correlation between the ownership levels. Any other unobserved psychological factors common to the choice of passenger cars and motorcycles could be relevant. Below, an introduction to the bivariate ordered probit model is given briefly.

Let *pac* and *m* represent the number of passenger cars and the number of motorcycles respectively owned by a household, and the equation is as follows:

$$y^*_{1h} = \boldsymbol{\beta}'\mathbf{x}_h + \varepsilon_{1h},\ y_{1h} = pac \text{ if } \mu_{1,pac} < y^*_{1h} \leq \mu_{1,pac+1},$$
$$\text{c} = 0,1,2,\ldots,\text{PAC}$$
$$y^*_{2h} = \boldsymbol{\gamma}'\mathbf{z}_h + \varepsilon_{2h},\ y_{2h} = m \text{ if } \mu_{1,m} < y^*_{1h} \leq \mu_{1,m+1},$$
$$\text{m} = 0,1,2,\ldots,\text{M} \qquad (1)$$

where y^*_{1h} and y^*_{2h} represent the underlying unobserved responses for household *h*'s ownership of *pac* passenger cars and *m* motorcycles which are observed by variables y_{1h} and y_{2h} respectively, $\boldsymbol{\beta}$, $\boldsymbol{\gamma}$ are vectors of parameters, **x** and **z** are vectors of independent variables associated with the household, μ is the threshold value that divides a continuous joint distribution of error terms ε_{1h}, ε_{2h} into intervals associated with different levels of ownership. In this equation system, the two error terms are distributed as the bivariate standard normal distribution:

Table 5 Descriptive statistics of additional independent variables used in the enhanced model for Jabotabek metropolitan area

		Min.	Max.	Mean	Std. Dev.
Residential location, land use and transportation system	Center city indicator[1]	0.00	1.00	0.63	0.48
	DKI Jakarta indicator	0.00	1.00	0.39	0.49
	Average land use diversity[2]	1.00	2.90	1.54	0.42
	Ratio of commercial land use	0.00	0.16	0.03	0.08
	Ratio of residential land use	0.00	0.92	0.56	0.28
	Ratio of undeveloped land	0.00	0.87	0.32	0.29
	Length of major roads passing through the neighborhood	0.00	8.31	1.21	1.49
	Length of all roads in the neighborhood	0.06	110.20	25.54	19.90
	Distance to DKI Jakarta city center	0.36	70.32	23.83	15.34
	Median of total bus lines on street segments	0.00	915.00	67.96	100.58
	Ratio of lands within one-kilometers of rail station	0.00	47.18	0.02	0.71
	Residential density[3]	9.49	571.76	137.63	82.24
	Job density[4]	2.49	385.84	37.24	40.63

1: DKI Jakarta, cities of Tangerang, Bekasi, Bogor and Depok.
2: For each hectare grid, sum of different urban land uses covering eight neighboring grid cells is averaged over all grid cells with urban land use in a transportation zone.
3: Population/Area of developed land (information is available in large zones which cover more than two transportation zones in DKI Jakarta, fewer than two in other locations).
4: Total number of jobs/Area of developed land (information is available in large zones which cover more than two transportation zones in DKI Jakarta, fewer than two in other locations).

$$\phi(\cdot) = \phi(\varepsilon_{1h}, \varepsilon_{2h}, \rho_{12}) \quad \text{..(2)}$$

where ρ represents correlation between the error terms. The corresponding cumulative distribution is denoted by

$$\Phi(\cdot) = \Phi(\varepsilon_{1h}, \varepsilon_{2h}, \rho_{12}) \quad \text{...(3)}$$

Using equations (1) and (3), the joint probability of household ownership of c cars and m motorcycles is as follows:

$$\begin{aligned} P_{h,pc,m} = {} & \Phi[(\mu_{1,pac+1} - \beta' \mathbf{x}_h), (\mu_{1,m+1} - \gamma' \mathbf{z}_h) \rho_{12}] \\ & - \Phi[(\mu_{1,pac} - \beta' \mathbf{x}_h), (\mu_{1,m+1} - \gamma' \mathbf{z}_h) \rho_{12}] \\ & - \Phi[(\mu_{1,pac+1} - \beta' \mathbf{x}_h), (\mu_{1,m} - \gamma' \mathbf{z}_h) \rho_{12}] \\ & + \Phi[(\mu_{1,pac} - \beta' \mathbf{x}_h), (\mu_{1,m} - \gamma' \mathbf{z}_h) \rho_{12}] \end{aligned}$$

The parameters of the equation system above are estimated by the log-likelihood function, which can be given as:

$$\log L = \sum_{h=1}^{H} \sum_{pac=0}^{PAC} \sum_{m=0}^{M} Z_{h,pac,m} P_{h,pac,m} \quad \text{.............................. (4)}$$

where $Z_{h,pac,m}$ is an indicator taking value one when household h owns pac cars and m motorcycles. The likelihood function given above is written in GAUSS™ code and maximized with GAUSS™ maximum-likelihood procedure[17].

4.2 Estimation results

The models estimated are presented in Table 6 and Table 7. In Table 6, the results of the basic model with only household characteristics for three metropolitan areas are given; note that as there are only a few cases of two or more than two motorcycle ownership levels in Manila metropolitan area, the relevant equation for motorcycle ownership automatically reduces to a binary case, hence there are no estimated threshold values for Manila metropolitan area. Table 7 presents the results of the enhanced model with neighborhood characteristics in addition to household characteristics. This model is estimated only for Jabotabek metropolitan area. As for the correlations between ownership levels of motorcycle and cars, the results indicate that in both Jabotabek and Manila metropolitan areas, there is almost no relationship between motorcycle and car ownership levels. However, for Kuala Lumpur metropolitan area, we obtain a relatively moderate negative correlation indicating that motorcycle and car ownership levels affect each other negatively.

As regards the motorcycle ownership in three metropolitan areas, the results generally show consistency across metropolitan areas. However only for Kuala Lumpur metropolitan area, all parameter values of motorcycle ownership levels are significant. All other things being equal, propensity to own a motorcycle is highest in Kuala

Table 6 Estimation results for bivariate ordered probit models of household motorcycle and car ownership (the basic models with household characteristics only)

Variable	Jabotabek				Kuala Lumpur				Manila			
	Motorcycle		Car		Motorcycle		Car		Motorcycle		Car	
	Parameter	t-score	Parameter	t-score	Parameter	t-score	Parameter	t-score	Parameter	t-score	Coefficient	t-score
Constant term	−0.65	−14.70	−2.92	−43.70	−0.23	−5.17	−0.43	−11.41	−2.52	−17.51	−2.94	−37.42
Household income	0.04	6.50	0.56	69.31	0.00	7.75	0.00	−5.54	0.08	4.99	0.33	38.08
Household size	0.12	17.22	−0.13	−12.10	−0.02	−2.73	0.04	4.62	0.01	0.64	−0.02	−1.45
Average age of household members	−0.01	−8.31	0.01	4.50	−0.01	−6.12	0.01	18.44	0.00	−0.84	0.01	8.11
Number of male household members	0.00	0.13	0.06	3.74	0.19	17.25	0.00	0.31	0.01	0.24	0.11	6.30
Number of employed household members	0.00	−0.19	−0.08	−4.58	0.04	6.20	0.11	15.69	0.03	0.98	−0.01	−0.54
Threshold values												
μ_1 : one and two	1.24	73.89	1.25	51.44	1.53	100.88	1.41	113.36	–	–	0.99	38.42
μ_2 : two and three	2.45	48.70	2.69	48.74	2.26	90.15	2.44	113.12	–	–	1.71	35.24
Correlation ρ	−0.07		−39.36		−0.22		−82.45		0.04		25.64	
SAMPLE SIZE	14,545				15,654				15,024			
LOG-L(0)	−10,469.36				−16,006.74				−3,630.27			
LOG-L($\boldsymbol{\beta};\boldsymbol{\gamma}$)	−8,707.67				−15,623.66				−3,144.62			

Lumpur metropolitan area followed by Jabotabek metropolitan area. Although the household income variable does not give way to direct comparision across metropolitan areas, it was found to be positively influential on motorcycle ownership levels in all metropolitan areas. However, household size was found to have mixed effects across metropolitan areas. The increase in household size increases the propensity to own a new or an additional motorcycle in Jabotabek; contrasting to this, in Kuala Lumpur metropolitan area the reverse is the case: a big household has lower propensity to own a motorcycle or is more likely to dispose of a motorcycle already in the household register, and switch to a car. For the next two variables presented in Table 3, average age of household members and number of employed household members display consistency for both Jabotabek and Kuala Lumpur metropolitan areas: as the household gets older, a motorcycle was not preferred, and as the number of males increases in the household, the motorcycle is more likely to be added to the household register in Kuala Lumpur metropolitan area; also in Kuala Lumpur metropolitan area, households are more likely to buy a new or add one more motorcycle to their registers. Lastly, the threshold estimated for adding another motorcycle to the already owned motorcycle in the household register is higher for the Kuala Lumpur metropolitan area than the Jabotabek metropolitan area between one and two motorcycles; for having three motorcycles, the threshold was found to be higher for the Jabotabek metropolitan area. When the estimated threshold values are considered together with the constant values estimated, the difference between two metropolitan areas approximately decreases for the lower threshold, and increases for the higher threshold.

Contrary to the estimated coefficient results obtained for motorcycle ownership levels, estimated coefficients for car ownership levels in all metropolitan areas display generally mixed results. Also, for almost all but two variables we obtain significant coefficient values for all metropolitan areas. Among three metropolitan areas, all other things being equal, the propensity to own a car is highest in the Kuala Lumpur metropolitan area, the remaining two metropolitan areas display almost similar propensities of car ownership levels. However, household income is most effective in the Jabotabek metropolitan area, followed by the Manila metropolitan area. Surprisingly, the coefficient value turned out to be negative for the Kuala Lumpur metropolitan area, calling for other specifications of income instead of crude ordered income levels. Also, the Kuala Lumpur metropolitan area distinguishes itself with positive coefficient values for both household size and number of employed household members, which are negative for the Jabotabek metropolitan area, and not significant for the Manila metropolitan area. Together with the results obtained for motorcycle ownership levels, we can concluded that in the Jabotabek metropolitan area, big households are more inclined to own motorcycles than cars. Coefficient values of the number of male household members are positive and significant only for the Jabotabek and Manila metropolitan areas. Threshold value estimated for the Manila metropolitan area was the lowest among all metropolitan areas; however, together with the constant terms, it is easiest in Kuala Lumpur to switch from one to two and from two to three or more cars, all other things being equal.

The enhanced model with neighborhood characteristics is estimated only for the Jabotabek metropolitan area (Table 7). The enhanced model is significantly better than the basic model with household characteristics according to a Log-likelihood Ratio test (significance less than $p = 0.01$ level). The variables that are carried to the enhanced model from the basic model have coefficient values estimated very close to the values estimated in the basic model. The same is also true for the estimated threshold and correlation values.

On the other hand, for neighborhood characteristics estimated coefficient values turn out to be significant for only four variables both motorcycle ownership and car ownership levels. Relative location of the residential location is measured by three variables: center city indicator, DKI Jakarta location indicator and distance to the DKI Jakarta city center. Among these three variables only, distance to the DKI Jakarta city center has consistently negative estimated values for both motorcycle and car ownership. However, their absolute values stayed at very low levels. Center city indicator, which means residential location in either DKI Jakarta or any of the surrounding city centers in the metropolitan area has a

Table 7 Estimation results for bivariate ordered probit model of household motorcycle and car ownership (the enhanced model for Jabotabek with household and residential location characteristics too)

Variable	Motorcycle		Car	
	Parameter	t-score	Parameter	t-score
Constant term	−0.52	−3.96	−2.99	−16.29
Household income	0.04	6.57	0.57	69.26
Household size	0.12	17.30	−0.13	−11.81
Average household age	−0.01	−8.26	0.01	4.44
Number of males	0.00	−0.07	0.06	3.64
Number of workers	0.00	−0.26	−0.08	−4.68
Neighborhood characteristics				
Center city indicator	0.01	0.41	0.08	1.78
DKI Jakarta indicator	−0.09	−2.34	−0.01	−0.26
Distance to DKI Jakarta city center (meters)	−3.93	−2.93	−3.90	−2.09
Average land use diversity	0.00	−0.02	0.02	0.37
Ratio of commercial land use	0.04	0.23	−0.64	−2.32
Ratio of residential land use	−0.07	−0.78	−0.14	−1.21
Ratio of undeveloped land	−0.05	−0.48	0.10	0.69
Residential density	0.00	0.24	0.00	1.47
Job density	0.00	−0.90	0.00	0.47
Length of major roads passing through the neighborhood (kilometers)	0.01	1.67	−0.01	−0.93
Length of all roads in the neighborhood (meters)	0.80	1.31	3.12	3.77
Median of total bus lines on street segments	0.00	0.90	0.00	−0.74
Ratio of lands within one-kilometers of rail station	0.03	2.38	−9.64	0.00
Threshold values				
μ_1 : one and two	1.24	73.92	1.26	51.44
μ_2 : two and three	2.45	48.68	2.72	48.59
Correlation ρ	−0.08		−43.57	
SAMPLE SIZE	14,545			
LOG-L(0)	−10,469.36			
LOG-L(β;γ)	−8,693.04			

positive and significant coefficient value for only car ownership. On the other hand, location in DKI Jakarta, the core of the metropolitan area, has a significant and negative estimated coefficient value for motorcycle ownership levels.

None of the density, as well as diversity variables have significant values for motorcycle ownership levels; on car ownership levels, only ratio of commercial land use, a density variable, is estimated to have a negative and significant effect. Among the variables characterizing the transportation system in the residential neighborhood, road supply in the neighborhood has a significant positive effect on car ownership levels and rail access (ratio of land within one-kilometer of a railway station) has a significant and positive effect on motorcycle ownership levels.

5. CONCLUSIONS

The analyses in this study illustrate that the motorization is seriously increasing throughout the Asian region, and it is likely that with the introduction of competition by Chinese and Indian car producers in the market it will soon cover the whole Asian region adding to the already galloping motorization trends. The linear-regression model estimated by using a 20-year-14 countries data set gives us a fixed income elasticity, which is estimated to be 1.75. Also two different sets of countries are identified regarding the effects of factors other than income. Sri Lanka, India, Nepal, Philippines, Pakistan, Indonesia, and Thailand with slopes characterizing the pace of motorization are detected as diverging (significantly higher) from the rest of the countries analyzed.

Among the three metropolitan areas analyzed, motorization has attained the highest level in the Kuala Lumpur metropolitan area, whereas, the Manila metropolitan area experiences the lowest motorization. High household car ownership levels in both Kuala Lumpur and Jabotabek—though not as much as Kuala Lumpur—indicate primacies in their respective countries. The analysis conducted on the three metropolitan areas indicated that simultaneous ownership of motorcycles and cars is either independent from each other (Jabotabek and Manila) or negatively related to each other (Kuala Lumpur).

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