EFFECTS OF ROAD DEVELOPMENT, INCOME INEQUALITY AND ECONOMIC GROWTH ON PRIVATE VEHICLES OWNERSHIP GROWTH

By

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This study postulated that the ratio of motorcycle to car ownership (MPC) could provide an indication of the level of traffic mix that help policy makers push for the best strategy according to the per capita gross domestic product (GDP), relative improvements in road mobility over road accessibility (MPA) and income inequality (GINI). Using a panel dataset of 53 countries between 1963 and 2013, three empirical studies using fixed-effects linear regression and Gompertz function were conducted to test the above argument.

The first empirical study indicated that a rise in MPA led to increases in MPC at lower per capita GDP but led to decreases in MPC once per capita GDP exceeds USD$3,081. When the income level surpasses USD$44,767, rising MPA led to increases in MPC again. In the presence of MPA effects, MPC was found to be influenced by income inequality in a reverse U-shaped relationship. In the absence of MPA effects, the reverse U-shaped relationship between MPC and per capita GDP was found to exist under high income inequality condition. The second empirical study found that the direct effects of GDP on MPC were found to be positive at low levels of GDP and turned negative at higher levels of GDP. The indirect effects were transmitted through changes in GINI as GDP rises. The overall effects were found to be greater than the direct effects at both the lower and higher ends of GDP but marginal at GDP level of USD$7,436. The third empirical revealed that the rate of CAR was the highest under mid-range MPA and lower GINI conditions. In contrast, the rate of CAR was the lowest under extreme MPA and higher GINI conditions.

In conclusion, lower income countries are expected to observe a rapid rise in motorcycle use if high mobility roads dominate the road network which in turn would face a serious road safety issue. As such, these countries should introduce new or enhance existing regulations on motorcycling, while looking into

the feasibility of building dedicated road infrastructure for motorcycles. On the other hand, higher income countries with narrow income gaps and a balanced mix of high mobility and high accessibility roads would observe rapid increase in car use. These countries are recommended to strategize interventions to handle the rise in traffic demand such as increasing the road capacity or introducing policies to control car use.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

KESAN PEMBANGUNAN JALAN RAYA, KETIDAKSEIMBANGAN PENDAPATAN DAN PERTUMBUHAN EKONOMI KE ATAS PERTUMBUHAN PEMILIKAN KENDERAAN PERSENDIRIAN

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Kajian ini bertanggapan bahawa nisbah pemilikan motosikal berbanding kereta (MPC) dapat dijadikan sebagai satu indikasi tahap keseragaman trafik yang membolehkan penggubal polisi membuat strategi berlandaskan keluaran dalam negara kasar per kapita (GDP), nisbah tahap mobiliti jalan berbanding tahap kebolehcapaian jalan (MPA) dan ketidakseimbangan pendapatan (GINI). Bagi menentukan kesahihan hujah ini, tiga (3) kajian empirikal telah dijalankan ke atas data panel untuk 53 negara di antara tahun 1963 dan 2013 menggunakan kaedah regresi linear kesan tetap dan fungsi Gompertz.

Kajian empirikal yang pertama mendapati bahawa seiring dengan peningkatan nisbah MPA, nisbah MPC didapati meningkat pada tahap GDP yang rendah, tetapi menunjukkan penurunan setelah tahap GDP melangkaui USD$3,081. Nisbah MPC dilihat meningkat lagi apabila GDP melepasi tahap USD$44,767. Di bawah pengaruh MPA, nisbah MPC menunjukkan peningkatan pada kadar GINI yang rendah sebelum menunjukkan corak menurun apabila GINI mencapai nilai 27.4. Sekiranya tanpa pengaruh MPA, corak perubahan nisbah MPC yang meningkat dan kemudian menurun tersebut dapat dilihat di bawah kadar GINI yang tinggi sahaja. Kajian empirikal kedua mendapati bahawa pada tahap GDP yang rendah, GDP mempunyai kesan langsung yang positif ke atas MPC dan kesan langsung yang negatif pada tahap yang tinggi. Kesan tidak langsung GDP ke atas MPC pula boleh dilihat menerusi GINI yang berubah seiring dengan perubahan tahap GDP. Di kedua-dua penghujung rendah dan tinggi tahap GDP, kesan keseluruhan GDP ke atas nisbah MPC adalah didapati lebih besar berbanding kesan langsung sahaja, manakala cuma menunjukkan perbezaan yang tidak ketara pada tahap GDP USD$7,436. Kajian empirikal ketiga pula menunjukkan bahawa kadar pertumbuhan CAR adalah paling tinggi di bawah julat nisbah MPA pertengahan dan kadar GINI yang rendah. Sebaliknya, kadar

pertumbuhan CAR didapati paling rendah apabila nisbah MPA berada pada julat yang ekstrem dan kadar GINI berada pada kadar yang tinggi.

Kesimpulannya, negara berpendapatan rendah dijangka akan mengalami pertumbuhan mendadak dalam penggunaan motosikal sekiranya lebih banyak jalan bertahap mobiliti tinggi dibina berbanding jalan bertahap kebolehcapaian tinggi di mana isu keselamatan jalan raya akan bertambah serius. Oleh itu, negara sebegini perlu memperkenalkan undang-undang baharu atau memperkasakan undang-undang jalan raya sedia ada berkaitan keselamatan motosikal di samping mengkaji keperluan penyediaan infrastruktur khas bagi pengguna motosikal. Sebaliknya, negara berpendapatan tinggi yang mempunyai jurang pendapatan kecil dan nisbah yang seimbang antara jalan bertahap mobiliti tinggi dan jalan kebolehcapaian tinggi dijangka akan mengalami pertumbuhan mendadak dalam penggunaan kereta. Negara-negara ini adalah disarankan untuk merangka intervensi-intervensi bagi menampung peningkatan kereta di atas jalan raya seperti meningkatkan kapasiti jalan atau memperkenalkan polisi untuk mengawal penggunaan kereta.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

EKC	Environmental Kuznets Curve
GDP	Per Capita Gross Domestic Product
GINI	Income Inequality
KCv	Kuznets Curve
IRF	International Road Federation
ITF	International Transport Forum
MKCv	Motorcycle Kuznets Curve
MPA	High Mobility Roads to High Accessibility Roads Ratio
MPC	Motorcycle to Car Ownership Ratio
PVG	Private Vehicle Ownership Growth
PWT	Penn World Table
SWIID	Standardized World Income Inequality Database
WDI	World Development Indicator
WHO	World Health Organization

CHAPTER 1

INTRODUCTION

This chapter first describes the supply and demand of the road transportation system and the role of transport policies in maintaining a balance between them. It then provides some statistics on vehicle ownership growth and road development for selected countries of different income levels to highlight the issues related to environmental degradation and road traffic injuries. In order to explain the theoretical framework that this study used, this chapter also highlights the work of Simon Kuznets who revealed the relationship between economic growth and income inequality as an inverse-U shaped curve. This chapter then outlines several research questions, study objectives and explain the significance of the study. The last part of this chapter included a brief overview of the content of other chapters in this dissertation.

1.1 Background of the Study

Over the past decades, the vehicles and the roads have been evolving over time as new technology advances rapidly due to the effect of globalization. They become fundamental components of the economic activities whereby economic activities are more likely to take place if there are good accessibility to markets and resources. The presence of road infrastructure and vehicles hence supports mobility of humankind in their daily lives of which one critical purpose is moving to and from the workplace. In other words, the road transportation system is composed of a supply factor (road infrastructure) and the demand factor (vehicle use). Crafting transport policies to maintain a healthy balance of the interdependency between the supply and demand of the road transportation system is therefore an utmost priority of any country ever since.

The level of a balanced supply and demand of the road transportation system is heavily depended on the incomes of the people which also determines the type of vehicle owned and used. As a matter of fact, people do shift from one mode to the other as the level of incomes changes. Among the various type of vehicle used, the motorcycle is the cheapest mode in terms of the cost of the machine, the amount of fuel consumed and the cost to service the machine. In addition, no toll collection is imposed on the use of motorcycles and the cost of parking is relatively low. All these costs are significantly higher for the cars. Motorcycles can be considered as inferior goods whereby when income increases, the demand for it decreases as people would want to use the car which are more comfortable, more prestige and safer (Poi et al., 2021).

Figure 1.1 illustrates the average change in the level of motorcycle and car ownerships for selected countries of different income levels between 1990 and 2013 analyzed using data obtained from the International Road Federation (IRF)

World Road Statistics (IRF, 2010; IRF 2015). The countries were grouped according to the income classifications of the World Bank for incomes in 2013. One notable observation is that low-income countries experienced the highest increase in both motorcycle and car ownership while high income countries showed a very little increase in car ownership per capita. Some high-income countries even demonstrated a reduction in car ownership. This shows a contrasting scenario in vehicle ownership growth for countries with different income levels which requires different policy approaches to address the negative impacts brought upon by each vehicle mode. The rise and fall of each vehicle mode could affect how transport policies are to be formulated to sustain a balanced supply and demand of the road transportation system.

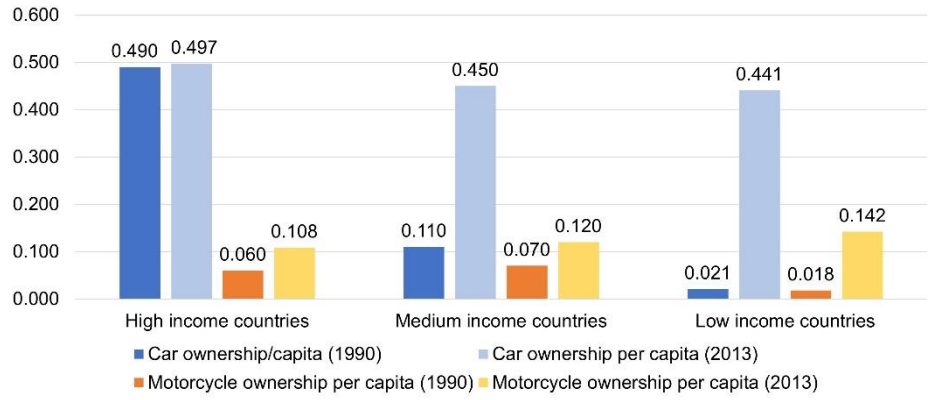

Figure 1.1 : Average change in motorcycle and car ownership per capita by income group between 1990 and 2013

On the supply side, one important role transport policies play is to control the design and construction of land transport infrastructure to meet the mobility needs of the people and to ensure sustained economic growth. One significant role is to develop the land public transportation landscape to provide a reliable, safe, and affordable rail system to the public such as the interurban passenger train and the mass rapid train in urban areas. When most of the travels happen on public transportation, the benefits include slower degradation of the environment and lower economic losses due to road traffic injuries. Another important role of transport policies is none other than to regulate road infrastructure development where they should ensure that urban growth happens in an orderly manner. This includes ensuring the existence of a good integration of road functions to balance the demand of mobility as well as accessibility of road travel. In this regard, sustainable road development policies would ensure that the road network is served by a balanced blend of high mobility roads (roads that provide high speed travel and low level of interruption due to exiting or entering traffic) and high accessibility roads (roads that provide low to medium travel speed and high level of interruption due to exiting or entering traffic).

According to data published by the International Road Federation (IRF), the development rate of these roads differs among countries in which the level of economic growth (income level) is one major factor. Figure 1.2 shows the change in average road length for selected countries between 1990 and 2013 analysed using data obtained from IRF World Road Statistics. As economic activities expand at a higher rate in low and middle-income countries, the road development rate in these countries especially high mobility roads is higher compared to high-income countries. The most notable impacts of road development on economic growth have been the savings in transportation times and increased accessibility to labour markets (Konishi, 2000; Gunasekera et al., 2008; Duncan, 2007).

On the demand side, sustainable transport policies would encourage the people to opt for public transport and reduce dependency on private vehicles. These policies are used to maintain the vehicle population at a level that can be supported by the existing road infrastructure and the road capacity planned for the future. More importantly, they should be able to control the growth of motorcycles when dedicated facilities for motorcycling are not extensively built across the road networks. And they should be effective in curbing the growth of cars before most road networks reach their capacity. In this respect, policy makers should be well informed of the factors influencing the demand of vehicle ownership that range from the people's income, socioeconomic wellbeing, household and geographical characteristics to alternative transport modes (Delbosc, 2013; Nolan, 2010; Chiou et al., 2009; De Jong et al., 2004).

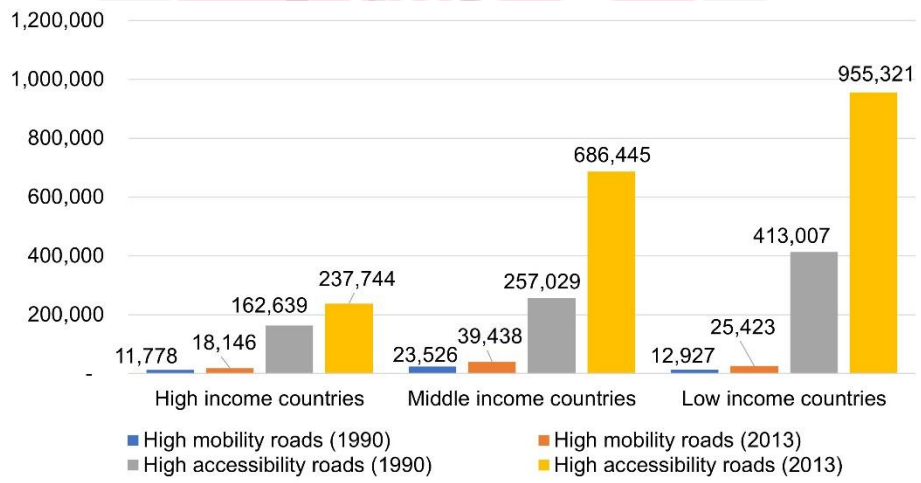

Figure 1.2 : Change in average road length (kilometre) by income group between 1990 and 2013

When transport policies fail to achieve the above, uncontrolled use of private vehicles can cause detrimental effects on the people. The most critical issue with

the use of motorcycles on high mobility roads is the high risk of sustaining severe injuries especially in low- to middle-income countries. According to a report published by the World Health Organization (WHO), the risk of a road traffic death in low-income countries is more than 3 times higher compared to high-income countries, with more than 40% of road traffic deaths in South-East Asia (where most of the countries are low to middle income) are among motorcyclists. On the contrary, countries with excessive use of cars often face with the problems of road congestion as well as air pollution especially in large and developing cities (Lu et al., 2021; Anderson, 2014). The International Transport Forum (ITF) estimated that by 2050, CO2 emissions due to land passenger transport will increase by up to 110% globally (OECD/ITF, 2015) with the road transportation contributing the largest share among all transportation modes (Albuquerque et al., 2020).

Interventions to overcome the excessive use of motorcycles and cars are different and as such there is no “one size fits all” policy to address all the negative impacts. Also, certain interventions designed to address impacts from the use of motorcycles may not be friendly for cars and vice versa. For example, retrofitting existing roads with dedicated motorcycle lanes to segregate motorcyclists from other vehicles may require the removal of the shoulder which is not safe for car users. On the other hand, building more high mobility roads as a measure to accommodate increased car use increases the exposure of motorcyclists to high-speed vehicles. Also, effective formulation and implementation of interventions greatly depends on the constraints faced by each country. Low-income countries typically suffer from insufficient financial resources while richer countries have always need to face with land constraint and public opposition to government interventions.

In order to formulate effective and sustainable transport policies to reduce the adverse impacts of private vehicle use as early as possible, understanding the growth pattern of motorcycles and cars is important. But a more important knowledge policy makers should acquire is the evolution of the motorcycle to car ownership ratio (MPC). As mentioned earlier, people tend to shift their mode of transport from motorcycle to car as their income increases. The time at which this shift happen would help policy makers to anticipate the forthcoming dominant mode of transport and thereby determine how soon the relevant preventive policies should be introduced.

To my best knowledge at present, the first study that investigated the turning point of MPC with respect to per capita gross domestic product (GDP) was published by Law et al. (2015). The study used a dataset of 80 countries with varying income levels for the period between 1963 and 2010 to explore factors that could have significant effects on the link between MPC and per capita GDP. The results showed that MPC changes in response to per capita GDP in an inverse-U shaped pattern or more commonly known in the literature as the Kuznets curve (KCv). The other contributing factors to the relationship were urbanisation, road length and vehicle purchasing power.

The Kuznets curve is used by researchers to illustrate the inverse-U shaped relationship between economic growth and another subject of interests, based on the original work of Simon Kuznets that examined the rise and fall of income inequality as the per capita income grows. The study revealed that income inequality is low at the beginning of economic development, rises during the era of industrialisation and falls as the economy reaches maturity (Kuznets, 1955). This hypothesis has sparked a great interest among economists as well as researchers from other fields to test the relationship and the relationship has been replicated ever since. The first motorcycle ownership study using KCv as the theoretical framework was published by Nishitateno and Burke (2014) who investigated factors influencing the decision to own and use a motorcycle. The authors identified that the level of affordability, safety and comfort all contributed to the level of motorcycle ownership across 153 countries.

Considering that income level and income inequality has a strong relationship, several studies attempted to examine the effect of such relationship on vehicle ownership. Some studies indicated that income inequality has a certain degree of influence on policies targeting poverty reduction (Kyroglou, 2017; Ravallion, 2014; Naschold, 2002). An interesting study found that low-income groups in fact benefit from rising income inequality when prices of goods are made more affordable to accommodate their low buying power (Bergh and Nilsson, 2012). The existence of income inequality does impose a certain degree of disadvantage with respect to transport expenditure and economic growth. In studying the shift of vehicle ownership mode between motorcycle and car, the effect of income inequality should not be discounted.

Based on the above, several research gaps were identified. The indicator of economic growth which is the per capita GDP is often used to represent the income level. However, road development which was proven to have a significant impact on economic growth was only considered in very few studies to predict the growth of vehicle ownership. Even so, the road development variable accounted for in these studies was taken in the form of road density (Cao and Huang, 2013), road length (Law et al., 2015) and road area per capita (Yang et al., 2017), whereby the function of the road was not accounted for. It is believed that the effects on vehicle ownership differ by road functions, especially if high mobility roads such as the highways are compared to high accessibility roads such as the local roads, and a country should have a balanced ratio of these roads to spur economic activities.

Prioritizing road development and reducing income inequality impose a huge burden on a country's development fund. Smart investment policies are needed to optimize the benefits and costs from these developments, and it is crucial to understand the relationships between these factors and vehicle ownership growth. At present, there is no study exploring the effects of the interaction between economic growth, road development and income inequality on vehicle ownership growth particularly MPC. For example, both road development and income inequality were found to affect economic growth, but these relationships were investigated independently. It is worthwhile to examine the interaction

effect between these two variables on economic growth, and then understand how these could change the role of economic growth on MPC. Policy makers could then make use of such relationships to formulate appropriate road development policies to counter the effect of worsened or improved income inequality condition to control the growth of motorcycle and car use on the road.

These arguments pointed to the fact that both road development and income inequality are significant factors that should be considered in any studies predicting vehicle ownership growth. However, there are several questions to be answered but have not been addressed in any studies at present. They are:

1. When will the turning point of MPC KCv happens with respect to per capita GDP?
2. What is the impact of relative improvement in high mobility over high accessibility roads (MPA) and income inequality on the turning point of MPC KCv?
3. Are there any indirect effects of income inequality on MPC brought about through changes in per capita GDP? And if yes, how does it change the turning point of MPC KCv?
4. What is the impact of relative improvement in high mobility over high accessibility roads (MPA) and income inequality on car ownership growth?

1.2 Objectives of the Study

The primary objective of this study was to assess the impacts of relative improvements in high mobility over high accessibility roads (MPA) and income inequality on the relationship between the motorcycle to car ownership ratio (MPC) and economic growth. The specific objectives were as follows:

1. To determine the effects of MPA, income inequality and per capita GDP on MPC and the effects of the interactions between these factors.
2. To determine the direct and indirect effects of per capita GDP on MPC transmitted through the impacts of per capita GDP on income inequality.
3. To determine the effects of MPA and income inequality on the S-shaped growth curve relationship between car ownership and per capita GDP.

1.3 Significance of the Study

Economic growth improves the livelihood of people and is something that every country experiences over time regardless of income levels. However, it also comes with negative effects on the environment and the socioeconomic wellbeing of the people if appropriate measures are not in place especially with regard to controlling vehicle growth. Developed countries have scientifically proven policies to reduce private vehicle use because they have adequate resources and advanced technical competencies. Low and middle-income

countries do not have the same luxuries to do the same. The best way therefore is for these countries to reduce the anticipated adverse impacts by implementing the right preventive measures at the right time to address the right issue within their available resources.

Developing the road infrastructure is by far one of the most common strategies in every country to boost economic growth. In this regard, it is critical for a country to have the right blend of road functions to support the different needs of the public and economic industry that change with the level of economic development. This is because the extent of positive impacts on economic growth differs by the type of road and the level of economic development of a country (Ng et al., 2017). Further, prioritizing development of a particular road type may even generate economic loss in tandem with increasing use of a particular vehicle mode. As highlighted earlier, building more high mobility roads to cater for car use in low and middle-income countries is not a viable investment when motorcycles use is increasing. However, statistics as shown in Figure 1.2 indicated that these countries observed a rapid rise in high mobility roads which could have a significant impact on road traffic injuries. The study by Law et al. (2015) could have provided a better explanation to this issue had it included MPA in examining the rise and fall of MPC with economic growth.

There is a growing believe that income inequality has significant effects on the impact of income growth on vehicle ownership that cannot be neglected but were not examined in earlier studies. Adams Jr. (2004) claimed that income inequality does exist in every country whereby it affects the effectiveness of poverty reduction measure through economic growth. However, the evidence associated with the relationship between inequality and economic growth is rather mixed, and most literatures pointed to a negative relationship. Trouve et al. (2020) described that the relationship between income distribution and private car motorization becomes stronger as economic progresses especially among households in metropolitan areas where the need for motorized mobility is very much critical. As such, when income inequality is not addressed, it can cause the problem of transport disadvantage among the poor which then affect the pattern in vehicle ownership growth.

Hence, this study was carried out based on the following premises:

a) People do shift from motorcycles to cars as their income rises. The MPC KCv can be used to indicate the turning point of the shift.
b) Roads of different functional classification have different impacts on the use of motorcycles and cars at different income levels. The MPA ratio can be used to indicate the extent of the impact.
c) Income inequality influences the purchasing power of the people which could then affect the MPC ratio.

This study however acknowledged the possibility of disturbances in the use of the MPC ratio to study the shift between the modes of vehicle. When income rises in lower income countries, not all motorcyclists would shift to car use. There is the possibility that a small number of them would remain using motorcycles due to convenience or choose the public transport in countries where infrastructure to support car use such as parking space is not adequate. Also, cars may not replace motorcycles when road congestion is so severe in some countries. Nevertheless, these scenarios were believed to be negligible and would not affect the trends of MPC as the economy grows.

1.4 Scope of the Study

This study focused on the growth of motorcycles and cars, road development, income inequality and economic growth and used a panel dataset of 53 countries over a 51-year-period (1963 to 2013). The sources of all data used were drawn from:

1. International Road Federation (IRF) World Road Statistics (2010) and (2015).
2. Penn World Table 7.1 (PWT 7.1), published by the Centre for International Comparison of Production, Income and Prices at the University of Pennsylvania, United States.
3. World Development Indicator (WDI) by the World Bank Group.
4. Standardized World Income Inequality Database (SWIID) by Frederick Solt.

1.5 Outline of the Thesis

This thesis starts with Chapter 1 which introduces the background of the study on the growth of motorcycle and car ownership, the study objectives and its contribution to policy making. It provides some statistics on vehicle ownership growth and road development for countries of different income levels to highlight the existing problems which could be addressed in this study. The chapter also lists the scope of the study.

Chapter 2 provides a review covering topics of interest related to the impact of road development, income inequality and economic growth on private vehicle use. Most of the studies included in this review were selected from mainly transportation research and transport economics journals based on their relevance to the topics using the keywords private vehicle ownership, economic growth, road infrastructure development and income inequality. Also, this chapter describes the theoretical basis of the Kuznets curve and how it was applied on the study.

Chapter 3 outlines the methodology of the study. This chapter begins by presenting a flow chart of the study design. The frameworks and model for the

three empirical studies are then presented. This chapter also outlines the data sources and descriptions of the variables, in addition to the methodology employed in analyzing the data.

Chapter 4 presents the results and discussion sections. In total, three empirical studies were conducted. The first empirical study assessed the impacts of MPA and income inequality on the relationship between MPC and per capita GDP. This study used the fixed-effects panel regression on a panel data for 53 countries at various levels of economic growth between 1963 and 2013. The second empirical study examined the direct and indirect effects of per capita GDP on MPC under the moderating effect of income inequality. It used two fixed-effects panel data models to obtain the estimates of the direct and indirect components in the relationship between MPC and per capita GDP. The third empirical study examined the effects of MPA and income inequality on the relationship between car ownership and economic growth. It used the Gompertz function to model changes in the growth rate of car ownership and the income elasticities.

Chapter 5 summarizes the research findings from the three empirical studies and discusses the study contributions, policy implications, limitations, and directions for future research.

REFERENCES

Abdul Manan, M. M., & Várhelyi, A. (2012). Motorcycle fatalities in Malaysia. IATSS Research, 36: 30-39.

Acutt, M. Z., & Dodgson, J. S. (1998). Transport and global warming: modelling the impacts of alternative policies. Transport Policy and the Environment, 20–37.

Adams, Jr., & Richard, H. (2004). Economic growth, inequality and poverty: estimating the growth elasticity of poverty. World Development, 32(12): 1989-2014.

Albuquerque, F. D. B., Maraqa, M. A., Chowdhury, R., & Mauga, T. (2020). Greenhouse gas emissions associated with road transport projects: current status, benchmarking, and assessment tools. Transportation Research Procedia, 48: 2018–2030.

Anderson, M. L. (2014). Subways, strikes, and slowdowns: The impacts of public transit on traffic congestion. The American Economic Review, 104(9): 2763-2796.

Agénor, P.R. (2010). A theory of infrastructure-led development. Journal of Economic Dynamics and Control, 34: 932–950.

Albalate, D., Gragera, A. (2020). The impact of curbside parking regulations on car ownership. Regional Science and Urban Economics, 81: 103518.

Aschauer, D. (2000). Public capital and economic growth: issues of quantity, finance, and efficiency, Economic Development and Cultural Change, 48: 391-406.

Barro, R. J. (2000). Inequality and growth in a panel of countries. Journal of Economic Growth, 5: 5-32.

Basu, R., & Ferreira, J. (2020). Understanding household vehicle ownership in Singapore through a comparison of econometric and machine learning models. Transportation Research Procedia, 48: 1674–1693.

Bergh, A., & Nilsson, T. (2012). When more poor means less poverty: On income inequality and purchasing power. Research Institute of Industrial Economics Stockholm.
https://project.nek.lu.se/publications/workpap/papers/WP12_2.pdf.

Besley, T. & Burgess, R. (2003). Halving global poverty. Journal of economic perspectives, 17(3): 3-22.

Boarnet, M. G., Hong, A., & Santiago-bartolomei, R. (2017). Urban spatial structure, employment subcenters, and freight travel, Journal of Transport Geography, 60: 267–276.

Bourguignon, F. (2003). The growth elasticity of poverty reduction: explaining heterogeneity across countries and time periods. In T. Eicher & S. Turnovski (Eds.), Growth and Inequality (pp. 3-26). MIT Press.

Brock, W. A., & Taylor, M. S. (2006). Economic growth and the environment: A review of theory and empirics. In: P. Aghion & S. N. Durlauf (Eds.), Handbook of Economic Growth, (pp. 1749-1821). Elsevier.

Brüllhart, M., & Spergami, F. (2009). Agglomeration and growth: Cross-country evidence. Journal of Urban Economics, 65(1): 48-63.

Button, K., Ndoh N., & John, H. (1993). Modeling vehicle ownership and use in low income countries. Journal of Transport Economics and Policy, 51-67.

Canh, N. P., Schinckus, C., Thanh, S. D., & Hui Ling, F. C. (2020). Effects of the internet, mobile, land phones on income inequality and The Kuznets curve: Cross country analysis. Telecommunications Policy, 44(10): 102041.

Cao, X., & Huang, X. (2013). City-level determinants of private car ownership in China, Asian Geographer, 30(1): 37–53.

Cater, C.I. (2017). Tourism on two wheels: Patterns on motorcycle leisure in Wales. Tourism Management, 61: 180-189.

Chiou, Y.C., Wen, C.H., Tsai, S.H., & Wang, W.Y. (2009). Integrated modeling of car/motorcycle ownership, type and usage for estimating energy consumption and emissions. Transportation Research Part A: Policy and Practice, 43(7): 665–684.

Chong, A. (2004). Inequality, democracy, and persistence: Is there a political Kuznets curve? Economics and Politics, 16(2): 189-212.

Chu, M. Y., Law, T. H., Hamid, H., Law, S. H., Lee, J. C. (2022). Examining the effects of urbanization and purchasing power on the relationship between motorcycle ownership and economic development: A panel data. International Journal of Transportation Science and Technology, 11(1): 72-82.

Clark, S.D. (2007). Estimating local car ownership models. Journal of Transport Geography, 15(3): 184–197.

Copeland, B. R., & Taylor, M. S. (2004). Trade, growth, and the environment. Journal of Economic Literature, 42(1): 7-71.

Crafts, N., & Leunig, T. (2005). The historical significance of transport for economic growth and productivity. Research Annex, 1.

Dargay, J., & Hanly, M. (2007). Volatility of car ownership, commuting mode and time in the UK. Transportation Research Part A: Policy and Practice, 41(10): 934–948.

Dargay, J., & Gately, D., (1999). Income's effect on car and vehicle ownership, worldwide: 1960–2015. Transportation Research Part A: Policy Practice, 33(2): 101–138.

Dargay, J., & Gately, D. (1997). Vehicle ownership to 2015: implications for energy use and emissions. Energy Policy, 25: 1121–1127.

Datta, S. (2012). The impact of improved highways on Indian firms. Journal of Development Economics, 99(1): 46–57.

Delbosc, A. (2013). Household composition and within-household car saturation in Melbourne. Transport Policy, 25: 94-100.

Dercon, S., Giligan, D. O., Hoddinott, J., & Woldehanna, T. (2009). The impact of agricultural extension and roads on poverty and consumption growth in fifteen Ethiopian villages, American Journal of Agriculture Economics, 91(4): 1007-1021.

De Jong, G., & Van de Riet, O. (2008). The driving factors of passenger transport. European Journal of Transport Infrastructure and Research, 8(3): 227–250.

De Jong, G., Gunn, H., & Ben-Akiva, M. (2004). A meta-model for passenger and freight transport in Europe. Transport Policy, 11: 329-344.

Duncan, T. (2007). Findings from studies of poverty impacts of road projects. Asian Development Bank Manila. https://www.adb.org.

Duffy M., & Robinson, T. (2004). An econometric analysis of motorcycle ownership in the UK. International Journal of Transport Management, 2: 111–121.

Dunkerley, J., & Hoch, I. (1986). The pricing of transport fuels, Energy Policy, 14 (4): 307–317.

Ecola, L., Rohr, C., Zmud, J., Kuhnimhof, T., & Phleps, P. (2014). The Future of Driving in Developing Countries. RAND Corporation. https://www.rand.org.

Fan, S., & Chan-Kang, C. (2008). Regional road development, rural and urban poverty: evidence from China. Transport Policy, 15(5): 305–314.

Feenstra, R. C., Robert, I., & Marcel, P. T., (2015). The next generation of the Penn World Table (9.0) [Data set], available for download at https://www.ggdc.net/pwt.

Franses, P. H. (1994). A method to select between Gompertz and logistic trend curves. Technological Forecasting and Social Change, 46 (1): 45–49.

Ghate, A. T., & Sundar, S. (2013). Can we reduce the rate of growth of passenger car ownership? Economic and Political Weekly, 48(23): 32-40.

Greene, W.H. (2003). Econometric Analysis. Prentice Education, Upper Saddle River.

Grossman, G. M., & Krueger, A. B. (1991). Environmental impacts of a North American Free Trade Agreement. National Bureau of Economic Research. https://www.nber.org/papers/w3914.

Gunasekera, K., Anderson, W., & Lakshmanan, T. R. (2008). Highway-induced development: evidence from Sri Lanka. World Development, 36(11): 2371–2389.

Hansen, M., & Huang, Y.L. (1997). Road supply and traffic in California urban areas. Transportation Research Part A: Policy Practice, 31(3): 205-218.

Haque, B., Choudhury, C., Hess, S., & Crastes, R. (2019). Modelling residential mobility decision and its impact on car ownership and travel mode. Travel Behaviour and Society, 17: 104–119.

Heil, M., & Selden, T. M. (2001). International trade intensity and carbon emissions: A cross-country econometric analysis. The Journal of Environment and Development, 10(1): 35-49.

Holzer, H. J., Ihlanfeldt, K. R., Sjoquist, D. L. (1994). Work, search and travel among white and black youth. Journal of Urban Economics, 35: 320-345.

Hsiao, C. (2003). Analysis of Panel Data. Cambridge University Press, Cambridge, UK.

Huo, H., & Wang, M. (2012). Modeling future vehicle sales and stock in China. Energy Policy, 43: 17–29.

Huo, H., Wang, M., Johnson, L., & He, D. (2007). Projection of Chinese motor vehicle growth, oil demand, and CO2 Emissions through 2050. Transportation Research Record Journal Transportation Research Board, 2038: 69–77.

Hymel, K. (2019). If you build it, they will drive: Measuring induced demand for vehicle travel in urban areas. Transport Policy, 76: 57-66.

Iacono, M., & Levinson, D. (2016). Mutual causality in road network growth and economic development. Transport Policy, 45: 209–217.

IRF World Road Statistics, (2015). IRF World Road Statistics 2015: Data 2008-2013. International Road Federation, Geneva. https://worldroadstatictics.org/wrs-data.

IRF World Road Statistics, (2010). IRF World Road Statistics 2010: Data 1963-2008. International Road Federation, Geneva. https://worldroadstatictics.org/wrs-data.

Ismail, N.W., & Mahyideen, J.M. (2015). The impact of infrastructure on trade and economic growth in selected economies in Asia. Asian Development Bank Institute Tokyo. https://www.adb.org/sites/default/files/publication/177093/adbi-wp553

Jamson, S., & Chorlton, K. (2009). The changing nature of motorcycling: Patterns of use and rider characteristics. Transportation Research Part F, 12: 335-346.

Jou, R., & Chen, T. (2014). Factors affecting public transportation, car, and motorcycle usage. Transportation Research Part A, 61: 186–198.

Khan, A., & Willumsen, L. (1986). Modelling car ownership and use in developing countries, Traffic Engineering Control, 27 (11): 554–560.

Klein, N. J., & Smart, M. J. (2017). Millennials and car ownership: Less money, fewer cars. Transport Policy, 53: 20-29.

Kohler, U. & Kreuter, F. (2009). Data analysis using Stata. StataCorp, LP.

Konishi, H. (2000). Formation of hub cities: Transportation cost. Journal of Urban Economics, 48: 1–28.

Kuznets, S., 1955. Economic growth and incomes inequality. American Economic Review, 1: 1-28.

Kyroglou, G. (2017). The importance of income inequality at the top end of the distribution as opposed to the bottom end as determinant of growth. [Doctoral dissertation, Uppsala Universitet].

Lam, W.H.K., & Tam, M.L. (2002). Reliability of territory-wide car ownership estimates in Hong Kong. Journal of Transport Geography, 10(1): 51–60.

Law, T. H., Hamid, H., Goh, C. N. (2015). The motorcycle to passenger car ownership ratio and economic growth: a cross-country analysis. Journal of Transport Geography, 46: 122-128.

Law, T.H. (2015). Factors associated with the relationship between non-fatal road injuries and economic growth. Transport Policy, 42: 166-172.

Law, T. H., Noland, R. B., & Evans, A. W. (2009). Factors associated with the relationship between motorcycle deaths and economic growth. Accident Analysis and Prevention, 41(2): 234–240.

Le, T. H., Nguyen, C. P., Su, T. D., & Tran-Nam, B. (2020). The Kuznets curve for export diversification and income inequality: evidence from a global sample. Economic Analysis and Policy, 65: 21-39.

Lee, J. E. (2006). Inequality and globalization in Europe. Journal of Policy Modeling, 28: 791-796.

Lescaroux, F. (2010). Car ownership in relation to income distribution and consumers' spending decisions. Journal of Transport Economics and Policy, 44(2): 207–230.

Lessmann, C. (2014). Spatial inequality and development – is there an inverted-U relationship? Journal of Development Economics, 106: 35-51.

Li, S., Zhao, P. (2017). Exploring car ownership and car use in neighborhoods near metro stations in Beijing: does the neighborhood built-environment matter? Transport Research Part D: Transport and Environment, 56: 1–17.

Li, Y., DaCosta, M. M. (2013). Transportation and income inequality in China: 1978-2007. Transportation Research Part A, 56-71.

Ling, Z., Cherry, C. R., Yang, H., Jones, L. R. (2015). From e-bike to car: A study on factors influencing motorization of e-bike users across China. Transportation Research Part D: Transport and Environment, 41: 50–63.

Litman, T. (2001). Generated traffic and induced travel. ITE Journal, 71(4): 38-47.

Lu, J., Li, B., Li, H., & Al-Barakani, A. (2021). Expansion of city scale, traffic modes, traffic congestion, and air pollution. Cities, 108: 102974.

Marquet, O., Miralles-guasch, C. (2016). City of Motorcycles. On how objective and subjective factors are behind the rise of two-wheeled mobility in Barcelona. Transportation Policy, 52: 37–45.

Melia, S. (2018) Does transport investment really boost economic growth? World Transport Policy and Practice, 23(3&4): 118-128.

Melo, P. C., Graham, D. J., Noland, R. B. (2012). The effect of labor market spatial structure on commuting in England and Wales. Journal of Economic Geography, 12(3): 717–737.

Mulalic, I., Rouwendal, J. (2020). Does improving public transport decrease car ownership? Evidence from a residential sorting model for the Copenhagen metropolitan area. Regional Science and Urban Economics, 83: 103543.

Muvawala, J., Sebukeera, H., & Ssebulime, K. (2021). Socio-economic impacts of transport infrastructure investment in Uganda: insight from frontloading expenditure on Uganda's urban roads and highways. Research in Transportation Economics, 88: 100971.

Naschold, F. (2002). Why inequality matters for poverty. In L. Turner (Ed.), Inequality Briefing (Vol. 2, Issue 2). Overseas Development Institute.

Nasir, A. B. M. and Mridha, H. A. (2017). Does income inequality dampen growth effect on poverty? Evidence from the US country data. The Journal of Developing Areas, 51(4): 167-177.

Ng, C. P., Law, T. H., Mohd Jakarni, F., Kulanthayan, S. (2018). Relative improvements in road mobility as compared to improvements in road accessibility and urban growth: a panel data analysis. Transportation Research Part A: Policy and Practice, 117: 292–301.

Ng, C. P., Law, T. H., Wong, S. V., Kulanthayan, S. (2017). Relative improvements in road mobility as compared to improvements in road accessibility and economic growth: a cross-country analysis. Transport Policy, 60: 24-43.

Nishitateno, S., Burke, P. J. (2014). The motorcycle Kuznets curve. Journal of Transport Geography, 36: 116–123.

Nolan, A. (2010). A dynamic analysis of household car ownership. Transportation Research Part A: Policy and Practice, 44(6): 446–455.

Oberdabernig, D. A. (2013). Revisiting the effects of IMF programs on poverty and inequality. World Development, 46: 113-142.

Ong, P. M. (1996). Work and automobile ownership among welfare recipients. Social Work Research, 30(4): 255-262.

Organisation for Economic Co-operation and Development (OECD)/International Transport Forum (ITF). (2015). ITF Transport Outlook. https://read.oecd-ilibrary.org/transport/itf-transport-outlook-2015_9789282107782.

Pang, T. Y., Radin Umar, R. S., Azhar Abdul, A., Harwant, S., Shahrom, A. W., Abdul Halim, M., Zahari, N., & Mohd Shafiee, O. (1999). Fatal injuries in Malaysian motorcyclist. International Medical Research Journal, 3(2): 115 - 119.

Panayotou, T. (1993). Empirical tests and policy analysis of environmental degradation at different stages of economic development. International Labour Organization. http://www.ilo.org/public/libdoc/ilo/1993/93B09_31_engl.pdf.

Park, J. S., Seo, Y. J., Ha, M. H. (2019). The role of maritime, land, and air transportation in economic growth: panel evidence from OECD and non-OECD countries. Research in Transportation Economics, 78: 100765.

Paweenawat, S. W., & McNown, R. (2014). The determinants of income inequality in Thailand: a synthetic cohort analysis. Journal of Asian Economics, 31-32: 10-21.

Poi, A. W. H., Law, T. H., Hamid, H., Mohd Jakarni, F., (2021). Motorcycle to car ownership: the role of road mobility, accessibility, and income inequality. Transportation Part D: Transport and Environment, 90: 102650.

Pokharel, R., Bertolini, L., te Brömmelstroet, M., & Acharya, S. R. (2021) Spatio-temporal evolution of cities and regional economic development in Nepal: does transport infrastructure matter? Journal of Transport Geography, 90: 102904.

Pongthanaisawan, J., & Sorapipatana, C. (2010). Relationship between level of economic development and motorcycle and car ownerships and their impacts on fuel consumption and greenhouse gas emission in Thailand. Renewable and Sustainable Energy Reviews, 14(9): 2966–2975.

Purwanto, J. (2016). Does a rise in income inequality lead to rises in transportation inequality and mobility practice inequality? Social Inclusion, 4(3): 110–132.

Radin Umar, R. S. (2005). Updates of road safety status in Malaysia. IATSS Research, 29(1): 106–108.

Raux, C. (2021). Real-world experiences of congestion pricing. International Encyclopedia of Transportation (pp. 134-138). Elsevier.

Ravallion, M. (2014). Income inequality in the developing world. Science, 344(6186): 851–855.

Ravallion, M. (2001). Growth, inequality and poverty: Looking beyond averages. World Development, 29(11): 1803–1815.

Ravallion, M. (1997). Can high-inequality developing countries escape absolute poverty? Economics letters, 56(1): 51-57.

Rota, M. F., Carcedo, J. M., & Garcia, J. P. (2016). Dual approach for modelling demand saturation levels in the automobile market. The Gompertz curve: Macro versus micro data. Investigación Económica, 75(296): 43-72.

Saidi, S., Mani, V., Mefteh, H., Shahbaz, M., & Akhtar, P. (2020) Dynamic linkages between transport, logistics, foreign direct Investment, and economic growth: Empirical evidence from developing countries. Transportation Research Part A: Policy and Practice, 141: 277–293.

Seethepalli, K., Caterina, M. B., & Veredas, D. (2008). How relevant is infrastructure to growth in East Asia? The World Bank. https://openknowledge.worldbank.org/handle/10986/6727.

Senbil, M., Zhang, J., & Fujiwara, A. (2007). Motorization in Asia. IATSS Research, 31(1): 46–58.

Shao, J., Xiao, Z. G., & Xu, R. F. (2011). Estimation with unbalanced panel data having covariate measurement error. Journal of Statistical Planning and Inference, 141(2): 800-808.

Souche. S., Mercier, A., & Ovtracht, N. (2015). Income and access inequalities of a cordon pricing. Research in Transportation Economics, 51: 20–30.

Sillaparcharn, P., (2007). Vehicle ownership and trip generation modelling: a case study of Thailand. IATSS Research, 31(2): 17-26.

Sirajudeen, A. O., Law, T. H., Wong, S. V., Ng, C. P. (2022). The motorcycle deaths to passenger car deaths ratio and economic performance: a panel data analysis. Accident Analysis and Prevention, 165: 106533.

Sirajudeen, A. O., Law, T. H., Wong, S. V., Ng, C. P. (2021). The sources of the Kuznets relationship between the road deaths to road injuries ratio and economic growth. Journal of Safety Research, 78: 262-269.

Sohn, J., (2005). Are commuting patterns a good indicator of urban spatial structure? Journal Transport Geography, 13(4): 306–317.

Solt, F. (2014). The Standardized World Income Inequality Database, SWIID Version 4.1. Social Science Quarterly, 97(5): 1267-1281.

Stares, S. & Liu, Z. (1995). China's urban transport development strategy: proceedings of a symposium in Beijing. World Bank Group.

Stead, D., & Marshall, S. (2001). The relationship between urban form and travel patterns. An international review and evaluation. European Journal of Transport Infrastructure Research, 1(2): 113-141.

Storchmann, K. (2005). Long-run gasoline demand for passenger cars: The role of income distribution. Energy Economics, 27: 25–58.

Trouve, M., Lesteven, G., & Leurent, F. (2020). Worldwide investigation of private motorization dynamics at the metropolitan scale. Transportation Research Procedia, 48: 3413–3430.

Tao, S., He, S. Y., Kwan, M., & Luo, S. L. (2020). Does low income translate into lower mobility? an investigation of activity space in Hong Kong between 2002 and 2011. Journal of Transport Geography, 82: 102583.

Tung, S. H., Wong, S. V., Law, T. H., Radin Umar, R. S. (2008). Crashes with roadside objects along motorcycle lanes in Malaysia. International Journal of Crashworthiness, 13(2): 205–210.

Valenzuela-Levi, N. (2018). Why do more unequal countries spend more on private vehicles? evidence and implications for the future of cities. Sustainable Cities and Society, 43: 384–394.

Valenzuela-Levi, N. (2021). The rich and mobility: A new look into the impacts of income inequality on household transport expenditures. Transport Policy, 100: 161–171.

Wan, G., & Zhang, Y. (2018). The direct and indirect effects of infrastructure on firm productivity: evidence from Chinese manufacturing, China Economic Review, 49: 143–153.

Wang, C., Lim, M. K., Zhang, X., Zhao, L., Lee, P. T. W. (2020). Railway and road infrastructure in the Belt and Road Initiative countries: estimating the impact of transport infrastructure on economic growth. Transportation Research Part A: Policy and Practice, 134: 288–307.

Wang, Y. N. (2005). Car ownership forecast in China - an analysis based on Gompertz equation, Research on Financial and Economic Issues, 11.

Wen, C. H., Chiou, Y. C., Huang, W. L. (2012). A dynamic analysis of motorcycle ownership and usage: a panel data modelling approach. Accident Analysis and Prevention, 49: 193-202.

Wooldridge, J. M. (2002). Econometric analysis of cross section and panel data. MIT Press.

World Bank Group (2015). World Development Indicators (2015) [Data set]. World Bank Group. https://databank.worldbank.org/source/world-development-indicators.

Wu, Y., & Yao, H. (2015). Income inequality, state ownership, and the pattern of economic growth – A tale of the Kuznets curve for China since 1978. Atlantic Economic Journal, 43: 165-180.

Wu, T., Zhao, H., and Ou, X. (2014). Vehicle Ownership Analysis Based on GDP per Capita in China: 1963–2050. Sustainability, 6: 4877–4899.

Yamamoto, T. (2009). Comparative analysis of household car, motorcycle and bicycle ownership between Osaka metropolitan area, Japan and Kuala Lumpur, Malaysia. Transportation, 36: 351–366.

Yang, Z. S., Jia, P., Liu, W. D., Yin, H. C. (2017). Car ownership and urban development in Chinese cities: a panel data analysis. Journal of Transport Geography, 58: 127-134.

Yurko, A. V. (2011). How does income inequality affect market outcomes in vertically differentiated markets? International Journal of Industrial Organization, 29(4): 493–503.

Zhang, X., Wan, G., Wang, X. (2017). Road infrastructure and the share of labor income: evidence from China's manufacturing sector. Economic Systems, 41(4): 513–523.

Zhang, Z., Jin, W., Jiang, H., Xie, Q., Shen, W., & Han, W. (2017). Modeling heterogeneous vehicle ownership in China: a case study based on the Chinese national survey. Transport Policy, 54: 11–20.

Zhao, H. M. (2012): The medium and long term forecast of China's vehicle stock per 1000 person based on the Gompertz model. Industrial Technology & Economics, 7: 7–23.

Zheng, B., Huo, H., Zhang, Q., Yao, Z. L., Wang, X. T., Yang, X. F., Liu, H., & He, K. B. (2013). A new vehicle emission inventory for China with high spatial and temporal resolution, Atmospheric Chemistry and Physics, 13: 32005–32052.

Zhong, S. P., Gong, Y. H., Zhou, Z. J., Cheng, R., & Xiao, F. (2021). Active learning for multi-objective optimal road congestion pricing considering negative land use effect. Transportation Research Part C, 125: 103002.