รายงานวิจัยฉบับสมบูรณ์

โครงการ

การสร้างแบบจำลองทางเศรษฐมิติของความต้องการใช้พลังงานในภาคขนส่งทางถนนของประเทศไทย (**Modeling road transportation of energy demand for Thailand)**

โดย

ผศ.ดร. จารุวรรณ ชนม์ธนวัฒน์

Jaruwan Chontanawat, PhD

(Assistant Professor in Energy and Environmental Economics)

สังกัด

ภาควิชาสังคมศาสตร์และมนุษยศาสตร์ คณะศิลปศาสตร์ มหาวิทยาลัยเทคโนโลยีพระจอมเกล้าธนบุรี กรุงเทพมหานคร (**Department of Social Sciences and Humanities, School of Liberal Art, King Mongkut's University of Technology Thonburi, Bangkok)**

ธันวาคม 2554

(December 2011)

สัญญาเลขที่ MRG5280244

รายงานวิจัยฉบับสมบูรณ์

โครงการ

การสร้างแบบจำลองทางเศรษฐมิติของความต้องการใช้พลังงานในภาคขนส่งทางถนนของประเทศไทย (Modeling road transportation of energy demand for Thailand)

ผู้วิจัย

ผศ.ดร. จารุวรรณ ชนม์ธนวัฒน์

Jaruwan Chontanawat, PhD

(Assistant Professor in Energy and Environmental Economics)

สังกัด

ภาควิชาสังคมศาสตร์และมนุษยศาสตร์ คณะศิลปศาสตร์ มหาวิทยาลัยเทคโนโลยีพระจอมเกล้าธนบุรี กรุงเทพมหานคร (Department of Social Sciences and Humanities, School of Liberal Art, King Mongkut's University of Technology Thonburi, Bangkok)

สนับสนุนโดยสำนักงานคณะกรรมการการอุดมศึกษา

และสำนักงานกองทุนสนับสนุนการวิจัย

Acknowledgements

This study has been conducted within the framework of the Collaborative Projects between King Mongkut's University of Technology Thonburi, Thailand and Thailand Research Fund (TRF) that receives funding from the Thailand Research Fund and the Office of the Higher Education Commission, Thailand.

I would like to express my sincere thanks to TRF in providing me with this great opportunity, funding and advice to conduct this research. My special thanks also goes to my research mentors: Professor Lester C hunt, Department of Economics, University of Surrey, United Kingdom, and Associate Professor Chumnong Sorapitpattana, Joint Graduate School of Energy and Environment, King Mong's University of Technology Thonburi, Thailand for their instructive comments and suggestions.

The results of this research were presented at the 3rd International Conference on Applied Energy which was held in Perugia, Italy during 16-18 May 2011. I would like to thank the anonymous referees of the conference for their helpful and valuable comments on an earlier draft of the paper. This research work was also presented in the 11st TRF conference, Bangkok, Thailand during 19-21 October 2011. I would like to thank the commentators of the conference for their constructive comments and suggestions. I am also grateful for the comments received following these presentations.

This report reflects my views only, and I am responsible for all errors or omissions.

Abstract

Project Code : MRG5280244

Project Title : Modeling road transportation of energy demand for Thailand

Investigator : Dr. Jaruwan Chontanawat,

Assistant Professor (Energy and Environmental Economics)

Institution : Department of Social Sciences and Humanities, School of Liberal Arts,

King Mongkut's University of Technology Thonburi,

126 Pracha Uthit Rd., Bangmod, Thungkru, Bangkok 10140, Thailand;

Tel: +00 (662) 4708737; Fax: +00 (662) 4283375;

Email address: Jaruwan.Cho@kmutt.ac.th , J.chontanawat@gmail.com

Project Period : 2 Years

This study aims to model road transportation demand for Thailand. Two main fuels; gasoline and diesel demand functions are estimated for the period 1982-2008. Unlike the studies in previous literature on the subject, this study investigates how different time-series econometric estimation methods perform in terms of modelling these disaggregate fuel demands and estimating the key income and price elasticities and from the results determining what is most useful in formulating energy policies. The results show that the demands are principally dominated by income rather than price and therefore non-pricing policies would tend to be more appropriate in the long term.

Key Words: Oil demand estimation, Transportation, Modeling, Thailand

บทคัดย่อ

รหัสโครงการ : MRG5280244

ชื่อโครงการ :การสร้างแบบจำลองทางเศรษฐมิติของความต้องการใช้พลังงานในภาคขนส่งทางถนนของประเทศไทย

ชื่อนักวิจัย : ผศ.ดร. จารุวรรณ ชนม์ธนวัฒน์
(ด้าน เศรษฐศาสตร์พลังงานและสิ่งแวดล้อม)
สถาบัน : ภาควิชาสังคมศาสตร์และมนุษยศาสตร์ คณะศิลปศาสตร์ มหาวิทยาลัยเทคโนโลยีพระจอมเกล้าธนบุรี
126 ถนนประชาอุทิศ บางมด เขตทุ่งครุ กรุงเทพ 10140, ประเทศไทย
โทรศัพท์-โทรสาร : +00 (662) 4708737; Fax: +00 (662) 4283375;
Email address: Jaruwan.Cho@kmutt.ac.th , J.chontanawat@gmail.com
ระยะเวลาโครงการ: 2 ปี

งานวิจัยนี้มีวัตถุประสงค์เพื่อสร้างแบบจำลองทางเศรษฐมิติด้านการขนส่งทางบกของประเทศไทย โดยทำการประมาณสมการการใช้นำมันเบนซินและดีเซล โดยใช้ข้อมูลในระหว่างปี 2525-2551 งานศึกษานี้มีความแตกต่างจากงานศึกษาในอดีต กล่าวคืองานศึกษานี้ได้ใช้แบบจำลองทางเศรษฐมิติประเภทต่างๆ เพื่อประมาณหาค่าความยืดหยุ่นของการใช้นำมันเบนซินและดีเซล ที่มีต่อปัจจัยทางด้านรายได้หรือผลผลิต และปัจจัยทางด้านราคาเชื้อเพลิง ผลการศึกษาชี้ให้เห็นว่าปัจจัยทางด้านรายได้มีอิทธิผลต่อการใช้พลังงานทั้งสองประเภทมากกว่าปัจจัยทางด้านราคา ดังนั้นมาตรการที่ไม่ใช่ด้านราคา อาทิเช่นมาตรด้านการส่งเสริมการอนุรักษ์พลังงานน่าจะมีส่วนช่วยลดการใช้พลังงาน และทำให้การใช้พลังงานของประเทศเป็นไปอย่างมีประสิทธิภาพมากขึ้น โดยไม่บั่นทอนความเจริญเติบโตทางเศรษฐกิจในอนาคต

คำสำคัญ : การประมาณการใช้น้ำมัน, ภาคขนส่ง, แบบจำลอง, ประเทศไทย

TABLE OF CONTENTS

1. Introduction

Energy use throughout the world in the transportation sector is substantial. In today's society transportation is seen as a basic prerequisite of peoples' lives whether they reside in the developed or developing economies. Currently, more than half of the world's oil is consumed in the transportation sector. Moreover, in non-OECD/developing countries there is still considerable potential for expansion in road transportation. This comes from the high expansion of economic activities, urbanisation which imply an ever increasing freight and passenger transport requirement.

During the past ten years, energy consumption in Thailand has continuously increased and transportation has been the largest energy consumer – accounting for nearly 40 % of total energy demand. About 80% of this sector was for road transport[1] and gasoline and diesel are the main fuels used for road transport in Thailand, followed by LPG and NGV.

Energy consumption in the road transportation sector in Thailand has increased significantly over the past decades. Moreover, it's share of total energy consumption has also increased. There are various factors which determine transportation fuel demand such as income, cost of transport as well as socio-demographic factors and geographic factors. Therefore, it is crucial to understand the source of this growth, the principal drivers behind it and the implications for future indigenous oil consumption. In order to fully understand the growth, and more importantly, to predict future energy consumption and the resultant effect on the environment, it is vital that energy demand is modelled appropriately. It is also important to accurately measure the price and income elasticities of demand. Accurate and reliable energy demand estimations are crucial to a developing country like Thailand where most of the fuel used in transportation comes from oil imports. This will be beneficial to the Government in forming appropriate energy policies.

[1] There has been an enormous expansion of road-base transport during the past few decades due to the historical national economic and social development plans. As a result, the other transport modes such as water or rail, which used to be the main transport for Thai people, gradually declined.

2. A brief overview of Thailand's transportation sector

Thailand's transportation sector is responsible for the largest share of final energy use. This share increased from 25 % in 1980 to 38 % in 2005, although it was slightly fell back to 35 % in 2008. The growth rate of energy consumption in this sector was also the highest amongst the major energy consuming sectors during 1980-1990. Between 1995 and 2000 the growth rate declined due to the Asian economic crisis. However it turns to increase during 2000-2005. In summary, the energy consumption for road transportation rose from 4,010 thousand ton of oil equivalent (ktoe) in 1980 to 23,097 ktoe in 2008, representing an average growth of 6.5% per year. (see Tables 1.1a and 1.1b).

Table 1.1a: Energy consumption in Thailand (thousand tonnes of oil equivalent)

	Energy consumption													
	1980		*1985*		*1990*		*1995*		*2000*		*2005*		*2008*	
Transportation Sector	4,010	25%	5,852	31%	10,928	36%	17,979	39%	18,022	38%	23,491	38%	23,097	35%
Industrial Sector	4,141	26%	5,530	30%	8,946	29%	16,968	37%	16,208	34%	22,643	36%	24,195	37%
Residential Sector	5,992	38%	5,279	28%	7,642	25%	7,447	16%	7,433	16%	8,933	14%	9,958	15%
Other Sector	1,781	11%	1,935	10%	2,874	9%	3,623	8%	6,143	13%	7,330	12%	8,640	13%
Total Final Consumption	15,924	100%	18,596	100%	30,390	100%	46,017	100%	47,806	100%	62,397	100%	65,890	100%

Source : IEA and Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy, Thailand.

Table 1.1b: Energy consumption in Thailand (thousand tonnes of oil equivalent)

	Annual Growth Rate						
	80-85	*85-90*	*90-95*	*95-00*	*00-05*	*05-08*	*80-08*
Transportation Sector	7.9%	13.3%	10.5%	0.0%	5.4%	-0.6%	6.5%
Industrial Sector	6.0%	10.1%	13.7%	-0.9%	6.9%	2.2%	6.5%
Residential Sector	-2.5%	7.7%	-0.5%	0.0%	3.7%	3.7%	1.8%
Other Sector	1.7%	8.2%	4.7%	11.1%	3.6%	5.6%	5.8%
Total Final Consumption	3.2%	10.3%	8.7%	0.8%	5.5%	1.8%	5.2%

Source : Author's calcuation

Energy consumption in the Thai transportation sector is characterized by its rigid structure with most transportation relying on gasoline or diesel engine powered vehicles. As shown in Tables 1.2a and 1.2b below, road transportation accounts for about three-fourths of total energy consumption in the sector. In short, it grew from 3,295 ktoe in 1980 to 17,551 ktoe in 2008, an increase of 6.2% per year on average.

Table 1.2a: Energy consumption in Thailand's Transportation Sector (tonnes of oil equivalent)

	Energy consumption													
	1980		*1985*		*1990*		*1995*		*2000*		*2005*		*2008*	
Road	3,295	82%	4,417	75%	8,558	78%	15,022	84%	14,244	79%	18,209	78%	17,551	76%
Rail	0	0%	0	0%	105	1%	115	1%	98	1%	103	0%	76	0%
Others	715	18%	1,435	25%	2,265	21%	2,842	16%	3,680	20%	5,179	22%	5,470	24%
Total Transportation	4,010	100%	5,852	100%	10,928	100%	17,979	100%	18,022	100%	23,491	100%	23,097	100%

Source : IEA and Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy, Thailand.

Table 1.2b: Energy consumption in Thailand's Transportation Sector (Annual Growth Rate)

	Annual Growth Rate						
	80-85	*85-90*	*90-95*	*95-00*	*00-05*	*05-08*	*80-08*
Road	6.0%	14.1%	11.9%	-1.1%	5.0%	-1.2%	6.2%
Rail	na.	na.	1.8%	-3.1%	1.0%	-9.6%	na.
Others	15.0%	9.6%	4.6%	5.3%	7.1%	1.8%	7.5%
Total Transportation	7.9%	13.3%	10.5%	0.0%	5.4%	-0.6%	6.5%

Source : Author's calcuation

Between 1985 and 2008 the number of registered vehicles increased from 1.56 million to 9.89 million. The share of commercial vehicles increased from 53 % in 1985 to 58 % in 2008 whereas the share of passenger vehicle decreased from 47% in 1985 to 42% in 2008. The growth rate of commercial vehicles during this period was 8.8 % p.a. and that of passenger vehicles was 7.8 % (see Tables 1.3a and 1.3b). An important reason for the differing growth rates is the heavy import and sales taxes imposed on cars, influencing consumers to favor commercial vehicles[2]. Due to the more favorable tax rates on the commercial category and the large share of the population engaged in agriculture (about 70 %), one-ton pick up trucks account for between 50 to 60 % of new vehicle demand (Ishiguro and Akiyama, 1995). Demand for all forms of vehicles and especially cars, is centered on the capital city, Bangkok.

Table 1.3a: Motor Vehicle in Use in Thailand (in thousands)

	Energy consumption											
	1985		*1990*		*1995*		*2000*		*2005*		*2008*	
Commercial car	822	53%	1,457	54%	2,736	59%	4,220	61%	4,689	59%	5,707	58%
Passenger car	739	47%	1,222	46%	1,913	41%	2,665	39%	3,272	41%	4,188	42%
Total	1,561	100%	2,680	100%	4,649	100%	6,886	100%	7,961	100%	9,895	100%

Source : Department of Land Transport (DLT), Thailand

2 However, the import tax on passenger vehicles was reduced in July 1991

Table 1.3b: Motor Vehicle in Use in Thailand (Annual Growth Rates)

	Annual Growth Rate					
	85-90	***90-95***	***95-00***	***00-05***	***05-08***	***85-08***
Commercial car	12.1%	13.4%	9.1%	2.1%	6.8%	8.8%
Passenger car	10.6%	9.4%	6.9%	4.2%	8.6%	7.8%
Total	11.4%	11.6%	8.2%	2.9%	7.5%	8.4%

Source : Author's calcuation

Tables 1.4a and 1.4b below illustrate the structure of energy use in road transportation, with diesel oil representing the main fuel source in this sector. Diesel's share accounts for around two-thirds with gasoline making up most of the remainder.

Table 1.4a: Energy Use in Road Transportation (thousand tons of oil equivalent)

	Energy consumption													
	1982		***1985***		***1990***		***1995***		***2000***		***2005***		***2008***	
Diesel Oil	1,897	55%	3,578	67%	6,117	69%	9,642	67%	9,246	64%	12,654	71%	7,579	67%
Gasoline	1,420	41%	1,496	28%	2,680	30%	4,572	32%	4,959	34%	4,808	27%	2,706	24%
LPG	129	4%	257	5%	129	1%	152	1%	192	1%	353	2%	977	9%
Total	3,446	100%	5,331	100%	8,926	100%	14,366	100%	14,397	100%	17,815	100%	11,262	100%

Source : IEA and Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy, Thailand.

Table 1.4b: Energy Use in Road Transportation (Annual Growth Rate)

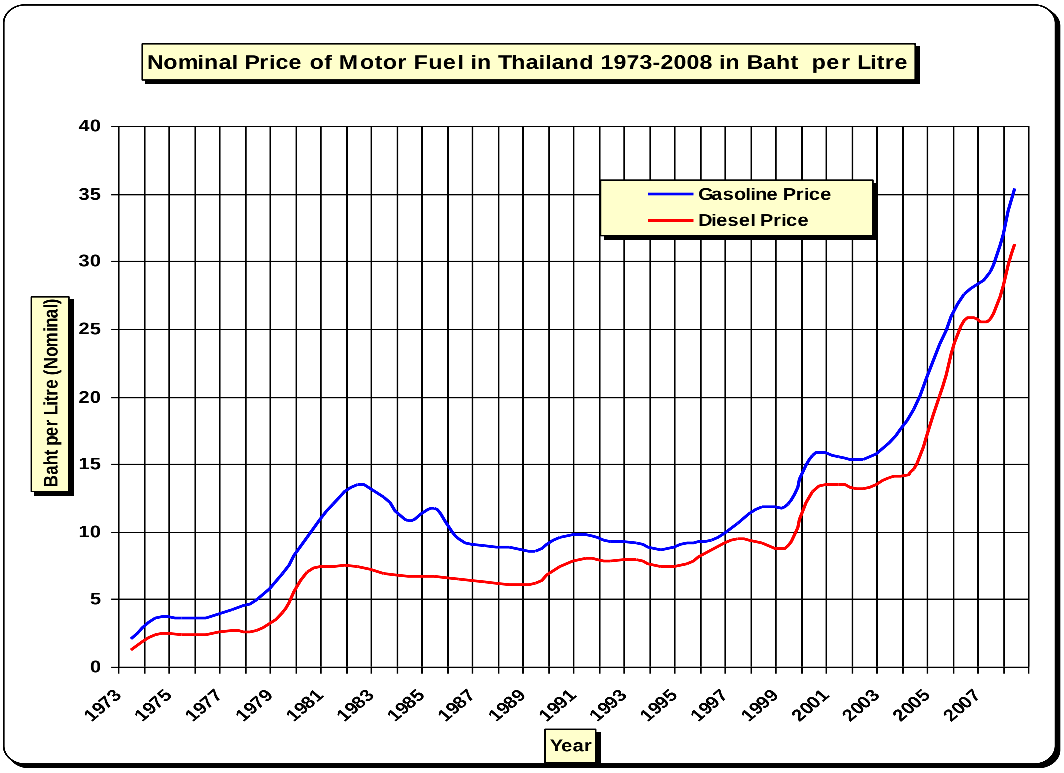
	Annual Growth Rate						
	82-85	***85-90***	***90-95***	***95-00***	***00-05***	***05-08***	***82-08***
Diesel Oil	23.6%	11.3%	9.5%	-0.8%	6.5%	-15.7%	5.5%
Gasoline	1.8%	12.4%	11.3%	1.6%	-0.6%	-17.4%	2.5%
LPG	25.8%	-12.9%	3.3%	4.8%	13.0%	40.4%	8.1%
Total	15.7%	10.9%	10.0%	0.0%	4.4%	-14.2%	4.7%

Source : Author's calcuation

During the period 1982-2008 the growth rate of diesel consumption was 5.5 % p.a. while that of gasoline was 2.5 % p.a. Diesel engines are generally preferred due to the lower cost of diesel coupled with increased fuel economy. Because of differences in taxes, the price of diesel is 30 % lower than regular gasoline. This is due to the Thai Government's desire to subsidise diesel users - essentially the manufacturing and farming sectors and low-income users - and hence limit the use of gasoline.

The pattern of gasoline and diesel prices in nominal terms for the period 1973 – 2008 is shown in Figure 1.1 below.

Figure 1.1 Nominal Price of Motor Fuel in Thailand, 1973-2008



Source : IEA and Energy Policy and Planning Office (EPPO), Ministry of Energy, Thailand

3. A literature review

3.1 Fuel demand modeling

There are a number of previous studies investigating fuel demand during the last few decades. These studies have generally considered a single country or at most a small group of countries. There have been a range of methodologies employed; partly explained by the development of econometric techniques.

The pioneer work use the conventional methodologies developed by Pindyck (1979), Griffin (1979), Baltagi and Griffin (1983), Dargay (1993)**,** Drollas (1984), Wasserfallen and Guntensperger (1988), and Sterner and Dahl (1992). They mainly use the basic concept of utilization and efficiency of vehicle stock to derive fuel demand function. The structural form model and reduce form model are developed to estimate fuel demand.[3] The reduce form model is quite popular since it is simple and the model does not require many detail variables but only the main variables such as income, price and

---

3 See more detail in Appendix A1.

the stock of vehicles. The model can explain short-run and long-run elasticities by using dynamic econometric approach.

The latter ones use cointegration and Error Correction Models which were originally developed by Engle and Granger (1987). This model takes the stationarity property of data into account in estimation fuel demand. The main concept of this approach is that the variables used in the model are generally non-stationary. But the model can adjust toward long-run equilibrium if these non-stationary variables are cointegrated. This method is widely known as 'Engle and Granger two steps procedure (EG)'. In the first step, testing stationary of data (test the unit root of variable) and the most popular tests are Dicky Fuller (DF) Test and Augmented Dicky Fuller (ADF). There are also other tests such as Cointegrating Regression Durbin-Watson (CRAW) Test and Phillips-Perron (PP) Test. The second step is to test of cointegration of the variables or in other words, is to test for the long-run relationship of the variables. If the variables are found to be non stationary (or have unit roots), then the second step is to test the stationarity of error term from the long-run equilibrium model. If error term is stationary (or has no unit roots), the variables in the model are cointegrated and error-correction model can be estimated. Another well-known method is so called 'Johansen' method[4] which uses Multivariate Maximum likelihood framework. This method is suitable for the model that contains many variables.

The significant studies using cointegration and error correction model are Hunt and Manning (1989) (England), Hunt and Lynk (1992) (England), Bentzen and Engsted (1993) (Denmark), Bentzen (1994) (Denmark), Eltony and Al-Mutari (1995) (Kuwait), Ramanathan (1999) (India), Akinboade et al (2008) (South Africa) and Iwayemi et al. (2010) (Nigeria).

The third use the Structure Time-Series Model which were first introduced and developed by Harvey et al. (1986), Harvey (1989), and Harvey (1997). The idea is due to the fact that technical progress is the special characteristic of fuel demand such as gasoline or diesel demand. These fuel demands are derived, hence gasoline/diesel

---

4 See more detail in Appendix A2.

consuming engines (cars) are required for any transport services. The amount of fuel consumption to achieve the desired level of services depends on the efficiency of gasoline/diesel-consuming cars (capital stock). Since technical progress is not directly observable it is important to distinguish the effect of technical progress from the effect of price and income on these fuel demands. The significant studies using Structure Time-Series Model are Hunt et al. (2003a), Hunt et al. (2003b), Hunt and Ninomiya (2003). They define the concept of 'the underlying energy demand trend (UEDT)' as the more general definition of trend in energy demand. The idea is that there is not only technical progress that influences energy demand trend but also other exogenous factors such as consumer tastes and economic structure. These factors can have positive and negative effects on energy demand. They also stated that technical progress can be divided into endogenous and exogenous. Endogenous technical progress is the improvement in efficiency of capital stocks, which is derived by sustainable increase in price and income whereas exogenous technical progress come from several factors, for instance environmental pressures and regulations and mandated energy efficiency standards.

3.2 Fuel demand studies in developing countries and Thailand

In terms of the past empirical work, it can be found that there are a small number of fuel studies for developing countries when compared with the studies for developed countries. The important problem of an energy study in developing countries is the availability and reliability of data. Most diesel/gasoline demand studies in developing countries use a simple log-linear equation to estimate fuel demand. Notwithstanding the fact that the model does not require substantial amounts of micro data the results are nonetheless robust. The important studies in this area are the works of Dunkerly and Hoch (1987), Birol and Guerer (1993), McRae (1994), Dahl (1994), Ishiguro and Akiyama (1995), Ghouri (1996), Gately and Streifel (1997), Dahl and Kurtubi (2001), Belhaj (2002), Chandrasiri (2006), Narayan and Smyth (2007), Akinboade et al. (2008), Iwayemi et al. (2010).[5] The details of these studies are shown below.

[5] From these studies, only five (Dunkerly and Hoch (1987), Birol and Guerer (1993), McRae (1994), Ishiguro and Akiyama (1995), and Gately and Streifel (1997)) include Thailand in their group countries studied. These studies use conventional log linear to estimate disaggregate transport fuel demand such as

Dunkerly and Hoch (1987) in their study 'Energy for Transport in Developing Countries' refer to the fact that transportation is the major market for liquid fuels in many developing countries. Road transport is the largest single transport sector with the most rapid growth. Gasoline is the major fuel component in this sector. However, diesel consumption has increased more rapidly than gasoline in 1970s and, in the poorest developing countries, diesel is the major transportation fuel. This study demonstrated that there are close associations between levels of income, transport fuel consumption and number of vehicles. The regression results show that in the period 1971-1981, there is a relatively high income elasticity for transport fuel (value above 1.0) contrasted with the relatively low price elasticity (values around 0.5 or below).

Birol and Guerer (1993) provided a significant study of fuel demand including diesel on road transportation in developing countries (including Thailand). They use time-series data from 1970-1990 to estimate fuel demand. For gasoline demand, short-run and long-run price elastic ties are -0.2 and -0.6 respectively. Income elasticities in the short-run and long-run are 0.45 and 0.69. For diesel demand, price elasticitiy is -0.38 whereas the income elasticity is 1.63.

The dynamic log linear model was estimated as follows:

$$\ln D_t = c + \alpha \ln Y_t + \beta \ln P_{d,t} + \delta \ln D_{t-1}$$

where	D_t	=	total diesel demand in the transportation sector
	Y_t	=	real GDP or real GDP per capita
	$P_{d,\,t}$	=	real price of diesel

McRae (1994) used cross-sectional time series data to estimate gasoline demand for middle-income countries. Short and long run price elasticities for Thailand are -0.32 and

---

gasoline and diesel.

-0.6, whereas the income elasticities are 0.57 and 1.7 for the short- and long-run respectively

Dahl (1994) in her study “A Survey of Oil Product Demand Elasticities for Developing Countries” reviewed more than 35 studies. The studies cover demand for aviation fuels and kerosene, gasoline, diesel fuel, transport fuel, fuel oil, LPG and other oil products. The result shows that oil product demand is price inelastic (below –0.5) and income elastic (above 1). The results are stronger for income than for price and suggest that, with a constant price, there will be a move towards lighter oil products as countries continue to develop.

Ishiguro and Akiyama (1995) examined the structures and trends in energy demand in five major developing countries of Asia. These were China, India, Indonesia, Korea and Thailand and data was analysed by sector and sub sector. The authors used econometric models to estimate price and income elasticities of energy demand in the principal sectors such as transportation, industry and residential and project energy demand through to 2005.

For the transportation sector, the study focused on road energy demand which was disaggregated into gasoline and diesel oil demand. Gasoline demand was specified as a product of the number of passenger vehicles and gasoline consumption per vehicle. The number of vehicles was specified as a function of population and real GDP and gasoline consumption per vehicle was a function of real gasoline price and income.

Demand for diesel is specified as a function of price and GDP, since demand for truck transportation is closely related to changes in general economic activity.

The result shows that income elasticities of gasoline/diesel demand are higher than price elasticities. In Thailand income and price elasticities of diesel oil are 1.60 and –0.26 while those of gasoline are 0.88 and –0.37 respectively.

Price elasticity of diesel oil demand for each country was found to be considerably lower than those for gasoline, suggesting that diesel oil is mainly used for transportation of commercial and industrial goods and thus, as a derived demand, is not significantly affected by fuel prices. Income elasticities for diesel demand were close to unity, except in the case of Thailand where they were considerably in excess of unity. The projections from the model show that the levels of energy demand of the five countries in 2005 will be 2.5 to 3 times as high as those in 1990, given that no significant energy conservation measures are implemented.

Ghouri (1996**)** estimated petroleum demand in Pakistan in 1970-1982 based on the static model and dynamic model. The static model describes petroleum consumption (gasoline, diesel and kerosene) as a function of real income, real price and number of particular vehicles. The dynamic model explains petroleum consumption as a function of real income, number of vehicles, rural population, time trend and lagged prices because changes in the demand for petroleum constitute a dynamic process where reactions cannot be completed within a single period. He indicates that the phase-out of old, inefficient vehicles, the manufacture of small, fuel-efficient and cost-effective vehicles, the substitution of fuel-based vehicles by gas- or other cheaper fuel-based vehicles are the components embedded in the long-term price elasticity. Thus consumer response to price changes will be spread out over several years. The estimated results show that price elasticities are rather low at -0.01 and -0.0018 while income elasticities are 0.74 and 0.55 for the static and dynamic models.

Gately and Streifel (1997) studied growth in oil product demand in 1971-1993 focusing on 37 of the largest oil consuming developing countries, including Thailand. The study covers 8 major petroleum products- LPG, naphtha, gasoline, jet fuel, kerosene, diesel, heavy fuel oil and others.

Several alternative equation specifications of per capita oil product demand as a function of per capita real income and the real crude oil price are examined in the study. For diesel oil, Gately and Streifel used specifications of demand as a function of income (symmetric) and price (asymmetric: with possibly different responses to an increase in the maximum historical price, to price cuts and to price recoveries), explained by 2 Koyck-lag specifications. The standard form and specification with no income lag are as follows:

$$D_t = a + \beta_m P_{\max,t} + \beta_c P_{cut,t} + \beta_{rec,t} + \gamma GDP_t + \lambda D_{t-1}$$

$$D_t = a + \beta_m \sum_{i=0}^{\infty} \Phi_P^i P_{\max,t-i} + \beta_c \sum_{i=0}^{\infty} \Phi_P^i P_{cut,t-i} + \beta_r \sum_{i=0}^{\infty} \Phi_P^i P_{rec,t-i} + \gamma GDP_t$$

The result shows that there has been a much greater demand response to income growth than to changes in oil prices. Furthermore, there has been greater demand response to the oil price cuts of the 1980s, in contrast to the OECD where there has been relatively little demand response to the price cuts.

The results were fairly good for gasoline, diesel, LPG and other oil products. In the case of diesel demand in Thailand, income elasticity is 1.12, with price elasticities of –0.20, -0.10 and –0.06 for maximum price, price recoveries and price cuts respectively.

The study indicates that oil demand will double by the year 2010 relative to the 1993 level and that the largest growth will continue to be in Asia.

Dahl and Kurtubi (2001) estimated demand for six oil products in Indonesia using a cointegration technique and compared the result with a partial adjustment model during 1970-1995. They specified the demand for each oil product as fuel price and income in the log-linear form.

The result shows that all variables are integrated of order 1. They used Johansen's technique to estimate the Error Correction Model in a vector autoregressive form applying a maximum likelihood procedure.

Belhaj (2002) estimates vehicle and fuel demand for Morocco during the period 1970-1996 using OLS. The results show that price elasticity of petrol is -0.13 and the income elasticity is 0.22 while the price elasticity of diesel is -0.15 and the income elasticity is 0.01.

Chandrasiri (2006) estimated the demand for road fuel (petrol and auto diesel) for Sri Lanka for the periods 1964-2002 using OLS and SURE models. The results show that the short-run and long-run price elasticities of petrol are -0.076 and -0.48 whereas the short-run and long-run price elasticities of diesel are -0.081 and -0.669 respectively. The short-run and long-run elasticities of petrol are 0.117 and 0.134 while the short-run and long-run elasticities of diesel are 0.84 and 0.543 respectively.

Narayan and Smith (2007) analysed the demand for oil for the Middle East countries using a panel cointegration during the period 1971-2002. The short-run and long-run price elasticities are -0.008 and -0.015 while the short-run and long-run income elasticities are 0.17 and 1.014 respectively.

Akinboade et al. (2008) estimated gasoline demand in South Africa using co-integration for the period 1978-2005. He found that the estimated price and income elasticities are -0.47 and 0.36.

Iwayemi et al. (2010) estimated petroleum demand for Nigeria using a multivariate cointegration approach for the period 1977-2005. The results show that, for the petrol demand estimation, the short-run price elasticity is -0.415 and the income elasticity is 0.801 while the long-run price elasticity is 0.108 and the income elasticity is -0.100. For the diesel estimation, the short-run price and income elasticities are -0.249 and 0.302 whereas the long-run price and income elasticities are -0.055 and 0.747 respectively.

The results from most studies for fuel demand in these developing countries indicate that there are close associations between fuel consumption, fuel price, income and number of vehicles. The results also show that income elasticities are generally greater than one, or close to one, whereas price elasticities are generally less than 1. Short-run elasticities are relatively less than long-run elasticities.[6]

It can be seen that there are very few studies in the literature investigating fuel transport demand for the case of Thailand and most use conventional methods in their estimations. As far as it is known there are no studies focusing on Thailand as a single case study. This study therefore is the first attempt to address this issue and attempts to

[6] For the case of diesel demand in Thailand, price elasticities range from -0.10 to -0.38 whereas income elasticities range from 1.12 to 1.63. For the case of gasoline demand, price elasticities range from -0.3 to -

estimate such demand using both the conventional econometric approach and a latter econometric approach namely Cointegration and Error correction Model using the latest data series for Thailand. The results should be beneficial to the government in terms of energy policy planning.

4. Methodology

The past studies in the literature indicate that there are close relationships between levels of income, transport fuel consumption, fuel price and number of vehicles. This study therefore uses four main variables in the model: fuel demand (Gasoline/diesel), real GDP, fuel price, number of vehicles (commercial cars and passenger cars). Two main models have been constructed in this research, the conventional fuel demand model and the Cointegration and Error-Correction Model.[7]

4.1. The Conventional Fuel Demand Model

4.1.1 The static conventional fuel demand model

The static conventional gasoline demand model and diesel demand model are defined as the single reduced form of log linear function of each fuel demand and explanatory variables such its price, real GDP, stock of vehicles and time trend. These can be shown in equations (1) and (2) below :

Diesel demand model:

$$LD_t = \alpha_0 + \alpha_1 LY_t + \alpha_2 LPd_t + \alpha_3 LVc_t + \alpha_4 T + \varepsilon_t \tag{1}$$

Gasoline demand model :

$$LG_t = \alpha_0 + \alpha_1 LY_t + \alpha_2 LPg_t + \alpha_3 LVp_t + \alpha_4 T + \varepsilon_t \tag{2}$$

where LD_t is diesel demand per capita in road transportation,

---

0.6 whereas income elasticities range from 0.45 to 1.7.

[7] These models can also be modified by adding the time trend (T). This permits the capture of vehicle size, reflects technical progress, consumer preference or economic structure. Hunt et al. (2003a,b) added a time trend in the energy demand model to reflect the state of technology or changes in consumer tastes and economic structure. Bentzen (1994) and Ghouri (1996) also included a time trend in their vehicle models to capture the effect of increasing fuel efficiency.

LG_t is gasoline consumption per capita in road transportation,

LY_t is real income per capita,

LPd_t is real retail diesel price,

LPg_t is real retail gasoline price,

LVc_t is the vehicle stock (number of commercial vehicles) per capita,

LVp_t is the vehicle stock (number of passenger vehicles) per capita,

T is time trend.

Income and price are the basic variables in any demand function. According to Dahl and Sterner (1991), models that do not include some types of income and price variables are considered miss-specified.

The expected sign of income should be positive while that of price should be negative. This means that when income or GDP grows, the demand for transportation will rise and lead to an increased demand for fuel. On the other hand when the fuel price increases, the demand for transportation may be reduced and lead to a reduction in demand for diesel/gasoline oil. However, the overall demand for transportation may not necessarily decrease if there are other cheaper substitute fuels.

The terms α_1 and α_2 in the equations (1) and (2) are the estimators of short-run income and price elasticities of diesel/gasoline demand. These terms sometimes indicate medium-run elasticities because the model does not have any lagged variables. This model is called a 'simple static' model.

4.1.2 The dynamic fuel demand model

In dynamic model, lag of dependent and independent variables are included in the model which can be written in the equations (3) and (4) shown below:

Diesel demand model:

$$LD_t = \alpha_0 + \alpha_1 LY_t + \alpha_2 LPd_t + \alpha_3 LVc_t + \alpha_4 T + \sum_{i=1}^{4} \gamma_i LD_{t-i} + \mu_t \qquad (3)$$

Gasoline demand model :

$$LG_t = \alpha_0 + \alpha_1 LY_t + \alpha_2 LPg_t + \alpha_3 LVp_t + \alpha_4 T + \sum_{i=1}^{4} \gamma_i LG_{t-i} + \mu_t \qquad (4)$$

where LD_{t-i} in equation (3) are the lagged endogenous variables (diesel demand), and

LG_{t-i} in equation (4) are the lagged endogenous variables (gasoline demand).

In the equations (3) and (4), α_1 and α_2 represent short-run income and price elasticities while $\dfrac{\alpha_1}{1-\sum_{i=1}^{4}\gamma_i}$ and $\dfrac{\alpha_2}{1-\sum_{i=1}^{4}\gamma_i}$ represent long-run income and price elasticities.

The rationale behind the assumption of the models is that adaptation takes time. When income or prices change in the current year, the consumer may react by purchasing a smaller or larger commercial vehicle or moving from one area of domestic or business residence to another. This will continue to affect diesel/gasoline consumption for many years into the future. In other words, today's consumption does not only depend on today's income and price structure but also on prior incomes and prices.

The estimation is based on the 'Hendry's general to specific' approach. The model with 4 lags of these variables is first estimated. The insignificant lag variables are then removed from the model. The valid model should pass all the diagnostic tests[8].

4.2. The Cointegration and Error-Correction Model

Generally, time series data is likely to be trended or non-stationary. When dealing with such data there is the high probability of obtaining spurious results. Cointegration and Error Correction Modeling is a time series econometric technique that takes stationary properties into consideration. The main advantages of using this approach are two fold. Firstly, it is easy to distinguish between short and long run effects and secondly, the

[8] They are the tests for the presence of non-normality, serial correlation and heteroscedasticity.

speed of adjustment towards the long-run equilibrium value can be directly estimated. At this point long run elasticities are capable of being estimated from the cointegrating regression. Finally, short-run elasticities and the speed of adjustment can be estimated from the error-correction model.

It can be concluded that the principal of the model involves three main steps. The first step is to test whether or not the variable in the model contains unit root (implying non-stationary). The second step, if they have unit root, is to test for cointegration between these non-stationary variables. If they are cointegrated, then the long-run elasticities can be estimated from the long-run equation. The final step is to estimate short-run elasticities from the error-correctional model. The detail of each of the steps is shown below.

4.2.1 Unit Root Test for Variables

Initially, all variables in the models: LD and LG (diesel/gasoline consumption per capita), Pd and Pg (real diesel/gasoline price), LY (real income per capita), LVc and LVp (commercial/passenger vehicles per capita) are tested for unit root. These variables are examined using the most common used test: Augmented Dickey-Fuller (ADF) test to check whether they are stationary or non-stationary variables. The test involves estimating a form of the following equation by Ordinary Least Square (OLS) method:

$$\Delta X_t = \alpha_1 + \alpha_2 T + \delta X_{t-1} + \sum_{i=1}^{n} \lambda_i \Delta X_{t-i} + \varepsilon_t \qquad t = 1,\ldots\ldots n \qquad (5)$$

where X_t denotes any variables in the model (LD, LG, Y, LPd, LPg, LVc and LVp) over time. T is time trend. Δ is the different operator. The coefficient of particular interest is δ. The null hypothesis is that X_t is non-stationary or $\delta = 0$ which means that there is a unit root problem against the alternative $\delta<0$. Under the null hypothesis (variable is non-stationary) the computed t statistic on δx_{t-1} does not follow the standard Student t and F distributions but instead follows the ADF statistics, the critical values of which have also been tabulated. The statistics used for this test have the same asymptotic distribution.

4.2.2 Cointegration Tests

If the variables in the model are found to be non-stationary with the same order for instance I (1) or integrated at order one, the next step is to examine the cointegration among these variables.

There are many possible tests for cointegration. The most common tests are based on Engle and Granger (1987), Johansen (1988), Johansen and Juselius (1990), and Johansen (1991).

EG Method:

The most popular pioneering technique in testing for cointegration is the Engle and Granger (1987) approach. The general process starts with regressing the levels of variables in the model and then testing the stationarity of the error term. If the error term is found to be stationary, the variables in the model are cointegrated. This means that there are long-run relationships among them.

Johansen Method:

The EG method has some limitations since it cannot deal with the case where more than one cointegrating relationship is possible. To solve this problem Johansen's vector auto regression (VAR) test of integration Johansen (1988) uses a 'systems' approach to cointegration that allows determination of up to r linearly independent cointegrating vectors ($r \leq g - 1$), where r is the number of cointegration vectors and g is the number of variables tested for cointegration. Johansen's method treats cointegration vectors as homogeneous across members.

4.2.3 Estimating Long-run Equation and Constructing an Error Correction Model

If the variables in the model are found to be cointegrated, the next step is to construct the Error Correction Model to identify the short-run relationship among the variables. Following the Engle and Granger's two step procedure, the first process is to estimate the long run equations from the preferred models.

Suppose the preferred model is that demand is a function of income and price. The estimate equation gives:

$$LD_t^e = \beta_0 + \beta_1 LY_t + \beta_2 LP_t + \beta_3 V_t + \beta_4 T + \varepsilon_t \qquad (6)$$

where β_1 is long-run income elasticity and β_2 is long-run price elasticity

The error term (ECM) between the actual and estimated value of LD can be derived as follows:

$$ECM_t = LD_t - LD_t^e \tag{7}$$

Then, the Error Correction Model can be expressed in the following form:

$$\Delta LD_t = a_0 + \sum_{i=1}^{j} a_i \Delta LD_{t-i} + \sum_{i=0}^{j} b_i \Delta LY_{t-i} + \sum_{i=0}^{j} c_i \Delta LP_{t-i} + \sum_{i=0}^{j} d_i \Delta LV_{t-i} + \Phi ECM_{t-1} + \varepsilon_t \tag{8}$$

where b_0 is the short-run income elasticity, c_0 is short-run price elasticity, and Φ is the speed of adjustment to the equilibrium.

5. Data and Sources

Data used in the analysis is annual time-series data for 1982-2008. Per capita final diesel consumption (LD) and per capita gasoline consumption (LG) are measured in tonnes of oil equivalent (toe). Real GDP per capita (LY) is measured in Thai Baht. Diesel price and gasoline price are measure in baht per litre. Stock of passenger vehicles per capita (LVp) and stock of commercial cars per capita (LVc) are measure in unit per person. Data on fuel consumption was obtained from Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy, Thailand. Data on GDP was obtained from the National Economic and Social Development Board (NESDB), Thailand. Data on population was obtained from the Department of Provincial Administration, Ministry of Interior, Thailand. Data on fuel prices was obtained from the Energy Policy and Planning Office (EPPO), Ministry of Energy, Thailand. Data on stock of vehicles was collected from the Department of Land Transport (DLT), Ministry of Transport and Communications, Thailand. All data was converted into natural logarithms prior to conducting the empirical analysis.

6. Results

The estimated results are divided into two main parts. The first set of results is based on the conventional model and the second set from the Cointegration and Error Correction

Model.[9],[10]

6.1 Conventional Fuel Demand Model

According to the 'general to specific' approach for model selection, conventional fuel demand models with the maximum 4 lag specifications are estimated and compared. The highly statistically insignificant variables are excluded from the model. It was found that the dynamic conventional model yielded better results than the static conventional model. The preferable estimated results of diesel and gasoline demand models are shown in equations (9) and (10) respectively.

$$LD_t = -6.40 + 0.569LY_t - 0.229LPd_t + 0.568LD_{t-1} \tag{9}$$

t-stat: (-2.33) (2.39) (-3.10) (3.59)

$$LG_t = -4.060 + 0.353LY_t - 0.145LPg_t + 0.747LG_{t-1} \tag{10}$$

t-stat: (-5.68) (6.14) (-8.11) (16.75)

Each model represents the function of individual fuel's consumption with its own price, income, and 1 year lag of its own consumption.[11] The overall performance of the models is acceptable. All the coefficients in both equations have correct signs and are statistically significant at both 5 and 10% levels. The other statistics such as R-square and DW yield good values. Both models generally pass all diagnostic tests.

Price and income elasticities of diesel demand and gasoline demand are shown in Table 6.1c and 6.1d respectively.

---

9 The econometric package program EVIEW 5.1 is used for the estimation of these models.

10 The detailed results of the estimation can be supplied by the authors on request.

11 The vehicle stock variables and time trend are excluded from the models since they are not statistically significance.

Table 6.1c Price and Income elasticities estimated from *diesel* conventional model

Diesel	**Short-run**	**Long-run**
Price elasticity	-0.23	-0.53
Income elasticity	0.57	1.32

Table 6.1d Price and Income elasticities estimated from *gasoline* conventional model

Gasoline	**Short-run**	**Long-run**
Price elasticity	-0.14	-0.57
Income elasticity	0.35	1.40

It can be seen that the price and income elasticities for both models in the short run are lower than those in the long-run. Price elasticities are less than one while income elasticities are great than one.

6.2 Cointegration and Error Correction Fuel Demand Model

6.2.1 Unit root test result

The first step of this model is to test the unit root of the variables. ADF is used for unit root test. The detail results of the test are shown in Tables 6.2a and 6.2b.

Table 6.2a: Unit root tests of variables (level)

Variable	Test	t-Stat	Critical value*
LD	ADF with c and t	-0.540527	-3.595026
LG	ADF with c and t	-0.796664	-3.603202
LPd	ADF with c and t	-1.070540	-3.595026
LPg	ADF with c and t	-0.999849	-3.595026
LY	ADF with c and t	-1.963841	-3.603202
LVc	ADF with c and t	-0.459155	-3.622033
LVp	ADF with c and t	-0.589875	-3.612199

* indicates 5% critical value

Table 6.2b: Unit root tests of variables (first difference)

Variable	Test	t-Stat	Critical value*
LD	ADF	-2.389402	-1.955020
LG	ADF with c	-4.957154	-2.991878
LPd	ADF with c	-4.102807	-2.986225
LPg	ADF with c	-3.596432	-2.986225
LY	ADF with c	-2.744197	-2.632604**
LVc	ADF with c	-9.940049	-2.986225
LVp	ADF with c	-5.978725	-2.991878

* indicates 5% critical value
** indicates 10% critical value

Table 6.2a presents the ADF statistic of all variables which indicates that they have unit root. Table 6.2b shows the ADF test of the first difference of the variables which implies that they have no unit root. Therefore it can be concluded that all variable are integrated of order 1 or I(1).

6.2.2 Cointegration test results

6.2.2.1 Diesel demand

The cointegration test includes all variables in the model such as; LD, LPd, LY, LVc. The results show that these variables are cointegrated. The estimated result of the preferable long-run diesel equation is shown in equation (11) below.

$$LD_t = -16.927 + 1.480LY_t - 0.393LPd_t \qquad (11)$$

t-stat: (-16.42) (13.23) (-4.44)

By applying general to specific approach, the estimated result of the preferred error-correction models are shown in equation (12).

$$\Delta LD_t = 0.013 + 1.193\Delta LY_t + -0.327\Delta LPd_t - 0.471ECM_{t-1} \qquad (12)$$

t-stat: (0.41) (2.58) (-1.83) (-2.38)

The results from the estimation are acceptable.[12] All coefficients have correct signs and are statistically significant at the 5% level. The other statistics such as R-square and DW yield acceptable values. They all pass the diagnostic tests. The sign of the ECM_{t-1} term is negative as expected which indicates that the residual in the previous period adjusts the model to equilibrium. The speed of adjustment which can be seen from the coefficient of the error-correction term is at 0.47 indicating that for cases which are off the long-run diesel demand curve, diesel consumption can adjust quickly towards its long-run level with about 50 percent of the adjustment taking place within the first year. The short-run and long-run price and income elasticities are shown in Table 6.2e.

[12] The commercial vehicle variable (LVc) and time trend are excluded from the model since they are not statistically significance.

Table 6.2e: Price and Income elasticities estimated from *diesel* cointegration and ECM model

Diesel	Short-run	Long-run
Price elasticity	-0.33	-0.39
Income elasticity	1.19	1.48

6.2.2.2 Gasoline demand

The cointegration test includes all variables in the model such as LG, LPg, LY, LVp. The results show that these variables are cointegrated. The result of the preferable long-run gasoline equation is shown in equation (13).

$$LG_t = -5.851 + 0.518LY_t - 0.258LPg_t + 0.515LVp_t \qquad (13)$$

t-stat: (-2.30) (2.70) (-4.85) (3.77)

By applying general to specific approach, the preferred ECM gasoline model is shown in equation (14).

$$\Delta LG_t = 0.032 + 0.395\Delta LY_t + -0.235\Delta LPg_t - 0.279ECM_{t-1} \qquad (14)$$

t-stat**:** (2.41) (1.91) (-3.19) (-2.30)

The statistical results from the ECM model in general are quite good.[13] All coefficients have correct signs and are significant at 5% level.[14] The other statistics such as R-square and DW yield acceptable values. They all pass diagnostic tests. The error-correction term, ECM_{t-1} has negative sign indicating that the error term in the previous period adjusts the model to the equilibrium with the speed of adjustment of 0.28. In other words, gasoline consumption adjusts toward its long-run level with nearly 30% within the first year. The short-run and long-run price and income elasticities are shown in Table 6.2h.

---

[13] The passenger vehicle variable (LVp) and time trend are excluded from the model since they are not statistically significance.

[14] The coefficient of income variable is statistically significant at 10% level.

Table 6.2h: Price and Income elasticities estimated from *gasoline* cointegration and ECM model

Gasoline	**Short-run**	**Long-run**
Price elasticity	-0.24	-0.26
Income elasticity	0.40	0.52

In both cases, price elasticities are generally less than income elasticities and short-run elasticities are lower than long-run elasticities.

In summary, the results show that in all cases, income elasticities are greater than one while price elasticities are less than one.[15] Income elasticities from these models are ranging from 0.35 to 1.48 while price elasticities are ranging from -0.14 to -0.57. Furthermore, the price and income elasticities in the short run are generally lower than those in the long-run.[16] This means that in the short run the consumers are unlikely to respond to the change in price and income. In other words, the consumers can adjust to them better in the long run.

7. Conclusion

The findings from this study reveal that, in general, the models perform well and give significant coefficients and the correct sign. Income elasticities from these models are relatively high at 0.35 to 1.48 while price elasticities are relatively low at -0.14 to -0.57. The results suggest that these fuel demands are driven mainly by changes in income rather than price. Consequently, adopting pricing policies to reduce the demand is unlikely to be effective. Therefore, non pricing policies such as those which emphasise conservation, alternative fuels, improving public transportation and it's associated infrastructure are likely to yield more appropriate long term results.

15 It can be seen that income elasticity of fuel demand on road transportation is quite substantial. One of the main reasons is that road transport sector in Thailand is the largest transport sector.

16 The results are generally close to the results from the past literature for the case of Thailand.

However, this is preliminary work for time-series fuel demand estimation for Thailand and further work will be undertaken to investigate the relevance and impact of exogenous factors other than income and price.

8. References

Akinboade ,O.A., Ziramba, E., Kumo,W.L. (2008), ‘ The demand for gasoline in South Africa: An empirical analysis using co-integration techniques’, Energy Economics, vol. 30, pp. 3222–3229.

Baltagi, B.H., Griffin, J.M. (1983), ‘Gasoline demand in the OECD: An application of pooling and testing procedures’, European Economic Review, vol. 22, pp. 117-137.

Belhaj, M. (2002), ‘Vehicle and fuel demand in Morocco’, Energy Policy, vol. 30, pp. 1163–1171.

Bentzen, J. (1994), An empirical analysis of gasoline demand in Denmark using cointegration techniques, Energy Economics, vol. 16(2), pp. 139-143.

Bentzen, J., Engsted, T.(1993), ‘Short- and long-run elasticities in energy demand’, Energy Economics, vol. 15(2), pp. 9-16.

Birol, F., Guerer, N. (1993), ‘Modelling the transport sector fuel demand for developing economies’, Energy Policy, vol. 21(12), pp. 1163-1172.

Chandrasiri, S., (2006), ‘Demand for road-fuel in a small developing economy: The case of Sri Lanka, Energy Policy, vol 34, pp. 1833-1840.

Cheung, Y. W., Lai, K. S. (1993), ‘Finite-Sample Sizes of Johansen’s Likelihood Ratio Tests for Cointegration’, Oxford Bulletin of Economics and Statistics, vol. 55, pp. 313–328.

Climent, F., Pardo, A. (2007), ‘Decoupling factors on the energy–output linkage: The Spanish case’, Energy Policy, vol. 35, pp. 522-528.

Dahl, C. (1994), ‘A survey of oil product demand elasticities for developing countries’, OPEC Review, vol.18(1), pp. 47-86.

Dahl, C., Kurtubi (2001), ‘Estimating oil demand in Indonesia using a cointegrating error correction model’, OPEC Review, vol. 25(1), pp. 1-21.

Dahl, C. and Sterner, T. (1991), ‘Analysis gasoline demand elasticities: A survey’, Energy Economics, vol.13(3), pp 203-210.

Dargay, J.M. (1993), ‘The demand for fuels for private transport in the UK’, In: Hawdon, D. (ed.) Recent studies of the demand for energy in the UK, Surrey Energy Economics Discussion paper, No. 72, Surrey Energy Economics Centre (SEEC), Department of Economics, University of Surrey, Guildford, UK, pp. 25-40.

Department of Alternative Energy Development and Efficiency (DEDE)
Ministry of Energy, Thailand, Available on line at: http://www.dede.go.th/
Department of Land Transport (DLT), Thailand, Available on line at:

http://www.dlt.go.th/

Department of Provincial Administration, Ministry of Interior, Thailand, Available on line at: http://www.moi.go.th/

Drollas, L.P. (1984), 'The demand for gasoline: Further evidence', Energy Economics, vol. 16(1), pp. 71-82.

Dunkerly, J.,Hoch, I. (1987), 'Energy for transportation in developing countries', Energy Journal, vol. 8(3), pp. 57-72.

Eltony, M.N., Al-Mutairi, N.H. (1995), 'Demand for gasoline in Kuwait: An empirical analysis using cointegration techniques', Energy Economics, vol. 17(3), pp. 249-253.

Energy Policy and Planning Office (EPPO), Ministry of Energy, Thailand, Available on line at: http://www.eppo.go.th/

Engle, R.F and Granger, C.W.J. (1987), 'Cointegration and error correction: representation, estimation and testing', Econometrica, vol. 55, pp. 251-276.

Gately, D. and Streifel, S.S. (1997), 'The demand for oil products in developing countries', World Bank Discussion Paper No. 359. Washington D.C., USA.

Ghouri, S.S. (1996), 'Estimation of petroleum demand and price elasticities: the case of Paskinstan', OPEC Review, vol. 20(3), pp. 235-246.

Griffin, JM. (1979), Energy conservation in the OECD: 1989 to 2000, Ballinger publishing, Cambridge, MA.

Harvey, A.C. (1989), 'Forecasting, structural time series models and the Kalman Filter', Cambridge, UK: Cambridge University Press.

Harvey, A.C. (1997), 'Trends, cycles and autoregressions', Economic Journal, vol. 107(440), pp. 192-201.

Harvey, A.C., Henry, S.G.B., Peters, S. and Wren-Lewis, S. (1986), 'Stochastic trends in dynamic regression models: An application to the employment-output equation', Economic Journal, vol. 96(384), pp. 975-985.

Hunt, L.C., Judge, G., Ninomiya, Y., (2003a), 'Modelling underlying energy demand trends', Chapter in Energy in a Competitive Market, edited by Lester C. Hunt, Edward Elgar Cheltenham, UK.

Hunt, L. C., Judge, G., Ninomiya, Y. (2003b), 'Underlying trends and seasonality in UK energy demand: a sectoral analysis', Energy Economics, vol.25, pp. 93–118.

Hunt, L.C., Lynk, E.L. (1992), 'Industrial Energy Demand in the UK: A cointegration approach', Chapter 5 In: Hawdon, D. (ed.) Energy Demand :Evidence and Expectations, Guildford, UK Surrey University Press.

Hunt, L.C.,Manning, N. (1989), 'Energy price- and income- elasticities of demand: Some estimates for the UK using the cointegration procedure', Scottish Journal of Political Economy, vol. 36(2), pp. 183-193.

Hunt, L.C., Ninomiya, Y. (2003), 'Unravelling trends and seasonality: A structural time series analysis of transport oil demand in the UK and Japan', The Energy Journal, vol. 24(3), pp. 63-96.

Ishiguro, M., Akiyama, T.(1995), 'Energy Demand in Five Major Asian Developing Countries', World Bank Discussion Papers No. 277, World Bank, Washington D.C., USA.

Iwayemi, A., Adenikinju, A., Babatunde, M.A., (2010) 'Estimating petroleum products demand elasticities in Nigeria: A multivariate cointegration approach', *Energy Economics*, vol.32, pp. 73-85.

Johansen, S. (1988), 'Statistical analysis of cointegration vectors', Journal of Economics Dynamics and Control , vol.12, pp. 231-254.

Johansen, S. (1991), 'Estimating and hypothesis testing of cointegration vectors in Guaussian vector autoregressive models', Econometrica, vol. 59, pp. 1551-1580.

Johansen, S., Juselius, K. (1990), 'Maximum likelihood estimation and inference on cointegration with applications to the demand for money', Oxford Bulletin of Economics and Statistics, vol. 52, pp.169-210.

Lee, C. C., Chang, C. P. (2005), 'Structural breaks, energy consumption, and economic growth revisited: Evidence from Taiwan', Energy Economics, vol. 27, pp. 857–872.

Mac Kinnon, J. G., Haug, A. A., Michelis, L. (1999), 'Numerical distribution functions of likelihood ratio tests for cointegration', Journal of Applied Econometrics, vol. 14, pp. 563-577.

MaRae, R. (1994), 'Gasoline demand in Developing Asian countries', Energy Journal vol. 15(1), pp. 143-155.

Narayana, P.K., Smyth, R. (2007), 'A panel cointegration analysis of the demand for oil in the Middle East', Energy Policy, vol. 35, pp. 6258–6265.

National Economic and Social Development Board, Thailand, Available on line at http://www.nesdb.go.th

Pindyck, R.S. (1979), The structure of World Energy Demand, The MIT Press, Cambridge, MA, USA.

Ramanathan, R. (1999), 'Short-and long-run elasticities of gasoline demand in India: An empirical analysis using cointegration techniques', Energy Economics, vol. 21, pp. 321-330.

Sterner,T., Dahl, C.A. (1992), 'Modelling transport fuel demand', In: Sterner T(ed.) International Energy Economics, Chapman& Hall, London, UK. pp. 65-79.

Wasserfallen, W.,Guntensperger, H.(1988), 'Gasoline consumption and the stock of motor vehicles: An empirical analysis for the Swiss economy', Energy Economics, vol. 10(4). pp. 276-282.

APPENDICES

A1: Conventional fuel demand modeling

1. Pindyck (1979) Model :

According to Pindyck, energy demand in the transportation sector is highly dependent on the existing stocks of particular fuel-burning vehicles (cars, trucks, and airplanes), the use of those stocks, and their average fuel-burning efficiency. For diesel fuel, the demand should depend on the size and characteristics of the stock of trucks and commercial vehicles in use at a particular time. The equation for modeling a particular type of fuel consumption is as follows:

$$Q = (STK * TVPC) / EFF \quad (1)$$

where Q is particular fuel consumption, STK is stock of vehicles, TVPC is total traffic volume per car (average Km driven per car each year) representing the utilisation of the typical car, EFF is the fuel-burning efficiency of the stock of vehicles in mile per gallon(Km driven per unit fuel).

There are three equations (2, 3, and 4) for explaining the stock of vehicles (STK) as follows:

$$STK_t = (1-r)STK_{t-1} + NR_t \quad (2)$$

where r is the depreciation rate of the vehicle stock, NR represents the number of new registrations (total additional stock).

NR brings the actual stock of vehicle (STK) closer to the desired stock (STK*), where STK* is a function of car price (Pc), fuel price (Pf), and income (Y).

If $$\frac{NR_t}{POP_t} = w\left(\frac{STK_t^*}{POP_t} - \frac{STK_{t-1}}{POP_{t-1}}\right) + r\left(\frac{STK_{t-1}}{POP_{t-1}}\right) + \lambda\left(\frac{NR_{t-1}}{POP_{t-1}}\right)$$

And $$\frac{STK_t^*}{POP_t} = \alpha_0 + \alpha_1 Pc + \alpha_2 Pf + \alpha_3\left(\frac{Y_t}{POP_t}\right),$$

NR will be expressed by

$$\frac{NR_t}{POP_t} = \alpha_0 + \alpha_1 Pc + \alpha_2 Pf + \alpha_3 \frac{Y_t}{POP_t} - (w - r)\frac{STK_{t-1}}{POP_{t-1}} + \lambda\frac{NR_{t-1}}{POP_{t-1}} \quad (3)$$

where w, and $w\ /(1-\lambda)$ are the annual speed of adjustment in the short-run and long-run, respectively.

The depreciation rate (r) depends on per capita income and car price as follows:

$$r = \beta_0 + \beta_1 \frac{Y}{POP} + \beta_2 Pc \qquad (4)$$

Traffic volume per car (TVPC) is a function of per capita income, fuel price. This is given by:

$$\log TVPC = \delta_0 + \delta_1 \log(\frac{Y_t}{POP_t}) + \delta_2 \log Pf + \delta_3 \log TVPC_{t-1} \qquad (5)$$

Fuel efficiency of the stock of cars depends on changes in fuel price as follows:

$$\log(\frac{1}{EFF}) = \gamma_0 + \gamma_1 \log Pf + \gamma_3 \log(\frac{1}{EFF_{t-1}}) \qquad (6)$$

Short-run and long-run elasticities with respects to the price of fuel, the price of cars and per capita income have been calculated for the four endogenous variables explained by equations 3 through 6. According to the model, increases in the price of fuel decrease consumption by increasing the average efficiency of the stock. Both of these effects, however, occur with long lags. Consequently it is normal to expect large differences between short-run and long-run elasticities of fuel demand. Also, an increase in per capita income typically brings about an increase in new registrations along with an increase in traffic volume per car.

The Pindyck model provides a good theoretical basis for constructing a model for fuel demand. However, the model requires the data at the disaggregated level. Pindyck applied the structural form model to gasoline demand because of the availability of data.

The limited availability of data on other fuels such as diesel fuel, aviation gasoline and jet fuel does not permit the construction of this model. Consequently, a simple linear logarithmic model is used as an appropriate means of estimating the demand for other fuels. (Pindyck, 1979).

2. Griffin (1979) Model:

Griffin shows the theoretical model of fuel (gasoline/ diesel) consumption in the transportation sector. The model is explained by three separate factors: typical vehicle utilisation, gasoline efficiency and the vehicle stock, which form the consumption identity:

Gasoline Consumption = Mile driven x Gasoline Consumption x cars
per car per mile
= [Utilization:U X (1/Efficiency:E) X stocks of cars]
Identity 1

This identity is helpful to analyse the short-run and long-run effects of gasoline consumption. Changes in the utilisation of vehicles can occur in the short-run with the existing stock of vehicles while changes in the efficiency of vehicles require a long-run period to turn over the stock.

Because of a lack of overall mileage data including that of consumption per mile, the relationship in the gasoline consumption has to be adapted into a form described by utilisation (U) and efficiency (E).

GAS/CAR = U/E Identity 2

The utilisation is determined by per capita income and real gasoline price and stock of car per capita. Car weight (W) is added in the model to represent car efficiency. Then identity 1 is transformed in the log linear function as follow:

$$\ln \frac{GAS}{CAR} = \alpha_0 + \alpha_1 \ln \frac{Y}{N} + \alpha_2 \ln \frac{Pmg}{Pgdp} + \alpha_3 \ln \frac{CAR}{N} + \alpha_4 \ln W$$

Where W is a function of per capita income (Y/N), real gasoline price (Pg/Pgdp) and car price per pound (Pcp/Pgdp) as follows:

$$\ln W = \beta_0 + \beta_1 + \ln \frac{Y}{N} + \beta_2 \ln \frac{Pmg}{Pgdp} + \beta_3 \ln \frac{Pcp}{Pgdp}$$

CAR/N is explained by per capita income (Y/N) and the user cost of cars (Puser/Pgdp) as follow:

$$\ln \frac{CAR}{N} = \gamma_0 + \gamma_1 \ln \frac{Y}{N} + \gamma_2 \ln \frac{P_{USER}}{P_{GDP}}$$

This system gives the response of gasoline consumption to changes in price and income.

3. Baltagi and Griffin (1983) Model:

Similar to Griffin's approach, the basic idea is that fuel consumption for transportation can be broken down into two components: the demand for travel by car, e.g. in km, and fuel use per km. The first of these is mainly determined by socioeconomic factors while the second is largely caused by technological factors. Aggregate travel demand by car can be further broken down into the total number of cars (car ownership) and an average utilisation rate (km/vehicle). Fuel consumption can be written as the product of three components:

$$F_c = [F_c/Km] \times [Km/Car] \times Cars$$

The first component; fuel consumption per km, is the fuel use or the inverse of fuel efficiency. The second, Km per car is a measure of car use. The last is car ownership.

Each component can be explained by demand functions as follows:

$$F_c/Km = h(Y, P_P, Z_E)$$

$$Km/Car = g(Y, P_P, Z_U)$$

$$Cars = f(Y, P_C, P_P, Z_C)$$

Where Y is income, P_P is fuel price, P_C is the purchase price of cars, and Z is a vector of other relevant variables such as public transport prices or other car running costs.

4. Wasserfallen and Guntensperger (1988) Model :

Wasserfallen and Guntensperger defined the gasoline demand by the following identity:

$$C = U/E$$

Where C is the amount of gasoline, U is the total kilometers driven and E is the efficiency of cars. However the factors determining U and E are different. The demand for car transport (U) is assumed to be the function of real price of gasoline (Pg), real income(Y), real price of public transport (Pp) and stock of cars in the previous period (V_{t-1}). The average efficiency of the car at each period (E) is a function of lagged of real price of gasoline (Pg) and real income(Y). Substitute U and E with C=U/E gives:

$$C_t = c + \alpha Pg_t + \beta Y_t + \gamma Pp_t + \delta V_{t-1}$$

In this model, the desired and actual stock of vehicles is explained by a partial adjustment model. The desired stock of vehicles is a function of the lagged real price of gasoline, real income, user cost of new cars, quality of private and public transport.

In short, the structural form is widely used to estimate auto fuel demand especially when the availability of data does exist. In estimating the demands such as gasoline or diesel fuel where the micro data is unavailable, it is generally acceptable to use simple static and dynamic-logarithmic equations.

Appendix A2 : Johansen Method

Johansen (1988, 1991) and Johansen & Juselius (1990) developed a cointegration test using the VAR approach which has become known as the 'Johansen maximum likelihood procedure' or the 'Johansen procedure' for short. This approach has enabled testing for the presence of all long-run relationships that the Engle-Granger test might have failed to reveal. The Johansen procedure is a VAR based test on restrictions imposed by cointegration in the unrestricted VAR. The null hypothesis in consideration is H_0, that there are different numbers of cointegration relations, against H_1, that all series in the VAR are stationary. In order to determine the number of cointegrating equations, the Johansen maximum likelihood method provides two different likelihood ratio tests. One is based on the trace statistic. The trace statistic tests the null hypothesis (H_0) that there are r cointegration vectors, against the alternative hypothesis (H_1) that at least, r+1 cointegration vectors, where r goes from 0 to 1, exist. The other one is based on the maximum eigen value. The maximum eigen values tests the null hypothesis (H_0) that there are, as a maximum, r cointegration vectors, against the alternative hypothesis (H1) that exists, as maximum, r+1 cointegration vectors, where r goes from 0 to1.[17] It is to be noted that the variables in the model should have the same order(s), and in particular are integrated of order one (Engle & Granger 1987).

Johansen (1988, 1991) also pointed out that if cointegration does exist, a Vector Error Correction Model (VECM) may be estimated. He suggested that the model incorporates parameters that allow us to analyze the relationships among variables without incurring a specification error. This error would be made when analysing the relationship in an unrestricted VAR model, since the part corresponding to the detected cointegration relationship would be ignored and would be incorporated in the VECM model through the Error Correction Term. Thus, in order to test long- and short-run relationships among the time series, restrictions on the cointegration vectors, the adjustment coefficients and the short-run coefficients in VECM have been imposed (Climent & Pardo 2007).

---

[17] According to Cheung & Lai (1993), the trace test yield more robustness to both skewness and excess kurtosis in the residual than the max-eigen value test.

When performing cointegration tests, a sensible lag structure needs to be determined. The most common criteria used in the literature[18] is the Schwartz Information Criteria (SIC) with the critical values based on the response surface coefficients from MacKinnon et al (1999).

[18] Recent empirical energy economic studies that use SIC criteria when performing cointegration test are Lee & Chang (2005), Climent & Pardo (2007).

Appendix B1: Results from Cointegration test for diesel demand

1. EG Method :

1.1 Unit root test for level of error term

Null Hypothesis: ECMDV has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 2 (Automatic based on SIC, MAXLAG=6)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.158744	0.1162
Test critical values:	1% level	-4.394309	
	5% level	-3.612199	
	10% level	-3.243079	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(ECMDV)
Method: Least Squares
Sample (adjusted): 1985 2008
Included observations: 24 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ECMDV(-1)	-0.973513	0.308196	-3.158744	0.0052
D(ECMDV(-1))	0.608954	0.279811	2.176307	0.0424
D(ECMDV(-2))	0.502024	0.266149	1.886250	0.0746
C	0.016043	0.042434	0.378075	0.7096
@TREND(1982)	-0.001353	0.002658	-0.509132	0.6165

R-squared	0.373568	Mean dependent var	-0.014712
Adjusted R-squared	0.241687	S.D. dependent var	0.101624
S.E. of regression	0.088495	Akaike info criterion	-1.828686
Sum squared resid	0.148796	Schwarz criterion	-1.583258
Log likelihood	26.94423	F-statistic	2.832624
Durbin-Watson stat	1.867318	Prob(F-statistic)	0.053482

1.2 Unit root test for difference of error term

Null Hypothesis: D(ECMDV) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic based on SIC, MAXLAG=6)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-3.619707	0.0127

Test critical values:	1% level	-3.724070
	5% level	-2.986225
	10% level	-2.632604

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(ECMDV,2)
Method: Least Squares
Sample (adjusted): 1984 2008
Included observations: 25 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(ECMDV(-1))	-0.988020	0.272956	-3.619707	0.0014
C	-0.006087	0.022229	-0.273848	0.7866

R-squared	0.362921	Mean dependent var	-0.011558
Adjusted R-squared	0.335222	S.D. dependent var	0.136004
S.E. of regression	0.110890	Akaike info criterion	-1.483943
Sum squared resid	0.282820	Schwarz criterion	-1.386433
Log likelihood	20.54929	F-statistic	13.10228
Durbin-Watson stat	1.354430	Prob(F-statistic)	0.001439

2. Johansen method :

Sample (adjusted): 1984 2008
Included observations: 25 after adjustments
Trend assumption: Linear deterministic trend
Series: LD LPD LY LVC
Lags interval (in first differences): 1 to 1

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.757909	52.42350	47.85613	0.0175
At most 1	0.344784	16.96249	29.79707	0.6428
At most 2	0.222870	6.392743	15.49471	0.6491
At most 3	0.003555	0.089041	3.841466	0.7654

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.757909	35.46101	27.58434	0.0040
At most 1	0.344784	10.56974	21.13162	0.6900
At most 2	0.222870	6.303702	14.26460	0.5746
At most 3	0.003555	0.089041	3.841466	0.7654

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegrating Coefficients (normalized by b'*S11*b=I):

LD	LPD	LY	LVC
4.915880	2.183015	-14.84991	5.796662
-10.56481	-5.022559	2.995927	6.395321
-4.590617	-3.524790	10.41635	0.192831
18.45758	2.009579	-19.00061	-1.391737

Unrestricted Adjustment Coefficients (alpha):

D(LD)	-0.017038	0.061240	-0.006143	0.001156
D(LPD)	0.039295	-0.017000	0.027588	0.004145
D(LY)	0.001955	0.006060	-0.013346	0.000976
D(LVC)	-0.042042	-0.002183	0.001977	0.001051

1 Cointegrating Equation(s): Log likelihood 150.4588

Normalized cointegrating coefficients (standard error in parentheses)

LD	LPD	LY	LVC
1.000000	0.444074	-3.020804	1.179171
	(0.11469)	(0.36370)	(0.21720)

Adjustment coefficients (standard error in parentheses)

D(LD)	-0.083758
	(0.12102)
D(LPD)	0.193169
	(0.11038)
D(LY)	0.009612
	(0.03865)
D(LVC)	-0.206676
	(0.03395)

2 Cointegrating Equation(s): Log likelihood 155.7437

Normalized cointegrating coefficients (standard error in parentheses)

LD	LPD	LY	LVC
1.000000	0.000000	-41.81777	26.47252
		(8.02517)	(4.69673)
0.000000	1.000000	87.36596	-56.95750
		(17.5210)	(10.2542)

Adjustment coefficients (standard error in parentheses)

D(LD)	-0.730750	-0.344778
	(0.23556)	(0.11071)
D(LPD)	0.372772	0.171166
	(0.25765)	(0.12109)
D(LY)	-0.054411	-0.026168
	(0.09018)	(0.04238)
D(LVC)	-0.183613	-0.080815
	(0.08027)	(0.03773)

3 Cointegrating Equation(s): Log likelihood 158.8955

Normalized cointegrating coefficients (standard error in parentheses)

LD	LPD	LY	LVC
1.000000	0.000000	0.000000	0.320160
			(0.33832)
0.000000	1.000000	0.000000	-2.319807
			(0.67899)
0.000000	0.000000	1.000000	-0.625389
			(0.03302)

Adjustment coefficients (standard error in parentheses)

D(LD)	-0.702548	-0.323123	0.372494
	(0.25257)	(0.13134)	(0.37076)
D(LPD)	0.246125	0.073923	-0.347088
	(0.26534)	(0.13798)	(0.38950)
D(LY)	0.006854	0.020872	-0.149893
	(0.08901)	(0.04629)	(0.13067)
D(LVC)	-0.192688	-0.087783	0.638377
	(0.08609)	(0.04477)	(0.12637)

Appendix B2: Results from Cointegration test for gasoline demand

1. EG Method :

1.1 Unit root test for level of error term

Null Hypothesis: ECMGV has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic based on SIC, MAXLAG=6)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.456228	0.3449
Test critical values:	1% level	-4.356068	
	5% level	-3.595026	
	10% level	-3.233456	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(ECMGV)
Method: Least Squares
Sample (adjusted): 1983 2008
Included observations: 26 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ECMGV(-1)	-0.290395	0.118228	-2.456228	0.0220
C	-0.022289	0.017990	-1.238935	0.2279
@TREND(1982)	0.000944	0.001167	0.808497	0.4271

R-squared	0.218072	Mean dependent var	-0.010660
Adjusted R-squared	0.150078	S.D. dependent var	0.048277
S.E. of regression	0.044507	Akaike info criterion	-3.278156
Sum squared resid	0.045561	Schwarz criterion	-3.132991
Log likelihood	45.61602	F-statistic	3.207240
Durbin-Watson stat	1.296251	Prob(F-statistic)	0.059077

1.2 Unit root test for difference of error term

Null Hypothesis: D(ECMGV) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic based on SIC, MAXLAG=6)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.431158	0.0194
Test critical values:	1% level	-3.724070	
	5% level	-2.986225	

10% level	-2.632604

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(ECMGV,2)
Method: Least Squares
Sample (adjusted): 1984 2008
Included observations: 25 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(ECMGV(-1))	-0.668316	0.194779	-3.431158	0.0023
C	-0.005923	0.009573	-0.618756	0.5422

R-squared	0.338564	Mean dependent var	0.000714
Adjusted R-squared	0.309806	S.D. dependent var	0.056426
S.E. of regression	0.046878	Akaike info criterion	-3.205927
Sum squared resid	0.050543	Schwarz criterion	-3.108417
Log likelihood	42.07409	F-statistic	11.77284
Durbin-Watson stat	1.801393	Prob(F-statistic)	0.002280

2. Johansen Method :

Sample (adjusted): 1984 2008
Included observations: 25 after adjustments
Trend assumption: Linear deterministic trend
Series: LG LPG LY LVP
Lags interval (in first differences): 1 to 1

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.832479	75.54606	47.85613	0.0000
At most 1 *	0.514642	30.87987	29.79707	0.0374
At most 2	0.388728	12.80817	15.49471	0.1220
At most 3	0.019912	0.502835	3.841466	0.4783

Trace test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**

None *	0.832479	44.66619	27.58434	0.0001
At most 1	0.514642	18.07170	21.13162	0.1272
At most 2	0.388728	12.30533	14.26460	0.0997
At most 3	0.019912	0.502835	3.841466	0.4783

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegrating Coefficients (normalized by b'*S11*b=I):

LG	LPG	LY	LVP
-11.52680	-6.577325	4.273319	10.01616
8.767033	2.693978	2.824229	-7.745634
9.047674	3.978688	-17.51217	3.866801
10.43083	-1.240970	-7.669138	-2.959164

Unrestricted Adjustment Coefficients (alpha):

D(LG)	0.014786	-0.018835	-0.017117	-0.001692
D(LPG)	0.032641	0.061794	0.028441	0.000757
D(LY)	0.010370	-0.012706	0.005653	-0.004076
D(LVP)	-0.028229	0.012761	-0.025309	-0.003167

1 Cointegrating Equation(s): Log likelihood 181.8262

Normalized cointegrating coefficients (standard error in parentheses)

LG	LPG	LY	LVP
1.000000	0.570611	-0.370729	-0.868945
	(0.04924)	(0.13214)	(0.09096)

Adjustment coefficients (standard error in parentheses)

D(LG)	-0.170434
	(0.10679)
D(LPG)	-0.376244
	(0.26103)
D(LY)	-0.119531
	(0.09357)
D(LVP)	0.325388
	(0.13557)

2 Cointegrating Equation(s): Log likelihood 190.8620

Normalized cointegrating coefficients (standard error in parentheses)

LG	LPG	LY	LVP
1.000000	0.000000	1.130678	-0.900475
		(0.82949)	(0.55581)
0.000000	1.000000	-2.631225	0.055255

		(1.51393)	(1.01443)	

Adjustment coefficients (standard error in parentheses)

D(LG)	-0.335565	-0.147994	
	(0.11868)	(0.05825)	
D(LPG)	0.165503	-0.048218	
	(0.25574)	(0.12552)	
D(LY)	-0.230920	-0.102434	
	(0.10972)	(0.05385)	
D(LVP)	0.437263	0.220048	
	(0.16497)	(0.08097)	

3 Cointegrating Equation(s): Log likelihood 197.0147

Normalized cointegrating coefficients (standard error in parentheses)

LG	LPG	LY	LVP
1.000000	0.000000	0.000000	-0.128453
			(0.13404)
0.000000	1.000000	0.000000	-1.741333
			(0.25100)
0.000000	0.000000	1.000000	-0.682795
			(0.04586)

Adjustment coefficients (standard error in parentheses)

D(LG)	-0.490434	-0.216097	0.309744
	(0.12283)	(0.05859)	(0.13124)
D(LPG)	0.422830	0.064940	-0.184063
	(0.28021)	(0.13367)	(0.29941)
D(LY)	-0.179774	-0.079943	-0.090565
	(0.12746)	(0.06080)	(0.13620)
D(LVP)	0.208278	0.119352	0.358619
	(0.16736)	(0.07983)	(0.17882)

Appendix C : Research Output (Please see the next page)

UNIVERSITÀ DEGLI STUDI DI PERUGIA
DIPARTIMENTO INGEGNERIA INDUSTRIALE

LETTER OF INVITATION

Perugia, 5 April 2011

I undersigned Umberto Desideri, Professor of Thermal Machines at the University of Perugia and Conference Chair of the Third International Conference on Applied Energy (ICAE2011 - www.icae2011.org), inform that the paper Modeling transport fuel demand for Thailand, by Jaruwan Chontanawat, Lester C Hunt, and Chumnong Sorapipatana has been peer reviewed and accepted for presentation at the above conference.

Since it is required that all papers submitted to the conference are presented by one or more of the authors, it is my pleasure to invite Dr. Jaruwan Chontanawat to attend ICAE2011 and present his paper.

The conference will take place in Perugia, Italy, from 16 to 18 May 2011.

Sincerely,

Umberto Desideri
Conference Chair

DIPARTIMENTO INGEGNERIA INDUSTRIALE
STUDIUM GENERALE CIVITATIS PERUSII
A.D. MCCCVIII

VIA G. DURANTI, 67 - 06125 PERUGIA - Tel. 075.5853701/3702 - Fax 075.5853703

Modeling transport fuel demand for Thailand

Jaruwan Chontanawat[a,*], Lester C Hunt[b] and Chumnong Sorapipatana[c]

[a] Department of Social Sciences and Humanities, School of Liberal Arts, King Mongkut's University of Technology Thonburi, Bangkok, Thailand

[b] *Surrey Energy Economics Centre (SEEC),* Department of Economics, University of Surrey, Guildford, Surrey GU2 7XH, UK

[c] The Joint Graduate School of Energy and Environment (JGSEE), King Mongkut's University of Technology Thonburi, Bangkok, Thailand

***Corresponding Author**
Dr. Jaruwan Chontanawat: Assistant Professor (Energy Economics); Department of Social Sciences and Humanities, School of Liberal Arts, King Mongkut's University of Technology Thonburi, 126 Pracha Uthit Rd., Bangmod, Thungkru, Bangkok 10140, Thailand;
Tel: +00 (662) 4708737; Fax: +00 (662) 4283375;
Email address: Jaruwan.Cho@kmutt.ac.th, J.chontanawat@gmail.com .

1. Abstract

This study aims to model road transportation demand for Thailand. Two main fuels; gasoline and diesel demand functions are estimated for the period 1982-2008. Unlike the studies in previous literature on the subject, this study investigates how different time-series econometric estimation methods perform in terms of modelling these disaggregate fuel demands and estimating the key income and price elasticities and from the results determining what is most useful in formulating energy policies. The results show that the demands are principally dominated by income rather than price and therefore non-pricing policies would tend to be more appropriate in the long term.

Key Words: Oil demand estimation, Transportation, Modeling, Thailand

2. Introduction

Energy use throughout the world in the transportation sector is substantial. In today's society transportation is seen as a basic prerequisite of peoples' lives whether they reside in the developed or developing economies. Currently, more than half of the world's oil is consumed in the transportation sector. Moreover, in non-OECD/developing countries there is still considerable potential for expansion in road transportation. This comes from the high expansion of economic activities, urbanisation which imply an ever increasing freight and passenger transport requirement.

Over the past decades, Thailand has been on the ‘fast track’ of economic development, performing better in terms of growth than the average for the region. Even through the two oil shocks of the 1970s and early 1980s, Thailand economic growth rate was higher than that of developed countries and Thailand had two-digit annual growth rate for the three consecutive years during the 1988-1990.

During the past ten years, energy consumption in Thailand has continuously increased and transportation has been the largest energy consumer – accounting for nearly 40 percent of total energy demand. About 80% of this sector was for road transport and gasoline and diesel are the main fuels used for road transport in Thailand, followed by LPG and NGV.

Energy consumption in the road transportation sector in Thailand has increased significantly over the past decades. Moreover, it’s share of total energy consumption has also increased. There are various factors which determine transportation fuel demand such as income, cost of transport as well as socio-demographic factors and geographic factors. Therefore, it is crucial to understand the source of this growth, the principal drivers behind it and the implications for future indigenous oil consumption. In order to fully understand the growth, and more importantly, to predict future energy consumption and the resultant effect on the environment, it is vital that energy demand is modelled appropriately. It is also important to accurately measure the price and income elasticities of demand. Accurate and reliable energy demand estimations are crucial to a developing country like Thailand where most of the fuel used in transportation comes from oil imports. This will be beneficial to the Government in forming appropriate energy policies.

3. A brief literature review

There are a number of previous studies investigating fuel demand during the last few decades. These studies have generally considered a single country or at most a small group of countries. There have been a range of methodologies employed; partly explained by the development of econometric techniques.

The pioneer work use the conventional methodologies developed by Pindyck [1], Griffin [2], Baltigi and Griffin [3], Dargay [4]**,** Drollas [5], and Wasserfallen and Guntensperger [6]. Sterner and Dahl [7]. They mainly use the basic concept of utilization and efficiency of vehicle stock to derive fuel demand function. The structural form model and reduce form model are developed to estimate fuel demand. The reduce form model is quite popular since it is simple and the model does not require many detail variables but only the main variables such as income, price and the stock of vehicles. The model can explain short-run and long-run elasticities by using dynamic econometric approach.

The latter use cointegration and the Error Correction Model which was originally developed by Engle and Granger [8]. This model take the stationarity property of data into account in estimation fuel demand. The main concept of this approach is that the variables used in the model are generally non-stationary. But the model can adjust toward long-run equilibrium if these non-stationary variables are cointegrated. The significant studies using cointegration and error correction model are Hunt and Manning [9] (England), Hunt and Lynk [10] (England), Bentzen and Engsted [11] (Denmark), Bentzen [12] (Denmark), Eltony and Al-Mutari [13] (Kuwait), Ramanathan [14] (India), Akinboade et.al [15] (South Africa) and Iwayemi et.al. [16] (Nigeria).

In terms of the past empirical work, It can be found that there are a small number of fuel studies for developing countries when compared with the studies for developed countries. The important problem of an energy study in developing countries is the availability and reliability of data. Most diesel/gasoline demand studies in developing countries use a simple log-linear equation to estimate fuel demand. Even though the model does not require substantial amounts of micro data the results are nonetheless robust. The important studies in this area are the works of Dunkerly and Hoch [17], Birol and Guerer [18], McRae [19], Dahl [20], Ishiguro and Akiyama [21], Ghouri [22], Galety and Streifel [23], Dahl and Kurtubi [24], Belhaj [25], Chandrasiri [26], Narayan&Smyth [27], Akinboade et al. [28].

The results from most studies for fuel demand in these developing countries indicate that there are close associations between fuel consumption, fuel price, income and number of vehicles. The results also show that income elasticities are generally greater than one, or close to one, whereas price elasticities are generally less than 1. Short-run elasticities are relatively less than long-run elasticities.

In these studies there are about five studies that include Thailand as their group countries studied. They are the work of Dunkerly and Hoch [17], Birol and Guerer [18], McRae [19], Ishiguro and Akiyama [21], and Galety and Streifel [23]. These studies use conventional log linear to estimate disaggregate transport fuel demand such as gasoline and diesel. Dunkerly and Hoch found that price and income elasticities of gasoline for Thailand are -0.2 and 1.4 respectively. Birol and Guerer found that for the case of Thailand, for gasoline demand, short-run and long-run price elasticities are -0.3 and -0.6 respectively whereas income elasticities in the short-run and long-run are 0.45 and 0.69. For diesel demand, price elasticity is -0.38 whereas the income elasticity is 1.63. McRae studies gasoline demand and found that short-run and long-run price elasticities for Thailand are -0.32 and -0.6, whereas the income elasticities are 0.57 and 1.7 for the short- and long-run respectively. Ishiguro and Akiyama found that in Thailand income and price elasticities of diesel oil are 1.60 and –0.26 while those of gasoline are 0.88 and –0.37 respectively. Galety and Streifel found that for the case of Thailand, price elasticity of Diesel is -0.10 whereas income elasticity is 1.12.

It can be seen that there are very few studies in the literature investigating fuel transport demand for the case of Thailand and most use conventional methods in their estimation. As far as it is known there are no studies focusing on Thailand as a single case study. This study therefore is the first attempt to address this issue and attempts to estimate such demand using both the conventional approach and a new econometric approach using the latest data series for Thailand. The results should be beneficial to the government in terms of energy policy planning.

4. Methodology

The past studies in the literature indicate that there are close relationships between levels of income, transport fuel consumption, fuel price and number of vehicles. This study therefore uses four main variables in the model: fuel demand (Gasoline/diesel), real GDP, fuel price, number of vehicles (commercial cars and passenger cars). Two main models have been constructed in this research, the conventional fuel demand model and the Cointegration and Error-Correction Model.

4.1. The Conventional Fuel Demand Model

4.1.1 The static conventional fuel demand model

The static conventional gasoline demand model and diesel demand model are defined as the single reduced form of log linear function of each fuel demand and explanatory variables such its price, real GDP, stock of vehicles. These can be shown in equations (1) and (2) below :

$$LD = \alpha_0 + \alpha_1 LY + \alpha_2 LPd + \alpha_3 LVc + \varepsilon \qquad (1)$$

$$LG = \alpha_0 + \alpha_1 LY + \alpha_2 LPg + \alpha_3 LVp + \varepsilon \qquad (2)$$

where LD is diesel demand per capita in road transportation, LG is gasoline consumption per capita in road transportation, LY is real income per capita, LPd is real retail diesel price, LPg is real retail gasoline price, LVc is the vehicle stock (number of commercial vehicles) per capita, LVp is the vehicle stock (number of passenger vehicles) per capita.

Income and price are the basic variables in any demand function. According to Dahl and Sterner [29], models that do not include some types of income and price variables are considered miss-specified.

The expected sign of income should be positive while that of price should be negative. This means that when income or GDP grows, the demand for transportation will rise and lead to an increased demand for fuel. On the other hand when the fuel price increases, the demand for transportation may be reduced and lead to a reduction in demand for diesel/gasoline oil. However, the overall demand for transportation may not necessarily decrease if there are other cheaper substitute fuels.

The terms α_1 and α_2 in the equations (1) and (2) are the estimators of short-run income and price elasticities of diesel/gasoline demand. These terms sometimes indicate medium-run elasticities because the model does not have any lagged variables. This model is called a 'simple static' model.

4.1.2 The dynamic fuel demand model

In dynamic model, lag of dependent and independent variables are included in the model which can be written in the equations (3) and (4) shown below:

$$LD_t = \alpha_0 + \alpha_1 LY_t + \alpha_2 LPd_t + \alpha_3 LVc_t + \sum_{i=1}^{4} \gamma_i LD_{t-i} + \mu_t \tag{3}$$

$$LG_t = \alpha_0 + \alpha_1 LY_t + \alpha_2 LPg_t + \alpha_3 LVp_t + \sum_{i=1}^{4} \gamma_i LG_{t-i} + \mu_t \tag{4}$$

where LD_{t-i} in equation (3) are the lagged endogenous variables (diesel demand) and LG_{t-i} in equation (4) are the lagged endogenous variables (gasoline demand).

In the equations (3) and (4), α_1 and α_2 represent short-run income and price elasticities while $\dfrac{\alpha_1}{1-\sum_{i=1}^{4}\gamma_i}$ and $\dfrac{\alpha_2}{1-\sum_{i=1}^{4}\gamma_i}$ represent long-run income and price elasticities.

The rationale behind the assumption of the models is that adaptation takes time. When income or prices change in the current year, the consumer may react by purchasing a smaller or larger commercial vehicle or moving from one area of domestic or business residence to another. This will continue to affect diesel/gasoline consumption for many years into the future. In other words, today's consumption does not only depend on today's income and price structure but also on prior incomes and prices.

The model can also be modified by adding the time trend (T). This permits the capture of vehicle size, reflects technical progress, consumer preference or economic structure. Hunt, Judge and Ninomiya [30] added a time trend in the energy demand model to reflect the state of technology or changes in consumer tastes and economic structure. Bentzen [12] and Ghouri [22] also included a time trend in their vehicle models to capture the effect of increasing fuel efficiency.

The estimation is based on the 'Hendry's general to specific' approach. The model with 4 lags of these variables is first estimated. The insignificant lag variables are then removed from the model. The valid model has to pass all the diagnostic tests and should yield a good prediction test by means of the predictive failure test. The econometric package program EVIEW 5.1 [31] is used for the estimation of the conventional fuel demand models.

4.2 The Cointegration and Error-Correction Model

Generally, time series data is likely to be trended or non-stationary. When dealing with such data there is the high probability of obtaining spurious results. Cointegration and Error Correction Modeling is a time series econometric technique that takes stationary properties into consideration. The main advantage of using this approach are two fold. Firstly, it is easy to distinguish between short and long run effects and secondly, the speed of adjustment towards the long-run equilibrium value can be directly estimated. At this point long run elasticities are capable of being estimated from the cointegrating regression. Finally, short-run elasticities and the speed of adjustment can be estimated from the error-correction model.

It can be concluded that the principal of the model involves three main steps. The first step is to test whether or not the variable in the model contains unit root (implying non-stationary). The second step, if they have unit root, is to test for cointegration between these non-stationary variables. If they are cointegrated, then the long-run elasticities can be estimated from the long-run equation. The final step is to estimate short-run elasticities from the error-correctional model. The detail of each of the steps is shown below.

4.2.1 Unit Root Test for Variables

Initially, all variables in the models: LD and LG (diesel/gasoline consumption per capita), Pd and Pg (real diesel/gasoline price), LY (real income per capita), LVc and LVp (commercial/passenger vehicles per capita) are tested for unit root. These variables are examined using the most common used test: Augmented Dickey-Fuller (ADF) test to check whether they are stationary or non-stationary variables. The test involves estimating a form of the following equation by Ordinary Least Square (OLS) method:

$$\Delta X_t = \alpha_1 + \alpha_2 T + \delta X_{t-1} + \sum_{i=1}^{n} \lambda_i \Delta X_{t-i} + \varepsilon_t \qquad t = 1,\ldots\ldots n \qquad (5)$$

where X_t denotes any variables in the model (LD, LG, Y, LPd, LPg, LVc and LVp) over time. T is time trend. Δ is the different operator. The coefficient of particular interest is δ. The null hypothesis is that X_t is non-stationary or $\delta = 0$ which means that there is a unit root problem against the alternative $\delta < 0$. Under the null hypothesis (variable is non-stationary) the computed t statistic on δx_{t-1} does not follow the standard Student t and F distributions but instead follows the ADF statistics, the critical values of which have also been tabulated. The statistics used for both tests have the same asymptotic distribution.

4.2.2 Test for Cointegration

If the variables in the model are found to be non-stationary with the same order for instance I (1) or integrated at order one, the next step is to examine the cointegration among these variables.

There are many possible tests for cointegration. The most common tests are based on

Engle & Granger [8], Johansen [32], [33] and Johansen & Juselius [34].

EG Method:

The general process starts with regressing the levels of variables in the model and then testing the stationarity of the error term. If the error term is found to be stationary, the variables in the model are cointegrated. This means that there are long-run relationships among them.

Johansen Method:

The EG method has some limitations since it cannot deal with the case where more than one cointegrating relationship is possible. To solve this problem, Johansen's vector auto regression (VAR) test of integration Johansen [32] uses a 'systems' approach to cointegration that allows determination of up to r linearly independent cointegrating vectors (r ≤ g -1), where r is the number of cointegration vectors and g is the number of variables tested for cointegration. Johansen's method treats cointegration vectors as homogeneous across members.

4.2.3 Estimating Long-run equation and Constructing an Error Correction Model

If the variables in the model are found to be cointegrated, the next step is to construct the Error Correction Model to identify the short-run relationship among the variables. Following the Engle and Granger's two step procedure, the first process is to estimate the long run equations from the preferred models.

Suppose the preferred model is that demand is a function of income and price. The estimate equation gives:

$$LD_t^e = \beta_0 + \beta_1 LY_t + \beta_2 LP_t + \varepsilon_t \qquad (6)$$

Where β_1 is long-run income elasticity and β_2 is long-run price elasticity

The error term (ECM) between the actual and estimated value of LD can be derived as follows:

$$ECM_t = LD_t - LD_t^e \tag{7}$$

Then, the Error Correction Model can be expressed in the following form:

$$\Delta LD_t = a_0 + \sum_{i=1}^{n} a_i \Delta LD_{t-i} + \sum_{i=0}^{m} b_i \Delta LY_{t-i} + \sum_{i=0}^{p} c_i \Delta LP_{t-i} + \Phi ECM_{t-1} + \varepsilon_t \tag{8}$$

Where b_0 is the short-run income elasticity, c_0 is short-run price elasticity, and Φ is the speed of adjustment to the equilibrium.

5. Data and Sources

Data used in the analysis is annual time-series data for 1982-2008. Per capita final diesel consumption (LD) and per capita gasoline consumption (LG) are measured in tonnes of oil equivalent (toe). Real GDP per capita (LY) is measured in Thai Baht. Diesel price and gasoline price are measure in baht per litre. Stock of passenger vehicles per capita (LVp) and stock of commercial cars per capita (LVc) are measure in unit per person. Data on fuel consumption was obtained from Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy, Thailand. Data on GDP was obtained from the National Economic and Social Development Board (NESDB), Thailand. Data on fuel prices was obtained from the Energy Policy and Planning Office (EPPO), Ministry of Energy, Thailand. Data on stock of vehicles was collected from the Department of Land Transport (DLT), Ministry of Transport and Communications, Thailand. Data on population was obtained from the Department of Provincial Administration, Ministry of Interior, Thailand. All data was converted into natural logarithms prior to conducting the empirical analysis.

6. Estimation results

The estimated results are divided into two main parts. The first set of results is based on the conventional model and the second set from the Cointegration and Error Correction Model.

6.1 Conventional Fuel Demand Model

According to the 'general to specific' approach for model selection, conventional fuel demand models with the maximum 4 lag specifications are estimated and compared. The highly statistically insignificant variables are excluded from the model. It was found that the dynamic conventional model yielded better results than the static conventional model. The preferable estimated results of diesel and gasoline demand models are shown in equations (9) and (10) respectively.

$$LD_t = -6.40 + 0.569LY_t - 0.229LPd_t + 0.568LD_{t-1} \quad (9)$$

t-stat: (-2.33) (2.39) (-3.10) (3.59) R^2 = 0.95

$$LG_t = -4.060 + 0.353LY_t - 0.149LPg_t + 0.747LG_{t-1} \quad (10)$$

t-stat: (-5.68) (6.14) (-8.11) (16.75) R^2 = 0.99

This model represents the function of each fuel consumption with its own price, income, and 1 year lag of its own consumption. The overall performance of the model is acceptable. R-square yield high value about 0.95-0.99. All the coefficients in both equations have correct signs and are statistically significant at both 5 and 10% levels.

6.2 Cointegration and Error Correction Fuel Demand Model

6.2.1 Unit root test result

The results from the ADF test show that all variables are integrated at order one or I(1) The detail results of the test of the variables are shown in Table 1.

Table 1: Unit root tests of variables

Variable	ADF test	Variable	ADF test
LD	-0.540527	**ΔLD**	-2.389402
LG	-0.796664	**ΔLG**	-4.957154
LPd	-1.070540	**ΔLPd**	-4.102807

LPg	-0.999849	**ΔLPg**	-3.596432
LY	-1.963841	**ΔLY**	-2.744197**
LVc	-0.459155	**ΔLVc**	-9.940049
LVp	-0.589875	**ΔLVp**	-5.978725

*** indicates 5% critical value**

**** indicates 10% critical value**

6.2.2 Cointegration test results

6.2.2.1 Diesel demand

The cointegration test includes all variables in the model such as; LD, LPd, LY, LVc . The results show that these variables are cointegrated. The estimated result of the prefer long-run diesel equation is shown in equation (11) below[1],[2].

$$LD_t = -16.927 + 1.480LY_t - 0.393LPd_t \tag{11}$$

t-stat: (-16.42) (13.23) (-4.44) $R^2 = 0.92$

By applying general to specific approach, the estimated result of the preferred error-correction models are shown in equation (12).

$$\Delta LD_t = 0.013 + 1.193\Delta LY_t + -0.327\Delta LPd_t - 0.471ECM_{t-1} \tag{12}$$

t-stat: (0.41) (2.58) (-1.83) (-2.38) $R^2 = 0.49$

The results from the estimation are acceptable. All coefficients have correct signs and are statistically significant at the 5% level. They all pass the diagnostic tests.[3] The sign of the ECM_{t-1} term is negative as expected which indicates that the residual in the previous period adjusts the model to equilibrium. The speed of adjustment which can be seen from the coefficient of the error-correction term is at 0.47 indicating that for cases which are

[1] The commercial vehicle variable (LVc) is excluded from the model since it is not statistically significant.

[2] The detailed results of the estimation can be supplied by the authors on request.

[3] All estimated coefficient pass all diagnostic tests except normality test.

off the long-run diesel demand curve, diesel consumption can adjust very quickly towards its long-run level with about 50 percent of the adjustment taking place within the first year.

6.2.2.2 Gasoline demand

The cointegration test includes all variables in the model such as LG, LPg, LY, LVp . The results show that these variables are cointegrated. The result of the prefer long-run gasoline equation is shown in equation (13)[4].

$$LG_t = -5.851 + 0.518LY_t - 0.258LPg_t + 0.515LVp_t \qquad (13)$$

t-stat: (-2.30) (2.70) (-4.85) (3.77) $R^2 = 0.96$

By applying general to specific approach, the preferred ECM gasoline model is shown in equation (14).

$$\Delta LG_t = 0.032 + 0.395\Delta LY_t + -0.235\Delta LPg_t - 0.279ECM_{t-1} \qquad (14)$$

t-stat: (2.41) (1.91) (-3.19) (-2.30) $R^2 = 0.60$

The statistical results from the ECM model in general are quite good. All coefficients have correct signs and are significant at 5% level[5]. They pass diagnostic tests. The error-correction term, ECM_{t-1} has negative sign indicating that the error term in the previous period adjusts the model to the equilibrium with the speed of adjustment of 0.28. In other words, gasoline consumption adjusts toward its long-run level with nearly 30% within the first year.

6.3 Price and Income Elasticities

---

4 The detailed results of the estimation can be supplied by the authors on request.

5 Except for the coefficient of income variable which is significant at 10% level.

Table 2 illustrates the price and income elasticities of diesel and gasoline demands from the conventional model whereas Table 3 represents the price and income elasticities of these fuels from the cointegration and error correction model.

Table 2: Elasticities from Conventional fuel demand

Diesel :	Short-run	Long-run
Price elasticity	-0.23	-0.53
Income elasticity	0.57	1.32
Gasoline :	Short-run	Long-run
Price elasticity	-0.14	-0.57
Income elasticity	0.35	1.40

Table 3 Elasticities from Cointegration and error correction model

Diesel:	Short-run	Long-run
Price elasticity	-0.33	-0.39
Income elasticity	1.19	1.48
Gasoline:	Short-run	Long-run
Price elasticity	-0.24	-0.26
Income elasticity	0.40	0.52

The results show that in general, income elasticities are greater than one while price elasticities are less than one. Income elasticities from these models are ranging from 0.35 to 1.48 while price elasticities are ranging from -0.14 to -0.57. Furthermore, the price and income elasticities in the short run are generally lower than those in the long-run.[6] This means that in the short run the consumers are unlikely to respond to the change in price and income. In other words, the consumers can adjust to them better in the long run.

7. Conclusion

The findings from this study reveal that the models perform well and give significant

[6] The results are generally close to the results from the past literature for the case of Thailand.

coefficients and the correct sign. Income elasticities from these models are relatively high at 0.35 to 1.48 while price elasticities are relatively low at -0.14 to -0.57. The results suggest that these fuel demands are driven mainly by changes in income rather than price. Consequently, adopting pricing policies to reduce the demand is unlikely to be effective. Therefore, non pricing policies such as those which emphasise conservation, alternative fuels, improving public transportation and it's associated infrastructure are likely to yield more appropriate long term results.

8. References

[1] Pindyck, R.S. (1979), The structure of World Energy Demand, The MIT Press, Cambridge, MA, USA.
[2] Griffin, JM. (1979), Energy conservation in the OECD: 1989 to 2000, Ballinger publishing, Cambridge, MA.
[3] Baltagi, B.H., Griffin, J.M. (1983), 'Gasoline demand in the OECD: An application of pooling and testing procedures', *European Economic Review*, vol. 22, pp. 117-137.
[4] Dargay, J.M. (1993), 'The demand for fuels for private transport in the UK', In: Hawdon, D. (ed.) Recent studies of the demand for energy in the UK, Surrey Energy Economics Discussion paper, No. 72, Surrey Energy Economics Centre (SEEC), Department of Economics, University of Surrey, Guildford, UK, pp. 25-40.
[5] Drollas, L.P. (1984), 'The demand for gasoline: Further evidence', *Energy Economics*, vol. 16(1), pp. 71-82.
[6] Wasserfallen, W.,Guntensperger, H.(1988), 'Gasoline consumption and the stock of motor vehicles: An empirical analysis for the Swiss economy', *Energy Economics*, vol. 10(4). pp. 276-282
[7] Sterner,T., Dahl, C.A. (1992), 'Modelling transport fuel demand', In: Sterner T(ed.) International Energy Economics, Chapman& Hall, London, UK. pp. 65-79.
[8] Engle, R.F and Granger, C.W.J., (1987), "Cointegration and error correction: representation, estimation and testing", *Econometrica*, Vol. 55, pp. 251-276.
[9] Hunt, L.C.,Manning, N. (1989), 'Energy price- and income- elasticities of demand: Some estimates for the UK using the cointegration procedure', *Scottish Journal of Political Economy*, vol. 36(2), pp. 183-193.
[10] Hunt, L.C., Lynk, E.L. (1992), 'Industrial Energy Demand in the UK: A cointegration approach', Chapter 5 In: Hawdon, D. (ed.) Energy Demand :Evidence and Expectations, Guildford, UK Surrey University Press.
[11] Bentzen, J., Engsted, T.(1993), 'Short- and long-run elasticities in energy demand', *Energy Economics*, vol. 15(2), pp. 9-16.
[12] Bentzen, J. (1994), An empirical analysis of gasoline demand in Denmark using cointegration techniques, *Energy Economics*, vol. 16(2), pp. 139-143.
[13] Eltony, M.N., Al-Mutairi, N.H. (1995), 'Demand for gasoline in Kuwait: An

empirical analysis using cointegration techniques', *Energy Economics*, vol. 17(3), pp. 249-253.

[14] Ramanathan, R. (1999), 'Short-and long-run elasticities of gasoline demand in India: An empirical analysis using cointegration techniques', *Energy Economics*, vol. 21, pp. 321-330.

[15] Akinboade ,O.A., Ziramba, E., Kumo,W.L. (2008), ' The demand for gasoline in South Africa: An empirical analysis using co-integration techniques', *Energy Economics*, vol. 30, pp. 3222–3229.

[16] Iwayemi, A., Adenikinju, A., Babatunde, M.A., (2010) "Estimating petroleum products demand elasticities in Nigeria: A multivariate cointegration approach", *Energy Economics*, Vol.32, pp. 73-85.

[17] Dunkerly, J.,Hoch, I. (1987), 'Energy for transportation in developing countries', *Energy Journal*, vol. 8(3), pp. 57-72.

[18] Birol, F., Guerer, N., (1993), "Modelling the transport sector fuel demand for developing economies", *Energy Policy*, Vol. 21(12), pp. 1163-1172.

[19] MaRae, R., (1994), "Gasoline demand in Developing Asian countries", *Energy Journal* , Vol.15(1), pp. 143-155.

[20] Dahl, C., (1994), "A survey of oil product demand elasticities for developing countries", *OPEC Review*, Vol.18(1), pp. 47-86.

[21] Ishiguro, M., Akiyama, T., (1995), "Energy Demand in Five Major Asian Developing Countries", World Bank Discussion Papers No. 277, World Bank, Washington D.C., USA.

[22] Ghouri, S.S. (1996), "Estimation of petroleum demand and price elasticities: the case of Paskinstan", *OPEC Review*, Vol. 20(3), pp. 235-246.

[23] Gately, D. and Streifel, S.S., (1997), "The demand for oil products in developing countries", World Bank Discussion Paper No. 359. Washington D.C., USA.

[24] Dahl, C., Kurtubi (2001), 'Estimating oil demand in Indonesia using a cointegrating error correction model', OPEC Review, vol. 25(1), pp. 1-21.

[25] Belhaj, M. (2002), 'Vehicle and fuel demand in Morocco', *Energy Policy*, vol. 30, pp. 1163–1171.

[26] Chandrasiri, S., (2006), "Demand for road-fuel in a small developing economy: The case of Sri Lanka", *Energy Policy*, Vol 34, pp. 1833-1840

[27] Narayana, P.K., Smyth, R., (2007), "A panel cointegration analysis of the demand for oil in the Middle East", *Energy Policy*, Vol. 35, pp. 6258–6265.

[28] Akinboade ,O.A., Ziramba, E., Kumo,W.L., (2008), "The demand for gasoline in South Africa: An empirical analysis using co-integration techniques", *Energy Economics*, Vol. 30, pp. 3222–3229.

[29] Dahl, C. and Sterner, T. (1991), 'Analysis gasoline demand elasticities: A survey', *Energy Economics*, vol.13(3), pp 203-210.

[30] Hunt, L.C., Judge, G., Ninomiya, Y., (2000), "Underlying trends and seasonality in UK energy demand: A sectoral analysis", *Discussion Paper, No. 134*, Department of Economics, University of Portsmouth, Portsmouth, UK.

[31] *EVIEWS 5.1*, Econometric Software Package, Quantitative Micro Software, CA, USA., http://www.eviews.com

[32] Johansen, S., (1988), “Statistical analysis of cointegration vectors”, *Journal of Economics Dynamics and Control*, Vol.12, pp. 231-254.
[33] Johansen, S., (1991), “Estimating and hypothesis testing of cointegration vectors in Guaussian vector autoregressive models”, *Econometrica*, Vol. 59, pp. 1551-1580.
[34] Johansen, S., Juselius, K., (1990), “Maximum likelihood estimation and inference on cointegration with applications to the demand for money”, *Oxford Bulletin of Economics and Statistics*, Vol. 52, pp.169-210.

9. Acknowledgements

This study has been conducted within the framework of the Collaborative Projects between King Mongkut’s University of Technology Thonburi, Thailand and Thailand Research Fund that receives funding from the Thailand Research Fund and the Office of the Higher Education Commission, Thailand. This paper reflects my views only, and I am responsible for all errors or omissions.