Price Volatility and Demand for Oil:
A Comparative Analysis of Developed and Developing Countries

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Abstract

During the past three decades the global oil market has seen significant price volatility. The literature has not sufficiently analysed the cross-country effect of the recent episode of price instability. Previous studies have either not considered this period or have not utilised panel data techniques and therefore have not provided a comparative analysis of developed and developing countries. This paper explores the income and price elasticities between these two country groups and the implication of the results. We use a panel data analysis accounting for income and price asymmetry with dynamic fixed-effects methodology to separate panels for developed and developing countries for the period 1980-2012. Sixteen countries are included in this analysis which account for over 65% of total global oil consumption. Particular focus is on the income and substitution effects. The results indicate heterogeneous response to oil price shocks. Developing countries have an income effect 6.3 times stronger than developed countries. The substitution effect in developed countries is 2.1 times stronger than in developing countries. Policy recommendations include the pursuing of oil-efficiency improving technology, and ensuring that regional consumption pattern variations are considered in policy formation.

Key words: Oil price, oil demand, income effect, price effect

JEL classification: Q37, Q41, Q43

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1. Introduction

Global energy consumption is valued at around $3.65 trillion annually, making up approximately 5 percent of global GDP (BP, 2014; World Bank, 2014). More than one-third of world energy use is from oil, more than any other fuel (Rubin, 2012). Especially, oil as a transit fuel is of paramount importance for the economies worldwide. The volatility of global oil prices is, therefore, widely viewed as a source of concern for the world economy. At the same time, we have witnessed rapid economic growth in emerging economies and the rising living standards in these countries has seen a strong increase in oil usage. The developing countries are climbing the 'energy ladder' and moving to industrial enterprise.

The price of oil is important for most economic activities. Rubin (2012, p. 33) states an oil shock can "deep-six" an economy, as other consumption suffers as the effect of high oil prices is transmitted to the wider economy. Historical oil price shocks were caused primarily by supply disruptions and are strongly correlated with major geopolitical disturbances (Hamilton, 2003). Baumeister and Kilian (2016) give a recent review of previous oil price shocks. In the 2007-2008 price increase, no major war or instability is attributed to the shock. In fact supply remained constant (BP, 2014). The main cause suggested was a shock to demand. Hamilton (2009) postulated the cause as a classic shortage situation. The increased global demand required significant supply increases to sustain the pre-shock price level. This was not experienced and the primary issue was scarcity due to a demand shock.

The distribution of oil consumption is also changing. Demand in China is expected to surpass the US in 2029 and non-OECD Asian demand is expected to grow by six million-barrels per day through to 2030 (BP, 2013). In contrast, in OECD countries, demand fell between 2006-08 with the price increases suspected to have played a role (Wurzel *et al.*, 2009). Yet the disparate consumption pattern between developing and developed countries is only scarcely analysed. A hypothesis is that the elasticities of income and price vary between developed and developing countries. Consideration of elasticities is taken by previous papers e.g. Gately and Huntington (2002); Hamilton (1983).

This paper analyses the oil consumption effects of developed and developing countries during the period of an oil price shock. We use two cross-country panels which enable the comparison of consumption patterns between the two country groups (Appendix 1). We also use decomposition of the price and income series to account for asymmetric effect of these on consumption. In developing countries demand is expected to be fuelled by economic expansion (income effect), whereas, in developed economies, the substitution effect plays a larger role. Price elasticity of demand for oil should vary between the two panels. The period of analysis is 1980-2012, which provides a wide coverage of oil price instability and considers a more up to date panel than has previously been published.

The paper is structured as follows: Section 2 reviews the literature on the oil market and the development in estimation techniques. Section 3 considers the driving forces of an oil price shock and analyses their significance in the 2007-08 price shock. Section 4 sets out the methodology which underpins the analysis undertaken. Section 5 presents and interprets the results and establishes policy implications. Section 6 is conclusions.

2. Previous Studies of Oil Price and Consumption

The literature surrounding the economics of the oil market has evolved considerably since the 1970's. Studies initially sought to establish how oil consumption and other macroeconomic indicators were interrelated. Since the late 1980's, the use of asymmetric decomposition has been applied however there is varied support for its relevance. Newer studies have focused more on the developing economies and their growing energy demands. For example, Ratti and Vespignani (2015; 2013) found that increased liquidity in developing countries such as China and India had a large effect on real oil price increases.

A cross-country panel data analysis can aid understanding of global consumption patterns. However, due to the proximity of the recent oil shock there is a scarcity of literature investigating its economic impact.

Hamilton (1983) in his seminal work discussed the relationship with oil consumption and the wider economy. The paper highlights that all US recessions are preceded by an oil shock, where typically an increase in oil prices is followed 3-4 quarters later with a shock to domestic output. The study illustrated one of the first explicit relationships between oil and the lagged transmission to the economy and used causality testing to establish that the oil price was a key factor in the signalling of recession. Numerous studies following Hamilton (1983) have found a relationship between oil consumption and variables such as income, inflation, and exchange rates. Burbidge and Harrison (1984) find that during the period 1962-1981 in Canada, Japan, West Germany, USA and UK a shock of one-deviation to oil price leads to a rise in wages and inflation. They also found a significant decline in industrial production (a proxy for growth) following the shock in the US and UK though the effect is less significant in other countries.

Despite these findings the macroeconomic relationship has been questioned. Mork (1989) noted that in the period investigated in Hamilton's study all price movements were positive and questioned if the relationship would hold in periods of price decline. Through specifying separate variables for price increases and decreases, Mork mirrors the results of Hamilton (1983) during price increases. However, for price declines the result is statistically insignificant. Consequently, only positive price changes appear to transmit to the US economy. One must consider if such results would also hold for developing economies.

The asymmetry of oil prices was investigated using a Koyck (1954) lag-demand function with an additional price and/or income decomposition term in Gately and Huntington (2002). Results for OECD countries echo the findings of Mork (1989) - that price increases have greater effect on demand for oil than price decreases. Therefore failure to account for price asymmetry may bias estimations of demand. OECD countries experience an income response, which is "dramatically different from its effect in the developing countries" (Gately and Huntington, 2002, p. 16).

Indeed, the *global* effect may be negligible but that is a net effect. Comparison of developing versus developed economies yields different results. Rubin (2012) considers in the present scenario where oil demand is outstripping supply to be a 'zero-sum' situation. The analysis shows that emerging economies are price insensitive to oil in comparison to the industrialised economies. In part this is attributable to China and India experiencing large increases in income. This is due to what he describes as a "transformational development in the way life is lived" (Rubin, 2012, p. 142). It is argued that as the living standards change the income elasticity will be nearing unity.

There is a gap in the literature on economic impact of oil price shocks in developing countries. Tang *et al.* (2010) consider the Chinese economy, and observed that a rise in oil price leads to an increase in inflation and interest, but a negative effect on output and investment. The authors highlight the price controls and that they prevent the market from operating. Nonetheless, China reacts to price shocks, however this is significantly dampened as a result of price controls. They show that price elasticity of demand for energy is very low in the short-term, but in the longer term the consumption of energy is more sensitive to higher prices.

A number of studies have calculated demand elasticities. Cooper (2003) estimates the price elasticity of demand for 23 countries in the period 1971-2000 and established the demand for oil to be price-inelastic in the short term and ranging from -0.016 (Finland) to -0.109 (Iceland). In the long run countries experience greater responsiveness to price. Cooper does not consider asymmetric decomposition. Dargay (1992) looked at the UK elasticities in the period 1960-1990. Price elasticities were found to react significantly to the 1979-81 oil price rise, with a short-run elasticity of -0.5 deviating from a mean elasticity of -0.1. Nonetheless, the period saw great increases in energy efficiency. The study notes there would need to be a large price rise to incite such changes in energy demand. One could consider if this has been the case in the recent price shock.

A study by the IMF demonstrated the economic transmission of an unexpected $5 increase in oil prices using the global economic model MULTIMOD to establish the effects. It showed that the price shock would cause a 0.3 per cent decline in global output in the two years after the event and the effect would be 0.4 per cent in the developed economies of the USA and European Union (IMF, 2001). This indicates a difference in developed economies response which could be attributed to greater reliance on energy intensive technology and a slower rate of adjustment.

According to Fisher-Vanden *et al.* (2004) China has experienced energy efficiency gains since its economic liberalisation in the 1970's. The scope for efficiency gains is present in a developing nation, as manufacturing processes have not yet reached maturity. They report a gain of 30 per cent in efficiency of oil products, and to an extent attribute this to rising energy costs. Hang and Tu (2007) validate the results through elasticities, noting pre-1995 oil price elasticity was -0.544 and post-1995 at -0.059; confirming the declining ability to adjust for prices as the ability for further energy efficiency gains approaches a minima. The makeup of the Chinese economy as a newly industrialising nation could have caused a disparity from industrialised economies and consequently may react uniquely to an oil price shock.

Hamilton (2009) considers the recent oil price shock in the United States through a comprehensive theoretical and empirical analysis of the recent price shock. It argued that demand was the main driving factor in the recent episode, yet this was multiplied due to speculative activity. It is estimated that the increase in oil prices caused real US GDP growth to be 0.7 per cent lower than expected during 2007Q4 - 2008Q3. A main cause of price rise is attributed to increased demand from developing countries, yet Hamilton does not analyse these nations.

Aastveit *et al.* (2012) examines the effect of the price shock on a global scale. They find that different geographical regions have varying responses to oil shocks, with the developed economies suffering greater negative shocks. They report that European and US economic activity is permanently reduced by an oil shock but in emerging economies activity falls to a lesser degree and in some cases a temporary increase in activity is experienced following a supply shock. However, the approach used is time-series and not a cross-country pooled approach, hence a shortcoming in the literature exists.

3. Determination of Oil Price

Oil prices during the period of study have seen great volatility, entering into what could be regarded as the third epoch of crude oil pricing (Dvir and Rogoff, 2010). Figure 1 illustrates the structural breaks in oil pricing since 1861. Epoch I is characterised by price instability as the new discovery of oil is commercialised and unsteady supply is prevalent. Epoch II is the era of 'cheap' energy, steady prices, and the formalisation of the oil market resulted in more stable prices. In Epoch III, the market experienced high levels of volatility. There is a significant peak in 1986 following a reversal of the oil industry shock at the turn of the 1980's. The introduction of formula netback pricing in 1986 linked the production sale price to a crude oil benchmark price (Downey, 2009) and could be seen to have remedied the issue of mispricing. The 1980 price shock was followed by a return to stability, but this was soon upturned by the price shock in the 2000's.

The 2007-2008 price shock is of particular interest to this study. The real price of oil in 2008 was the highest since 1864. There are different explanations of this rapid surge in prices; the main theories are focused around disequilibrium in supply and demand (Cantore *et al.*, 2012). Emerging economies are increasing their demand for oil; while advanced industrialised economies are reducing consumption (Rubin, 2012). Nonetheless, global oil consumption is increasing year-on-year (BP, 2013). The 2007-2008 shock is primarily characterised by a rapid increase in demand as opposed to a supply shock. This is in stark contrast to previous oil shocks (Hamilton, 2009). The remainder of this chapter we follow the framework of Cantore *et al.* (2012) to examine the key factors in the 2008 price shock.

The global supply of oil is deemed not to be a limiting factor in meeting projected demand till 2035 (IEA, 2012). According to the *BP Statistical Review of World Energy* in the past decade global proved reserves have increased by 26 per cent; and the R/P ratio[1] has increased to 52.9 years from 48.3 years (BP, 2014). The global proven reserves has arisen in 70 percent of cases from revisions to estimations of already discovered fields. As technology improves a high recoverable rate is achievable (IEA, 2012). New fields are no longer solely conventional oil. Technological advances and higher energy prices have led to extraction of tar sands, tight oil, and deep-water drilling operations (Rubin, 2012) and offshore oil in the Artic has been described as the "final frontier" (IEA, 2012, p. 110).

[1] R/P ratio is the "reserves-to-production" ratio and represents the length of time production could continue based on the current reserves and production rate.

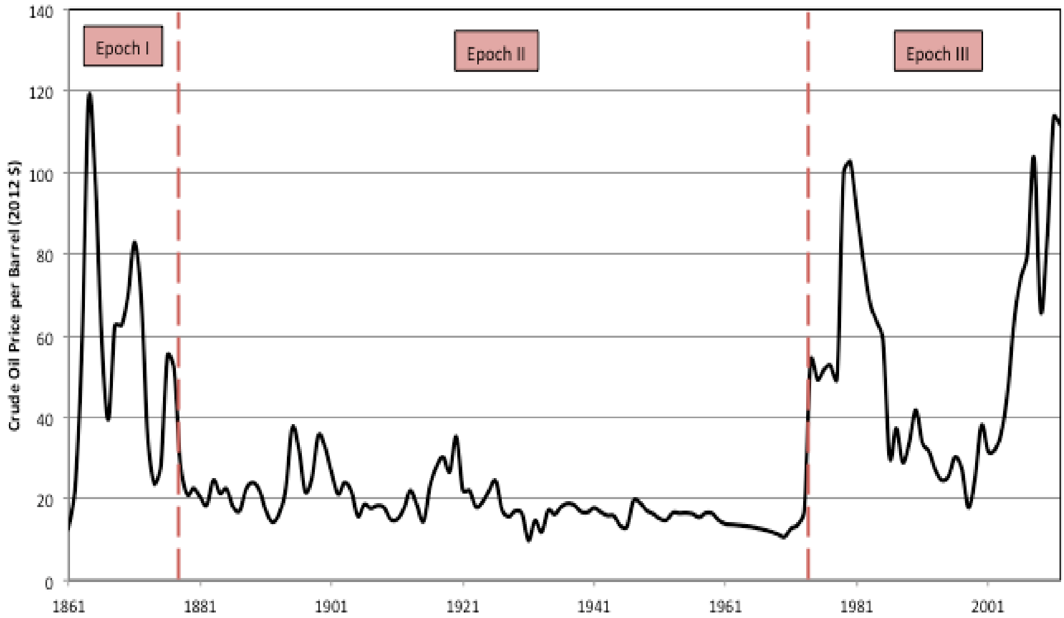

Figure 1: Historical Prices 1861-2012 separated into three epochs.

Data Source: BP (2014)

As previously conjectured, the 2007-2008 oil shock was the result of disequilibrium in the market fundamentals and not due to a supply shock as in previous price shocks (Hamilton, 2009). Consideration of output levels by OPEC and non-OPEC countries highlights a stalling of production during the period 2004-2008 in comparison to the forecast. Kaufmann (2011) hypothesises that the halt to production in non-OPEC countries caused a reduction in OPEC spare capacity. Production hiatus from non-OPEC producers was unexpected as Kaufmann (2011) reports the US Energy Information Administration expected that non-OPEC supply would increase by approximately 9 million barrels daily (EIA, 2005). A slowdown in supply would lead to a shortage and a rise in prices.

During the oil price shock some global events influenced the supply of oil causing negative supply shocks. Table 1 outlines the main global events. However, the principal trend has not been one of supply reduction but rather has been a failure to increase production levels (Hamilton, 2009). Saudi Arabia has an influential position as the world's largest crude oil reserves (BP, 2014). The Kingdom maintains crude reserves which have compensated the global supply in times of supply interruptions (Huntington *et al.*, 2012). Yet, the Saudi production was 850,000 barrels a day lower in 2007 than in 2005 (Hamilton, 2009).

Since the 1980's global oil consumption has increased at a staggering rate. There has been a doubling in oil demand from non-OECD countries since 1980, representing an additional 24 million barrels of oil a day (BP, 2014). Figure 2 shows the compounding growth of non-OECD demand. Petrie (2011) estimate an additional 1.4 million barrels per day on average will be demanded until 2015. However, in recent years, the OECD countries are seen to be reducing oil demand. This is especially evident between 2005 and 2009 indicating potential differences in elasticity of demand between the two country groups.

Table 1: Geopolitical disturbances and their impact on supply

Source: Hamilton (2009, 2011) and BP (2014)

Date	Event	Impact on Supply
2001-onwards	War on Terror	Iraq war cut 2.2 MBD during April-July 2003
2003	Venezuela Unrest	General strike cut supply for two months by 2.1 MBD on previous year
2005	Gulf of Mexico Hurricanes	Reduction of 0.064 MBD on previous year Damage to offshore oil platforms
2006-08	Nigerian Conflict	Cut of 0.5 MBD during turmoil

Decomposition of the recent oil price shock reinforces the importance of demand from developing countries. It is estimated that the emerging markets added 55 dollars in real terms to the peak price of oil in 2008 (Aastveit *et al.*, 2012). Without reduced demand from developed countries the price would have risen even higher. Countries have heterogeneous tolerance to oil prices and are able to tolerate oil price rises to a certain point, beyond which they will adjust consumption patterns. Table 2 shows the estimates of this price. Despite the reliance on oil in the short term as experienced in developing countries, the EMEA (Europe, Middle East, and Africa) tolerate the highest prices. Therefore, the reductions in demand from developed countries over the price shock could be due to factors such as energy efficiency or substitution to other forms of energy.

Economic growth is assumed to have a linear relationship with per capita oil demand *ceteris paribus* (Huntington *et al.*, 2012). Galli (1998) observes a correlation between energy use and economic growth in non-OECD countries, but the converse is observed in OECD countries. However, recent studies have estimated that the linear relationship for developing countries still holds. This is explained by increasing energy intensity during economic development (Benthem and Romani, 2009). The 2007-2008 price shock is often regarded to be result of a demand shock. Indeed, development in non-OECD countries has been extensive and is expected to have contributed to increased oil consumption. Yet, one must consider if different countries have different experiences to the recent price shock. According to Kilian and Hicks (2009), unexpected growth in demand would have been a major contributing factor in explaining the recent price shock.

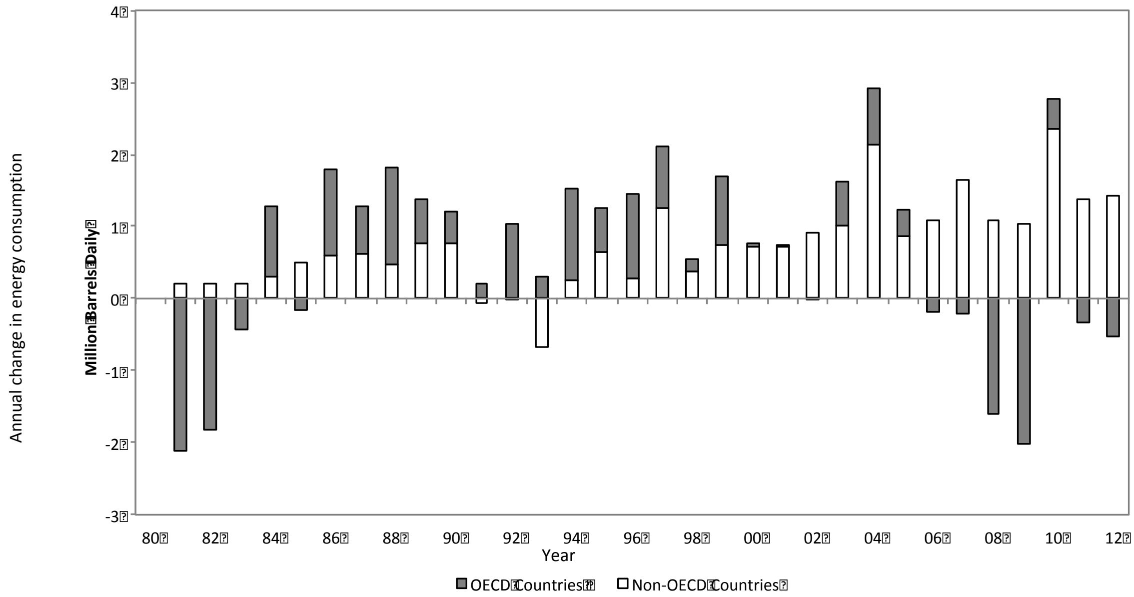

Figure 2: Annual change in oil consumption OECD vs. non-OECD countries.

Data Source: BP (2014)

Table 2: Peak tolerable oil price.

Source: Petrie (2011)

Location	Peak Price (Barrel USD)
US	145
Eurozone	120-130
Emerging Asia	120-130
Latin America	130-140
EMEA	150+

4. Methodology

4.1 Methodological Advancements

Energy consumption models came to the forefront following the oil crisis of the 1970's. A key study by Pindyck (1979) analysed global energy demand and estimated demand models for different oil products. Pindyck recognises the issue of data availability and reliability in developing countries. Consequently a simple log-linear model for price and income incorporating a lag term to account for the dynamic adjustment is employed. The use of a lagged term overcomes the potential model breakdown in periods of unstable energy prices (Westoby and Pearce, 1984). The model postulated by Pindyck (1979) has been used in many estimations of income and price elasticity of oil (e.g., Dargary, 1992; Gately and

Huntington, 2002; Cooper, 2003). Pindyck found that developing countries have high income-elasticity but low price-elasticity, thus economic growth fuels demand for energy and predicts that higher prices would impede growth prospects. This early paper recognises that energy usage is strongly correlated to the economic growth rate.

The development of econometric analysis enabled the application of pooled models and provided a better understanding of demand patterns as the use of a pooled data model can substantially increase the efficiency of an econometric model. Adelman (1984, p. 5) suggests that the global oil market is "one great pool." Baltagi and Griffin (1997) pooled data for gasoline demand for 18 OECD countries and establish that pooling data sets increases the model efficiency especially over a longer period. However, as their data is across a set of comparable countries, OECD nations, one must consider if the pooled data model would work across a more global data set.

Fawcett and Price (2012) use a global pooled model with a more heterogeneous group of countries during the period 1984-2009 to provide a robust estimation. In order to establish the differences in groups of countries, they run cross-country panel data models for G7, remaining OECD, developing Asia and Latin America. Estimation of different panels can reduce the cross sectional heterogeneity which arise from pooling dissimilar economies following Pesaran *et al.* (1995). This study does not undertake asymmetry decomposition and therefore the effect of the shock is not established.

Despite the amass of research to date, there has been little research which considers specifically what effect the 2007-08 oil shock had on countries with varied levels of development. Research that encompasses the period of the price shock is limited and only considers a time-series model, for example, Aastveit *et al.* (2012). The literature has not yet considered an asymmetric decomposition during the recent period of unstable pricing.

4.2 Conceptual Model

Considering previous research the most efficient modelling technique is to follow the conceptual ideas of Gately and Huntington (2002), van Benthem and Romani (2009), and Fawcett and Price (2012). Not only does the small number of variables increase the likelihood of data availability in developing countries, it also allows the results of study to be compared to previous research. Therefore, it is assumed oil demand can be represented as:

$$D_{i,t} = f\left(Y_{i,t}, P_t, \theta_i\right) + \varepsilon_{i,t} \qquad (1)$$

Table 3 highlights the variables to be used and provides a summary of the symbols which will be employed in this paper. The dependent variable of per-capita oil demand is employed to account for the natural requirement of energy due to the size of the population. As noted previously, population growth is one of the key drivers of oil demand (Petrie, 2011). Consequently, a considerable number of studies model per-capita oil demand (Pindyck, 1979; Cooper, 2003; Fawcett and Price, 2012). Modelling demand as the dependent variable in logarithmic form provides elasticities of demand.

Table 3: Variables and symbols used

Variable	Symbol	Description	Data Source
Demand	$D_{i,t}$	Natural logarithm of per-capita oil demand, in country i in year t	BP (2014)
Income	$Y_{i,t}$	Natural logarithm of GDP per-capita (current US$), in country i in year t	World Bank (2014)
Price	P_t	Natural logarithm of the real price of a barrel of oil	BP (2014)
Country	θ_i	Country fixed effect variable	N/A
Random Error	$\varepsilon_{i,t}$	Random stochastic error term	N/A

We consider the effect of oil demand during a period of price shock. Accordingly, a measure of oil price is included in the models. This study uses for 1980-1983 Arabian Light prices and from 1984-2012 Brent spot prices are employed. The panel assumes the price of oil to be exogenous to each country. Therefore no individual country 'pump' oil prices are considered which helps avoid the problem of endogeneity. Fawcett and Price (2012) utilise this assumption to combat the downward biased price elasticities as suggested by Kilian and Murphy (2010). Oil prices are expected to have a negative relationship with demand, consistent with demand theory.

The income variable is measured as the gross domestic product (GDP) per capita and provides a cross-country comparison of relative wealth. Data is obtained from the World Bank and the variable is calculated as current US dollar prices to account for inflationary differences. In a review of oil price elasticity studies, it is found most major studies have employed an income term using GDP or GNP per capita (Hoffman, 2012).

4.3 Model Specification

As specification can significantly adjust the parameters obtained (Dahl, 1993), a number of forms will be estimated.

4.3.1 Static and Dynamic Linear Models

A panel data model approach based on the work of Gately and Huntington (2002) is employed in this study. Initially, the relationship is to be estimated as:

$$D_{i,t} = \alpha_0 + \alpha_1 Y_{i,t} + \alpha_2 P_t + \theta_i + \varepsilon_{i,t} \qquad (2)$$

The simple nature of this specification enables the elasticities of income and price to be estimated with ease as:

$$\epsilon_Y = \alpha_1 \text{ and } \epsilon_P = \alpha_2 \tag{3}$$

Income elasticity estimates the responsiveness of oil demand to economic growth rate. Price elasticity is expected to be negative. As the price of the commodity rises, demand theory suggests consumption will fall. Developed countries are more likely to be sensitive to prices than developing countries as they are more mature in their energy profile.

The addition of a lagged dependent variable for one period allows for estimation of long-term price elasticity as it considers the speed of adjustment to price and income changes. The addition of a lagged term gives a dynamic model that can "provide robust forecasts" (Bhattacharyya and Timilsina, 2009, p. 44). Dynamic models can account for psychological, technological and institutional factors. The oil market is subject to effects of the same factors. Psychological effects occur due to inertia in demand. Technology needs time to adapt to price changes due to the widespread use of oil. Institutional obligations in the form of futures contracts influence future demand. Short-run elasticities will therefore be lower than the long-run counterparts. The addition of a Koyck-lag to the demand term as a lagged dependent variable specifies the elasticities to represent the short term (Koyck, 1954). The dynamic model is:

$$D_{i,t} = \alpha_0 + \ \alpha_1 Y_{i,t} + \alpha_2 P_t + \gamma D_{i,t-1} + \theta_i + \varepsilon_{i,t} \tag{4}$$

The addition of the lag to equation (2) enables more flexibility as it accounts for adjustments occurring overtime. The lagged term does however assume that the adjustment speed for both price and income is equal. In order to estimate the long run elasticity for equation (4), we divide the short-term elasticities by $1 - \gamma$ (van Benthem and Romani, 2009).

4.3.2 Asymmetric Decomposition

Some studies highlight the need to consider asymmetric response or imperfect price-reversibility (Mork, 1989; Hogan, 1993; Gately, 1993). A pooled model for the OECD oil demand rejected the use of a symmetric model over the period 1966-1990 (Hogan, 1993). Hogan notes that during the sharp drop in prices in 1986, one could expect a much larger demand increase than experienced. We expect a similar result following the 2008 price fall. Gately and Huntington (2002) illustrate the expected results for demand response for both symmetric and asymmetric reactions. Using real price of oil versus oil demand per capita over the period 2004-2012, the diagrams in Figure 4 resemble the stylised functions illustrated in Gately and Huntington (2002) and show the evidence to proceed with the asymmetric decomposition.

Decomposition of price into three monotonic series follows a method used in agricultural commodity analysis in Gately (1993) noting that prior to this approach, structural breaks were used which have less explanatory power. Asymmetric price effects also control for instances of technological improvement and acts as proxy for energy saving technological change (van Benthem and Romani, 2009). We use a similar decomposition as in Gately (1993). We expect to find greater response to prices rises than to price decreases. Gately and Huntington (2002) undertake a decomposition of income to consider asymmetry to income changes. This is of interest in this paper due to the occurrence of the global financial crisis during the period of study.

In order to estimate asymmetries a decomposition of the price and income is undertaken. In order to present the concept of variable decomposition the term X will be used. In our study X can represent either price (P) or income (Y). The technique can be applied to any time series independent variable. We decompose in logarithmic form: the cumulative sum of increases in the maximum value, the cumulative sum of decreases (cuts) in the variable and the cumulative sum of sub-maximum increases (recoveries) in the variable. In order to establish the decomposition, the annual change in the variable is calculated. The base year is a given and is indicated as X_1 which in this study is 1980.

The variables in the decomposition are defined as:

$X_{max,\ t}$ = cumulative series maximum rises in the logarithmic value of the variable; monotonically increasing: $\Delta X_{max,t} \geq 0$

$X_{cut,\ t}$ = cumulative falls in the logarithmic value of the variable; monotonically decreasing: $\Delta X_{cut,t} \leq 0$

$X_{rec,\ t}$ = cumulative sub maximum rises in the logarithmic value of the variable; monotonically increasing: $\Delta X_{rec,t} \geq 0$

Therefore, a variable e.g. P or Y, can be presented in the form:

$$X_t = X_1 + X_{max,t} + X_{cut,t} + X_{rec,t} \qquad (5)$$

Illustration of the decomposition clearly indicates the effect it has on the series. Over the time period of study (1980-2012), the decomposition of price is depicted in Figure 5. Equally, income decomposition can be illustrated as in Figure 6 for the UK.

Therefore, equation (4) can be now expressed to account for asymmetric prices and income. The base asymmetric specification is presented as:

$$D_{i,t} = \alpha_0 + \alpha_1 Y_{max,i,t} + \beta_1 Y_{cut,i,t} + \beta_2 Y_{rec,i,t} + \alpha_3 P_{max,t} + \beta_3 P_{cut,t} + \beta_4 P_{rec,t} + +\gamma D_{i,t-1} + \theta_i + \varepsilon_{i,t} \qquad (6)$$

The model will account for period of declines in price and income, which may not produce significant changes because of the nature of technological development (Hogan, 1993). Elasticities for Model (6) will be estimated using the parameter on $Y_{max,i,t}$ and $P_{max,i,t}$, as in Gately and Huntington (2002).

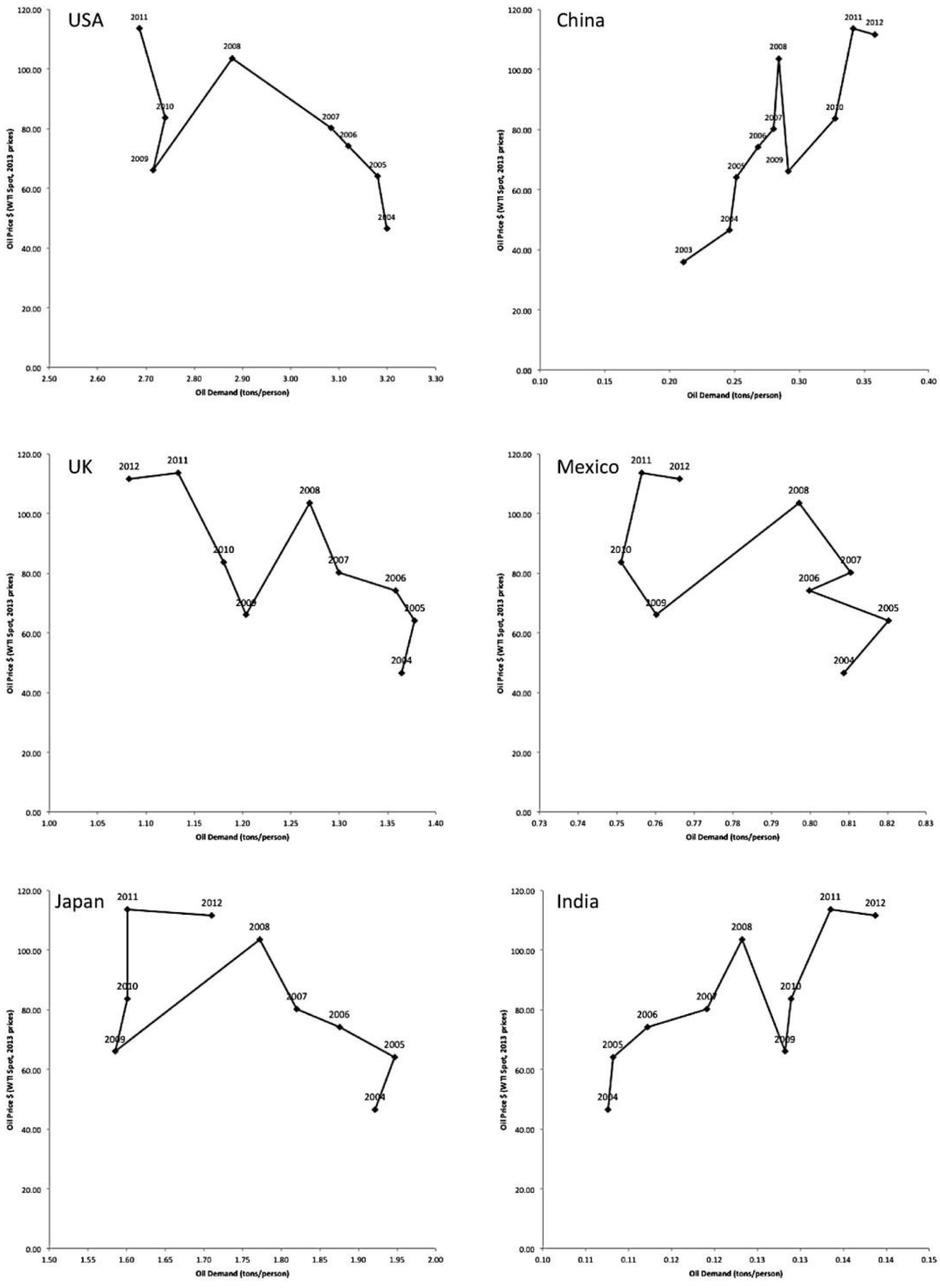

Figure 4: Price response functions (oil price versus demand).

Source: Author panel data

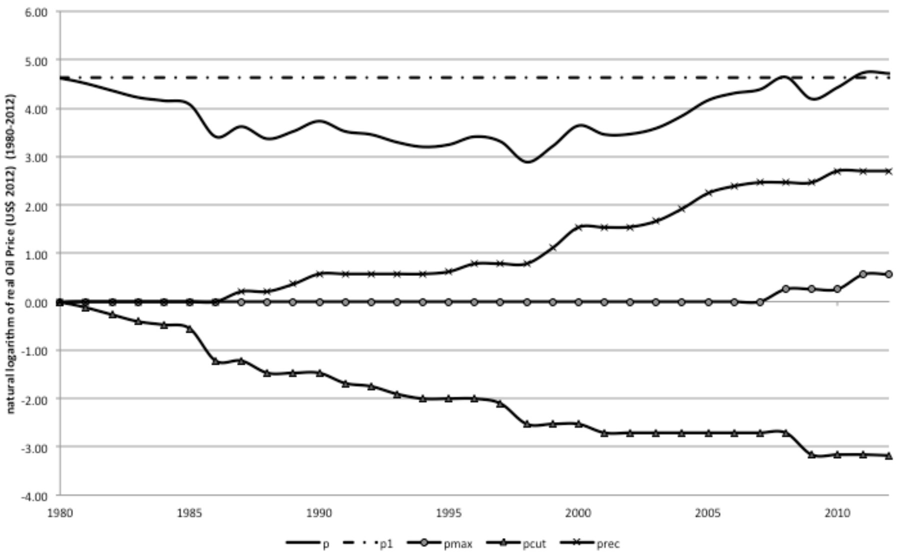

Figure 5: Decomposition of oil price in the period 1980-2012

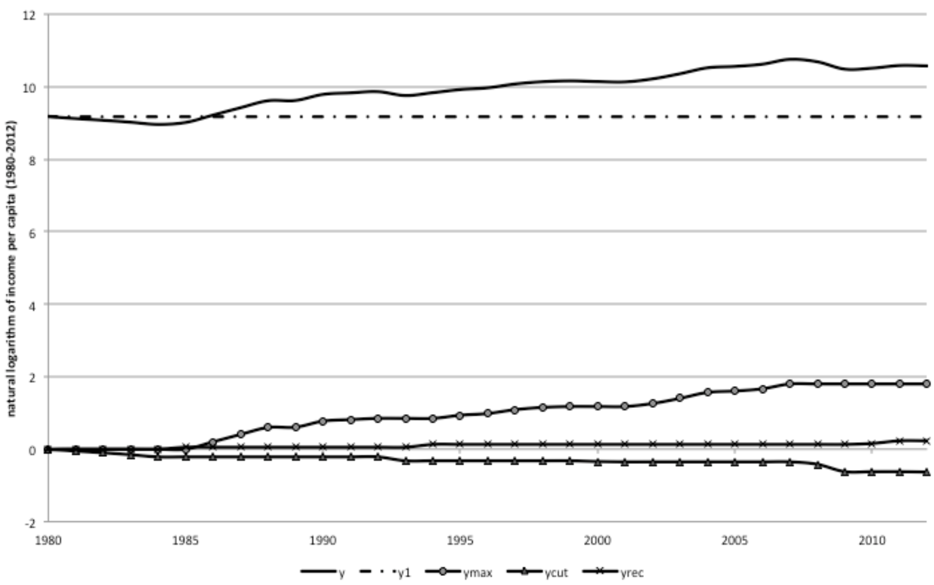

Figure 6: Decomposition of UK income in the period 1980-2012

4.4 Estimation Technique

Following Gately and Huntington (2002) we analyse multiple specifications of the model to compare the elasticities obtained. In order to establish difference between developed and developing nations a separate panel will be estimated for each group of countries. The definition of developing and developed countries for the purpose of this paper is as defined in Appendix 1, the decision for classification is based upon the average GDP per capita in that country over the period of the study. The use of two separate panels not only improves the efficiency of estimation over separate time series regressions, but also helps to correct mis-specification caused by cross-sectional heterogeneity (Fawcett and Price, 2012).

We use Ordinary Least Squares (OLS) method to estimate our models. Hamilton (2003) suggests that OLS provides high quality estimation for oil demand models. In addition, cross-country fixed effects will be used. This estimates a different intercept variable (constant) for each country and is used to regulate static differences in countries (van Benthem and Romani, 2009). The intercept in a fixed effects model (FEM) is assumed to be time invariant, and consequently the slope coefficients do not change over time (Gujarati, 2003). One may consider each country to have a heterogeneous starting demand. This would theoretically fit with the FEM. The suitability of this approach is tested using the Redundant Fixed Effects – Likelihood Ratio.

Initially, we estimate symmetric static models and then a dynamic element will be introduced through the introduction of a lagged term. If this is statistically significant it will provide further insight into the responsiveness of oil demand. The use of asymmetric decomposition for both price and income will be considered. The suitability of the approach will be tested using a Wald test. The preferred model for each panel will be established after consideration of the economic merit and statistical significance.

A dynamic panel model with fixed effects can cause bias in the results (Webb, 2006). Individual (country) FE is suggested to give unreliable estimates as the number FE estimators tend to infinity when time period is fixed (Nickell, 1981). The FE yields significant importance in this analysis as it controls for bias from omitted variables (Wooldridge, 2010). Even through the separation of country groups there still exists heterogeneity between the groups. Estimations without FE produce elasticities that are unrealistically large. However, with a sufficiently long panel in time dimension, e.g. when T=30, average bias is reduced drastically, although the model is not the most efficient estimation (Judson and Owen, 1999). Consequently, FE is suggested to be the most suitable approach for estimation.

An alternative panel data estimation, a first-differenced generalised moment model (GMM) instead of using OLS, could increase model efficiency (Judson and Owen, 1999). Arellano and Bond (1991) proposed the GMM method for dealing with bias in dynamic panel data models. This has been applied to a study of OECD energy demand, but found similar elasticities to previous studies (Lui, 2004). Therefore, despite the potential for bias the country FE approach used in this model has been suitable and explains the prevalence of previous studies following this estimation technique.

4.5 Data

The data employed consists of 562 observations for 16 countries over the period 1980-2012. These countries account for over 65 percent of oil demand in 2012; 32 percent of the consumption is from just the USA and China. Less developed countries (LDCs) in 1980 accounted for 7.9 percent, but in 2012 made up 21.9 percent of the global demand. Figure 7 shows a positive relationship between growth in income and growth in oil demand. A notable deviation from the linear trend is India. Based upon the growth in energy consumption in India, a higher level of GDP growth would be expected and signals potential energy inefficiency in these countries. Nonetheless, we expect to find a positive relationship between income and oil demand. Table 4 shows an overview of the data used in this study.

Figure 7: Average growth in GDP per capita and oil consumption (1980-2012).

Source: Authors' panel data

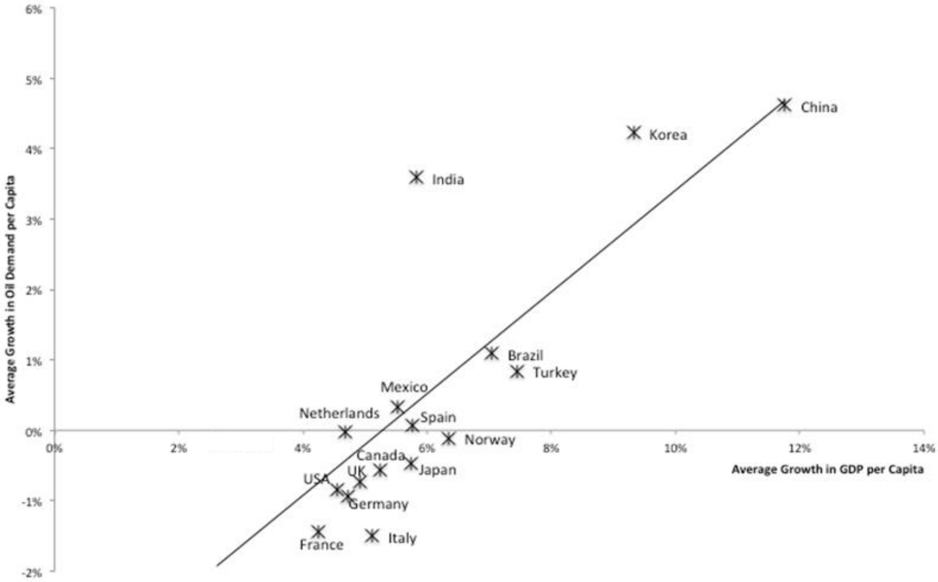

Table 4: Summary of data

	Oil Demand per Capita (mbd)			GDP per Capita (2012 USD)		
Country	1980	2012	Av. Growth	1980	2012	Av. Growth
Brazil	1,163	2,805	1.10%	1,931	11,340	7.04%
Canada	1,898	2,412	-0.56%	10,934	52,219	5.23%
China	1,690	10,221	4.61%	193	6,091	11.76%
France	3,020	2,358	-1.44%	12,500	39,772	4.25%
Germany	3,020	2,358	-0.94%	11,746	41,863	4.72%
India	644	3,652	3.59%	271	1,489	5.82%
Italy	1,930	1,345	-1.50%	8,148	33,072	5.12%
Japan	4,905	4,714	-0.46%	9,308	46,720	5.74%
Korea	476	2,458	4.22%	1,674	22,590	9.32%
Mexico	1,048	2,074	0.34%	2,763	9,749	5.53%
Netherlands	780	933	-0.02%	12,775	45,955	4.67%
Norway	199	247	-0.11%	15,595	99,558	6.34%
Spain	1,044	1,278	0.08%	6,037	28,624	5.76%
Turkey	295	685	0.84%	1,567	10,666	7.44%
UK	1,647	1,468	-0.73%	9,623	39,093	4.93%
USA	17,062	18,555	-0.85%	12,598	51,749	4.54%

5. Results and Analysis

5.1 Results

5.1.1 Symmetric Models

We first use a simple model to estimate the basic relationship in each country group is estimated (equation 2). Table 5 reports the first set of results. In the static model, developing countries have larger income and price elasticities of demand, 0.40 and -0.14 respectively. In developed countries, income elasticity is 0.01 (statistically insignificant) and price elasticity is -0.04. A clear difference in elasticities for the two panels is evident. The estimation suggests developing countries are more responsive to oil price rises. This is contrary to the literature. Yet, the model does estimate income growth to be fuelling oil demand, consistent with *a priori* expectations.

The addition of the lag term (equation 4) alters the elasticity results. The long-term income elasticity falls to 0.49 in developing economies and rises to 0.11 in developed economies. Interestingly the dynamic model results do not differ greatly from the static model in developed countries, this could be due to the mature energy profile unlike developing economies that are on a steep growth trajectory. The lagged term has significant advantage for econometric analysis by accounting for long-term elasticities, and hence will be utilised in future regressions.

Table 5: Results for Models (2) and (4)

Variable	Developing		Developed	
Equation	2	4	2	4
Constant	-3.564 (-24.93)**	-0.2686 (-3.06)**	-0.6512 (6.22)**	0.0757 (1.79)*
Y	0.404 (23.08)**	0.0414 (4.07)**	0.0146 (1.46)	0.0123 (3.04)**
P	-0.140 (-5.73)**	-0.030 (-3.612)**	-0.0384 (-3.8)**	-0.0357 (-8.82)**
$D_{(t-1)}$	-	0.9157 (43.22)**	-	0.8910 (39.91)**
FEM	Yes	Yes	Yes	Yes
Observations	198	192	330	320
Countries	6	6	10	10
R^2	0.973	0.998	0.907	0.987
R^2 (adjusted)	0.972	0.998	0.904	0.986
F-statistic	967.22**	9434.77**	282.69**	1865.56**
Jarque-Bera	6.178*	8.824**	25.559**	515.418**
Durbin Watson	0.245**	-	0.488**	-
AR(2)	-	1.243	-	1.872
Redundant FE	166.178**	5.861**	319.300**	3.241**
Hausman RE	0.000	11.426**	0.000	23.876**
ϵ_Y	0.404	0.491	0.015	0.113
ϵ_P	-0.140	-0.356	-0.038	-0.328

i) t-statistics are in parenthesis
ii) Elasticities ϵ_Y and ϵ_P are long-term elasticities and are comparable
**1% significance level; *5% significance

The main consideration from the symmetric models is to establish the correct panel data estimation technique. The Hausman test is found to be inconclusive in equation (2) for both country groups, and the use of random effects is strongly rejected in the dynamic model.

The use of fixed effects is strongly supported by the Redundant Fixed Effects Likelihood ratio for both equations (2) and (4). Accordingly, in all future estimations fixed effects will be applied as it fits statistically and theoretically with the approach undertaken.

5.1.2 Asymmetric Models

Theoretical and empirical support for the application of asymmetric response functions is established earlier. Econometric analysis using decomposition of the income and price series (equation 6) yields more noteworthy results that can be applied to the recent price shock. Table 6 provides the estimation and diagnostic tests.

The initial estimation combines both income and price decompositions in one model. In both panels the Wald test finds that the use of decomposition is not redundant. The P_{max} term is the largest elasticity for both country groups. The difference in long-run price elasticities is less than 0.03, with both groups adjusting demand similarly. The elasticities for P_{cut} illustrate energy maturity in developed countries, with elasticity of -0.03 compared to -0.05 in developing countries. Hence if price fell by $10/barrel, in the short-run, developing countries will *ceteris paribus*, demand an additional 1.04mbd in excess of developed economies.

Table 6: Results for Model (6)

Variable	**Developing**	**Developed**
Constant	-0.1829 (-5.01)**	0.0480 (2.74)**
Y_{max}	0.0591 (3.34)**	0.0270 (2.06)*
Y_{cut}	0.1642 (5.68)**	0.0852 (2.67)**
Y_{rec}	0.0308 (1.05)	0.0799 (2.09)*
P_{max}	-0.0473 (-1.47)*	-0.0573 (-2.95)**
P_{cut}	-0.053 (-4.47)**	-0.0281 (-3.65)**
P_{rec}	-0.017 (-1.36)	-0.0313 (-4.97)**
$D_{(t-1)}$	0.8641 (36.37)**	0.8731 (35.31)**
Country Fixed Effect (FE)	Yes	Yes
Observations	192	320
Countries	6	10
R^2	0.998	0.987
R^2 (adjusted)	0.998	0.986
F-statistic	7455.12**	1420.00**
Jarque-Bera	4.769*	677.616**
Redundant FE Likelihood	7.48**	3.72**
AR(2)	0.911	1.89
Wald Test	24.67**	27.78**
ϵ_Y	0.435	0.213
ϵ_P	-0.348	-0.389

i) t-statistics are in parenthesis
ii) Elasticities ϵ_Y and ϵ_P are long-term elasticities and are comparable
**1% significance level; *5% significance

For developing countries, the largest income elasticity is when income falls (Y_{cut}) with an elasticity of 0.16, indicating that falls in income have the strongest effect on oil demand. Over the time period most income rises in developing countries are increases in the maximum value (i.e. Y_{max}). Long-run income elasticity based on this variable is 0.43. Contrasting to developed economies, increases in the maximum income are not as strong and shows maturity in the energy cycle. This yields a long-run elasticity of 0.21. Thus, the developing countries demand for oil is fuelled significantly by income growth.

The models do not pass autocorrelation tests indicating that the variables are correlated over time. This could be due to misspecification by the use of two decomposed time-series. In fact, van Bentham and Romani (2009) have issues with autocorrelation and re-specification helped reduce the effect.

5.1.3 Adjustments to the decomposed model

As previously highlighted the models suffer from autocorrelation. Accordingly, two variations on equation (6) will be presented, each with one decomposed series (price or income). Re-specification can be used to correct for autocorrelation (Gujarati, 2003). This is because inference may occur between the two decomposed series if included in one model.

$$D_{i,t} = \alpha_0 + \alpha_1 Y_{i,t} + \alpha_2 P_{max,t} + \beta_3 P_{cut,t} + \beta_4 P_{rec,t} + +\gamma D_{i,t-1} + \theta_i + \varepsilon_{i,t} \quad (6p)$$

$$D_{i,t} = \alpha_0 \; \alpha_1 Y_{max,i,t} + \beta_1 Y_{cut,i,t} + \beta_2 Y_{rec,i,t} + \alpha_2 P_t + +\gamma D_{i,t-1} + \theta_i + \varepsilon_{i,t} \quad (6y)$$

Estimation of the improved equations is presented in Table 7. The models still suffer from autocorrelation in developing countries and non-normality in developed economies. However, the significance is lower and therefore Models (6p) and (6y) are better specified to highlight differences between the elasticities in the two panels. The non-normality in developed economies can be attributed to outliers for the UK in 1984 and 1985 which significantly deviates from the fitted line (see Figure 8). This might have been in part due to the miners' strike which caused greater dependency on oil (Ledger and Sallis, 1995). This could be controlled using a dummy variable, but the inference on the estimated parameters is low.

The partial use of asymmetry in equations (6y) and (6p) yield elasticities that indicate the substantial disparity between the two country groups for income elasticity. In equation (6y) income elasticity is 0.67 in developing and 0.18 in developed economies. The decomposition indicates short-run income elasticity to be nearly four times larger in developing countries when there is an increase in the series-maxima. The effect of a price shock that increases the series-maxima (P_{max}) is insignificant in developing countries, thus indicating the price shock had little statistical importance on consumption.

Across all regressions the income elasticity is approximately 0.2 in developed economies and between 0.5-0.7 in developing economies. Demand has tended to adjust more to increases, rather than decreases in price, except in one instance for developing economies. The price elasticity is generally stronger in developed countries indicating clear differences between the country groups and the driving factors behind their demand across the time period. The heterogeneity between the two panels has implications on policy and in understanding the recent price shock.

Table 7: Results for Models (6y) and (6p)

Variable	**Developing**		**Developed**	
Model	6y	6p	6y	6p
Constant	-0.011 (-0.36)	-0.669(-5.30)**	0.195 (8.80)**	-0.262 (-2.43)*
Y		0.081 (5.21)**		0.033 (2.75)**
Y_{max}	0.081 (6.22)**		0.021 (3.41)**	
Y_{cut}	0.141 (5.24)**		0.093 (3.03)**	
Y_{rec}	0.052 (1.87)*		0.079 (2.19)*	
P	-0.037 (-4.68)**		-0.034 (-8.22)**	
P_{max}		-0.045 (-1.35)		-0.065 (-3.46)**
P_{cut}		-0.016 (-1.60)		-0.023 (-3.49)**
P_{rec}		-0.047 (-4.20)**		-0.033 (-5.89)**
$D_{(t-1)}$	0.878 (38.51)**	0.912 (43.69)**	0.886 (39.69)**	0.867 (35.38)**
Country FE	Yes	Yes	Yes	Yes
Observations	192	192	320	320
Countries	6	6	10	10
R^2	0.998	0.998	0.987	0.987
R^2 (adjusted)	0.998	0.998	0.986	0.986
F-statistic	8811.83**	7928.85**	1625.78**	1616.21**
Jarque-Bera	3.750	5.70*	674.92**	595.08**
Redundant FE	6.528**	7.55**	3.60**	3.901**
AR(2)	1.30	1.43	1.84	1.97*
Wald Test	4.96**	2.23	8.97**	48.07**
ϵ_Y	0.668	0.921	0.184	0.248
ϵ_P	-0.303	-0.511	-0.298	-0.489

i) t-statistics are in parenthesis

ii) Elasticities ϵ_Y and ϵ_P are long-term elasticities and are comparable

**1% significance level; *5% significance

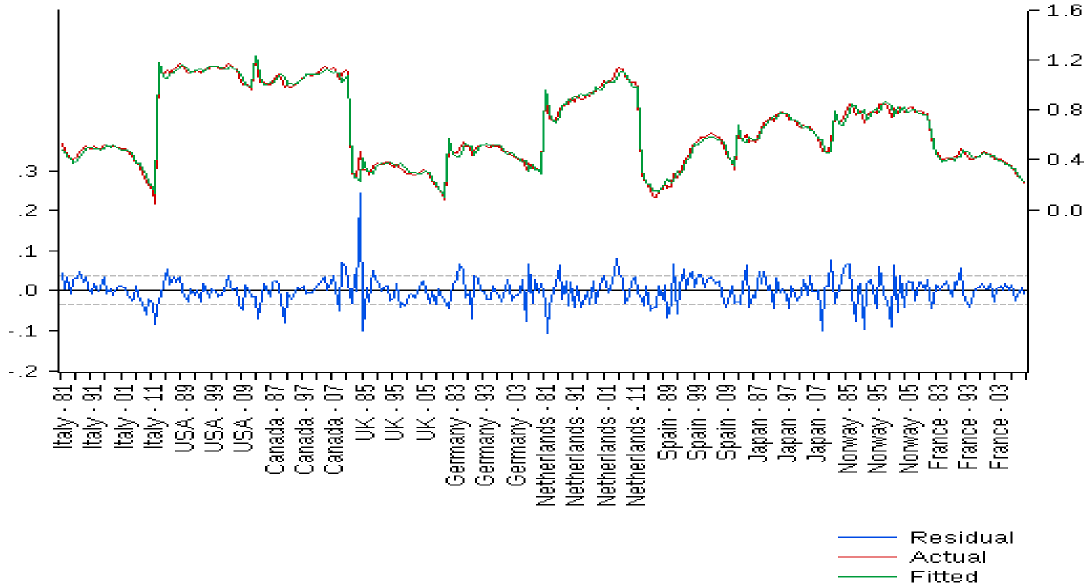

Figure 8: Residual plot for Model (6y), developing countries.

The preferred models for further analysis are Model (6y) for developing countries and Model (6p) for developed countries. In developing countries, consistent with *a priori* expectations the key driver for demand has been income. Model (6y) suitably captures this and allows consideration of the income effect. In developed countries, more stable growth has had less effect on oil consumption, thus price plays a greater role on consumption patterns. Consequently, Model (6p) will be used. The crucial elasticities are indicated in Table 8.

Table 8: Crucial elasticities

Panel	Income Elasticity	Price Elasticity
Developing	0.668	-0.303
Developed	0.248	-0.489

5.2 Income and Substitution Effect

Income elasticity is significantly closer to unity in comparison to developed economies. This indicates a dependency on oil for economic development. Yet, if oil is a key driver in development, why is consumption in developing countries affected significantly less in the event of an oil price shock? One might consider this in the context of energy intensity and the structure of industry in the countries.

Analysis of the decomposed price Model (6p) shows a insignificant parameter for P_{max}. This indicates that developing countries have been unaffected by the price shock; as the P_{max} term is only activated during the period of price shock. Additionally, considering the model with both series decomposed (6) in the lead up to the price shock (P_{rec}) the short-term demand adjustment is only about 1.7 percent and nearly one-half of that of developed economies.

The strong income effect in developing countries indicates that they are to a lesser degree affected by the price of oil. Calculation of the Slutsky equation for each panel of countries provides indication of the compensated demand for oil, and thus indicates the relative income and substitution effects.[2] Table 9 shows that the income effect is 6.3 times stronger in developing countries showing income growth is fuelling oil demand. Additionally, the substitution effect is 2.08 larger in developed countries indicating a larger responsiveness to the price shock.

[2] The Slutsky equation allows derivation of income and substitution effects based upon the elasticities obtained and the equation in elasticity form can be expressed as:

$$\varepsilon_{ii} = \sigma_{ii} - s_i\eta_i$$

where ε_{ii} denotes price elasticity of demand (i.e. α_2), the share of oil expenditure as percentage GDP (calculated from panel), η_i is income elasticity of demand (α_1), σ_{ii} denotes substitution effect, and income effect is $s_i\eta_i$.

Table 9: Income and substitution effects (derived from crucial elasticities)

Country Group	Oil Spending (% Income)	Income Effect	Sub. Effect
Developing	11.09	0.074	-0.229
Developed	4.77	0.011	-0.478

5.3 Explanations for Variation in Consumption Patterns

Income in developing countries has increased on average by seven per cent in the time period studied. The compound effect of this is a doubling of national income, this major change in economic activity is sure to cause changes in consumption patterns and provides an explanation to the strength of the income effect in developing countries. Nonetheless, the current per capita oil consumption is still very low and any growth in disposable income will increase oil demand further.

Behr (2009) regards the increases in oil demand to have had a disproportionate effect on global oil prices. One of the main components fuelling the surge was the increased demand for transport fuel and in particular diesel for the Asian market (Yergin, 2008). In order to sustain this oil demand will have to increase by 128 million barrels a year (Petrie, 2011). Projecting oil demand to 2035, the key driver of oil demand will be transport fuels and expected to account for 40 percent of the overall demand increase (IEA, 2012). They expect road freight in non-OECD countries to grow nine-times in part due to increased construction and industrial activity.

Growing economies require large amounts of infrastructure creation. Such projects are linked with income growth and this is a good indication as to why the income effect is so large in developing countries. Barclays (2012) report that most developing economies are in a stage of rapid development and creation of infrastructure, with demand outstripping supply on these projects. The construction of motorways in these countries will make car ownership more appealing so increasing fuel demand.

One could consider that during a period of rapid economic growth in developing countries little regard was paid to energy efficient technologies. The data used in this paper shows that developing countries use 3.6 times more oil per unit of GDP than developed economies. Inefficient use of energy in developing countries caused levels of consumption that could otherwise have kept global prices lower (Merrill Lynch, 2012). However, energy intensity has been declining in all regions globally in part attributed to China becoming less energy-intensive recently (BP, 2013).

Asian developing countries often have price controls which prevent the transmission of crude prices rises in order for the country to continue on an uninterrupted growth trajectory. Price controls reduce the substitution effect as there is less incentive to be more energy efficient in the face of price increases (Economist, 2008). The monetary size of fuel subsidies is large. In 2013, India spent $23bn in reducing fuel costs (Mallett, 2014). If pump costs were reflective of the global price of oil consumers may have reduced oil demand and the price shock could have been dampened. However, as this paper uses a single price we are unable to further analyse these effects.

In contrast, developed countries already have a mature energy profile. Oil is primarily used as a transportation fuel, with electricity production now undertaken using other fossil fuels or alternative forms of energy (Merrill Lynch, 2012). The consumer faces the brunt of oil price shocks in economies where transportation fuel is the primary use of oil, as crude prices are easily transferred to the pumps. This is the case in most OECD countries, with minimal fuel subsidies in place (Economist, 2008). Therefore, the substitution effect is likely to be greater. Indeed, the USA witnessed a slowdown in automobile purchases in 2008 in light of higher oil prices (Hamilton, 2009).

The difference in consumption patterns between the two panels is noteworthy due to three factors. *Firstly*, growth has caused a structural change to the developing economies. The move to greater personal transportation shows no sign of slowing and consumers are unlikely to reverse their lifestyle because of fuel price increase if incomes continue to rise. The income effect is greater in developing countries as the middle classes seek higher standard of living. In contrast, developed countries have mature energy profiles and have little rationale to rapidly increase long-term transport fuel demand. *Secondly*, the rapid expansion may have neglected energy saving. If alternative energy forms were in place there would be a greater substitution effect from a shock in developing countries. It is possible as concerns with air pollution and climate change continue alternative transport fuels are promoted more strongly as with compressed natural gas in South Asia. *Finally*, oil subsidies prevent the transmission of global prices hence fuelling consumption and biasing the substitution effect downwards in the developing economies.

5.4 Policy Implications

Preventing spikes in oil prices is difficult to achieve due to the complex nature of the market as highlighted in this paper. Nonetheless, economic policy could be used to smooth prices based upon the work of Behr (2009) and Wurzel *et al.* (2009). This paper has a number of policy recommendations.

Oil intensity has reduced significantly in China and other developing countries (Figure 9). The indicator provides a measure of consumption per unit of output in the economy. Reducing oil intensity acts as a safeguard if oil prices do increase, as spare capacity exists within the economy (Wurzel *et al.*, 2009). They note in the event of a demand shock as witnessed in the last oil price shock lower energy intensity would have reduced the impact of rising incomes. The need to lower intensity is also a recommendation reported by Gately and Huntington (2002). This paper has found a strong link between economic development and increased oil consumption. Unless intensity reduces, the potential for future demand shocks will still exist.

As noted, income growth at earlier stages of economic development leads to strong growth in demand for energy and oil in particular. The demand growth has trade balance, security of supply, and air pollution as well greenhouse gas emissions implications. In both developing and developed countries, given the high socio-economic costs of these, policy makers can adapt polices that meet the demand for energy services while at the same time these are met from renewable energy, new technologies, and energy efficiency measures. The potential for these measures are particularly high in developing countries. At the same time, many developing economies continue to subsidise the use of oil and other energy sources. Instead, these countries can use energy subsidy reforms to increase the efficiency of energy use and redirect this to alternative sources of fuel.

This paper has highlighted the difference in consumption patterns between the two panels. Clearly demand functions differ based on the level of development in an economy, therefore policies cannot be globally homogenous. Each panel exhibits different responses when asymmetric decomposition is applied. Global elasticities could therefore be biased and thus incorrect policy decisions would be made. Each country has specific energy mix and varied uses of oil. OECD countries use 80 percent of their oil consumption for transportation. This value is around 15 percent lower in developing economies (Merrill Lynch, 2012). Consequently, blanket reduction policy cannot be applied. International collaborations and policies can be devised to address region specific issues.

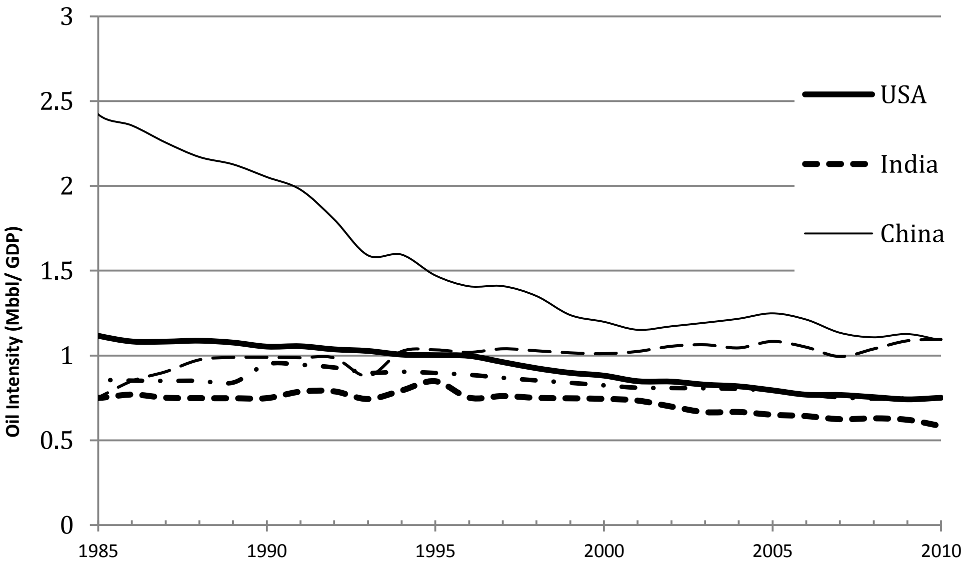

Figure 9: Global oil intensity

Source: BP (2013)

6. Conclusions

This paper investigated price and income elasticities in a period of global oil price volatility. A scarcity of research has been undertaken in light of the recent price shock. Previous studies had introduced the use of asymmetric decomposition and cross country panel analysis, but the techniques had not been applied to a dataset that covered the recent price volatility. Analysis of late has concentrated on a time-series approach and this has failed to capture the efficiency gains obtained from panel data.

Currently in Epoch III oil pricing, the previously established global trade flows appear to be changing. Fundamental economic analysis established the price rises following the millennium to have occurred as a result of disequilibrium. Supply hiatus from non-OPEC producers coupled with geopolitical events resulted in supply growth stalling. The recent price shock was characterised not by a supply shock as in previous episodes, but rather a failure to escalate production to satisfy demand. Unexpected levels of demand were the primary contributing factor in causing the disequilibrium.

A dynamic cross country fixed effects specification was used to capture the heterogeneous intercept level of demand in each country. As the period of study was greater than thirty-years the potential for parameter bias resulting from FE was substantially reduced. Estimation of the models including asymmetric decomposition for both income and price yielded two distinct consumption patterns. *Firstly,* the effect of income falls is larger than income rises, with income elasticities being stronger for developing countries in all specifications. *Secondly,* when oil price rises the elasticity is larger in contrast to price falls, but this effect is only significant in developed countries.

Subsequent analysis of these observations through the use of Slutsky decomposition emphasised the results obtained in the regression. Developing countries have an income effect which is 6.3 times larger than in developed countries. Thus, in a period of significant economic growth for developing countries it is evident why oil consumption increased so dramatically. Moreover, the substitution effect in developed economies was 2.1 stronger than in developing countries. This explains the more responsive adjustment of consumption of developed countries in reaction to the price shock of 2007/08.

The results obtained are explainable in relation to the difference in economic structure between the two panels. Developing countries have not yet reached relative energy maturity in relation to fossil fuels. Consumers increasingly use oil as a transportation fuel as the higher disposable income is expended on car ownership. This explains the relative strength of the income effect in developing countries. Economic development has been at the expense of lower energy efficiency, in turn reinforcing the size of the income effect in developing countries. We suggested the implementation of oil-intensity reduction policy in order to maximise efficiency. Such policy would enable a buffering if oil prices rise as a result of a demand shock. A crucial policy consideration postulated is the recognition of heterogeneous consumption patterns between country groups and that a one size fits all policy should not be undertaken.

There is potential for future research. This paper considered two independent panels separated by the level of economic development. However, by increasing the dataset and incorporation of more countries, alternative panels could be estimated. These could include oil importers, oil exporters and geographical regions. Granulation of the current approach would allow more tailored policy development and a better understanding of income and price responses which would aid economic forecasting. Furthermore, research could be considered into the effect of subsidies on consumption by utilising country price data.

This paper has contributed to the existing literature on oil consumption patterns during Epoch III pricing. The dominance of the income effect in developing countries has been staggering. In conclusion, oil consumption patterns during the period 1980-2012 varied significantly between developing and developed countries and failure to account for this will bias the effectiveness of energy policies.

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Appendix 1: Country Groups

Tables 10 and 11 outline the classification of developed and developing country applied in this study. The study has separated the countries based on their GDP per capita into these country groups. The difficulty in obtaining data for low income (developing country) reduces the number of available countries of analysis. Note that Korea is included among the developing countries as the economy featured characteristics of a developing economy for much of the period under study.

Table 10: Developing country group

Country	GDP Growth Rate	Demand Growth
Brazil	7.04%	1.10%
China	11.76%	4.61%
India	5.82%	3.59%
Korea	9.32%	4.22%
Mexico	5.53%	0.34%
Turkey	7.44%	0.84%
Average	7.82%	2.45%

Table 11: Developed country group

Country	GDP Growth Rate	Demand Growth
Canada	5.23%	-0.56%
France	4.25%	-1.44%
Germany	4.72%	-0.94%
Italy	5.12%	-1.50%
Japan	5.74%	-0.46%
Netherlands	4.67%	-0.02%
Norway	6.34%	-0.11%
Spain	5.76%	0.08%
UK	4.93%	-0.73%
USA	4.54%	-0.85%
Average	5.13%	-0.65%