Rahmaniah Occasional Paper 04

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Abstract

The wide uncertainty surrounding the oil market dynamics in the aftermath of the financial crisis did not prevent many market analysts from making bold predictions that market fundamentals are likely to tighten in the future. These predictions are based on the combination of three factors: a very limited growth in non-OPEC supply; a slowdown in investment in OPEC countries; and a rapid growth in global oil demand fuelled mainly by non-OECD economies. This paper focuses on one element underlying the current predictions of tight oil market fundamentals: global oil demand dynamics. The paper provides a general overview of the current corpus of knowledge concerning the determinants of oil demand both in the short run and in the long run. Rather than focusing on the very divergent demand projections by international organisations such as the IEA, OPEC or EIA, the paper analyses ten key relationships that are important to understanding the dynamics of global oil demand and explores some of the underlying causes for the divergent projections on global oil demand.

Introduction

The future fundamentals of the oil market could not be more uncertain. Global oil markets are still adjusting to highly uncertain economic conditions following one of the most severe financial crises since the 1929 Great Depression and a very sharp price cycle which saw the annual average oil price rise for seven consecutive years between 2002 and 2008 before spectacularly collapsing to low levels in December 2008.

A major challenge in predicting 'medium-term' or 'long-term' oil market fundamentals is that there are too many unknown variables that can play an important role in shaping these future fundamentals, many of which originate from outside the oil market. These include the pace of the global economic recovery, changes in consumer behaviour, fiscal and monetary policy responses, regulatory changes, geopolitical factors, technological innovations in the transport sector, technological developments in oil exploration and extraction, changes in key producers' behaviour, and the potential impact of energy security and climate change policies on oil markets, just to mention a few variables.

The great uncertainty surrounding the oil market dynamics in the aftermath of the financial crisis, however, did not prevent many market analysts from making bold predictions that market fundamentals are likely to tighten in the future. These predictions are based on three main pillars: (1) a very limited growth in non-OPEC supply due to peak oil and/or over-ground constraints such as geopolitical factors and hardening fiscal terms on oil production; (2) a slowdown in investment in OPEC countries due to variety of factors such as geopolitical and the incapability and/or unwillingness of these countries to invest in their oil sectors in the presence of large spare capacity and amidst demand uncertainty; and (3) a rapid growth in global oil demand fuelled mainly by non-OECD economies.

Based on these three pillars, some analysts claim that the world faces an energy crisis and argue that oil prices 'did not remain high enough for long enough to generate a solution to the energy problem, which has not gone away'. According to this view, there will be a 'likely return to energy shortages as dwindling OPEC spare capacity is likely unable to meet rising demand as non-OPEC production growth is restricted by limited investment in oil production infrastructure'.(1) Others claim that 'at least the day of cheap and easy oil is over' and that there is a 'risk of a crunch in the oil supply...when demand picks up because not enough is being done to build up new supplies of oil to compensate for the rapid decline in existing fields'(2).

On the other hand, some observers argue that rather than just focusing on supply shortages and peak oil, the debate after the crisis should consider the possibility that oil demand may be peaking before oil supply. This view points to the convergence of three main drivers that would eventually put downward pressure on oil demand in the long term: the

(1) Kate Mackenzie (2009) 'Goldman Sachs and the Unrecognised Energy Crisis', 4 June 2009, http://blogs.ft.com/energy-source/2009/06/04/goldman-sachs-and-the-unrecognised-energy-crisis/).

(2) An interview with Dr Fatih Birol, 'Warning: Oil Supplies are Running Out Fast', The Independent, August 3, 2009 available from: http://www.independent.co.uk/news/science/warning-oil-supplies-are-running-out-fast-1766585.html).

new environment of high and volatile oil prices, the growth of efficiency gains in the transport sector, and the impact of government policies driven by concerns of energy security and climate change.(1) A recent report declares the 'end of the 20th Century of Oil' and announces the entry of the world into 'the 21st Century of Electricity'.(2) There is a growing belief that the oil demand in OECD 'may well have peaked' with the IEA pointing to 'an oil-less' economic recovery in OECD(3).

The effects of these predictions are far from neutral as they can shape market outcomes, influence policy and investment decisions, and filter directly and indirectly into market participants' expectations. Changes in expectations can, in turn, impact short-term and long-term prices and, more importantly, the interaction between the front part and the back end of the futures price curve(4).

This paper focuses on one element which underlies the current predictions of tight market fundamentals: global oil demand dynamics. The paper provides a general overview of the current corpus of knowledge concerning the determinants of oil demand both in the short run and the long run. Rather than focusing on the very divergent demand projections by international organisations such as the IEA, OPEC or EIA, the paper analyses key relationships that

(1) Arthur D. Little (2009) 'The Beginning of the End for Oil? Peak Oil: A Demand-side Phenomenon?' February 2009, avilable from: http://www.adl.com/reports.html?&no_cache=1&view=356

(2) Kate Mackenzie 'Deutsche: the end is nigh for the Age of Oil', October 6, 2009, available from: http://blogs.ft.com/energy-source/2009/10/06/deutsche-the-end-is-nigh-for-the-age-of-oil/

(3) IEA (2010) Oil Market Report, February

(4) Fattouh, B. (2010) 'Oil Market Dynamics through the Lens of the 2002-2009 Price Cycle', OIES WPM 39.

are important to understanding the dynamics of global oil demand and analyse the underlying causes for the divergent projections on global oil demand.

Shifts in Oil Trade Flows

One of the most important shifts in oil market dynamics in recent years has been the acceleration of oil consumption in non-OECD economies. Between 2000 and 2009, demand growth in non-OECD countries outpaced that of OECD in every year (see Figure 1). During this period, non-OECD oil consumption increased by around 10.5 million barrels per day (mb/d) while that of OECD dropped by 2.1 mb/d. At the heart of this growth lies the Asia-Pacific region, which accounted for more than 50% of this incremental change in demand during this period. This current shift towards non-OECD is likely to accelerate as households' incomes in emerging economies improve and car ownership rates increase.

The emergence of non-OECD as the main source of growth in global oil demand has had far-reaching implications on the dynamics of oil trade flows. This is perhaps best illustrated in the shift in the direction of oil flows from Saudi Arabia and Russia, the two biggest oil producers in the world, towards the East. As shown in Figure 2, in 2002 Saudi Arabia's share of oil exports to the U.S. and Europe amounted to 28.2% and 17.9% respectively. In 2009, these shares declined to 17.8% for the U.S. and 10% for Europe. In 2009 Saudi Arabia abandoned its St Eustatius storage facility in the Caribbean, which was mainly used to feed the U.S. market, and instead obtained storage facility in Japan to feed Asian markets.

So far, Russia's exports have been heavily concentrated towards Europe where in 2009 it exported around 7 mb/d there compared with 1.17 mb/d to Asia Pacific.[1] These dynamics, however, are likely to change in the next few years as Russia builds new infrastructure in an attempt to shift part of its oil exports towards the Far East. The inauguration in December 2009 of the first section of the Eastern Siberia Pacific Ocean (ESPO) pipeline represents a marginal but, nonetheless, an important step in that direction. The first section of ESPO is a 2,757 km long pipeline connecting Taishet in East Siberia to Skovorodino in Russia's Far East, near the border with China. It has a capacity of 600,000 b/d and is expected to grow to 1 million b/d by 2012, and potentially to as much as 1.6 million b/d at a later date. The second stage of project involves linking Skovorodino to a new export terminal at Kozmino on the Pacific coast so as to supply some of the rapidly growing oil demand in Asia. China and Russia have agreed to construct an offshoot from Skovorodino to Daqing in China. The offshoot has a capacity of 300,000 b/d and is expected to be completed by end of 2010.

Such changes in trade flow patterns are likely to accelerate as the centre of consumption growth shifts from OECD to emerging economies. The EIA[2] predicts that between 2007 and 2035, oil consumption will increase by around 24 mb/d

(1) BP (2010) BP Statistical Review of World Energy, June.
(2) EIA (2010) International Energy Outlook 2010, U.S. Energy Information Administration, Table A.5.

from 86.1 mb/d to 110.6 mb/d with non-OECD accounting for almost all of this increase during this period. This shift in trade flows is likely to have wide geopolitical and economic implications and will affect many aspects of the oil market such as the emergence of new trade routes, refining centres, and pricing benchmarks.

The Determinants of Global Oil Demand

Oil demand is often modelled as a function of a wide range of variables such as world economic activity and the structure and distribution of that activity, global demographical factors, demand-side technology, oil prices, the relative price of competing energies and taxation policies. Despite this wide range of factors, the literature has persistently found that one of the main determinants of oil demand is economic activity either measured in terms of GDP in macro studies or household income in household surveys. However, as discussed below, this relationship is not linear and differs considerably across countries depending on their level of economic development, degree of urbanisation and industrial structure.

Regarding the price determinants, there is more than one concept of price to consider. These include the price level; the relative price in the energy mix; price volatility; and price swings. These price determinants affect demand either directly through the usual price elasticity channel; through changing the importance of oil in the energy mix; and/or through their impact on economic growth and consumer behaviour. As in the case of income, the relationship between oil demand and prices is not linear and may be subject to threshold effects.

In addition, there are non-price determinants which could have a lasting impact on oil demand. These include policy measures driven by energy security concerns; policy measures driven by climate change concerns; and technological developments, especially in the transport sector. In recent years, there has been convergence between the energy security and the climate change agendas in most consuming countries, though in some instances the two objectives can diverge. Furthermore, policy measures should not be analysed in isolation of oil price dynamics. Their effectiveness and impact on oil demand are directly linked to oil price behaviour. For instance, one can assign a low probability that a certain policy measure will be implemented in a low oil price environment. However, as oil prices rise and or become more volatile, the probability that the same measure will be implemented increases. In other words, energy policy should not be considered as an exogenous variable that can explain oil demand patterns; it is an endogenous variable affected by a large array of factors both inside and outside the oil market.

Finally, the recent financial crisis has clearly shown that factors outside the oil market such as financial fragility and regulatory failures can have a drastic and long lasting impact on oil demand. Such factors affect oil market through their impact on key macroeconomic indicators such as economic growth, output, and employment;

through their impact on consumer behaviour; and through their impact on short-term and long-term expectations and thus on oil price behaviour.

In what follows, we restrict our attention to ten key relationships that are central to understanding future global oil demand dynamics, drawing some lessons from each of these relationships.

Oil Demand and Price Elasticity

The bulk of the empirical literature has focused on estimating the short-run and long-run price elasticity, which measures the relationship between the change in quantity of oil demanded and the change in price.(1) While there is a wide variation in the estimates of price elasticity, it is possible to draw some general conclusions regarding the responsiveness of oil demand to prices:

- Changes in wholesale oil prices tend to have a small (and often insignificant) effect on demand for crude oil in the short run;
- The long-run price elasticity of demand is significantly higher than the short-run elasticity due to substitution and energy conservation, although that elasticity often remains relatively small in absolute value;

(1) See for instance, Dahl, C. (1993) ‘A survey of oil demand elasticities for developing countries‘ OPEC Review, 17(4), pp. 399–419; Gately, D. and Huntington, H (2002) ‘The asymmetric effects of changes in price and income on energy and oil demand’, The Energy Journal, 23(1), pp. 19–58; Griffin, J.M. and Schulman, G.T. (2005) ‘Price asymmetry in energy demand models: A proxy for energy-saving technical change’. The Energy Journal, 26(2), pp. 1–21; Ibrahim, I.B. and Hurst, C. (1990) ‘Estimating energy and oil demand functions: A study of thirteen developing countries’, Energy Economics, 12(2), pp. 93–102.

- Oil demand may respond asymmetrically to changes in prices. For instance, an increase in the oil price would eventually reduce demand but it is not necessarily true that the decrease in the oil price would reverse the decline in oil demand. (1) In other words, demand may demonstrate an element of hysteresis. The increase in price may, for example, induce investment and a shift towards more efficient equipment and/or substitution which leads to a permanent reduction in oil demand. A typical example is the demand reduction in response to the price shocks of the 1970s. The decline in demand caused by fuel-switching from fuel oil towards natural gas in power generation in the OECD was not reversed by the oil price collapse in the 1980s(2);
- Some studies point out that the response of oil demand to an increase in the maximum historical price would not be the same as demand response due to price recovery.(3) It is possible to decompose prices into: price increases that lead to new historical prices, price increases that return to some previously observed price levels, and price decreases. Using this decomposition, Gately and Huntington (2002) find that price elasticities are significantly different across price falls and price increases, and that the most elastic price response of oil demand is due to new price maxima;

(1) Gately, D. and Huntington, H (2002) 'The asymmetric effects of changes in price and income on energy and oil demand',. The Energy Journal, 23(1), pp. 19–58.
(2) Dargay, J.M., Gately, D. and Huntington, H. (2007) 'Price and Income Responsiveness of World Oil Demand, by Product', Energy Modeling Forum OP 61.
(3) Gately, D. and Huntington, H (2002) 'The asymmetric effects of changes in price and income on energy and oil demand', The Energy Journal, 23(1), pp. 19–58.

- There might be threshold effects, such that below a certain price the demand response is very low but once the price exceeds the threshold, there is a strong demand response (to be discussed in details in Section 5).

In sum, the above analysis suggests the impact of oil price is not always linear, that it affects demand with a lag, not always reversible, and may often depend not only on current price levels but also on the past history of oil prices.

Demand Destruction and Price Elasticity

An issue that has attracted some attention in the recent price cycle is whether the decline in oil demand due to high oil prices is recoverable or destroyed.(1) Demand destruction refers to a permanent shift in the demand for oil induced by a prolonged period of high and volatile oil prices, technological breakthroughs, government policy or change in consumer behaviour. For instance, in the developed world, the oil price shock in the early 1980s resulted in a substitution for oil in power generation. Since then, oil has never made serious inroads into power generation. Also as discussed above, increases in price may induce a shift towards more efficient equipment, including cars, and the decrease in price would not reverse the impact of the prior capital investment. The decline in oil demand in the aftermath of the 2008 financial crisis brought to the fore the issue of demand destruction. In a recent report, OPEC(2) points out that

(1) See for instance, Kurt Cobb (2006) ‘Demand Destruction: who gets destroyed?’ Energy Bulletin, January 14.

(2) OPEC, Monthly Oil Market Report, November 2009.

> **… even if the expected economic recovery materializes, it remains to be seen whether demand would be able to return to pre-crisis levels. Energy policies and behavioural changes are bound to have some impact on consumption and this will gradually feed into overall demand patterns, especially in key sectors such as transportation (p. 3).**

Regardless of whether the slowdown in demand is just a temporary phenomenon or reflects structural changes in behaviour, it is important to note that oil demand 'destruction' will not necessarily reduce its price elasticity. The oil demand that is usually replaced first is the easiest to eliminate. Over time it is more difficult, more expensive, and would take a longer time to permanently reduce the demand for an extra barrel of oil.

The implications of this feature are twofold. First, the remaining oil demand after substitution will become more price-inelastic. As a result the oil market will become more prone to shocks in the short term as sharp price movements are needed to equilibrate the market. Second, current policies of changing the energy mix away from oil involve a cost which tends to rise over time. Hence substitution policies are not growth neutral, and thus it is important to analyse the impact of transitioning into new sources of energy on key macroeconomic variables such as output, growth, employment, and economic structure. Many countries consider investment in oil-switching technologies not only in terms of cost but also as an opportunity to create new jobs and spur technological innovations and productivity improvements. For instance, in the 2010 Economic Report of the President, the authors argue that through the American Reinvestment and Recovery Act of 2009 the U.S. aims to create a new generation of jobs and placing the country 'on a path to becoming a global leader in clean energy'.[1] Such objectives imply that over time energy policy will become more strongly intertwined with general economic policy in consuming countries.

Oil Demand in OECD: The Income Effect

The relationship between oil demand and economic activity is usually examined within the context of the income elasticity of demand, which measures the relationship between the change in quantity of oil demanded and the change in income or the growth rate. The estimates vary widely according to the method used and the period under study. Despite the widely varying estimates, it is possible to draw the following general conclusions:

- Oil demand is more responsive to income growth than changes in oil prices;
- Income elasticity is not constant across countries and over time and tends to vary with the level of economic development or income;
- There is a large heterogeneity in estimated income elasticity across countries and/or regions with developing and emerging economies exhibiting

(1) (2010) 'Economic Report Of The President', Washington DC: United States Government Printing Office.

higher income elasticity than OECD;

- Oil demand increases faster than GDP below some income threshold but slows down beyond this threshold.

The last observation is important for understanding oil dynamics in the U.S. and the rest of the OECD and thus requires some further discussion. As seen in Figure 3, the U.S. income elasticity has been in decline over the years and since the 1979 oil price shock, income elasticity has fallen to below unity. In other words, for a given price, the percentage growth in oil demand is less than the percentage growth in income.(1) Other things being equal, declining income elasticity implies that total expenditure on oil as a percentage of household income tends to decline over time.(2) However, other things are not equal and one needs to take into account the price effect. Given the short-run price elasticity of demand, a certain percentage increase in the oil price will induce a smaller percentage change in the quantity of oil demanded. Consequently, the expenditure share on oil out of a household's total budget will increase as prices increase(3).

These dynamics can explain oil demand behaviour in the U.S. and OECD during the last price cycle. At the beginning of the boom, the share of oil expenditure of households' budgets was relatively small due to a general

(1) This reflects among other things the structural change in OECD oil use away from the power and industrial sectors and towards the final consumer and, most particularly, private transportation.
(2) Hamilton J.D. (2008) 'Understanding Crude Oil Prices', NBER Working Paper No. 14492
(3) Hamilton J.D. (2008) 'Understanding Crude Oil Prices', NBER Working Paper No. 14492

decline in income elasticity and a relatively low oil price environment for most of the 1990s. As seen from Figure 4, at the beginning of the boom in 2002, the ratio of expenditure on gasoline and other energy goods to personal consumption expenditure (PCE) on non-durable goods hovered at less than 10% in the first quarter of 2001. As such, in the early phase of the boom, households did not change their behaviour in response to the rise in oil prices as these increases did not hit hard their budgets. However, as prices continued on their upward path, the share on oil expenditure out of households' budget became quite substantial. As Figure 4 shows, at the peak of the oil price cycle, the percentage of expenditure on gasoline and other energy goods to personal consumption expenditure (PCE) on non-durable goods reached to more than 19% in the third quarter of 2008. This large increase in the share of expenditure on gasoline and other fuels eventually induced consumers to react and to alter their consumption patterns.

Thus, concerning OECD demand, one can draw the following lessons. Despite the decline in income elasticity or the oil intensity of GDP in OECD, there is a threshold price above which a change in oil price can induce a substantial reduction in oil demand as this will hit households' budgets hard. Oil producers need to monitor very closely the share of energy expenditure out of households' total budget as this is the key factor that would induce a change in consumer behaviour(1). Looking ahead, unlike the latest price boom, the price that would alter consumer behaviour

(1) See for instance, Jad Mouawad 'As gasoline costs soar, U.S. households cut total spending', New York Times, February 27, 2008.

will be reached much faster this time round. The share of oil expenditure out of total household's budget is higher today than at the beginning of the previous price boom. Thus, in the future, an increase in the oil price would induce a faster reaction in OECD demand.

Oil Demand in Non-OECD: The Income Effect

The above analysis is also useful for studying the dynamics of oil demand in emerging economies. This is vital as most of the future growth in oil demand is expected to originate from economies outside the OECD mainly in Asia and the Middle East (See Section 2). As discussed above, oil income elasticity in non-OECD is found to be higher than that in OECD. Based on the experience of developed economies, the income elasticity is bound to rise at early stages of development before it falls at high levels of income. This is due to variety of factors. One explanation focuses on the changing nature of economic structure along the process of economic development. As the economy develops, the share of manufacturing relative to non-manufacturing in GDP tends to rise. [1] Given that the energy intensity of production of manufactured goods is higher than non-manufactured goods, the changing composition of GDP can change the overall elasticity of oil demand.

Other studies focus on transport demand and evolution of car ownership. Evidence from countries with long time-

(1) Lo, M., Sawyer, W.C. and Sprinkle, R.L. (2007) 'The Link between Economic Development and the Income Elasticity of Import Demand', Journal of Policy Modelling 29, 133–40.

series data such as the US, Japan and European countries shows a slow growth of car ownership at early stages of economic development. As income per capita reaches a certain threshold ownership rates increase very rapidly. This threshold effect is expected given that owning a car is costly and constitutes a lumpy investment which households can only afford after their income has reached a certain threshold.(1) As income per capita crosses that threshold, the growth in car ownership is twice as much as the growth in income. At high income levels, growth in car ownership tends to slow down but will continue to grow as fast as income.(2) The relationship between income per capita and the income elasticity of vehicle ownership is depicted in Figure 5. This stylised fact also applies across countries. Countries with relatively lower income per capita tend have lower car ownership rates. However, once countries have crossed a certain income threshold, ownership rates tend to increase faster than income(3).

Various theoretical and empirical studies have also suggested the existence of a fuel continuum that varies with the level of income or economic development.(4) As incomes rise, households tend not only to consume more of the same

(1) Chamon, M., Mauro, P. and Okawa, Y. (2008) 'Mass Car Ownership in the Emerging Market Giants', Economic Policy, 24396.

(2) Although many expect for OECD economies to reach a saturation point very soon, the evidence of such a saturation effect is not yet very strong.

(3) Chamon, M., Mauro, P. and Okawa, Y. (2008) 'Mass Car Ownership in the Emerging Market Giants', Economic Policy, 243–96.

(4) Barnes, D.F and Floor, W.M. (1996) 'Rural Energy in Developing Countries: A Challenge for Economic Development', Annual Review of Energy and the Environment, 21: 497–530. It is widely recognised, however, that the transition from one type of energy to another is not monotonic or automatic. Others are more critical, suggesting that the energy ladder is a conceptual construct with no association with reality, especially where many households in developing countries are constrained in their decisions regarding fuel choice.

fuel but also move up the energy ladder towards higher quality fuels.[(1)] For instance, some analysts suggest the existence of an energy ladder in cooking and lighting, which are the dominant energy-using activities for households in developing economies.[(2)] The energy ladder ranges from traditional biomass or solid fuels (dung cake, crop waste, charcoal, coal) to liquid fuels (kerosene) to gaseous fuels (LPG, gas) to electricity (see Figure 6). As we move up the energy ladder, the source of energy becomes more efficient, cleaner and more convenient – but it also becomes more costly. The determinants of switching from traditional fuels to modern fuels have been widely analysed in the literature. Existing studies suggest that fuel choices depend on a complex set of factors, such as the level of income, fuel availability, capital costs, fuel prices, household size, gender roles, wage rates and cultural preferences.[(3)] There is some evidence that a similar ladder exists for the choice of mode of transport. The ladder ranges from walking to bicycles to public transport to small and then to large vehicles. One of the key factors determining the transition is the level of income per capita though the relationship is not linear.

Household survey data from Asia are consistent with macroeconomic data. The ownership of automobiles among households remains limited in many emerging economies with car ownership standing at less than five

(1) See Barnes, D. and M. Toman (2006) 'Energy, Equity and Economic Development', in Lopez, R. and M. Toman (eds), Economic Development and Environmental Sustainability: New Policy Options. Oxford University Press.

(2) Bruce, N. (2005) 'The Health Burden of Indoor Air Pollution: Overview of the Global Evidence', in World Health Organization (ed.), 'Indoor Air Pollution and Child Health in Pakistan', Report of a seminar held at the Aga Khan University, Karachi, Pakistan, September.

(3) See for instance, Gupta, E. and A. Sudarshan (2009) 'Energy and Poverty in India' in L. Noronha and A. Sudarshan (eds) India's Energy Security, Routledge.

per hundred households in China and India. This is in contrast to ownership of other durable goods (see Table 1). When evidence is available, it shows that ownership varies positively with income per capita. For instance, in the case of Sri Lanka (see Table 2), a large percentage of households in the lowest income groups don't own any vehicles. However, as we move up the income ladder, the percentage of households with no vehicles decreases, reaching 18.2% for the highest deciles. Interestingly, in the case of Sri Lanka, the fastest increases are in the categories of motor bicycles/scooters and motor cars or vans where the percentage of households who own these vehicles increases from negligible for the lowest income group to 40% and 35% respectively for the highest income groups. As expected, this increase in vehicle ownership is associated with an increase in the share of expenditure on transport and transport fuels out of household's total income. For instance, in the case of Sri Lanka, the share on transport fuels in household's budget increases from 2.94% for the lowest income group to 11.63% for the highest income group (see Table 3).

- The above observations suggest the following lessons concerning non-OECD demand:
- As income reaches a certain threshold, two effects will exert additional demand on liquid fuels. First, oil demand is likely to grow faster than income at low levels of income. Second, a group of new consumers will enter the market for modern fuels including transport fuels;
- The share on expenditure on energy in household's budget tends to rise at early levels of economic

development before declining at later stages of development. This implies that an increase in petroleum products prices will have a bigger impact on demand as there are two effects working in the same direction. Not only is the share of energy expenditure out of household budget increasing, but as oil prices rise, financing this share becomes more costly. Thus, in coming booms, non-OECD demand response to changes in oil prices is expected to be much faster and stronger. In the latest boom, fuel subsidies in many non-OECD economies weakened the price effect on oil consumption and consumer behaviour. Looking into the future however, it is most likely that consuming countries would abolish fuel subsidies. In fact, there is an increasing trend in many developing countries to raise revenues by imposing various forms of fuel taxes.[1] A recent IEA study estimates that between 2010 and 2020, phasing out energy subsidies could lead to a reduction of global oil demand by 6.5 mb/d, predominately in the transport sector[2].

Oil Prices and Economic Growth

The traditional view that dominated the thinking about oil markets was based on the premise that oil price shocks (or, more accurately, sharp increases in prices) adversely

(1) For instance, China introduced in 2009 a tax on oil products while reforming the pricing system so prices of petroleum products better reflect market forces. See Reuters, 'China studying carbon tax ideas: report', May 1, 2009. China also levies a heavy tax on fuel-oil consumption in an attempt to conserve energy use. Bloomberg, 'China to Raise Fuel-Oil Consumption Tax Starting 2009', December 19, 2008

(2) IEA (2010) 'Energy Subsidies: Getting the Prices Right', Office of the Chief Economist , June

affect economic growth and hence oil demand. There is a large theoretical and empirical literature that emphasises this inverse relationship. Proponents of this view assert that the majority of recessions in the OECD were preceded by oil price shocks and that the 2008 financial crisis was no different. [(1)] While this view recognizes that the origins of the 2008 crisis could be attributed to problems in financial markets, the impact of the crisis could not have been so profound if it were not for the high oil prices. Although the channel from oil prices to inflation to counter-inflationary measures is important for the traditional view, it is not the only one. Oil price shocks can induce recessions through different channels as price rises act like a tax that hits household incomes, affects key industries such as the motor industry, affects consumer sentiment and spending, and can make some capital stock redundant.[(2)] As to the argument that oil intensity of GDP has been in decline in OECD during the past two decades, as long as energy intensity is positive, rapid acceleration in oil prices may induce a large price shock. In fact, as can seen from Figure 7, the recent oil price shock measured in terms of GDP has been as large as the 1973 and the 1979 oil price shocks.

This traditional view, however, has been challenged in the upward phase of the cycle. According to the alternative view, oil price shocks are not special: they are just like many other shocks that hit the economy. [(3)] In effect, the impact of an oil price shock is similar to that of an indirect

(1) Hamilton, J.D. (2009) 'Causes and Consequences of the Oil Shock of 2007-2008', NBER Working Paper 15002, May.
(2) Idem.
(3) Segal, P. (2007) 'Why Do Oil Shocks No Longer Shock?', OIES WPM 35.

tax. It involves a transfer of income from importers to exporters and by doing so it lowers real disposable income and real consumption, generating a deflationary effect in oil importing countries. The ultimate impact of oil price shocks on the global economy, however, would depend on how oil exporters use the oil revenues and whether these revenues are being saved or spent. Furthermore, since oil price shocks have a deflationary effect, fiscal and monetary authorities can engage in offsetting policy responses. For instance, if there is no change in inflationary expectations, monetary policy can lower interest rates to counteract the impact of an oil price shock.

In fact, one of the most interesting features of the recent oil boom is the limited impact it has had on inflationary expectations. Compared to previous oil shocks, the impact of the oil price rise on the consumer price index in OECD has been muted this time. While the increase in the oil price generated first-round effects and led to immediate rise in consumer price inflation, the second-round effects on wage inflation have been muted (See Figure 8). In other words, oil price rises did not generate wage inflationary expectations, especially in OECD countries. This has been attributed to the decline in power of trade unions in OECD, a bigger pool of labour supply as India and China have become more integrated into the global economy, and the wide adoption of inflation targeting by central banks, which helped stabilise inflation expectations. Regardless of the causes, the absence of wage-inflation meant that monetary authorities did not have to pursue a contractionary monetary policy to combat inflation caused by higher food and energy prices.

The main implications of the view that oil price shocks are not special are two:

- The global economy can continue to grow even with persistent sharp rises in oil price. Alternatively, oil prices have to rise to very high levels before they induce recessionary pressures or a slowdown in economic growth. During the boom, this belief was reinforced by many international organisations and financial institutions that were predicting high growth rates and associated robust growth in global oil demand despite the sharp rise in oil prices;
- The perception that rises in oil prices have limited impact on growth affected the expectations of key market players as it increased uncertainty about the timing and the size of an important feedback that could have placed a limit on oil price rises. This change in expectations had far-reaching implications for the behaviour of oil prices during the upward phase of the 2002-2009 cycle.

It is premature to argue that the links from oil prices to economic growth have weakened to such an extent that the market could ignore this feedback mechanism in the medium to the long term. High oil prices would eventually have an impact on growth and consequently on global oil demand. There is, however, uncertainty about the time lags and about the level of oil price that should be reached before one would see a meaningful response from global economic growth. In other words, there is a large uncertainty as to how high the price of oil could rise before it endangers the growth prospects of the global economy.

Oil Price Volatility and Economic Growth

Rather than focusing on oil price shocks, another trend in the literature emphasises the impact of oil price volatility (or more precisely price swings) on economic growth. Specifically, by increasing the degree of uncertainty, sharp price movements increase the option to wait and thus can lead to postponement of investment and consumption decisions, with negative implications on output and economic growth.[(1)] Some empirical evidence provides support for this hypothesis. Guo and Kliesen (2005) find that that over the period 1984-2004 oil-price volatility had a significant and adverse effect on various key measures of the U.S. macroeconomy – such as fixed investment, consumption, employment, and the unemployment rate – concluding that an increase in the price of crude oil generally matters less than increased uncertainty about the future direction of prices[(2)].

However, the impact of volatility on oil demand is not always clear. Soest et al. (2000) find that uncertainity about future energy prices renders investments in more energy-

(1) Pindyck, R. (1991) ‘Irreversibility, Uncertainty, and Investment’, Journal of Economic Literature, 29(3), pp. 110-48.

(2) Guo, Hui and Kliesen, Kevin L. (2005) ‘Oil Price Volatility and U.S. Macroeconomic Activity’, Federal Reserve Bank of St. Louis Review, November/December 2005, 87(6), pp. 669–83.

efficient capital goods more sluggish.[1] Specifically, they find that volatility shocks influence future expectation of volatility and thus higher energy price uncertainty today increases the likelihood that energy price reversals will occur in the future. This would induce firms to postpone the adoption of new more energy-efficient capital goods, including vehicles[2].

Recessions, Step-Down in GDP and Oil Demand

The events of 2008-2009 revealed quite clearly that shocks external to the oil market can have a long-lasting impact on oil demand in particular. Regardless of its shape, recessions often involve a 'step down' in GDP or output loss (see Figure 9). The size of the step-down or the level effect of the recession can prove to be substantial. The loss in output occurs through various channels. For instance, financial crises may reduce the participation rate in the labour force by discouraging jobseekers and prompting employed workers to leave the labour force. Crises can also lead to an increase in the underlying structural unemployment rate. Finally, financial crisis may depress investment and cause a slowdown in capital accumulation, especially if credit market conditions tighten and access to credit becomes more restricted and costly[3].

(1) Soest, D.P. van, G.H. Kuper and J.P.A.M. Jacobs (2000) 'Threshold Effects of Energy Price Changes', Research Report, No. 00C31, Graduate School/Research Institute Systems, Organisations and Management, University of Groningen,

(2) It is important to stress that the impact of volatility on demand should not be discussed in isolation of its impact on supply. Oil price volatility by increasing uncertainty undermines investment in the oil sector and in alternative energy sources which in turn reinforces further volatility.

(3) IMF (2009) World Economic Outlook (WEO), 'Sustaining the Recovery', October.

Based on the history of previous financial crises, the IMF finds that the path of output tends to be substantially and persistently lower following banking crises. On average, the IMF finds that there is no rebound to the pre-crisis trend over the medium term. On the positive side though, the IMF finds that for most economies, growth returns to its pre-crisis rate. [1]

Since oil demand is linked to GDP, financial crisis can also result in a step-down in oil demand. As a result of the crisis, the level of oil demand would be lower than it would have been under the business-as-usual growth trajectory, and there is no rebound to the pre-crisis trend. In fact, a series of shocks originating from outside the oil market can result in substantial oil demand losses, which may take the oil market a few years to recover.

Oil Demand and Relative Prices of Energy

Relative prices affect the energy mix by substitution at the margin. When the relative price of a certain fuel goes down, its relative share in the fuel mix tends to rise. As seen in Figure 10, the share of oil in the energy mix has been in decline while that of coal continues to rise, making coal the fastest growing source of energy in the last few years. But relative prices of particular fuels can stay low only if the increase in demand can be satisfied by an elastic supply response. This has a number of implications:

- Government policies related to carbon pricing or subsidies, by affecting relative prices, can impact

(1) Idem.

the relative shares of oil in the energy mix;

- In the case of bio-fuels (especially those based on first generation), the supply response is likely to be muted in the long term especially where there are concerns that first-generation bio-fuels can impact the food supply. Thus, while the decrease in relative price of bio-fuels would initially increase demand, its limited supply response will cause the price of bio-fuels to rise eventually. To maintain the competitiveness of bio-fuels, importing governments have to resort to subsidies to increase its attractiveness in the energy mix. In other words, the share of ethanol in the energy mix will ultimately be determined by government policy;
- Although coal and gas are not direct competitors for oil, they can no longer be ignored in the transport sector with the entry of the electric vehicle and compressed natural gas (CNG) cars and the production of gas to liquids (GTL) and coal to liquids (CTL). Unlike ethanol, the supplies of coal and natural gas fuels are much more elastic and an increase in demand for these two energy sources will not necessarily change by much their relative prices in the energy mix, and hence are likely to remain competitive without government support. If a carbon tax is imposed, the relative attractiveness of natural gas in the transport sector will increase while that of coal will decrease (in the absence of CCS).

Technological Innovations and the Transport Sector

Assessing the impact of technological advances and policies on oil demand is not straightforward. The rate at which technological innovations occurs is affected by a wide range of factors including developments in the oil market and government policy. Furthermore, the effect of technological innovations on oil demand is difficult to measure and/or predict. For the foreseeable future, however, it is almost certain that the internal combustion engine will remain the dominant technology in the transport sector. Thus, rather than thinking of a disruptive technology that would transform the transport sector and cause a sudden change or collapse in oil demand over a short period of time, one should think of a series of small innovations originating from variety of sources. The impacts of technological innovations and government policies are likely to be manifested in a number of ways, the most important of which are:

- Encouraging technology advances in the transport sector through research subsidies and other unilateral or multilateral initiatives aimed to promote the efficiency of the transport sector.
- The increasing penetration of hybrids, flex-fuels, plug-in-hybrids, electric vehicles, and CNG cars into the transport sector (See Table 4 for a description of the different light-duty vehicle types). Most of these types of vehicles are currently

relatively uncompetitive without financial support,[1] but technological advances, economies of scale, government support, and relatively high oil prices have the potential to change the picture in the long run.

- Technological advances will not only originate in the developed world. While China has fallen behind in combustion engine technology, it is determined to become a leader in electric vehicle technology, with the objective of creating a world-leading industry. China is pursuing a set of policies to promote the electric vehicle through introducing plans to grant consumers tax credits on their purchase of electric vehicles, offering subsidies to taxi fleets, and encouraging cities to set up electric car charging stations. The Chinese government has also dispersed research subsidies for electric car designs.

- The promotion of the electric vehicle will increasingly become a subject of international coordination. In his latest visit to China, Chinese President Hu Jintao and U.S. President Barack Obama agreed on a far-reaching package of measures to strengthen the two nations' cooperation on clean energy, with special focus on jointly developing and

(1) Each of these technologies has its distinct challenges and thus their penetration in the transport sector is unlikely to progress at the same rate. For instance, the use of natural gas in the transport sector may have many advantages (large availability of gas reserves, its environmental impact) and the technology is well established. But CNG cars are still likely to make limited penetration in the transport sector due to infrastructure issues, size and weight of natural gas tanks, the purchase cost – just to mention few. There is also the issue of duplication of infrastructure costs and whether it is more effective to encourage a transition to one type of technology such as the electric/hybrid car.

> making electric vehicles and other clean cars. The two leaders stressed their countries' strong shared interest in speeding up the deployment of electric vehicles to reduce oil dependence, cut greenhouse gas emissions and promote economic growth. The package of measures include developing a joint U.S.-Chinese Energy Research Centre with initial research priorities on building energy efficiency, clean coal including carbon capture and storage, and clean vehicles. The two parties also launched a China-U.S. Electric Vehicles Initiative which saw the creation of the China-U.S. Electric Vehicle Forum, whose activities will include joint standards development, demonstrations, technical roadmap and public awareness and engagement.

Many observers strongly believe that hybrid cars and electric cars are destined to play a key role in the future. Deutsche Bank for instance predicts that in the U.S., hybrid and electric cars will account for around 25% of new vehicles by 2020 and 8-9% of the vehicles on the road. For China, it predicts that about two-thirds of new light vehicle sales will be highly efficient and half of all light vehicles will be electric or hybrid by 2030.(1) In its reference scenario, the EIA expects the market share of alternative vehicles to increase to 49 percent of new vehicle sales by 2035, rising from the 2008 level of 13 percent.(2) Other studies, on the other hand, point out that there are many limits to the penetration of electric vehicles, including constraints on resources such as

(1) Deutsche Bank (2009) 'The Peak Oil Market: Price Dynamics at the End of the Oil Age', 4 October.
(2) EIA (2010) Annual Energy Outlook 2010, US: Energy Information Administration.

lithium, which is needed for manufacturing batteries(1).

Such predictions are subject to a wide degree of uncertainty as many variables determine the composition of the vehicle fleet. Government policies and technology are only part of a wider set of factors that determine the decision to purchase a certain type of vehicle. Hence, the penetration of these types of vehicles into the transport sector on a large scale is not a foregone conclusion. That being said, it is important to make the following observations:

- The drive for improved fuel efficiency is already set in motion and is likely to continue unabated, driven by technological innovations which would improve the vehicle characteristics and by government policy which favours more efficient, greener and smaller cars;
- Technological innovations are not exogenous and are affected by developments inside and outside the oil market;
- The trend for improved efficiency is unlikely to be reversed by oil price declines. On the other hand, an increase in oil price or its volatility and concerns about the future availability of oil can accelerate the growth in efficiency. In other words, the pace in efficiency growth is asymmetric to price changes;
- The pursuit for improved efficiency will occur both in developed and developing economies, perhaps with greater vigour in the latter, and potential cooperation at the international level in key areas

(1) OPEC (2009) World Oil Outlook, Vienna: OPEC, Box 2.2.

such as advancement of electric car technology will consolidate over time;

- Since most of these electric vehicles will be powered by coal-fired power plants, the entry of electric vehicles on a large scale means an indirect penetration of coal into the transport sector. Similarly, the wide adoption of CNG cars also means an indirect penetration of natural gas into the transport sector. Currently, electric vehicles and CNG vehicles constitute a small share of the electric vehicle fleet. But these are growing very fast (see Figures 7a and 7b) encouraged by government policy and an increase in the relative price of oil in the energy mix;
- Although oil will continue to be the dominant fuel in the transportation sector for years to come, other sources of energy such as coal, gas, and ethanol have started to compete at the margin and hence fuels' relative prices will become more important over time;
- Despite the fact that these technological innovations will only impact oil demand at the margin, these effects are both cumulative and irreversible and hence cannot be ignored in the long term.

How will the above factors affect gasoline demand in the long run? Gasoline demand is a function of three factors: the number of vehicles on the road; the mean of miles travelled per year; and the efficiency of the vehicle fleet.[1] The first two factors exert a positive impact on gasoline demand while the last factor exerts a negative impact on gasoline demand. Understanding the determinants of each of these factors can help us make some predictions regarding the dynamics of oil demand.

Based on the analysis in Section 6, one would expect the rapid growth in developing countries and the associated improvements in income to be associated with a rapid growth of car ownership. This would have a positive impact on gasoline demand. In fact, prices will have a minimal impact on reversing this trend. Existing empirical evidence suggests that gasoline prices do not have a significant impact on car ownership.[2] High gasoline prices affect consumers' choice by encouraging the shift towards smaller and more efficient vehicles and in the number of vehicle miles travelled. There is also another asymmetry which is worth emphasising: vehicle ownership does not decline as fast in response to income falls as it increases in response to income rises.[3]

The relationship between car ownership and oil demand is also non-linear. At the lowest levels of vehicle ownership, fuel use per vehicle is relatively high. This is often explained in terms of the dominance of buses and trucks on the road

(1) Dargay, J. and D. Gately (1997) 'Vehicle ownership to 2015: Implications for energy use and emissions', Energy Policy 25(14-15): 1121–27; Deutsche Bank (2009) 'The Peak Oil Market: Price Dynamics at the End of the Oil Age', 4 October.

(2) See for instance, Johansson, O. and L. Schipper (1997) 'Measuring the Long-Run Fuel Demand of Cars', Journal of Transport Economics and Policy, 31, 3, 277–92; Storchmann, K. (2005) 'Long-Run Gasoline Demand for Passenger Cars: The Role of Income Distribution', Energy Economics, 27, 25–58.

(3) Dargay, J., Gately, D., Sommer, M. (2007) 'Vehicle ownership and income growth, worldwide: 1960-2030', The Energy Journal, Vol. 28 No.4, pp.143-70.

both of which use gasoline intensively. However, as vehicle ownership increases, more cars and other personal vehicles penetrate the vehicle fleet and these tend to use gasoline less intensively, reducing the fuel use per vehicle.[(1)]

The impact of price and income changes will be felt most strongly on the second component: vehicle usage or the number of miles travelled. Evidence from the U.S. shows that in response to higher prices at the pump and declining incomes, motorists adjust their driving habits by making fewer trips and by driving at a slower pace. But evidence also suggests that this demand is recoverable and once prices decline, the number of miles travelled will increase. We expect to see similar effects in developing countries.

In the final analysis, it is the interaction between the growth in the vehicle fleet and the overall efficiency gains which would determine the long-term trend for gasoline demand. In the next decade, the first effect is likely to dominate the latter effect and demand for transport fuels will continue to rise. However, eventually there would be an inflection point beyond which the overall efficiency gains would outweigh the growth in the number of cars. Estimates vary on the timing of the inflection point with some analysts predicting that this will occur as early as in the next decade. For instance, Deutsche Bank predicts the inflection point to happen around 2016-2017 after which 'gasoline demand will be on an inexorable and accelerating decline'[(2)].

Predicting the timing of the inflection point is bound

(1) Idem.
(2) Deutsche Bank (2009) 'The Peak Oil Market: Price Dynamics at the End of the Oil Age', 4 October.

to be subject to large uncertainty, limiting the usefulness of such an exercise. Instead, an understanding of the key factors that lead some observers to predict such timing and how these factors are evolving over time would prove more useful. Interestingly, in most of these predictions, the key variable that determines the timing of the inflection point is government policy.

Government Policies and Oil Demand

Consuming governments have been pursuing a wide range of policies aimed at reducing their oil dependency. These policies are often driven by energy security and climate change concerns though in some instances the two objectives can be conflicting. For instance, promoting the exploitation of heavy oil and the use of the large reserves of coal to produce liquids can enhance the energy security agenda while it poses serious environmental challenges. Policies vary considerably across countries but often fall under the following general categories:

- Measures that promote the development of clean energy technology through a combination of market and financial incentives schemes;
- Policies that promote the development of a more efficient vehicle fleet through regulations, incentives, subsidies, taxation, moral suasion, and/or combination of these instruments;
- Measures aimed at reducing car use by improving the public transportation system and increasing the relative cost of travelling by car through measures such as taxation;

- Policies aimed at reducing the share of oil in the energy mix by developing alternative fuels such as ethanol and natural gas to substitute for petroleum products in the transport sector;
- Policies aimed at changing the relative price of oil in the energy mix through taxation and/or carbon cap and trading systems which place a price on carbon;
- Policies aimed at increasing the Corporate Average Fuel Efficiency Standards.

Climate change and energy security policies, if implemented, will have a significant impact on oil demand. In a recent study, the IEA (2009) estimates that under the Scenario of 450 ppm, oil demand would be capped at 88.5 mb/d compared to current oil output of around 85 mb/d. Most studies that analyse the potential impact of Kyoto Protocol and long-term climate targets on oil markets have concluded that climate policies will cause a decline in exporters' oil revenues though the estimates of the lost revenues vary considerably across studies, depending on the model's structure and its underlying assumptions.[1] This has prompted Saudi Arabia to call for compensation for loss of income as consuming countries turn away from oil towards more renewable sources of energy. The loss in

(1) See for instance, Ghanem, S., Lounnas, R., Rennand, G. (1999) 'The impact of emissions trading on OPEC', OPEC Review 23, 79–112; van Vuuren, D.P., den Elzen, M.G.J., Berk, M.M., Lucas, P., Eickhout, B., Eerens, H., Oostenrijk, R. (2003) 'Regional Costs and Benefits of Alternative post-Kyoto Climate Regimes: Comparison of variants of the multi-stage and per capita convergence regime', Report 728001025, RIVM, Bilthoven, the Netherlands. However, a recent study has suggested that this may not be the case and oil exporters may profit. Since carbon policy will raise the cost of heavy oils and synthetic diesel from coal, gasoline and diesel from conventional oil will the command a higher price, which will benefit oil exporters. See Tobias A. Persson, C. Azar, D. Johansson and K. Lindgren (2007) 'Major oil exporters may profit rather than lose, in a carbon-constrained world', Energy Policy, Vol. 35, 6346–53.

oil income occurs through two main channels: a lower level of global oil consumption and lower oil rents accruing to oil exports due to lower oil prices.

However, it is important to recognise there is much uncertainty as to whether the various policies will be implemented[(1)] and to the potential impact of such policies on long term oil demand. The large sums of government investment in R&D, and financial incentives for alternative forms of energy and reducing dependency on oil are not new on the political agenda. Comparable investment pledges and incentives have been made in the past century with few tangible results. Furthermore, the policies and debates are very much influenced by economic developments and by oil price behaviour. Economic recessions, in combination with low oil prices, might dampen enthusiasm for some expensive alternative energy projects and government tax on carbon while high and volatile oil prices can speed up efforts for alternative energy projects.

That being said, it is important to make the following two points. First, the pressure to restructure the energy mix away from oil will not disappear. Despite potential setbacks on the way, efforts aimed at reducing dependency on oil will continue unabated. Apart from concerns about climate change, the availability of cheap and readily available alternatives such as coal will add pressure to restructure

(1) For instance, despite being approved by the House, the Senators engaged in preparing the climate legislation will propose abandoning cap-and-trade as it 'has become political poison'. See Washington Post, 'Senators to propose abandoning cap-and-trade', February 27, 2010.

the energy mix away from oil in many countries.[1] Second, the effects of policies on oil demand even when widely implemented will not be disruptive to the oil market. The impacts of these policies however are cumulative and most probably irreversible and hence cannot be ignored in the long term.

Implications on Global Oil Demand Projections

While projections of global oil demand by the IEA, EIA, OPEC are similar (varying between 105 mb/d and 108 mb/d by 2030), a recent study by Dargay and Gately[2] projects global oil demand to reach 134 mb/d by 2030, almost 30 mb/d above the international organisations' figures. Such a scenario has very serious implications since as noted by the authors, this 'rapid demand growth is unlikely to be supplied by conventional oil resources', and hence the 'imbalance would have to be rectified by some combination of higher real oil prices, much more rapid and aggressive penetration of alternative technologies for producing liquids, much tighter oil-saving policies and standards adopted by multiple countries, and slower world economic growth' (p.29).[3]

The debate as to whether such projections are realistic or not misses a key point. These projections should only be

(1) For instance, in the U.S. context, coal has some obvious advantages over oil: U.S. coal reserves are vast, and supply far outstrips demand every year, making coal a readily available, cheap, and price-reliable source of energy. Environmental-friendly technology such as CCS may render coal energy a potentially clean source of energy with a cost advantage over oil and gas in the long run, in particular if oil and gas prices remain high. The coal industry is a large provider of jobs in the U.S., and forms an important part of 22 states' economies, thereby holding an extremely strong lobby both at the state level and at the federal level, a framework which the U.S. oil lobby lacks. The latter one has further been weakened by the recent oil price hike, blamed in much of the American public on the greed of the oil companies.

(2) Dargay, J.M. and D. Gately (2010) 'World oil demand's shift toward faster growing and less price-responsive products and regions', Working Paper, New York University.

(3) Idem.

treated as a starting point for further analysis. Their main usefulness lies in that they can help us identify the key variables that are responsible for the large variation in the various projections, and then examine why various studies use very different assumptions about these key variables. It is also useful to examine the evolution of these projections over time. In the past few years, various organisations consistently revised downwards their projections of global oil demand for 2025 and 2030. For instance, between 2004 and 2010, EIA lowered its oil demand projections by more than 23 mb/d for the year 2025 and by more than 14 mb/d for the year 2030 (see Figure 12). This raises the question: What factors can explain this persistent drive towards downward revisions in global oil demand forecasts?

As expected, oil demand projections are highly reliant on the assumptions made about economic growth and the oil price trajectory. To appreciate the sensitivity of the results to the assumptions about economic growth, Figure 13 plots the EIA projections under the high growth, low growth and reference case scenarios made in 2010. As seen from Figure 13, the difference in demand projections between the high growth and low growth scenarios is more than 25 mb/d for the year 2035. Similarly, oil demand projections are sensitive to the assumptions about the oil price trajectory, with the difference in projections between the low oil price and the high oil price scenarios standing at more than 27 mb/d for the year 2035.

However, differences in assumptions about growth rates and oil prices are not the main factors that explain the divergence between the various projections. Even if one assumes similar growth and price trajectories, it is possible to reach very divergent projections about oil demand. The key determining factor that explains the large divergence in projections is the assumption made about income elasticity of oil demand, mainly that in non-OECD or emerging economies. While international organisations such as EIA, IEA and OPEC assume low income elasticity outside the OECD ranging between 0.14 and 0.33, Dargay and Gately (2010) assume a much higher income elasticity of 0.75. This raises a series of key questions: Why do studies make very different assumptions about income elasticity in non-OECD? How does income elasticity evolve over time in these projections? Are the consistent revisions in demand projections in the last few years due to revisions in growth expectations, income elasticity, or both? Most importantly, what are the main factors that are likely to affect the evolution of oil income elasticity over time?

Attempts to answer such and other similar questions will perhaps open fruitful areas for research that will ultimately improve the accuracy in some of these projections. This suggests that one should aim at understanding better the relationship between economic growth and oil demand growth, perhaps by resorting to more detailed studies at the micro level and by using household survey data to gain better understanding of consumer choice in non-OECD economies. It also suggests the importance of analysing how the various factors discussed in this paper affect on the one hand the price and growth expectations and on the other hand the price and income elasticity over time. As discussed in previous sections, many of these relationships are non-linear and subject to threshold effects while most of the projections assume linear relationships.

Conclusions

The above analysis suggests that the evolution of global demand dynamics is affected by a large number of interrelated factors. Expectations that global oil demand will continue on a robust and high-growth trajectory may materialise; but this is not a foregone conclusion. Oil exporters, companies, market analysts should somehow factor into their expectations the possibility of policy reversals, development setbacks, shocks originating from outside the oil market, and they should explore in more detail the role of price and income effects on long-term oil demand which can perhaps produce more balanced views. Unfortunately, this has not been done so far and expectation of robust growth in oil demand, which is essential for the story that market fundamentals will tighten, is accepted uncritically. Stories that China>s and India>s thirst for oil is impossible to quench are now widely believed. Similarly, stories that oil demand might be peaking before supply and that demand in OECD may have already reached its peak are also accepted uncritically. This should come as no surprise because if stories are to have an effect on market psychology they must sensationalise events surrounding oil market dynamics (peak oil supply, peak oil demand, future energy crisis, return to oil shortages, the end of cheap oil, just to mention few examples). While in the past such sensational stories had limited impact on the functioning of the oil market, this is no longer true. As noted by Akerlof and Shiller: 'But what if stories themselves move markets?...The stories no longer merely explain the facts; they are the facts'[1] (p.54).

(1) Akerlof, G.A. and Robert J. Shiller (2009) Animal Spirits: How Human Psychology Drives the Economy, and Why It Matters for Global Capitalism, Princeton University Press.

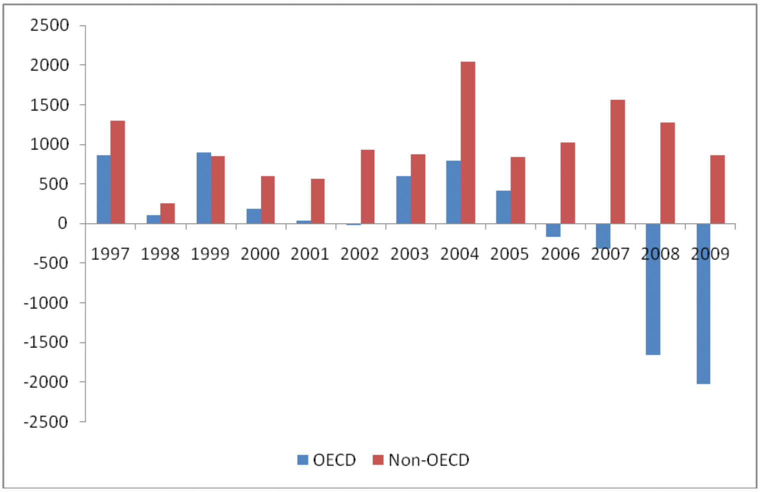

Figure 1: OECD and Non–OECD Oil Demand Dynamics

Source: BP (2010)

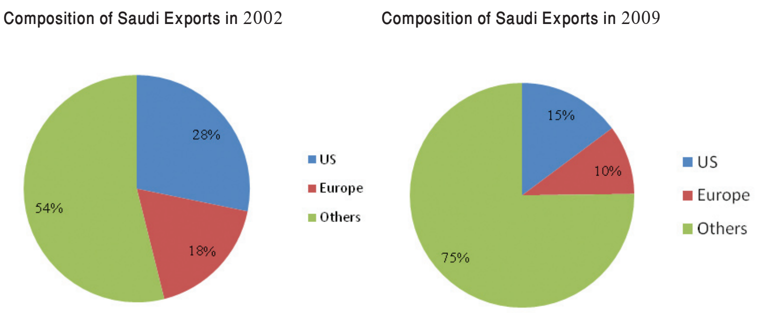

Figure 2: Change in Trade Flow Dynamics

Source: Barclays Capital, Oil Sketches, 23 April 2010

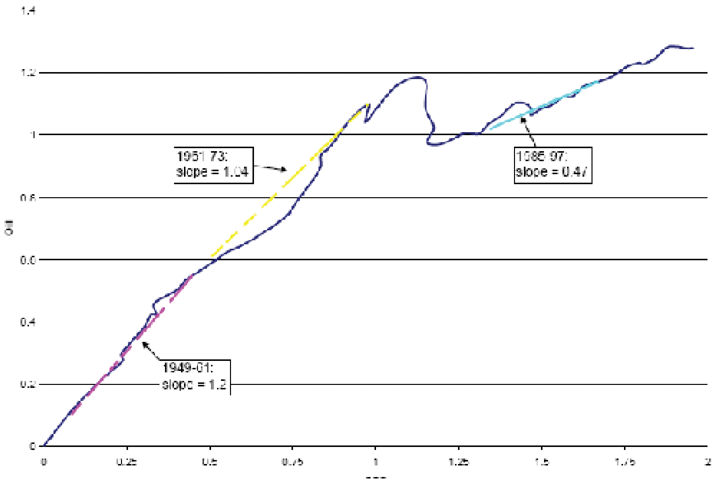

Figure 3: **Changes in U.S. Real GDP and Oil Consumption,** 1949–2006

Source: Hamilton (2008)

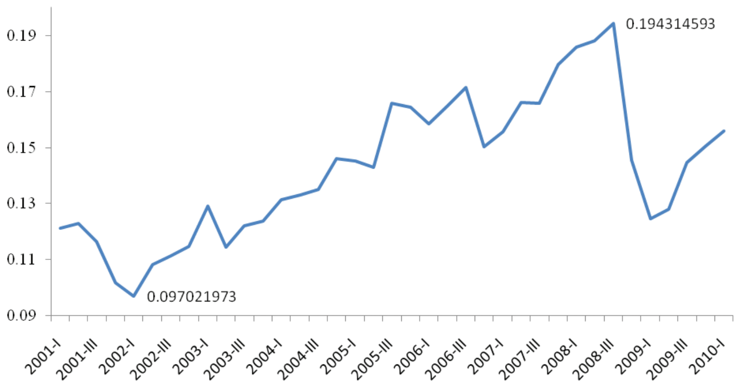

Figure 4: **Ratio of Expenditure on Gasoline and Other Energy Goods out of Total Personal Consumption Expenditure** (**PCE**) **on Non–Durables in the US**

Source: Bureau of Economic Analysis Website

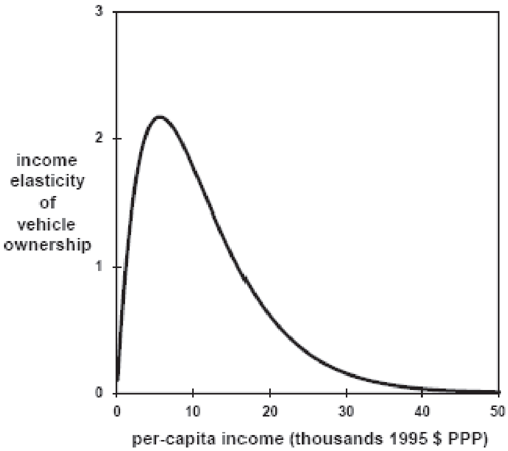

Figure 5: Income Elasticity of Vehicle Ownership and Per Capita Income

Source: Dargay, Gately and Sommer (2007)

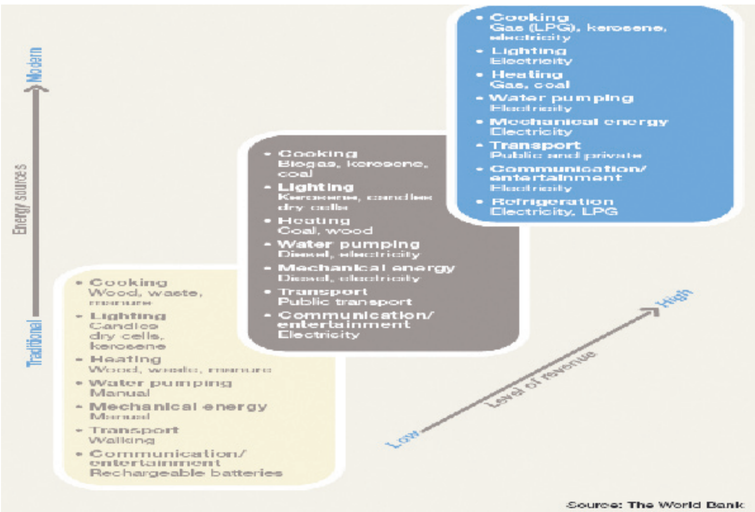

Figure 6: Climbing Up the Energy Ladder

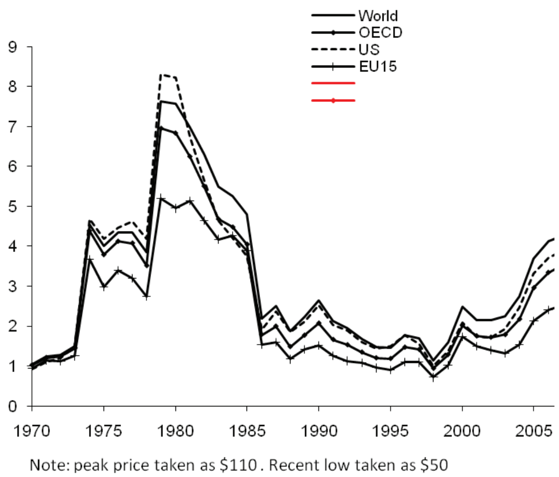

Figure 7: **Petroleum Expenditure as Share of GDP,**

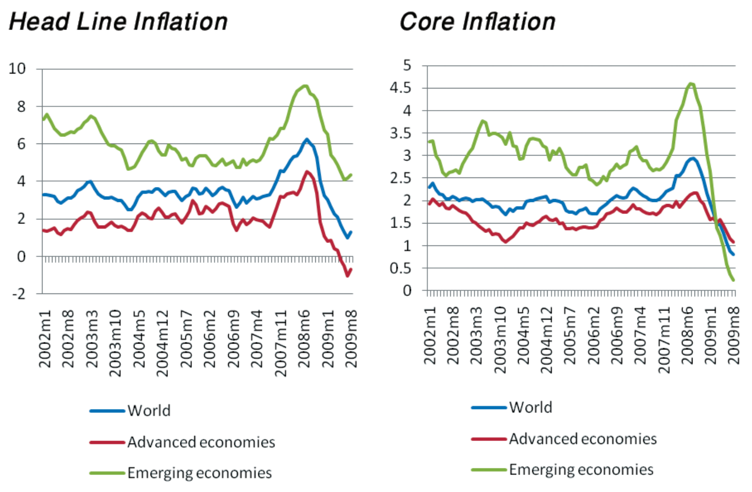

Figure 8: **Global Inflation**

Notes: Twelve-month change of the consumer price index

Source: IMF (2009), World Economic Outlook: Sustaining the Recovery, October

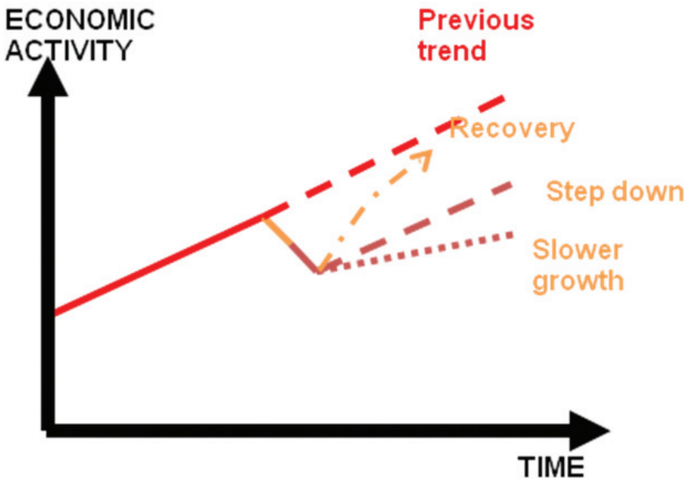

Figure 9: Recessions and Steps Down in Economic Activity and Oil Demand

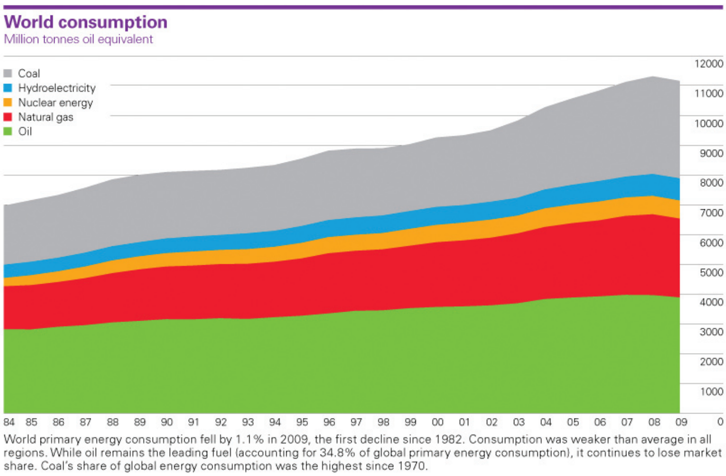

Figure 10: World Primary Energy Consumption by Fuel

Source: BP Statistical Review 2010

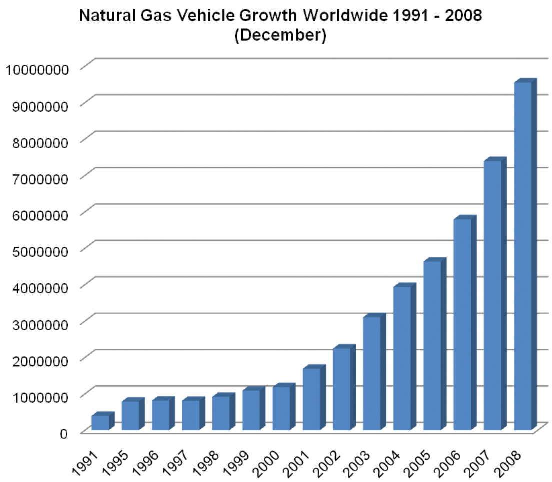

Figure 11a: Growth in Natural Gas Vehicles

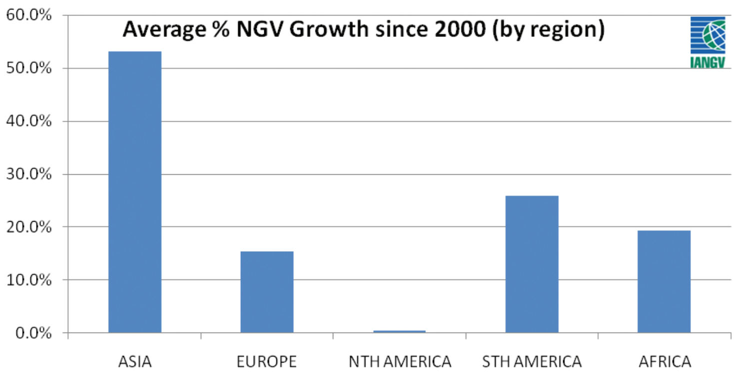

Figure 11b: Growth in Natural Gas Vehicles

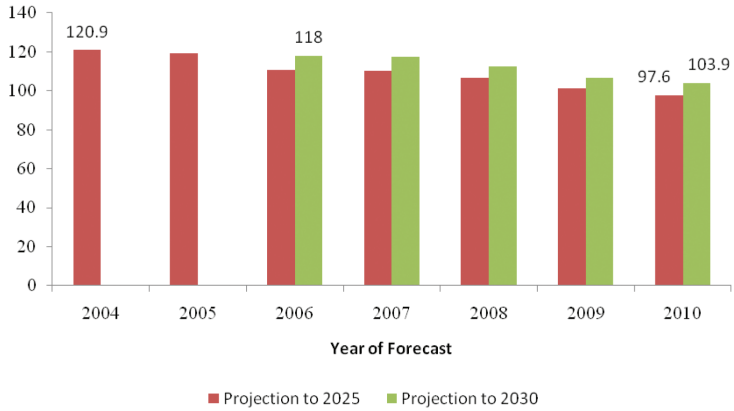

Figure 12: **Revisions in Oil Demand Projections for** 2025 **and** 2030 (**Reference Scenario, mb/d**)

Source: EIA, International Energy Outlook, Various Issues

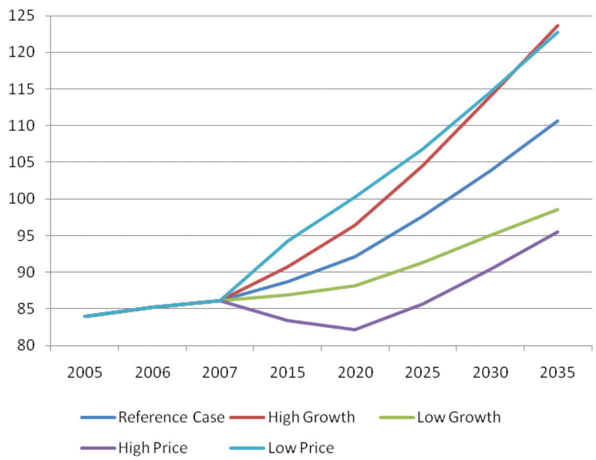

Figure 13: **Projections of Global Oil Demand in Different Scenarios** (**mb/d**)

Source: EIA, International Energy Outlook 2010

Table 1: Durable Consumer Goods per 100 Households (in 2006 or most recent available)

	China		India		
	Urban	Rural	Urban	Rural	Total
Automobiles	4.3	…	4	0.7	1.7
Bicycles	117.6	98.4	51.9	57.2	55.7
Cameras	48	3.7	0	0	0
Computer	47.2	…	0	0	0
Microwave Ovens	50.6	…	…	…	…
Motorcycles	20.4	44.6	28.3	7.9	13.6
Refrigerators	91.8	22.5	30.8	4.8	12.1
Telephones	93.3	64.1	…	…	…
Telephones: mobile	152.9	62.1	…	…	…
Televisions	137.4	89.4	70.4	27.5	39.5
Video Disc Players	70.2	…	8.2	1.7	3.6
Washing Machines	96.8	43	12.5	0.9	4.1

Source: Chamon, M., Mauro, P. and Okawa, Y. (2008)

Table 2: Household Ownership of Vehicles by Decile Group in Sri Lanka (2006–2007)

Decile Group	Bicycles	Motor bicycles/ Scooters	Three-wheelers	Motor cars/ Vans	Buses/ Lorries	No vehicle
Total	41.1	20.2	4.5	5.8	1.6	44.3
First	25	2	0.1	-	-	73.8
Second	34.8	3.6	0.2	0.1	-	63
Third	39.3	7	0.6	-	0.1	57
Fourth	41	12.2	1.2	0.4	0.2	52.2
Fifth	43.2	15.8	3.6	0.8	0.3	45.4
Sixth	46.5	22	4.8	1.4	0.6	40.2
Seventh	46.6	25.8	7.7	3.3	1.1	36.5
Eighth	45	33.6	7.7	5.7	1.9	31.7
Ninth	46.7	39.6	9.9	11.7	3.3	25.2
Tenth	42.9	40.5	9.4	34.4	8.3	18.2

Source: Household Income and Expenditure Survey - 2006/07

Department of Census and Statistics

Table 3: Expenditure Share on Transport by Income Group in Sri Lanka

(2006–2007)

Income Group	Expenditure Share
First	2.94%
Second	3.52%
Third	3.93%
Fourth	4.56%
Fifth	5.33%
Sixth	5.82%
Seventh	6.57%
Eighth	7.57%
Ninth	9.02%
Tenth	11.63%

Source: See Table 1

Table 4. Alternative Light–Duty Vehicle Types

Alternative Vehicle Type	Description
Flex-fuel	Vehicles that run on gasoline or any gasoline-ethanol blend up to 85 percent ethanol.
Mild Hybrid	Vehicles that use a gasoline engine with a larger battery and electrically powered auxiliary systems that allow the engine to be turned off when the vehicle is coasting or idle and then be quickly restarted. These vehicles are recharged using regenerative braking but do not provide electric traction to support motive power to the vehicle.
Hybrid Gasoline/ Diesel Electric	Vehicles that combine a mixture of internal combustion and electric propulsion but have an extremely limited all-electric range and batteries that cannot be recharged using grid power.
Plug-in Hybrid Electric	Vehicles that use battery power to drive the vehicle for some distance until a minimum level of battery power is reached, at which point the vehicle operates on a mixture of battery and internal combustion power. Plug-in hybrids can also be engineered to run in a blended mode of operation, where an onboard computer determines the most efficient use of battery and internal combustion power. The batteries can also be recharged from the grid by plugging a power cord into an electrical outlet.
Gaseous	Vehicles powered by compressed natural gas or liquefied petroleum gas exclusively or as a bi-fuel vehicle with gasoline.
Electric	Vehicles that operate by electric propulsion from batteries that use regenerative braking and are recharged exclusively using grid power.
Fuel Cell	Vehicles that use a fuel cell stack to convert a fuel such as hydrogen to electricity to drive the vehicle.

Source: EIA, ‘This Week in Petroleum’, March 3, 2010.