The pass through of oil prices into consumer liquid fuel prices in an environment of high and volatile oil prices[1]

Aidan Meyler, European Central Bank (Draft 25 May 2009)

JEL Codes: C22, C52, D40, E31, Q43; Energy, Prices, Macroeconomy

***Abstract**: Crude and refined oil prices have been relatively high and volatile on a sustained basis since 1999. This paper considers the pass through of oil prices into consumer liquid (i.e. petrol, diesel and heating) fuel prices in such an environment.*

The pass through of oil prices into consumer liquid fuel prices has already been addressed extensively in the literature. Nonetheless much of this literature has either focused on the United States or on a time period when oil prices where relatively stable, or has used monthly data. The main contribution of this paper is a comprehensive combination of many features that have been considered before but rarely jointly. These features include: (1) the analysis of the euro area as an aggregate and a large number of countries (the initial 12 member states); (2) the consideration of different time periods; (3) the modelling of the data in raw levels rather than in log levels. This turns out to have important implications for our findings; (4) the use of high frequency (weekly) data, which, as results will suggest, are the lowest frequency one should consider; (5) the investigation of the different stages of the production chain from crude oil prices to retail distribution – refining costs and margins, distribution and retailing costs and margins; (6) the examination of prices including and excluding taxes – excise and value-added; (7) the modelling of prices for three fuel types - passenger car petrol and diesel separately and home heating fuel oil; (8) lastly we also address the issue of possible asymmetries, allowing for the pass through to vary according to (a) whether price are increasing or decreasing and (b) whether price levels are above or below their equilibrium level.

The main findings are as follows: First, as distribution and retailing costs and margins have been broadly stable on average, the modelling of the relationship between consumer prices excluding taxes and upstream prices in raw levels rather than in logarithms has important implications for the stability of estimates of pass through when oil price levels rise significantly. Second, considering spot prices for refined prices improves significantly the fit of the estimated models relative to using crude oil prices. It also results in more economically meaningful results concerning the extent of pass through. Third, oil price pass through occurs quickly, with 90% occurring within three to five weeks. Fourth, using a relatively broad specification allowing for asymmetry in the pass through from upstream to downstream prices, there is little evidence of statistically significant asymmetries. Furthermore, even where asymmetry is found to be statistically significant, it is generally not economically significant. Lastly, these results generally hold across most euro area countries with few exceptions.

[1] The author has benefited from useful comments and assistance from Nicholai Benalal, Mariagnese Branchi, Ana Lima, Claudia Marchini, Jose Marin Arcas, Julian Morgan, Silvia Scopel and participants at internal ECB seminars. Useful comments have also been received from anonymous referees. Remaining errors and omissions are the responsibility of the author.

1. Introduction and background

Crude oil prices, having remained relatively stable, on average, between 1986 and 1998 – with the exception of a few months in 1990 during the First Gulf War – at a level between 15-20 US dollars per barrel, have, since 1999, increased significantly both in terms of average levels as well as in terms of volatility. The reasons behind these increases have been much discussed elsewhere (see, for example, Dees et al, 2008b and 2008a) and are not the focus of this paper. Rather, it is focused on their impact on consumer liquid fuel prices.

The impact of oil prices on the economy is multi-faceted. Oil, and refined oil products, are used in a widespread way - both as a final consumption good and as an input into the production process. In terms of price effects, the impact is often broken down into direct- and indirect-first-round and second-round effects.[2] The direct effects refer to the impact of changes in oil prices on consumer liquid fuel of 'oil energy' prices.[3] The indirect effects refer to the impact of changes on consumer prices that occur as oil prices impact on producer costs and prices.[4] So-called second round effects arise should oil price changes impact on wages specifically and inflation expectations and price setting more generally. Oil prices may also impact on the real side of the economy via purchasing power and terms of trade effects, etc.

Although, understanding the totality of these impacts is important for monetary policy makers, in this paper the focus is exclusively on the pass through of crude oil prices into consumer liquid fuel prices, i.e. the direct first round effect.[5] There are several reasons for this focus. First, this effect is often the most important, and generally, the most immediate one on consumer prices. For example, between 1999 and 2007, the annual rate of change in the overall euro area HICP was 2.1%, whereas excluding energy it was 1.8% - a cumulative difference of 2.5 percentage points.[6] Second, the overall impact of an oil price shock on the economy depends crucially on the characteristics of the shock, i.e. whether it is a supply or demand side shock and whether it is permanent or temporary. While these factors may also impact on the direct effect to some extent, they are less likely to have a significant impact. Lastly, as far as we are aware, an in-depth study of the direct effects of oil prices on consumer energy prices has not been carried out at the euro area level.[7] Given the launch of

---

2 This taxonomy of the breakdown of the pass through of oil prices into different effects is drawn from ECB (2004). Oil prices may also impact on prices via other channels, such as activity, trade, financial market developments, etc. However, it should be noted that the terminology is not uniform in the literature. For example, RBNZ (2005) refer to the impact of oil prices via the impact on activity as a third-round effect. Esteves and Neves (2004) refer to terms of trade effects, whilst, Bernanke (2006) includes indirect effects as part of second-round effects.

3 The direct effects is also sometimes used to encompass the impact on consumer 'non-oil energy' prices, such as electricity and gas, although this impact is usually indirect and more lagged than the impact on consumer 'oil energy' prices.

4 Examples of indirect effects include: goods which may include an oil-based input such as some chemical goods; transport services such as aviation which have a significant oil input; and the impact on the cost of selling goods owing to higher distribution costs.

5 Chen (2009) provides a recent update of the estimated overall impact on inflation from oil price pass-through.

6 HICP denotes Harmonised Index of Consumer Prices and is the official consumer price index for the euro area.

7 Arpa et al (2006), while presenting some analysis similar to parts of this paper for the EU-25 countries, in general however, do not report results for the euro area aggregation. Furthermore, their

Economic and Monetary Union (EMU), which has brought greater price transparency, it is possible that the behaviour of consumer energy prices in the euro has become more affected by features such as ‘fuel tourism’.[8]

In this paper we are primarily interested in the monitoring and understanding of short-term developments in consumer liquid fuel prices and not the overall, possibly joint, price determination of oil products. In this regard, the relationship between crude and refined oil prices is not of interest per se, as we observe both simultaneously in real time. Also, the wedge between prices including and excluding taxes is not modelled explicitly as it is largely determined by government policy. While these issues may be of substantial interest in other contexts, here we focus on the behaviour of the distribution and retailing costs and margins.

We hope to answer a number of interrelated questions concerning the direct oil price pass through. First, what is the amount and speed of pass through? Second, has it changed as a result of higher and more volatile oil prices and refining margins? Third, is there any asymmetry between oil price increases and decreases? Lastly, are there any significant differences across euro area countries?

The pass through of oil prices into consumer liquid fuel prices has already been addressed extensively in the literature. Nonetheless much of this literature has either focused on the United States or on a time period when oil prices where relatively stable, or has used monthly data. The main contribution of this paper is a comprehensive combination of many features that have been considered before but rarely jointly. These features include: (1) the analysis of the euro area as an aggregate and a large number of countries (the initial 12 member states); (2) the consideration of different time periods, since 1994, both when oil prices and refining margins were relatively stable and the period since 2000 up to 2008 when oil prices have been higher and more volatile on average; (3) the modelling of the data in raw levels rather than in log levels. This turns out to have important implications for our findings; (4) the use of high frequency (weekly) data, which, as results will suggest, are the lowest frequency one should consider; (5) the investigation of the different stages of the production chain from crude oil prices to retail distribution – refining costs and margins, distribution and retailing costs and margins, and the tax wedge; (6) the examination of prices including and excluding taxes – excise and value-added; (7) the modelling of prices for three fuel types - passenger car petrol and diesel separately and home heating fuel oil; (8) lastly we also address the issue of possible asymmetries, allowing for the pass through to vary according to (a) whether price are increasing or decreasing and (b) whether price levels are above or below their ‘equilibrium’ level.[9]

The main findings are as follows: First, as combined distribution and retailing costs and margins have been broadly stable on average, the modelling of the relationship

---

paper differs in other respects. For example, they do not consider the impact of refining margins nor do they model the data in raw levels but rather use logarithmic transformations.

8 For a discussion and empirical examination of the concept of ‘fuel tourism’, see, for example, Banfi et al (2005)

9 Galeotti et al (2003) report evidence in favour of asymmetries in exchange rate pass through. Although Geweke (2004, pg. 15) concludes in his review of the literature that they find “*little evidence of asymmetry*”

between consumer prices excluding taxes and upstream prices in raw levels rather than in logarithms has important implications for estimates of pass through when oil price levels rise significantly. More specifically, when the relationship is modelled in logarithmic form the estimated pass-through coefficients are not stable over the sample period and hence are biased when estimated over the entire sample period. Second, considering spot prices for refined prices improves significantly the fit of the estimated models relative to using crude oil prices. It also results in more economically meaningful results concerning the extent of pass through. Third, oil price pass through occurs quickly, with 90% occurring within three to five weeks. Fourth, using a relatively broad specification allowing for asymmetry in the pass through from upstream to downstream prices, we find little evidence of statistically significant asymmetries. Furthermore, even where asymmetry is found to be statistically significant, it is generally not economically significant. Lastly, these results generally hold across most euro area countries with few exceptions.

The layout of this paper is as follows. First we provide a brief overview of oil price developments since the 1980s. Second, we consider how energy prices enter into consumers' price baskets. Third, we present a brief stylised overview of the liquid fuel pricing chain. Fourth, we estimate the pass through of oil prices in to consumer liquid fuel prices, using weekly price data available from the European Commission's weekly Oil Bulletin. Fifth, we explore two extensions to our basic analysis, allowing for changes in pass through over time and asymmetries in pass through. Finally we conclude by providing an overview of the main findings and possible avenues for future work.

2. Overview of oil price developments since the mid-1980s

The oil price shocks of the 1970s ended decades of relatively stable oil prices and led to efforts at energy saving and energy product substitution, which, combined with a global recession in the early 1980s and depressed demand for oil put downward pressure on oil prices. Between 1986 and 1997 crude oil prices remained relatively stable with the noticeable exception of 1990 during the first Iraq conflict (see Figure 1a). However, since 2000 oil prices became more volatile and also tended to increase on average.

{Insert Figures 1a and 1b around here}

Another noticeable feature of more recent oil price developments, particularly since 2000, is the increased level and volatility of refining (costs and) margins for transforming crude oil into refined gasoline, diesel and gas oil (see Figure 1b).[10] The increase in crude prices and in refining margins largely reflects tight and relatively unresponsive supply conditions, with long lead times required to bring new

[10] Hereafter we use the term refining margins to denote refining costs and margins. Refining margins are calculated as the difference between the value of refined products and the cost of the crude oil used to make the products. These are also referred to as 'crack spreads' in the industry terminology. The crack spread is a function not only of the refined product made but also of the type of crude oil input. For instance, so-called 'heavy oil' is more difficult to refine into lighter products such as gasoline. 'Light sweet crude oil' is particularly suited to the production of gasoline, kerosene, and high-quality diesel. Brent is a light crude oil, though not as light or as sweet as, for example, West Texas Intermediate (WTI) oil. See Hagstromer and Wlazlowski (2007) for an overview of different crude oil types. They find that, despite declining importance, Europe Brent (along with West Texas Intermediate) is still a benchmark series in terms of setting prices for other crude oil products.

production or refining capacity on stream. It should also be noted that the direction of causality between crude and refined oil prices is not clear a priori and may depend on the market conditions. Indeed it has been argued by some that movements in refined oil prices (owing to tightness in that market) may have caused movements in crude oil prices rather than being the other way around. For example, Dees et al, 2008b consider the role of utilisation rates of refining capacity on crude oil price developments. They find that *"the refining sector plays an important role in the recent price increase, but not in the way described by most analysts. The relationship is negative such that higher refinery utilization rates reduce crude oil prices."* (pg. 6).

Between the late-1980s and 1999, refining margins (measured as the difference between refined oil prices in Rotterdam and the Brent crude oil price) were relatively stable at around 4 US dollar per barrel on average. However, since 2000, they have become more volatile and have increased on average – a feature which has been accentuated since 2005. The range between the lowest and highest gasoline (petrol) refining margins since 2005 was around 40 US dollars, which represents approximately three-quarters of the average crude oil price level observed over the same period. Similarly, refining margins for gas oil (diesel and home heating fuel oil) have also increased since 2005. Comparing margins, those for refining gasoline have tended to be more volatile but without a clear shift in levels, where those for gas oil show more persistence at higher levels. The higher level of the latter may reflect to some extent different price developments for different grades of crude oil (sweet/sour, light/heavy, etc.) but may also reflect capacity constraints for refining gas oil and the slow response of refining supply in light of what has been described as the 'dieselisation of Europe'.[11] An additional factor in the increase may be the need to move to fuel oil with lower sulphur content. However, it should be noted that refining margins for gas oil started to decline substantially in the fourth quarter of 2008, and declined to around 5 US dollars per barrel in the first quarter of 2009.

Table 1 illustrates numerically the increased average level and volatility of crude oil prices and of refining margins since 1994 as well as for some sub-periods. Crude oil prices averaged 29.6 euro per barrel between 1994 and 2008. However, this conceals considerable variation over the sample period - 14.6 euro between 1994 and 1999, and 53.5 euro between 2005 and 2008. Similarly, the volatility, as measured by the standard deviation of monthly changes, also rose from 1.2 to 5.1 across the two sub-periods. A similar pattern of increased mean and volatility is observed for refining margins for both gasoline and gas oil.

{Insert Table 1 around here}

We report developments since 1994 as this coincides with the start of our data availability for consumer prices which are used later in the analysis. For similar reasons of comparability we also report values in euro terms. The sub-periods (1994-

[11] See for example the Platts.com news feature 'the dieselization of Europe' - www.platts.com/Oil/Resources/News%20Features/eurodiesel/index.xml. See also EIA - www.eia.doe.gov/pub/oil_gas/petroleum/presentations/2006/ethanol/ethanol0806.ppt - "*The 'dieselization' of Europe is a phrase relating to changes in Europe's transportation sector. Europe has large incentives to purchase diesel-fuelled light-duty vehicles and use diesel fuel rather than gasoline. The resulting shift in new light duty vehicle sales has increased demand for diesel fuel in Europe, and decreased demand for gasoline as the share of gasoline versus diesel-fuelled light duty vehicles shifts.*"

1999, 2000-2004 and 2005-2008) were chosen primarily on the basis of the graphical evidence. However, tests for changes in the mean, using the Andrews-Ploberger structural break test, indicate the likelihood of structural breaks around these points.[12] For crude oil prices breaks in the mean were indicated for 1999Q4 and 2005Q1. For gasoline refining margins breaks in the mean were indicated for 2000Q1 and 2004Q1, were as for gas oil refining margins breaks were indicated for 2000Q3 and 2004Q3. Thus, these tests broadly support the selection of sub-periods used. Nonetheless, we return to this issue of possible structural breaks in more detail when considering our empirical analysis of the relationship between consumer prices and upstream prices.

Given that the focus of macroeconomic analysts and forecasters has tended to be on crude oil prices[13], this paper investigates whether accounting for movements in refining margins increases our ability to understand short-term consumer energy price developments.

3. Overview of consumer energy prices

Private consumption of energy accounts for approximately 10% of consumers' total expenditure (based on HICP weights). Furthermore, consumer energy prices are by far the most volatile component of the HICP. Since 1996 they have had a standard deviation of 1.4 per cent per month on average. This is significantly larger than that for other components, particularly when one considers seasonally adjusted data.[14] The corresponding figure (standard deviation) for the seasonally adjusted HICP excluding energy was 0.1 per cent per month. Hence, an understanding of the short-term movement in energy prices should facilitate a better analysis of overall inflation.

For the purposes of this paper we distinguish between (liquid fuel) or 'oil energy' prices and 'non-oil energy' prices. The former refer to prices of fuels for personal transport equipment (mainly petrol and diesel) and of liquid fuels for home heating and account for slightly over half (54%) of consumers' energy expenditure. The latter refer to prices of electricity, gas, solid fuels and heat energy. The main reason for this distinction is, as will be shown later, that 'oil energy' prices respond almost immediately to movements in oil prices; whereas 'non-oil energy' prices tend to respond with some lag.[15] Furthermore, high frequency (weekly) and very timely data are available consumer prices for the main 'oil energy' components (petrol, diesel and

---

[12] The tests were carried out using the APBreakTest procedure in WinRATS. The procedure was run over the entire sample period (1994-2008) as well as over sub-samples where structural breaks were indicated.

[13] See, for example, Chauvin and Devulder (2008) who present inflation forecasting models for the euro area. The use of crude oil prices mainly reflects the fact that the futures market for crude oil is much more liquid than for refined oil products. Furthermore, until recent years variations in the refining margin were not as volatile and were largely mean-reverting.

[14] The European Central Bank seasonally adjusts four of the five the main HICP special aggregates (unprocessed food, processed food, non-energy industrial goods and services) but not energy. This is because no stable and statistically significant seasonal pattern has been identified. These data are made available on its webpage – www.ecb.europa.eu.

[15] Of the non-oil energy sub-components, gas, solid fuels and heat energy price developments all have a clear correlation with oil prices, although the lags of peak correlation are somewhat long and variable at around ten months. Electricity prices appear to have less correlation with oil prices, which perhaps might be explained by differing types of inputs used to generate electricity (water, nuclear, etc.) as well as by administrative price controls and by the impact of deregulation in the European electricity industry.

heating oil). This enables us to consider the high frequency and very short-term pass through of oil prices into consumer liquid fuel prices.

In this paper we use primarily data from the European Commission's weekly Oil Bulletin rather than from Eurostat's HICP. The weekly Oil Bulletin (WOB hereafter) is a weekly product compiled by the European Commission (DG Energy and Transport), which reports actual consumer prices of petroleum products including (and excluding) duties and taxes from all European countries. Prices for three types of product are available: two for automobiles (petrol – Euro Super 95 – and diesel) and one for home heating (heating fuel oil).[16]

The WOB and HICP each have their relative advantages and disadvantages for considering oil price pass through. The detailed, high-frequency and timely nature of the WOB makes it superior for analysing the very short-term pass through of oil prices into consumer energy prices. It is also very timely, generally being available within 3 days of the reference period. Thus, data collected on the Monday are generally available by the Thursday. On the other hand, the higher statistical quality of the HICP and the fact that it is the representative inflation statistic in the European Union make it important. Fortunately, there is a strong and consistent relationship between the two data sources both for home heating and for transport oil – the correlation between monthly rates of change between the two data sources is 0.99.[17] In addition, the evolution of petrol and diesel prices has been somewhat different since 2000.[18] Hence, the additional breakdown in the WOB between petrol and diesel prices may be informative.

[16] Only 'oil energy' prices are available, i.e. other 'non-oil energy' sub-components - electricity, gas, solid fuels or heat energy - which account for slightly less than 50% of overall HICP energy, are not incorporated. However, these are substantially less volatile than the 'oil' energy components – the monthly standard deviation of 'non-oil energy' price changes since 1996 has averaged 0.6 percentage points, compared to 2.3 percentage points for car fuel and 4.7 percentage points for heating fuel.

[17] Mapping from the weekly data of the WOB to the monthly data of the HICP is not straightforward as, until recently (January 2008) countries often collected their HICP data over different time periods both in terms of the number of days over which prices are collected and in terms of the time of the month when prices are collected. Furthermore, the timing of collection of oil (and fresh fruit and vegetables) prices may vary from the collection of other HICP components. For example, for the Italian HICP data used to be collected from the middle of the previous month until the middle of the reference month, although oil data were only collected on the 1st and 15th of the month. Irish HICP data (both oil and non-oil) used to be collected on the second Tuesday of every month. Spain used to collect oil prices over the entire month, whilst other items are only collected up until around the 20th of the month. For the majority of countries the centre of the price collection period is between the 10th and the 15th of the month, i.e. on average slightly before the middle of the month. The author is grateful to Mariagnese Branchi (DG-Statistics, ECB) for this information.

[18] Furthermore, the share of diesel cars both in terms of new passenger car registrations and in the total stock of registered passenger cars has increased significantly over the last two decades. At the beginning of the 1990s, diesel cars accounted for approximately 15% of new passenger car registrations and the stock of passenger cars. Already since 2004, according to the European Automobile Manufacturers Association (ACEA), diesel cars accounted for over 50% of new registrations, although their share of the stock of passenger cars is somewhat lower at around one-third. The lagged nature of the share of diesel cars in the total stock relative to their share in new passenger car registrations reflects the fact that the average age of the European car fleet is about eight years. Ultimately the percentage of the stock of cars that are diesel powered may be expected to increase further over the coming years.

4. Stylised representation of the oil price chain

Figure 2 presents a stylised representation of the liquid fuel pricing chain from crude oil prices to final consumer prices. We breakdown the pricing chain into three stages:[19] (1) refining costs and margins, (2) distribution and retail costs and margins, and (3) taxes. We use the terms 'upstream' to refer to those prices at an earlier stage of the chain (e.g. crude oil prices) and 'downstream' to refer to prices at a later stage of the chain (e.g. consumer prices).

{Insert Figure 2 around here}

It should be borne in mind that this representation, which is driven to a large extent by data availability, is a stylised one. For example, in some cases the entire pricing chain may be under the control of one company that integrates exploration and production, refining, and transport and marketing activities.[20] However, Asplund et al (2000, pg. 104), who consider in detail the price adjustments by an individual gasoline retail chain, report that "*even those (companies) who operate their own refineries claim to use it as the transfer price between the producing and the selling divisions*".

In between crude oil prices and consumer prices excluding taxes, there are two important 'stages': (1) refining and (2) distribution and retail.

Refining of crude oil is necessary as crude oil in itself is generally not directly usable when it is extracted. Oil energy products used by consumers (gasoline, diesel and heating fuel) must first be refined. The refining processes vary according to the refined product required – gasoline, gas oil, etc. (including its exact specification, e.g. in terms of sulphur content) – and the type of crude oil used as an input. In addition to variations in refining costs (e.g. arising from crude oil input, the cost of switching from one product or specification to another, etc.), refining margins may vary for a number of reasons linked to variations in both supply of and demand for various refined products. For example, as shown in Figure 1b above, refining margins for gas oil have increased considerably on average since 2005. This has been attributed in part to increased demand for diesel products and a limited response in supply capacity. Unfortunately we are not able to observe directly refining costs. Therefore we must consider refining costs and margins jointly. It should be noted, in any case, that the focus of this paper is the understanding of the short-term behaviour of consumer energy prices using information available in real time. As both crude and refined oil prices are available almost instantaneously, we do not attempt to model the relationship between the two. Rather we focus on understanding the relative information content of each for explaining consumer prices, in terms of whether one is superior to the other or they are complementary.

The distribution and retail stage refers to all activities between the refining and the final sale of the product. In some cases this may be integrated within one company, in

[19] Of course the actual pricing chain may involve more steps and agents. For a more detailed discussion, see for example, EIA (2007 and 2006) and Burdette and Zyren (2003 and 2002) who provide an informative and useful overview of the factors determining gasoline and diesel prices. Berardi et al (2000, Fig. 1) also present a representation of the production chain similar to the one in Figure 2.

[20] For example, this is clearly the case with the six so-called 'supermajors' (ExxonMobil, British Petroleum, Royal Dutch Shell, Total S.A., Chevron Corporation and ConocoPhillips).

others it might involve a number of different agents. In any case, it entails a number of steps and costs including the transportation of the oil product to the local retail outlet, the marketing of the product, costs of operating the retail outlet – rent, overheads, wages, etc. Again, we are not in a position to calculate explicitly these components separately. We may only implicitly observe the total distribution and retailing costs and margins by reference to the difference between consumer prices excluding taxes and the cost of the refined product.

Finally, the prices paid by the consumer and those used for the purposes of compiling consumer price indices (such as the HICP) include taxes, which generally take the form of excise taxes and/or value-added taxes. The distinction between the two types of taxes is important for understanding the transmission of upstream prices to final consumer prices. Generally excise taxes are levied as a fixed amount per unit. Hence, they do not automatically vary with the upstream price, unless explicitly changed by taxation authorities. On the other hand, value-added taxes are usually levied as a percentage of the price (including the excise tax). Hence value-added taxes automatically increase in line with upstream prices. Furthermore, as they are also levied on excise taxes, an increase in the excise tax has more than a one-to-one impact on the selling price.

Although, as we shall see below, taxes are a major part of oil energy prices, we do not attempt to model them in our econometric analysis of the pass through of oil prices. This is because they are more likely to be driven by government policy (e.g. environmental concerns) and fiscal considerations.[21] Nonetheless when considering the pass through from oil prices to final consumer prices, it is important to be at least aware of the different forms of indirect taxes applied to oil energy products and their implications for the likely degree of pass through.

Before conducting an econometric assessment of the pass-through of oil prices into the final consumer prices, we first provide a descriptive overview. As explained above, to understand better the evolution of overall prices, for the period 1994-2008, we may breakdown the final consumer price into a number of components:[22] (a) crude oil prices (shown here as the spot price of Brent crude oil in cents per litre); (b) the 'refining margin' calculated as the difference between the crude oil price and the spot price of the refined product for delivery in Rotterdam;[23] and (c) distribution and retail costs and margins (–we calculate these by subtracting the cost of the refined product from the consumer price excluding tax);[24,25]

---

[21] An additional, and ultimately more compelling, reason is that our primary source of data, the European Commission WOB, does not explicitly report prices including taxes prior to 2000.

[22] The analysis presented here is similar to that used by the US Energy Information Agency - EIA - (2006 and 2007).

[23] Or the ARA (Amsterdam, Rotterdam, Antwerp) area.

[24] It should be noted that the distribution and retail costs and margins aggregate a number of important steps in the process. For a more detailed discussion, see for example, EIA (2007 and 2006). Unfortunately information on so-called terminal/rack and dealer tank wagon (DTW) prices are not available to the author to enable a more disaggregated analysis.

[25] The tax content of consumer oil prices, which comprises of both excise and value-added taxes may also be calculated simply by subtracting the consumer price excluding tax from that including tax. However, at present, data prior to 2000 are available only excluding taxes, and are hence not shown here.

{Insert Figures 3a, 3b and 3c around here}

Figure 3a shows that, in 2008, distribution and retailing costs and margins accounted for approximately 25% of the final (pre-tax) consumer price for petrol (13 cents out of 55 cents).[26] This represents a slight increase in nominal terms since 1996 (when they amounted to 11 cents on average) but is broadly unchanged in real terms given that overall euro area consumer prices have increased by approximately one quarter since 1996. Refining margins (as measured by the difference between Brent crude oil and Rotterdam refined gasoline prices) accounted for 1 cent per litre on average in 2008. This is the same as in 1996, when, as Figure 1b illustrates, refining margins were relatively low by historical standards.[27] The impact of the increase in crude oil prices is underscored by the rise in the contribution of crude oil from 10 cents a litre in 1996 (crude and refined oil together accounted for approximately the same as the distribution and retailing costs and margins in 1996) to 19 cents in 2000 and 41 cents a litre in 2008. Lastly the contribution of taxes, not shown, has also increased since 2000 from 67 cents a litre to 79 cents a litre. This rise is accounted for by a combination of excise and value-added taxes. Although value-added tax rates have not changed much since 2000, value added taxes account for approximately 50 percent of the 11 cent increase observed in the tax content of petrol because they are linked to prices.

The overall picture for diesel and fuel oil consumer prices is broadly similar (see Figures 3b and 3c), although there are some noteworthy differences. First, the contribution from refining margins for diesel and fuel oil has increased since 1996 from around 3 cents per litre to reach 11 cents per litre on average in 2008 (the higher increase may also be seen from Figure 1b) However, towards the end of 2008, refining margins for diesel and fuel oil declined substantially. Second, the contribution from distribution and retailing costs and margins also appear to have increased from 9 cents per litre in 1996 to 14 cents per litre in 2008 for diesel, and from 5 cents per litre in 1996 to 10 cents per litre in 2008 for fuel oil. The contribution from diesel taxes has risen from 47 cents in 2000 to 60 cents in 2008 (an increase of approximately the same magnitude observed for petrol) whereas the tax contribution from heating fuel taxes has increase by a smaller amount from 15 cents in 2000 to 22 cents in 2008.

Considering the levels of petrol, diesel and fuel oil prices including and excluding taxes (excise and value-added) across countries, a general observation is that the dispersion of prices excluding taxes is much smaller than that of prices including taxes.[28,29] For example, in 2008, average prices excluding taxes for petrol ranged from 51 cents (per litre) in Germany to 61 cents in the Netherlands, whereas the prices including taxes ranged from 112 cents (per litre) in Greece to 153 cents in the

---

[26] Hosken et al. (2008) report in a study of Washington DC suburban gasoline stations that the average ‘rack margin’ (that is the difference between the retail price excluding taxes and the so-called terminal or rack price – see footnote 24 above) was around 15 US cents per gallon (cpg) over the period from 1997-1999, but varied between 21 and 6 cpg . Furthermore, the spread between the 25th and 75th percentile was around 5 cpg on average.

[27] In fact, some commentators have ascribed previous experiences of over-capacity in the 1980s and early-1990s as one factor behind the relatively slow response of refining capacity to current high margins.

[28] For space considerations, these data are not reproduced here but are available upon request.

[29] A similar analysis and conclusion is presented by Arpa et al. (2006).

Netherlands. A similar pattern (of lower dispersion in prices excluding taxes) is observed for diesel and fuel oil prices. In terms of cross-country patterns, whilst these are to some extent product specific, a number of commonalities stand out. For example, excluding tax prices appear to be relatively high in Greece, Ireland, Italy, and the Netherlands, whereas those in France and Germany appear to be relatively low. With regard to taxes, these are relatively high in France, Germany, Ireland, Italy and the Netherlands, whereas they are relatively low for Greece, Luxembourg and Spain.[30]

With regard to the evolution of the dispersion of fuel prices across countries in the euro area since 1995, there has not been much convergence in prices before taxes.[31] This is particularly the case for petrol.[32] This also holds when one considers developments before and after 2002, when the euro notes and coins were introduced. Thus, in this instance, increased price transparency does not seem to have led to a convergence of prices. However, it should be noted that the amount of divergence (with a standard deviation of between 2 and 3 cents per litre) was already relatively small. Furthermore, the data we consider are national averages and may thus conceal sub-national developments, for example in border areas.[33] In addition, the coefficient of variation, which divides the standard deviation by the mean value, has declined, from around 15 in 1995 to 5 in 2007, owing to the combination of broadly stable standard deviations and rising mean values.

Another noteworthy observation is that for both petrol and diesel, the standard deviations of prices including taxes and the tax content are broadly similar. Furthermore, the correlations between the country rankings of the prices excluding tax and the tax content are essentially zero. Given the value-added tax component, which should give rise to a positive correlation, this implies that the excise content rankings are negatively correlated with the prices excluding taxes (i.e. countries with relatively low prices excluding taxes tend to have higher excise taxes, and vice versa).[34] It is interesting to note, that this (zero/negative correlation) does not hold for heating fuel (which is presumably not subject to 'fuel tourism'), where the standard deviation of prices including taxes is systematically higher than that of the tax content, and there is a positive correlation between prices excluding taxes and the tax content (which presumably owes to the relatively low excise content in heating fuel).

Thus far we have considered primarily descriptively developments in consumer prices for liquid fuels. We now turn to an econometric analysis of the behaviour of consumer

---

[30] Overall there is some consistency between these observations and analysis by Rietveld and van Woudenberg (2005), who report that small countries tend to have lower fuel taxes than large countries.

[31] For space considerations, these data are not reproduced here but are available upon request.

[32] The standard deviation of diesel prices excluding taxes has declined somewhat since 1995. This development owes primarily to differing developments in Greece/Austria, which went from being significantly below/above the mean to slightly above/below the mean.

[33] For example, Wlazlowski et al. (2009) and Banfi et al. (2005) report evidence supporting significant amounts of fuel tourism. Although, Dreher and Krieger (2007) argue that producer price dynamics (i.e. supply side factors) are the more important than fuel tourism and taxes, in driving price convergence.

[34] As mentioned earlier, this may be linked to country size and efficiency arguments. Rietveld and van Woudenberg (2005) report that small countries tend to have lower fuel taxes than large countries. It could also be worth investigating whether larger countries have lower costs than small ones, allowing them to have higher taxes.

oil energy prices using the data from the European Commission's WOB. Given that data excluding tax are available since 1994, this means we have 15 years of data and almost 800 observations to consider the very short-run and longer-run pass through from oil prices into consumer prices. Furthermore, as sufficient data are available before and after 2000 (a period of significant oil shocks), and before and after 2002 (the introduction of euro notes and coins), we can check whether pass through has changed over time.

5. Estimation results

We are primarily interested in understanding the behaviour of 'downstream' (i.e. consumer) prices, for which we have data for three different product types: petrol, diesel and heating fuel. In terms of 'upstream' prices, we have (daily) data both on crude oil as well as refined petroleum products. To arrive at our preferred estimation approach, we first carried out analyses of causality, stationarity and cointegration properties, as well as checking stability across different time periods.

{Insert Table 2 around here}

A general finding from the causality analysis was that causality from upstream prices to downstream prices was very strongly significant (see Table 2) and robust (i.e. generally not sensitive to the period of estimation or to the model specification (levels vs. first differences, lag length selection criteria, etc.). On the other hand, although sometimes causality was detected running from downstream prices to upstream prices, this was much less significant and was sensitive to both the period of estimation and the model specification. In view of the weak evidence in support of bi-directional causality, we opt for a straightforward bivariate, single-equation approach. This approach is supported by Geweke (2004).[35]

An analysis of Figure 1a would suggest that upstream (crude and refined) oil prices have been non-stationary (both in terms of mean and variance) over the period 1994-2008. This is confirmed, particularly for crude oil prices and gas oil refining margins, in Table 1 which reports Augmented Dickey-Fuller (ADF) unit root test statistics. Given the apparent non-stationary nature of our underlying data we allow for, and test, an error correction mechanism (ECM) term in our econometric framework. However, in view of the strong increase and heightened volatility of oil prices since 1999 and the fact that standard unit root tests have been shown by Perron (1989) to have low power in the presence of structural breaks, we combine our analysis of cointegration with tests for structural breaks and stability analysis. As there is a priori evidence of two shifts in oil prices and refining margins (towards the end of 1999 and during the course of 2004) we follow the approach of Hatemi-J (2008) who develops (building on work by Gregory and Hansen (1996)) a test "*for long-run equilibrium relationships (cointegration) between time series variables of interest when this potential relationship may shift twice during the period of study with unknown timing that is determined by the underlying data*". The basic premise of this approach follows that of Gregory and Hansen.[36]

---

[35] Geweke (2004, pg. 8) argues that "*bi-directional causality and feedback are issues only if the objective is to isolate the impact of shocks with economic interpretations*"

[36] Instead of following the standard Gregory and Hansen procedure of running the test statistics over the sub-sample (T_0+0.15N; T_0+0.85N), where T_0 is the start of the sample period and N is the number of available observations, and finding the point at which the minimum ADF statistic is

{Insert Table 3 around here}

The results of this analysis, which are presented in Table 3, show that the cointegration properties (ADF Statistics) are much stronger when the downstream prices are estimated in terms of raw levels (rather than logarithms) and using refined prices as the upstream price. In addition, there is no significant evidence of a breakpoint in the relationship between consumer petrol and refined gasoline prices in levels, whereas there are strong indications of two structural breaks between consumer petrol and crude oil prices in logarithms; Based on the observation of the minimum ADF statistics these occur during the course of 1999 and towards the end of 2004. Furthermore, whilst there is some evidence of structural breaks between consumer diesel and fuel oil on the one hand and crude oil and refined gas oil on the other, in both cases the ADF statistics are higher (in absolute values) when using refined gas oil prices. This suggests stronger evidence of cointegration and stability for our chosen econometric specification presented below.

In general, although there is some ambiguity about the precise timing of possible breaks, with the first one being around 1999-2000 and the second one around 2004-2005, this evidence supports the graphical evidence presented in Figures 1a and 1b. Therefore, in what follows we report results for the whole sample period (1994-2008) but also for selected sub-samples (1994-1999, 2000-2008, and 2005-2008) to check the robustness of the reported results.

Thus, following on from the analyses of causality, stationarity, cointegration and structural breaks, we estimate for consumer prices excluding taxes of each fuel type (petrol, diesel and heating fuel) the following equation with two types of oil input: (a) crude oil; (b) refined gasoline (in the case of petrol) or refined gas oil (in the cases of diesel and heating fuel). The equation estimated is a standard single equation bivariate model with an error correction mechanism (see Equation 1 below). As oil input prices (both crude and refined) have increased in level and volatility since 1999, we estimate the equations using Newey-West heteroskedacity and autocorrelation (HAC) consistent covariance estimates.[37] In addition, to consider whether the pass-through behaviour has changed over time we estimate the models over a number of different time periods as flagged above.

$$\Delta P_{i,t}^{C} = c_{i,j} + \sum_{k=1}^{n} \alpha_{i,j,k} \Delta P_{i,t-k}^{C} + \sum_{k=0}^{n} \beta_{i,j,k} \Delta P_{j,t-k}^{I} + \gamma_{i,j} \left(P_{i,t-1}^{C} - \theta_{i,j} P_{j,t-1}^{I} \right) \quad (1)$$

where, P_i^C is the consumer price (excluding taxes) of oil energy type i (petrol, diesel or heating fuel), P_j^I is the spot price of oil input j (crude oil, and refined gasoline or

achieved (BP1), the Hatemi-J procedure involves a two-stage procedure; first running the tests over the sub-sample (T_0+0.15N; T_0+0.70N) and finding the point at which the minimum ADF statistic is achieved (BP1) and then running again the test over a shorter sub-sample (BP1+0.15N; T_0+0.85N) and finding the point at which the minimum ADF statistic is achieved (BP2). Hatemi-J shows, using Monte Carlo simulations, that these "*tests have small size distortions and very good power properties*".

[37] Note we have not as yet tried testing for the impact of possible ARCH effects as suggested by Hamilton (2008). Investigating this avenue, whilst being potentially of interest, would require a separate paper in its own right.

refined gas oil). In addition, we allow for, and test, a time trend variable in the error correction term.

In total for the basic analysis, 312 equations are estimated (three fuel types – euro 95 octane petrol, diesel and heating fuel; two explanatory variables – crude oil and refined gasoline or gas oil; four time sub-periods (1994-2008, 1994-1999, 2000-2008, and 2004-2008), thirteen countries (euro area plus original twelve Member States i.e. Belgium, Germany, Ireland, Greece, Spain, France, Italy, Luxembourg, the Netherlands, Austria, Portugal and Finland).[38] It is worth noting here that we also tried the inclusion of standard seasonal dummies in the euro area wide model and that these were found to be of only marginal significance and did not change the results reported.[39]

{Insert Table 4 around here}

We report the results of the main equations for the euro area data in Table 4. Generally, when the model is estimated in raw levels form, the pass-through coefficients are close to unity and relatively stable, unlike those using the logs specifications (see below for a more detailed discussion of the economic significance of this result).[40,41] It should be noted that the error correction terms are generally economically meaningful with adjustment coefficients being both of the correct sign and statistically significant. Dropping the ECM terms is strongly rejected by the data.[42] It also results in a less parsimonious model in terms of significant lag lengths.

Note the fact that the pass through has been almost exactly 100% implies that distribution and refining costs and margins have not increased with refined oil prices, except for the ‘trend pattern’. This result is supported by the descriptive evidence shown in Figures 3(a-c).

As mentioned above, we estimate our models in raw levels. All series, including crude and refined oil prices, have been converted to euro per litre.[43] The intuitive economic reason, as opposed to the econometric one outlined above, for this is that, as shown in the descriptive analysis, distribution and retailing costs and margins have not increased by anywhere near as much as oil input prices since 1999. This means that

---

38 The equations are not estimated for Slovenia, Malta or Cyprus owing to lack data.

39 Note that we did not test for the presence of an Easter effect.

40 It should also be noted that although taking logs reduces slightly the problem of heteroskedacity, it by no means solves it, as oil prices changes since 1999 have been more volatile and larger in percentage terms also. Furthermore, as the properties of the equations estimated remain broadly similar the same whether estimated in logs or levels, we believe that the use of the levels specification does not cause problems for interpreting the results; rather the use of the logarithmic specification is problematic given the results reported in Table 5.

41 Arpa et al (2006) present an analysis of European energy prices also using WOB data for the EU25 and individual countries over the period up to 2005. However, their models are estimated using logs specifications and can therefore not be compared with the results we report here.

42 The F statistics for dropping the ECM term are 20.0, 36.4 and 26.3 for the petrol, diesel and fuel oil equations respectively, with associated probability values (based on almost 800 observations) of significantly below 1%.

43 We are similar to Burdette and Zyren (2003 and 2002) in this regard. They also report the degree of pass through for petrol and diesel in the United States. Their general finding, similar to ours, is that pass through occurs quite quickly, mostly within three weeks. They also report that there is no evidence of long-run amount asymmetry.

the percentage of the consumer price of oil energy accounted for by oil inputs has increased significant as oil prices have increased. If we were to estimate the models in log form, which has the advantage of providing estimates of elasticity, any estimate made using the data spanning the period before and after 2000 would be biased.[44] Table 5, which shows the estimated longer-run elasticity between crude oil prices and various (pre-tax) consumer prices, indicates clearly that elasticities estimated over the period 1994-1999 no longer hold for the more recent period. For example, the estimated longer-run coefficient in the equation between crude oil and petrol prices was 43% using 1994-1999. Considering data since 2000, the estimated elasticity has risen to 66%. A similar pattern is observed for diesel and fuel oil prices.

{Insert Table 5 around here}

Although not presented here, a general finding is that using refined oil prices rather than crude oil results in a consistent and significant improvement in the R^2 of each model. For example, considering the latest estimation period (2005-date), the R^2 of the petrol equation increases from 0.47 when using crude oil as the explanatory variable to 0.68 when using refined gasoline prices. This result holds across almost all fuel types, countries and time periods.[45] An important implication of this finding is that price shocks at the upstream level (refining costs and margins) are not completely buffered by prices at the downstream level (distribution and retailing costs and margins); otherwise the use of refined prices would add little relative to crude prices. Nonetheless, as the contemporaneous correlation between changes in refining and distribution/retailing costs and margins is -0.8 for each fuel type, this indicates a considerable degree of short-term buffering. However, as the pass through is generally almost 100% complete within three to five weeks, this indicates that any buffering by retailing margins is short-lived. This lack of buffering beyond the immediate short-run despite the presence of vertically-integrated companies is in line with Asplund et al. (2000) paper which reports the use of Rotterdam price as internal transfer price between the producing and selling divisions in vertically integrated companies.

{Insert Table 6 around here}

Table 6 shows the amount and speed of pass through from refined oil prices to consumer prices (excluding tax) for petrol in each country.[46] At the euro area level as a whole, the amount of pass through is generally 100% (i.e. a ten cent per litre increase in refined oil prices results in more or less a ten cent per litre increase in consumer prices before taxes). Furthermore, the speed of pass through is generally

[44] The estimation of the equations in raw levels rather than logs is also supported by specification tests. The former have higher R^2, a lower standard deviation of residuals when converted to the same dimension, and show greater stability in the estimated long-run coefficients. The difference between the two approaches is smaller in the earlier (1994-1999) period - where oil prices were more stable - when compared with the latter (2000-2008) period.

[45] Our results are similar to those of Brown and Virmani (2007) who find that, for the United States, although crude oil prices dominate movements in gasoline prices, seasonal and non-seasonal movements in consumption, refinery production, imports and inventories also exert a significant influence over gasoline prices. With their augmented-model, they find an improvement of over 50% in the one week ahead RMSE compared to a model using just crude oil prices.

[46] For space reasons, the tables for diesel and fuel prices are not presented here but are available upon request.

quite rapid, with 50% being passed through within two weeks, and 90% with three- to six-weeks.[47] For example, given a ten cents increase in refined oil prices, consumer petrol prices increase by 5.8 cents within two weeks, and by 9.1 cents within five weeks. The pass through from refined gas oil to consumer diesel prices (excluding taxes) appears even more rapid with 9.0 cents being passed through within three weeks. The pass through from refined gas oil to consumer heating fuel prices is of broadly the same pattern as for consumer petrol prices (i.e. 5.6 cents within two weeks and 9.1 cents within six weeks).

Considering individual country developments, it is clear that this pattern is broadly shared by most countries.[48] Pass through seems to be the quickest for Belgium, Germany, Luxembourg and the Netherlands. This may reflect the fact that the refined prices are those for delivery in Rotterdam (i.e. the Northwest Europe region). Perhaps using Mediterranean prices would provide a faster pass through for the Mediterranean countries.[49] However, given that refined oil products are relatively homogenous and the cost of shipping large amounts of liquid cargo is relatively small, significant price differentials should be arbitraged away quite quickly.[50]

The fact that both crude oil prices and refining margins have increased since 1999 means that pass-through rates using crude oil prices as the explanatory variable should be interpreted with caution. Impulse responses, not reported here, illustrate that using crude oil as the reference price suggests that the pass through from crude oil prices to consumer prices, at least in the short-run,[51] at around 130% has been significantly more than in the past. This owes to concurrent developments at the refining level rather than at the distribution and retails levels as many commentators have assumed.

The use of crude or refined oil prices as the reference also has an impact on the apparent change in pass through across different time periods. Estimated impulse responses using refined prices suggest that price pass through has remained broadly unchanged between the periods 1994-1999 and 2000-2008, with pass through in the

---

[47] Note, one feature of the weekly Oil Bulletin data may mean that the estimated speed of pass through is slightly understated. This is because the data are generally collected on a Monday. However, Asplund et al (2000) find that fewer price changes are made on Mondays. Their explanation is that the Rotterdam markets are closed over the weekend and thus any new information that may have arrived up to the Monday is not normally implemented until the following day.

[48] One exception is Ireland. However, here the data are generally only updated on a monthly frequency. In addition, the Irish petroleum market has been subject to a number of regulatory interventions, which may have distorted the link with market (Rotterdam) prices.

[49] Rotterdam (Northwest Europe or Amsterdam, Rotterdam and Antwerp – ARA) prices are considered to be the benchmark for Europe. Alongside New York Harbour and Singapore, Rotterdam is one of the three major trading areas for refined products. Rotterdam (168 million tonnes) is by far the biggest liquid bulk port in Europe owing to its nautical accessibility and the clustering of petrochemical facilities. Mediterranean ports that handle significant, but smaller, amounts of liquid petroleum products are Marseille in France (66 million tonnes) and Trieste in Italy (36 million tonnes) – see ESPO (2007) for further information. Berardi et al (2000) use Genoa prices in their study of asymmetries in the Italian market.

[50] For instance it is estimated that the cost of tanker transport amounts to only two or three U.S. cents per gallon (one US liquid gallon is equal to 3.785 litres) and that tankers are second only to pipelines in terms of efficiency. Source: Huber, Mark (2001). Page 211 Tanker operations: a handbook for the person-in-charge (PIC). Cambridge, MD: Cornell Maritime Press http://en.wikipedia.org/wiki/Oil_tanker

[51] The response function using crude oil prices as the input actually tends to return to 100% over a longer period of time.

latter period generally being within plus or minus one unit of the rate observed in the earlier period. Whereas using crude oil prices the pass through seems to have unambiguously increased, by more than two units for petrol and heating fuel, and by four units for diesel fuel.

The consideration of tax developments also matters for the degree of pass through estimated. Thus far, most of the results presented have been for consumer prices excluding taxes. The main reasons for this are the facts that it makes clear the role played by distribution and retailing costs and margins and that data are available for a longer time period. Considering the available data since 2000, generally the pass through into consumer prices including taxes is two units higher than that into consumer prices excluding taxes. That is, a ten cent per litre increase in crude oil prices gives rise to a 10 cent per litre increase in consumer prices excluding taxes, but a twelve cent per litre increase in consumer prices including taxes.[52] This is consistent with the fact that the average VAT rate in the euro area is approximately 20% and reflects the impact of VAT, which, unlike excise taxes, automatically increase as consumer prices excluding taxes increase.

6. Are there asymmetries in the pass through into consumer prices?

In times of high and volatile oil prices, there are frequent media reports and criticisms of asymmetric pricing behaviour by oil companies. In this section we focus on testing whether there is a statistically significant asymmetry in the response of consumer prices to petrol prices.[53]

Given the public and political debate, it is not surprising that the academic literature has also investigated the issue empirically. Honarvar (2006), Kaufmann and Laskowski (2005), Frey and Manera (2005) and Geweke (2004) all provide useful overviews of this literature, which unfortunately focuses mostly on the US. Geweke presents a comprehensive, if somewhat critical, overview of 18 papers in this so-called 'rockets and feather' literature.[54] However, as the literature has tended to be dominated by US studies, he focuses mainly on the US literature rather than the European one. Frey and Manera may be the most comprehensive analysis not only in terms of its classification of types of asymmetry, but also in its cataloguing of existing studies by country of analysis, type of asymmetry tested, model used, time period analysed, frequency of data used, etc. They also attempt to classify the different types of asymmetry tested for in the literature. They document eight types of asymmetries: (i) contemporaneous impact; (ii) distributed lag effect; (iii) cumulated impact; (iv) reaction time; (v) equilibrium adjustment path; (vi) momentum equilibrium adjustment path; (vii) regime effect; and (viii) regime equilibrium adjustment path. The relationship between their classification system and the forms of asymmetry that we test for is discussed below.

[52] For space reasons the impulse are not reported here but are available upon request.

[53] Note we do not investigate the possible sources of any asymmetry. For an overview of possible theoretical explanations, see Borenstein et al. (1997) and Oladunjoye (2008)

[54] This literature on asymmetry in gasoline prices got its name from a 1991 paper by R. Bacon entitled "Rockets and feathers: the asymmetric speed of adjustment of UK retail gasoline prices to cost changes".

One difficulty faced when comparing results in the asymmetry literature is that papers differ in their definition of asymmetry. For example, some papers consider asymmetry in response to own lags. Whilst this may be a source of asymmetry in downstream prices, it does not necessarily have to stem from asymmetric responses to changes in upstream prices. Geweke (2004, pg. 1) defines asymmetry as the *"systematic tendency for downstream prices in the oil well-to-service station gasoline industry to respond to increases in upstream prices more rapidly than downstream prices respond to decreases in upstream prices"*. This is broadly the definition we adopt in this paper, focusing specifically on the relationship between refined oil products and consumer prices excluding taxes.

Most studies distinguish between amount versus speed and pattern asymmetry. The former refers to asymmetry in the long-run relationship, whereas the latter refer to the short-run dynamics. Given the homogeneity of product, the relatively competitive and transparent nature of consumer pricing in this industry, there is unlikely to be amount asymmetry over longer periods of time.

As Geweke (2004, pg. 12) notes that *"yet there has been little attention to whether the asymmetric relation is itself stable"*, we also consider the evidence for asymmetry over the two broad sub-periods 1994-1999 and 2000-2008. Given the substantial change in the level and volatility of oil prices between these two periods, a change in the pass-through behaviour could be envisaged. On the one hand, given the large increases in oil prices, retailers might change their prices more frequently, thus given rise to less asymmetry (as possible threshold effects are not as meaningful). On the other hand, it could be the case that retailers would find it easier to camouflage increases in their margins in an environment of rising and volatile oil prices.

The model we estimate to test for asymmetry is shown in Equation 2 below. As discussed by Geweke (2004) and Honarvar (2006) there have been a wide range of models employed in the literature on asymmetry. We have chosen the formulation below because we are interested asymmetries of downstream prices in response to changes in upstream prices (the source of possible asymmetries in upstream prices is not of concern to us here).[55] We estimate the model using NLS – noting the result from Honarvar (2006) that, when using Monte Carlo methods, both two-step or single-equation error correction models testing for asymmetry can lead to biased estimates of asymmetric parameters and in some cases suggest symmetry in the estimated parameters.

$$\begin{aligned}\Delta P_{i,t}^{C} = {} & \Delta_{i,t}^{+}\left(c_{i,j}^{+} + \sum_{k=1}^{K1}\alpha_{i,j,k}^{+}\Delta P_{i,t-k}^{C} + \sum_{k=0}^{K2}\beta_{i,j,k}^{+}\Delta P_{j,t-k}^{I} + \gamma_{i,j}^{++}\left(P_{i,t-1}^{C} - \theta_{i,j}P_{j,t-1}^{I}\right)^{+} + \gamma_{i,j}^{+-}\left(P_{i,t-1}^{C} - \theta_{i,j}P_{j,t-1}^{I}\right)^{-}\right) \\ & + \left(1-\Delta_{i,t}^{+}\right)\left(c_{i,j}^{-} + \sum_{k=1}^{K1}\alpha_{i,j,k}^{-}\Delta P_{i,t-k}^{C} + \sum_{k=0}^{K2}\beta_{i,j,k}^{-}\Delta P_{j,t-k}^{I} + \gamma_{i,j}^{-+}\left(P_{i,t-1}^{C} - \theta_{i,j}P_{j,t-1}^{I}\right)^{+} + \gamma_{i,j}^{--}\left(P_{i,t-1}^{C} - \theta_{i,j}P_{j,t-1}^{I}\right)^{-}\right)\end{aligned} \qquad (2)$$

Of course, it should be borne in mind that the results presented in this paper are based on aggregated data. Whilst the degree of temporal aggregation (weekly) is limited and

[55] Note that the long-term coefficient in the ECM term is the same for increases and decreases in upstream prices. This is because it does not make sense to us that the long-term coefficient would vary according to short-term price changes. In any case we tested the euro area results allowing for different long-run coefficients and found that they were broadly similar.

unlikely to have a major impact on the estimation of asymmetry, spatial aggregation may be more important. In particular, our finding of limited asymmetry at national and euro area levels does not exclude asymmetric pricing behaviour at a more local level.

As discussed in Geweke (2004), in error correction models with a dynamic lag structure and asymmetry there are not just two but many possible regimes. These depend not only on whether the latest prices rose or fell, but also on lagged changes and whether the current value is above or below the equilibrium relationship. Hence we also allow for a differing adjustment coefficient on the ECM term depending on whether upstream prices are increasing or decreasing and whether downstream prices are above or below their 'equilibrium' level. The table below illustrates the possible interaction between possible asymmetries in short-run dynamics and equilibrium adjustment. The comparison between cases (b) and (c) should be the most clear-cut. In the former case, input (or upstream) prices are rising and downstream prices are lower than their equilibrium level. In this case, in the presence of asymmetry, one would expect the absolute size of any change in upstream prices to be larger than in the opposite case (c) where upstream prices are falling and downstream prices are above than their equilibrium level. In the other two case (a) and (d) there are possibly counteracting forces as the impact from the direction of movement of upstream prices (up or down) may be counteracted the error correction response to deviations from the equilibrium price.

Potential interaction between possible asymmetries in short-run dynamics and equilibrium adjustment

	ECM(+)	**ECM(-)**
dP(+)	(a) + -	(b) + +
dP(-)	(c) - -	(d) - +

Given that concern has been expressed in the literature about the power of F tests (see for example, Galeotti et al, 2003) for detecting asymmetry in these type of models, we report in Table 7 alongside the overall test for asymmetry, tests of asymmetry in (a) the autoregressive coefficients, both individually $\alpha^{\pm}_{i,j,k}$ and in sum, (b) the short-run dynamics, both individually $\beta^{\pm}_{i,j,k}$ and in sum, and (c) in the adjustment coefficient to deviations from the long-run equilibrium value $\gamma^{\pm}_{i,j}$.[56] We also report an additional test which checks for asymmetry in the adjustment to the ECM term depending on whether it is above or below zero (i.e. whether price below equilibrium levels respond more quickly to those above equilibrium levels).[57] These variants may be considered as somewhat similar to the contemporaneous impact ($\beta^{\pm}_{i,j,0}$), distributed lag effect ($\beta^{\pm}_{i,j,k}$), cumulated impact ($\sum \beta^{\pm}_{i,j,k}$), and equilibrium adjustment path asymmetries ($\gamma^{\pm}_{i,j}$) discussed by Frey and Manera (2005) – see above for more details.

[56] Note, for space reasons, results are only presented for petrol prices. Those for diesel and heating fuel oil are available upon request.

[57] This latter variant is similar to the approach of Chen et al. (2005) who find evidence of asymmetry for the United States at very short-run (less than four weeks) horizon.

{Insert Table 7 around here}

Generally we do not find pervasive evidence of asymmetry in the pass through of refined oil prices into consumer prices excluding taxes. Table 7 reports the statistical significance of the tests for asymmetry. However, beyond even the low power of these tests, they may be misleading in one of two ways. First, in a model with tight confidence intervals, it may be the case that coefficients are significantly different in a statistical sense but not in an economic sense. Second, in a model with wide confidence intervals, it may be the case that coefficients are not statistically significantly different owing to large standard errors, but if the point estimates are taken at face value, they may imply economically meaningful differences. Figures 4(a-c) show that for the euro area as an aggregate, and for the median, there is little in the way of economically meaningful asymmetry between the pass through of upstream price increases and decreases.

{Insert Figures 4a-c around here}

For some countries there is evidence of economically-significant asymmetry. However, these countries tend to be ones where the models are estimated with low explanatory power (R^2) and large standard errors and therefore do not necessarily show up in the statistical tests. The two main examples are Greece and Portugal. With regard to the former, the asymmetry in Greek diesel prices seems quite strong. However, the penetration of diesel cars in Greece is extremely low (below 3%). With regard to the latter, until 2002, petrol prices in Portugal were controlled administratively. Between September 1999 and February 2002 a large wedge opened up between Portuguese petrol prices and average euro area price. This wedge reached as much as 20 cents per litre, which is extremely large when one considers that euro area prices excluding taxes at that time were 25-30 cents per litre. A notable exception to the above caveats is the apparent asymmetry in heating fuel prices in Italy, which appears to be significant both from a statistical and an economic viewpoint.

Another interesting finding, which seems to be a broadly common feature across countries, is that any gain in terms of explanatory power from allowing for asymmetry seems to be largely eliminated in the more recent period, 2000-2008, when compared with the earlier period, 1994-1999. Although it should be noted that the gain in the earlier period in any case tended to be relatively small – with a median increase in R^2 of around 4%. This could be ascribed to increased competition or the removal of price restrictions. This may be the case in some countries - e.g. Italy removed price controls in the 1990s. However, given the relatively widespread nature of this finding (albeit limited in impact), an alternative and possibly more plausible explanation is threshold pricing. Our asymmetric model is a form of 'threshold autoregressive models', where the threshold is set arbitrarily to zero. We did not experiment with alternative thresholds. A more complicated model, although intuitively more appealing to us, would be one where large price rises and/or declines are passed-through differently to smaller price rises/declines. For example, it could be the case that small price declines are not passed through immediately but larger ones are, whereas this non-linearity might not hold for price rises. Al-Gudhea et al. (2007) report evidence in support of this hypothesis using so-called 'momentum-threshold autoregressive' (M-TAR) models. However, Honarvar (2006, pg. 21) notes that "*for the sake of obtaining less biased asymmetric parameters; the choice of the true threshold is crucial. Evidently a* *wrong selection of threshold may result in largely biased estimates*". Hence, although our findings may provide some tentative evidence in support of this, we did not peruse the threshold model route given the apparently relatively small gains in explanatory power in any case. In their study of the price setting by a large gasoline retail chain in Sweden, Asplund et al (2000) report that that the minimum absolute change is 2, which they suggest "*strongly indicates that there is some fixed cost associated with price changes that keeps firms from making very small adjustments*". However, it should be noted that the prices they use are Swedish Krona per 100 litres. Hence the per litre minimum absolute change is approximately 2 öre or around 0.2 euro cent. Thus, the fixed costs may not be so large in practice, which could have implications for the likely relevance and importance of threshold pricing.

Our finding of little significant asymmetry is contrary to the finding in much of the literature. However, although a majority of studies report evidence for asymmetry, there is much disagreement within the literature on the presence and type of asymmetry. For example, Burdette and Zyren (2003 and 2002) find little evidence of asymmetry, but report evidence of asymmetry in their 2005 paper (Ye et al). In their survey of the literature, Frey and Manera (2005) report from thirty eight studies of asymmetry in the gasoline market. Although half of these report evidence of asymmetry, five of them report symmetry and the remaining fourteen report mixed results. Furthermore, they survey 224 tests with the null hypothesis of symmetry and find that in slightly over one-third of cases there is no rejection.

Given this lack of uniformity in the literature and the finding of Görg and Strobl (2001), using a meta-analysis of the literature on multinational companies and productivity spillovers, that there may be a tendency for journals to publish papers that can reject their null hypothesis, i.e. produce statistically significant results, it could also be the case in the so-called rockets and feathers literature (i.e. looking at asymmetric responses in the gasoline market) that papers that find evidence of asymmetries are more likely to be published.

7. Conclusions:

In this paper we have considered the pass through of global oil prices into consumer liquid fuel prices in the euro area. In doing so we have answered a number of the questions posed in the Introduction. First, with regard to the amount of pass through it appears that it is complete in raw terms (i.e. a ten cent per litre increase in oil prices gives rise to a ten cent per litre increase in consumer prices excluding taxes) and does not appear to differ noticeably between fuel types (i.e. petrol, diesel and heating fuel). Second, the increased volatility in refining margins since 2000 needs to be taken into consideration when trying to understand very short-term dynamics in consumer oil energy prices. More specifically, considering refined product prices adds considerable information relative to crude oil prices. Third, with regard to the speed of pass through it seems to be relatively quick, with 50% occurring within two weeks and 70-90% within three weeks. This finding would also suggest that studies on the direct pass through of oil prices require weekly data at a minimum as monthly data are likely to be too low frequency. Fourth, once one estimates prices in raw level terms, it is evident that the pass through of oil prices is generally complete and that raw margins have remained broadly unchanged despite substantial increases in upstream oil prices. Nor does there appear to have been any significant change in pass through. However, use of logarithmic transformations will result in an increase in the estimated percentage pass through. This is because the percentage of the consumer price that is accounted for by oil prices has risen substantially over the sample period 1994-2008. Lastly, there is no significant evidence of systematic and widespread asymmetry in the relationship between increases and decreases in upstream (crude and refined product) and downstream (consumer) prices. However, it should be noted that this is an aggregate result and may not necessarily hold at a more disaggregated sub-regional level.[58]

In terms of additional questions one could hope to answer using the data from the WOB, a number of avenues are of possible interest. First, this paper has abstracted from the issue of exchange rate movements. Given that most global crude and refined petroleum products are quoted in US dollar terms this may have some impact. However, as we already find that the pass through is complete and relatively quick, this impact is likely to be limited. Second, we have noted that, despite the rapid pass through from refined prices to consumer prices, there is some buffering by distribution and retail margins. There also appears to be some geographic differences, possibly related to the use of Rotterdam prices. A more in-depth analysis of the relationship between refined and consumer prices and the factors determining the degree of buffering, could be informative for short-term inflation forecasting purposes.

Considering energy markets more generally, there are other issues we have not addressed here. For instance, the analysis in this paper has been premised very much on the causality running from upstream to downstream prices and has treated upstream prices as been exogenous. It may be the case, particularly at the very early stages of the production chain, that the causality runs in both directions. Although the focus of this paper has been on downstream consumer prices, for those interested in a holistic view of energy prices developments, allowing for possible bi-directionality may be desirable.

Lastly, given the additional information content gained from the consideration of spot prices for refined petroleum products, it could also be informative to consider the information content of futures markets for these products. Unfortunately, however, the most liquid futures market for refined petroleum products is the New York Mercantile Exchange (NYMEX) where prices are for delivery at New York Harbour. It is true that, owing to arbitrage possibilities, the spot prices of refined products for delivery in New York and Rotterdam co-move broadly over longer periods of time.[59] However, over shorter-term horizons, even when considering monthly average data, there are substantial fluctuations between the two. Furthermore, although Murat and Tokat (2009, pg. 89 – emphasis added) find some evidence that, after 2003, NYMEX crack spread futures have become a good predictor of oil price movements, they

[58] For instance, Duffy-Deno (1996) argues that "*since gasoline is purchased by the consumer in local markets, conclusions reached by studies of market pricing behaviour that rely on national data may not be relevant for* ***local*** *policy decisions*" (my emphasis). Furthermore, Eckert and West (2005) argue that a broad uniformity of pricing does not necessarily mean a competitive market. They find that, for the Vancouver metropolitan area (Canada) station level data are more consistent with tacitly collusive pricing behaviour.

[59] A clear example of global arbitraging in practice was when Hurricanes Katrina and Rita shut down over a quarter of U.S. refining capacity in 2005. Brown and Virmani (2007) report that "*American gasoline imports from Europe tripled, with an unprecedented 50 tankers crossing the Atlantic in the first week of September 2005*".

conclude that their "*forecasting performance is* ***nearly*** *as good as the crude oil futures*". In view of these caveats, and the relatively low forecasting power of crude oil futures in any case, consideration of futures prices for refined products may not, unfortunately, yield substantial additional insights. Nonetheless, it would be informative to confirm or deny this a priori assumption.

References

Al_Gudhea S, Kenc T and Dibooglu S. Do retail gasoline prices rise more readily than they fall? A threshold cointegration approach. Journal of Economics and Business 2007; 59; 560-574

Arpa M, Cuaresma J C, Gnan E and Silgoner M A. Oil price shock, energy prices and inflation – a comparison of Austria and the EU. Oesterreichische Nationalbank (ONB) Monetary Policy and the Economy 2006; Q1/06; 53-77

Asplund M, Eriksson R and Friberg R. Price adjustments by a gasoline retail chain. Scandinavian Journal of Economics 2000; 102; 1; 101-121

Bacon R W. Rockets and Feathers: the asymmetric speed of adjustment of UK Retail Gasoline Prices to Cost Changes. Energy Economics 1991; 13; 3; 211-218

Banfi S, Filippini M and Hunt L. Fuel tourism in border regions: The case of Switzerland. Energy Economics 2005; 27; 5; 689–707

Berardi D, Franzosi A and Vignocchi C. Il prezzo dei carburanti in Italia: asimmetrie e mispecificazioni. Contributo di Ricerca Istituto per la Ricerca Sociale (IRS) 2000; n. 50; July

Bernanke B. Energy and the economy. Speech made before the Economic Club of Chicago, Chicago, Illinois 2006; June 15

Borenstein S, Cameron A C and Gilbert R. Do Gasoline Prices respond symmetrically to Crude Oil Price Changes? Quarterly Journal of Economics 1997; 112; 305-339

Brown S P A and Virmani R. What's driving gasoline prices?, Federal Reserve Bank of Dallas Economic Letters 2007; 2; 10; October

Burdette M and Zyren J. Diesel fuel price pass through. US Energy Information Administration Mimeo 2002; July (available on www.eia.doe.gov)

Burdette M and Zyren J. Gasoline price pass through. US Energy Information Administration Mimeo 2003; January (available on www.eia.doe.gov)

Chauvin V and Devulder A. An inflation forecasting model for the euro area. Notes d'Études at de Recherche (NER) 2008; E # 192; January

Chen L H, Finney M and Lai K S. A threshold co-integration analysis of asymmetric price transmission from crude oil to gasoline prices. Economic Letters 2005; 89; 233-239

Chen S S. Oil price pass-through into inflation. Energy Economics 2009; 31; 1; 126-133

Dees S, Gasteuil A, Kaufmann R K and Mann M. Oil prices: The role of refinery utilization, futures markets and non-linearities. Energy Economics 2008b; 30; 5; September; 2609-2622

Dees S, Gasteuil A, Kaufmann R K and Mann M. Assessing the factors behind oil price changes. ECB Occasional Paper Series 2008a; No. 855; January

Dreher A, and Krieger T. Diesel price convergence and mineral oil taxation in Europe. Center for International Economics Working Paper Series 2007; 2007-01; August

Duffy-Deno K T. Retail price asymmetries in local gasoline markets. Energy Economics 1996; 18; 1-2; April; 81-92

Eckert A and West D S. Price uniformity and competition in a retail gasoline market. Journal of Economic Behaviour and Organisation 2005; 56; 219-237

Energy Information Administration (EIA). A primer on diesel fuel prices. Mimeo 2007; April - available on www.eia.doe.gov

Energy Information Administration (EIA). A primer on gasoline prices. Mimeo 2006; May - available on www.eia.doe.gov

ESPO (European Sea Ports Organisation). Annual Report 2006-2007. 2007

Esteves P Soares and Duarte Neves P. Oil prices and the economy. Banco de Portugal Economic Bulletin 2004; December; 51-62

European Central Bank (ECB). Oil prices and the euro area economy. ECB Monthly Bulletin Article 2004; November; 51-63

Frey G and Manera M. Econometric models of asymmetric price transmission. Fondazione Eni Enrico Mattei Note di Lavoro Series 2005; 100; September

Galeotti M, Lansa A and Manera M. Rockets and feathers revisited: An international comparison on European gasoline market. Energy Economics 2003; 25; 175-190

Görg H and Strobl E. Multinational Companies and Productivity Spillovers: A Meta-Analysis. Economic Journal 2001; 111; F723-F739

Geweke J. Issues in the 'Rockets and Feathers' Gasoline Price Literature. Report to the Federal Trade Commission 2004; March

Gregory A W and Hansen B E. Residual-based test for cointegration in models with regime shifts. Journal of Econometrics 1996; 70; 1; January; 99-126

Hagstromer B and Wlazlowski S. Causality in Crude Oil Prices. Munich Personal RePEc Archive (MPRA) Paper 2007; 1577; January

Hamilton J D. Macroeconomics and ARCH. NBER Working Paper Series 2008; 14151; June

Hatemi-J A. Tests for cointegration with two unknown regime shifts with an application to financial market integration. Empirical Economics 2008; 35; 3; November; 497-505

Honarvar A. Modeling of asymmetry between gasoline and crude oil prices: A Monte Carlo Comparison. Paper presented to CEA 40th Annual Meetings 2006; 26-28 May; Montreal

Hosken D S, McMillan R S and Taylor C T. Retail gasoline pricing: What do we know? International Journal of Industrial Organisation 2008; 26; 6; November; 1425-1436

Kaufmann R K and Laskowski C. Causes for an asymmetric relation between the price of crude oil and refined petroleum products. Energy Policy 2005; 33; 12; August; 1587-1596

Murat A and Tokat E. Forecasting oil price movements with crack spread futures. Energy Economics 2009; 31; 1; 85-90

Oladunjoye O. Market structure and price adjustments in the U.S. wholesale gasoline markets. Energy Economics 2008; 30; 3; May; 937-961

Perron P. The Great Crash, the oil price shock and the unit root hypothesis. Econometrica 1989; 57; 1361-1401

Reserve Bank of New Zealand (RBNZ). Oil prices and the New Zealand Economy. Bulletin 2005; 68; 4; December; 5-15

Rietveld P and van Woudenberg S. Why fuel prices differ. Energy Economics 2005; 27; 79-92

Wlazlowski S, Giulietti M, Binner J and Milas C. Price dynamics in European Petroleum Markets. Energy Economics 2009; 31; 1; 99-108

Ye M, Zyren J, Shore J and Burdette M. Regional comparisons, spatial aggregation, and asymmetry of price pass through in U.S. Gasoline Markets. Atlantic Economic Journal 2005; 33; 179-192

Table 1
Mean, standard deviation and unit root statistics for crude oil prices and refining margins

		mean (euro)	std. dev. (level)	std. dev. (monthly changes)	ADF t-statistic (prob)*
1994-2008	**crude oil**	**29.6**	**17.2**	**3.2**	**-1.5 (0.52)**
1994-1999		*14.6*	*3.2*	*1.2*	-0.8 (0.82)
2000-2004		*28.3*	*4.5*	*3.0*	-3.2 (0.02)
2005-2008		*53.5*	*12.4*	*5.1*	-1.1 (0.72)
1994-2008	**refining margin gasoline**	**4.3**	**3.5**	**2.4**	**-6.3 (0.00)**
1994-1999		*2.8*	*1.3*	*1.1*	-5.3 (0.00)
2000-2004		*5.3*	*3.5*	*2.6*	-3.6 (0.00)
2005-2008		*5.3*	*4.8*	*3.5*	-3.6 (0.00)
1994-2008	**refining margin gas oil**	**6.2**	**4.6**	**1.6**	**-3.3 (0.02)**
1994-1999		*3.2*	*1.1*	*0.7*	-4.8 (0.00)
2000-2004		*5.2*	*2.8*	*1.6*	-3.3 (0.02)
2005-2008		*11.9*	*4.5*	*2.5*	-2.5 (0.12)

Notes:
** prob denotes probability associated with null hypothesis that series has a unit root*

Table 2
Pairwise Granger Causality Tests*

		crude oil (in euro)	refined gasoline (in euro)	refined gas oil (in euro)	petrol (ex. tax)	diesel (ex. tax)	heating fuel (ex. tax)
		is not caused by					
crude oil (in euro)	does not cause	**X**	0.00	0.00	0.00	0.00	0.00
refined gasoline (in euro)		0.05	**X**	-	0.00	-	-
refined gas oil (in euro)		0.16	-	**X**	-	0.00	0.00
petrol (ex. tax)		0.05	0.64	-	**X**	-	-
diesel (ex. tax)		0.04	-	0.18	-	**X**	-
heating fuel (ex. tax)		0.57	-	0.54	-	-	**X**

Notes:
** Table reports probability of null hypothesis that one variable does not Granger Cause the other. Based on estimation in levels, over entire sample (1994-2008).*

Table 3
Combined tests for cointegration and data determined breakpoints following Hatemi-J (2008) approach

dependent variable	independent variable	ADF whole sample	ADF break point 1	comment	ADF break point 2	comment
log(petrol)	log(crude)	-5.4	-7.4	Minimum ADF statistic reached in Feb. 99; trough throughout 99	-7.3	Minimum reached in Sep. 04; trough throughout 04H2
petrol	refined	-8.7	N/A		N/A	
log(diesel)	log(crude)	-4.9	-6.1	Minimum reached in Mar. 99; trough throughout 99+00	N/A	
diesel	refined gas oil	-9.3	-10.4	Minimum reached in Nov. 00; trough throughout 00H2	-8.7	Minimum reached in Sep. 04; trough throughout 00H2
log(fuel oil)	log(crude)	-4.5	-5.7	Minimum reached in Apr. 99; trough throughout 99H1	-6.0	Minimum reached in Nov. 05; but trough through to end of sample
fuel oil	refined gas oil	-5.4	-6.2	Minimum reached in May 05; but trough through to end of sample	N/A	

Notes:
Critical values are 1% (-6.0); 5% (-5.5)

Table 4
Summary of main regression results (for euro area data)

Downstream (P^C)	Petrol	Petrol	Petrol	Petrol		Diesel	Diesel	Diesel	Diesel		Fuel Oil	Fuel Oil	Fuel Oil	Fuel Oil
Upstream (P^I)	Gasoline	Gasoline	Gasoline	Gasoline		Gas Oil	Gas Oil	Gas Oil	Gas Oil		Gas Oil	Gas Oil	Gas Oil	Gas Oil
Estimation period	94-08	94-99	00-08	05-08		94-08	94-99	00-08	05-08		94-08	94-99	00-08	05-08
$c_{i,j}$	9.8	7.0	17.9	21.8		10.1	3.3	11.5	21.5		7.8	4.8	8.2	26.1
(t statistic)	*(3.95)*	*(2.65)*	*(4.11)*	*(2.33)*		*(5.97)*	*(2.29)*	*(4.87)*	*(3.77)*		*(4.88)*	*(2.84)*	*(3.35)*	*(4.03)*
ECM adj ($\gamma_{i,j}$)	-0.09	-0.08	-0.16	-0.19		-0.23	-0.08	-0.29	-0.31		-0.10	-0.08	-0.11	-0.20
(t statistic)	*(-3.94)*	*(-3.10)*	*(-4.23)*	*(-2.43)*		*(-6.17)*	*(-3.50)*	*(-5.54)*	*(-4.35)*		*(-4.88)*	*(-4.00)*	*(-4.11)*	*(-3.96)*
LR coef ($\theta_{i,j}$)	1.01	1.07	1.00	1.01		1.05	1.09	1.05	1.05		0.98	1.15	0.98	1.00
(t statistic)	*(57.67)*	*(10.39)*	*(54.79)*	*(27.94)*		*(69.69)*	*(13.81)*	*(64.40)*	*(53.35)*		*(34.50)*	*(13.84)*	*(27.38)*	*(45.69)*
Time trend	-	0.08	-	-		0.03	0.04	0.04	-		0.08	0.10	0.09	-
(t statistic)		*(3.50)*				*(4.85)*	*(2.43)*	*(3.80)*			*(5.64)*	*(5.92)*	*(3.12)*	
Sum alpha ($\sum_{k=1}^{K1} \alpha_{i,j,k}$)	-0.59	-0.15	-0.50	-0.67		-0.73	-0.20	-0.70	-0.66		-0.10	0.21	-0.12	-0.50
max alpha lags	3	1	3	3		3	0	3	2		2	0	2	2
Sum beta ($\sum_{k=1}^{K2} \beta_{i,j,k}$)	1.36	0.71	1.17	1.32		1.22	0.94	1.10	0.92		0.92	0.53	0.93	1.23
max beta lags	4	3	4	4		3	2	3	2		3	2	3	3
adj R2	0.73	0.48	0.75	0.77		0.74	0.67	0.75	0.72		0.75	0.60	0.76	0.79
Regr S.E.	4.3	2.2	5.2	6.3		4.6	1.8	5.7	7.2		3.7	2.0	4.5	5.3
DW	1.96	2.00	1.96	1.94		1.96	2.00	1.96	1.95		1.98	1.98	1.98	2.01
No of obs.	774	304	470	270		774	304	470	209		774	304	470	209

Table 5
Change in estimated elasticity of oil energy prices to refined prices (using log specification)

	1994-2008	1994-1999	2000-2008	2004-2008
Petrol	53%	43%	66%	65%
Diesel	73%	59%	81%	84%
Fuel Oil	60%	50%	68%	72%

Notes:
Results from estimation models of form in equation 1 but with all variables transformed using logarithms.

Table 6
Pass through of 10 cent per litre change in refined gasoline price into consumer price (exc. taxes) for petrol (from models estimated over the period 2000-2008)

	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12
euro area	**1.9** **(1.5;2.3)**	***6.0*** **(5.5;6.4)**	**7.5** **(7.0;8.0)**	**8.4** **(7.9;8.4)**	**9.3** **(8.8;9.7)**	**9.3** **(8.8;9.8)**	**9.5** **(9.1;10.0)**	**9.7** **(9.2;10.2)**	**9.9** **(9.4;10.4)**	**9.9** **(9.4;10.4)**	**9.9** **(9.4;10.4)**	**9.9** **(9.5;10.3)**
be	1.8 **(0.9;2.8)**	*7.6* **(6.7;8.7)**	8.7 **(7.8;9.7)**	9.5 **(8.5;10.6)**	9.8 **(8.8;10.8)**	9.8 **(8.8;10.8)**	10.6 **(9.6;11.7)**	9.9 **(8.9;10.9)**	9.3 **(8.3;10.4)**	9.5 **(8.8;10.3)**	9.9 **(9.3;10.6)**	10.0 **(9.4;10.5)**
de	1.9 **(1.0;2.7)**	*7.4* **(6.4;8.3)**	8.8 **(7.9;9.8)**	9.7 **(8.8;10.6)**	10.6 **(9.7;11.6)**	10.0 **(9.1;10.9)**	9.8 **(8.9;10.7)**	10.2 **(9.2;11.2)**	10.3 **(9.3;11.3)**	10.2 **(9.4;11.0)**	10.1 **(9.4;10.7)**	10.1 **(9.5;10.6)**
ie	1.2 **(0.1;2.1)**	0.7 **(-0.6;1.8)**	1.5 **(0.1;2.7)**	1.9 **(0.5;3.2)**	2.2 **(0.9;3.5)**	2.7 **(1.3;4.1)**	3.2 **(1.7;4.6)**	4.2 **(2.7;5.7)**	*5.3* **(3.9;6.7)**	6.2 **(4.9;7.5)**	6.9 **(5.8;8.1)**	7.6 **(6.5;8.9)**
gr	1.2 **(0.6;1.7)**	*6.2* **(5.6;6.9)**	8.6 **(7.9;9.3)**	9.7 **(9.0;10.3)**	10.0 **(9.4;10.7)**	10.2 **(9.6;10.9)**	10.3 **(9.6;11.0)**	10.3 **(9.6;11.0)**	10.4 **(9.7;11.1)**	9.9 **(9.3;10.6)**	9.8 **(9.2;10.4)**	9.9 **(9.4;10.4)**
es	1.6 **(1.3;2.0)**	4.5 **(4.0;4.9)**	*6.2* **(5.7;6.7)**	7.7 **(7.1;8.2)**	8.6 **(8.0;9.2)**	9.1 **(8.5;9.7)**	9.3 **(8.6;9.9)**	9.6 **(9.0;10.2)**	9.7 **(9.1;10.3)**	9.8 **(9.2;10.4)**	9.8 **(9.2;10.4)**	9.8 **(9.2;10.4)**
fr	1.6 **(1.2;2.0)**	*6.1* **(5.6;6.6)**	8.0 **(7.5;8.6)**	8.9 **(8.4;9.5)**	9.6 **(9.0;10.2)**	9.6 **(8.9;10.2)**	9.6 **(8.9;10.2)**	9.7 **(9.1;10.3)**	10.1 **(9.4;10.7)**	10.0 **(9.3;10.8)**	9.9 **(9.2;10.7)**	9.9 **(9.3;10.7)**
it	1.4 **(1.0;1.8)**	4.7 **(4.1;5.2)**	*6.5* **(5.9;7.0)**	7.5 **(6.8;8.1)**	8.6 **(7.9;9.2)**	8.9 **(8.1;9.6)**	9.7 **(9.0;10.3)**	9.5 **(8.8;10.2)**	9.8 **(9.0;10.5)**	9.6 **(9.0;10.3)**	9.7 **(9.1;10.4)**	9.7 **(9.2;10.4)**
lu	2.5 **(1.8;3.1)**	*8.5* **(7.9;9.0)**	9.5 **(8.9;10.1)**	9.8 **(9.2;10.5)**	10.7 **(10.1;11.3)**	10.4 **(9.8;11.1)**	10.3 **(9.7;10.9)**	10.0 **(9.4;10.6)**	10.4 **(9.8;11.0)**	10.4 **(9.9;10.8)**	10.3 **(10.0;10.6)**	10.3 **(10.0;10.5)**
nl	*5.8* **(5.2;6.5)**	9.9 **(9.2;10.6)**	10.6 **(9.9;11.3)**	10.5 **(9.7;11.2)**	11.0 **(10.3;11.7)**	10.3 **(9.6;11.0)**	10.1 **(9.4;10.9)**	10.6 **(9.9;11.4)**	10.4 **(9.6;11.2)**	10.7 **(10.0;11.4)**	10.6 **(10.1;11.2)**	10.6 **(10.1;11.1)**
at	1.2 **(0.6;1.8)**	*5.0* **(4.3;5.8)**	6.4 **(5.6;7.3)**	7.5 **(6.6;8.4)**	8.3 **(7.3;9.1)**	8.6 **(7.8;9.5)**	8.9 **(8.1;9.8)**	9.1 **(8.3;10.0)**	9.3 **(8.4;10.2)**	9.5 **(8.6;10.3)**	9.4 **(8.5;10.2)**	9.3 **(8.5;10.1)**
pt	0.3 **(-0.6;1.2)**	1.3 **(0.2;2.4)**	2.7 **(1.4;4.1)**	4.5 **(3.1;6.0)**	*6.2* **(4.7;7.8)**	7.5 **(5.9;9.1)**	7.4 **(5.6;9.1)**	7.7 **(5.8;9.7)**	8.3 **(6.3;10.4)**	8.7 **(6.6;10.8)**	9.0 **(6.9;11.3)**	9.1 **(7.0;11.5)**
fi	3.3 **(2.1;4.6)**	*5.6* **(4.2;7.2)**	5.0 **(3.4;6.4)**	4.8 **(3.2;6.5)**	6.2 **(4.7;7.7)**	7.1 **(5.4;8.6)**	9.0 **(7.3;10.5)**	10.6 **(9.1;12.3)**	10.1 **(8.5;11.7)**	9.6 **(8.3;10.8)**	9.5 **(8.3;10.8)**	9.2 **(8.0;10.6)**

Notes:
Figures underlined and in italics denote 50% pass through reached. Figures underlined denote 90% pass through reached. Figures in parenthesis represent the 99% confidence intervals calculated using bootstrap techniques (10,000 iterations).

Table 7
Wald tests for asymmetry in pass through of gasoline into petrol prices*

	Overall all coefficients	AR sum ($\sum \alpha_i$)	AR(i) (α_i)	dynam. sum ($\sum \beta_i$)	dynam.(i) (β_i)	EC adjust. ($\gamma_{i,j}^{\pm}$)	ECM**
euro area	0.52	0.96	0.83	0.90	0.69	0.12	0.20
be	0.59	0.84	0.22	0.73	0.96	0.86	0.57
de	0.39	0.44	0.33	0.38	0.90	0.15	0.64
ie	0.94	0.28	0.68	0.99	0.76	0.83	0.65
gr	0.11	0.12	0.35	0.23	0.35	0.13	0.41
es	0.88	0.61	0.69	0.99	0.48	0.35	0.53
fr	**0.02**	0.47	0.26	0.74	0.62	**0.03**	0.09
it	0.19	0.63	0.19	0.43	0.76	0.59	0.96
lu	**0.02**	0.29	0.02	0.48	0.07	0.58	0.73
nl	0.21	0.44	0.37	0.59	0.19	0.06	0.31
at	0.82	0.24	0.81	0.78	0.76	0.39	0.98
pt	0.30	0.01	**0.04**	0.29	0.42	0.65	0.42
fi	0.39	0.05	0.08	0.29	0.61	0.50	0.63

Notes:
* *checks for asymmetry in the adjustment to the ECM term depending on whether it is above or below zero (i.e. whether price below equilibrium levels respond more quickly to those above equilibrium levels)*
** *Bold values indicate test for asymmetry significant at 5% level*

(a) Crude and various refined oil prices **(b) Various refining margins**

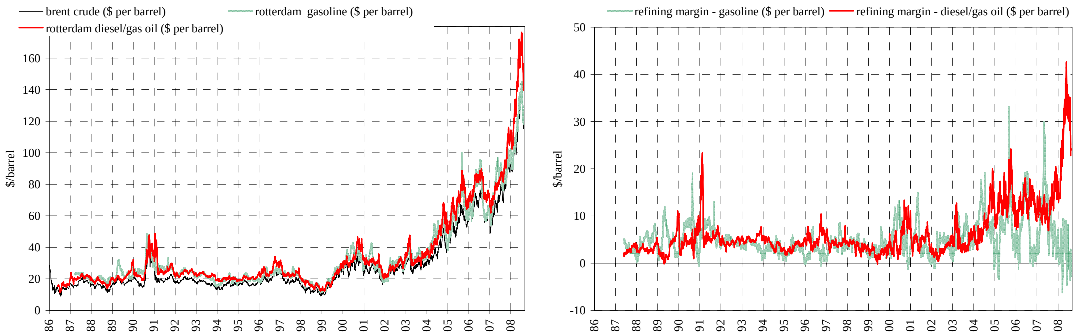


Figure 1
Crude and refined oil prices

Sources: US Energy Information Agency, Reuters and authors calculations

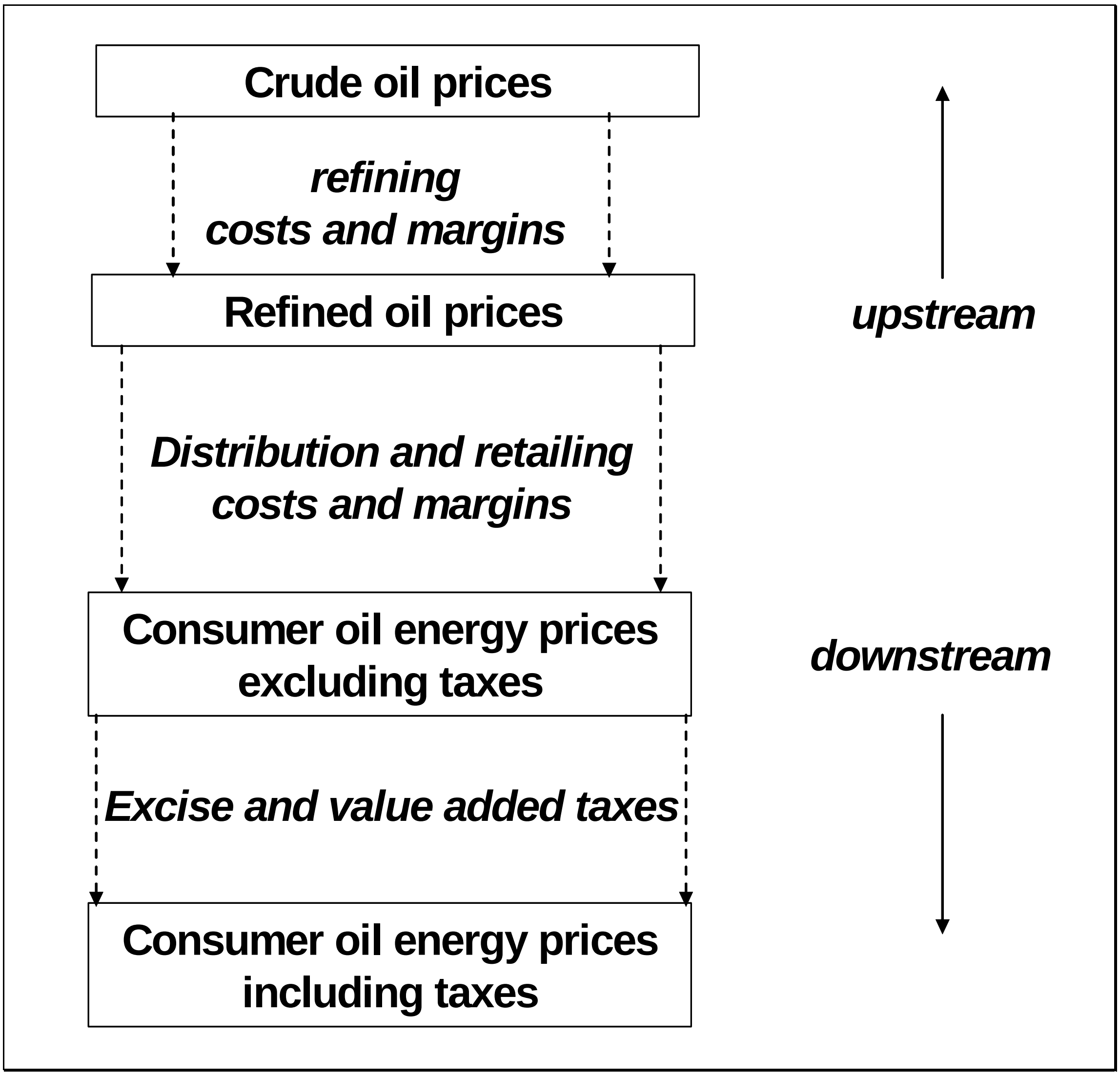
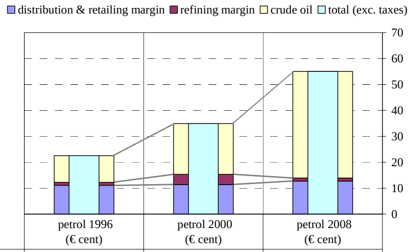


Figure 2
Stylised representation of the consumer liquid fuel pricing chain

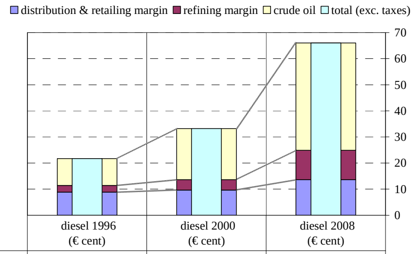
Notes:
The entries with borders are the prices that we may observe. The entries without borders are measured implicitly as the gap between observed prices

(a) Petrol



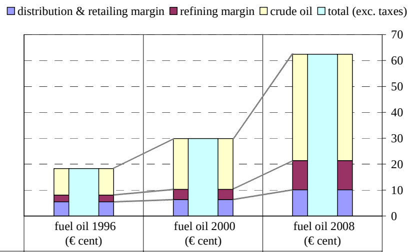
	petrol 1996 (€ cent)	petrol 2000 (€ cent)	petrol 2008 (€ cent)
crude oil	10	20	41
refining margin	1	4	1
distribution & retailing margin	11	11	13
total (exc. taxes)	23	35	55

(b) Diesel



	diesel 1996 (€ cent)	diesel 2000 (€ cent)	diesel 2008 (€ cent)
crude oil	10	20	41
refining margin	3	4	11
distribution & retailing margin	9	10	14
total (exc. taxes)	22	33	66

(c) Fuel oil



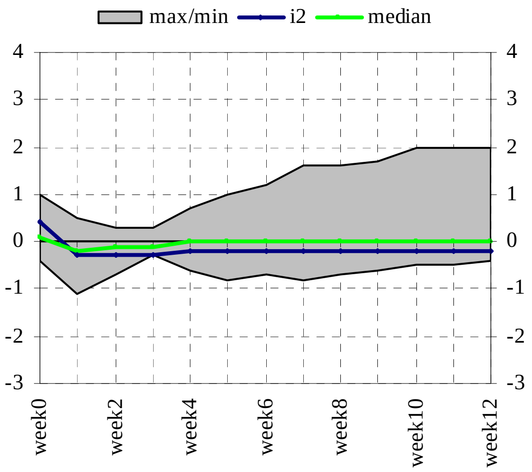
	fuel oil 1996 (€ cent)	fuel oil 2000 (€ cent)	fuel oil 2008 (€ cent)
crude oil	10	20	41
refining margin	3	4	11
distribution & retailing margin	5	6	10
total (exc. taxes)	18	30	62

Figure 3

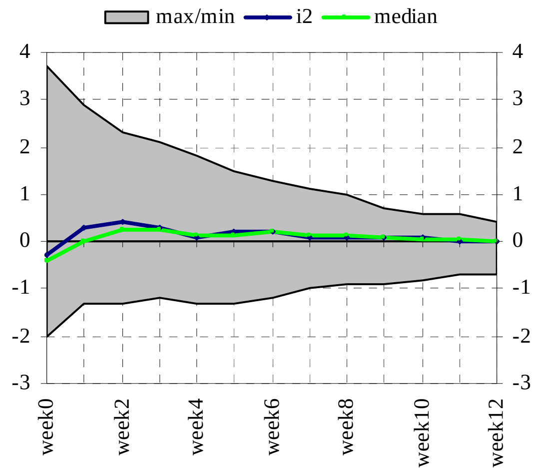
Decomposition of euro area petrol, diesel and gas oil prices

Sources: European Commission DG-TREN, Reuters, US Energy Information Agency, and authors calculations

(a) Petrol



(b) Diesel



(c) Heating fuel

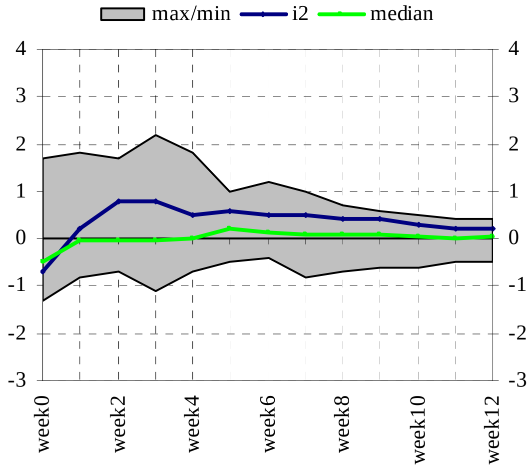


Figure 4

Difference between responses of consumer prices to increases and deceases in refined upstream price

Notes:

Max/min denotes the range between the highest and lowest differences across the 12 euro area countries estimated. The median shows the median difference across the countries. Calculated using the models estimated over the period 2000-2008.' i2' denotes euro area aggregate