The behaviour of consumer gas prices in an environment of high and volatile oil prices

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THE BEHAVIOUR OF CONSUMER GAS PRICES IN AN ENVIRONMENT OF HIGH AND VOLATILE OIL PRICES[1]

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1. Overview

In this paper we examine the relationship between oil prices and consumer gas prices in the euro area. The main features of the paper are: (1) the combination of low frequency (semi-annual) consumer gas price data on price levels from Eurostat with higher frequency (monthly) index HICP data; (2) the consideration of the different stages in the supply chain - from oil prices, to wholesale (border and spot market prices) to consumer prices; (3) analysis at the aggregated euro area and individual country level; and (4) a sample period covering from 1995 to 2010, covering a period with relatively low and stable oil prices, but also one with higher and more volatile oil prices. The questions we address are: (a) what is the behaviour of gas prices and in particular the pass through of upstream oil and gas prices into consumer prices (i.e. how much is passed through and how quickly) and (b) are there differences across countries.

Our main findings are that: First, on average, gas import prices are passed through fully in to consumer gas prices, albeit with some lag. An implication of this is that the elasticity of consumer prices with respect to upstream prices is an increasing function of their level. Second, accounting for the regular calendar for price ‘resetting’ significantly improves the fit of the estimations. However, this cannot be done via regular seasonal dummies but they must be interacted with the error correction term as the reset adjustment may be up or down. Third, in general the fit of the estimations is higher using oil prices as the explanatory variable rather than gas import prices. This may be because gas price setters take into account the signal from current oil price levels when resetting their prices, whereas gas import prices are generally backward looking as in Europe they are mostly index-linked to oil price developments in the preceding months. Fourth, regarding cross-country patterns, there is some evidence of differences which may be linked to differences in the degree of market liberalisation. Lastly, whilst there are signs of some changes in historical long-term relationship between oil prices and gas import prices, these are too recent to be identified robustly using the relatively low frequency, aggregate data we utilise in this paper.

The structure of the paper is as follows: Section 2 discusses the link between oil and gas import prices. Section 3 considers the pass-through of movements in upstream prices for oil and gas import prices into consumer gas prices. Section 4 concludes.

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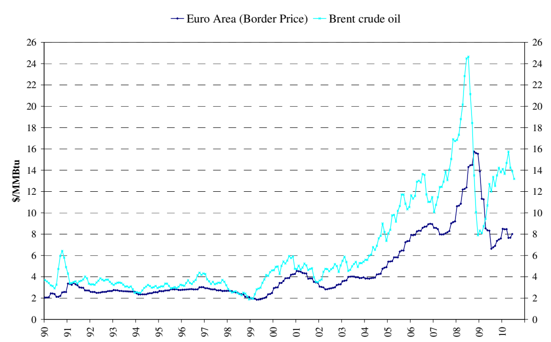
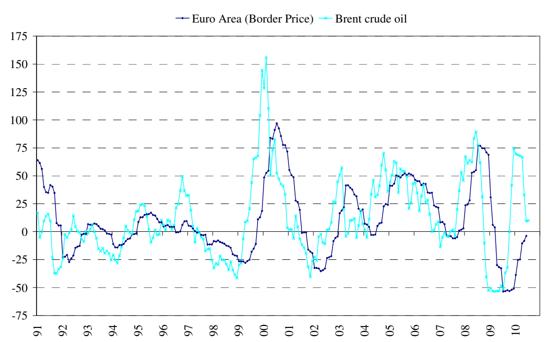
[1] The views expressed in this paper do not necessarily represent those of the ECB, the National Bank of Belgium or the European System of Central Banks. This paper is drawn from work undertaken for the 2010 Structural Issues Report on “Energy markets and the euro area macroeconomy” ECB (2010).

2. The link between oil and gas import prices

Although it is not the main focus of this paper in this section we first consider the relationship between oil prices and gas import prices. A key and well-known feature of natural gas price developments is their strong co-movement with crude oil prices.[2] This strong co-movement mainly reflects economic factors, in particular, the substitutability of, and competition between, gas and oil for certain purposes such as electricity generation, and common factors such as global demand for energy commodities. However, the particularly strong co-movement in Europe also reflects institutional arrangements whereby many long-term gas supply contracts are explicitly linked to oil prices.[3] An important feature of global gas markets is that they are less integrated than oil markets.[4] This owes to the facts that gas is less storable and shippable than oil and that most gas is still transmitted by pipeline.[5] This implies that, in the absence of explicit indexing on oil prices, regional supply and demand developments would have more impact on gas price movements. However, in the long run, the economic factors outlined above would, in any case, probably generate a degree of co-movement. Chart 1a and Chart 1b, which show the evolution of crude oil prices and border prices for gas (i.e. mainly cross-border pipeline prices), highlight the strong co-movement between the two series as well as the slight lag in gas prices.[6] Thus, natural gas border prices having fluctuated at around 3$ per million British thermal units (MMBtu) increased substantially (given the perspective at that time) between mid-1999 and mid-2001 to a level of around 4$/MMBtu. Thereafter, in line with crude oil prices, they eased back somewhat up to mid-2004 although remaining at a higher level than previously at around 3-4$/MMBtu. Between mid-2004 and late-2008, gas prices increased significantly to reach a level above 15$/MMBtu (more than six times higher than levels observed ten years earlier in 1998). Since then, they have fallen back to a level of around $8/MMBtu in the first half of 2010 (i.e. very much below the levels reached in 2008 but still very high by historical standards).

Chart 1a Crude oil prices and Euro Area border gas prices – levels	**Chart 1b Crude oil prices and euro area border gas prices – yoy rates of change**
	

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2 There has been a substantial amount of analysis on why and how oil and gas prices co-move – Brown and Yücel (2009), IEA (2009), Neumann (2009), Onour (2009), Brown and Yücel (2007), Hartley et al (2007), Robinson (2007), Asch et al (2006), Baschmeier and Griffin (2006), Villar and Joutz (2006), Siliverstovs et al (2004) and Serletis and Ricardo (2004). The more recent literature has confirmed that this relationship holds although the growing importance of LNG, developing sport markets, increasing market integration and technological changes may have altered it somewhat.

3 The European index-linked pricing model dates originates from the pricing model developed by the Dutch authorities in the 1960s following the discovery of the Groningen field, which subsequently became the pricing model adopted throughout Europe. For a more detailed discussion see Energy Charter (2007) Chapter 4.4 and Konoplyanik (2010).

4 Nordhaus (2009), given the high degree of integration in regional oil markets, compares the overall oil markets to a giant 'bath tub' albeit with multiple inputs and outputs. The implication of this bath tub model is that regional oil prices (e.g. WTI, Brent Crude, etc.) co-move very strongly with only minor differences owing to fuel specifications in terms of sulphur content, etc.

5 However, the emergence of liquefied natural gas has diminished slightly the regional nature of gas markets. Although price differences and costs of transport mean that regional markets still remain somewhat fragmented. See Neumann (2009) for a discussion on the impact of LNG on the linking of natural gas markets.

6 The correlation between the two series peaks at a lag of five months both in level and year-on-year terms, and at four months in month-on-month terms. This means that euro area gas border prices tend to lag crude oil prices by approximately four to five months on average.

Sources: DataStream, Energy Intelligence, Haver Analytics, ESCB staff calculations
Notes: Euro area border gas prices based on average for Germany, France, Italy, Spain, the Netherlands and Belgium.

The charts above, present graphical evidence in favour of the co-movement between oil and gas prices. Using an approach similar to Brown and Yücel (2007), who model the equilibrium relationship between gas and oil prices, we present some quantitative evidence on the relationship between oil and gas prices.[7] Their functional form is motivated by the so-called ' burner-tip parity' rule – see Barron and Brown (1986) – which takes into account the energy content of a barrel of oil and the higher costs of transporting gas compared to oil. Hence gas prices are modelled as a function of a constant plus a portion of oil prices.

However, before presenting the estimation results we first consider the time series properties of oil and gas prices in terms of stationarity, causality and cointegration – Table A1 in the Appendix reports the results in more detail. ADF tests indicate that both series are clearly non-stationary. The pair-wise Granger causality tests indicate that causality runs from oil prices to gas prices, with little evidence of reverse causality. The cointegration analysis suggests one cointegrating relationship, with both the error correction term and long-run coefficient being of the correct sign and strong significant. Therefore, we proceed with the Brown and Yücel type estimation (Equation 1), where P^{BG} is the border price of natural gas and P^{O} is the price of oil.[8]

$$P^{BG} = \alpha + \beta P^{O} \qquad (1)$$

The results of the estimation in levels (which provides the long-run values) are presented in Table A1. The value of 0.67 (0.12 when estimated using $ per barrel[9]) on the brent crude oil price term is quite similar to that found by Brown and Yücel in the United States on WTI oil (0.14). It should be noted that the residuals increase towards the end of the sample period, particularly since 2008. This reflects in part the fast run-up and subsequent sharp decline in oil prices. However, it may also reflect other fundamental factors. First, as highlighted already, we estimated the equation using Brent crude oil prices, but long-term contracts are often specified in terms of refined petroleum products. In 2008 a large gap opened up between refined gas oil and crude oil prices. This explains some of the error in 2008. Second, since 2009, predicted border gas prices were initially below actual prices (particularly between March and June), and since October 2009 have been above actual prices. The more recent developments may reflect the growing importance of spot markets for gas and downward pressure exerted from this source – this issue is discussed in more detail below.

As noted above, a key feature of gas import prices is that they tend to be determined by long-term contracts index-linked to oil, with prices being 'reset' at a regular frequency. Table 1 reports which months tend to exhibit the most changes (calculated as the mean absolute change in that month as a percentage of the mean absolute change across all months). For border gas prices it is clear that most price changes tend to take place at a regular quarterly frequency (generally in January, April, July and October), with 77.1% of euro area border gas price changes taking place during these four months. The percentage is higher for pipeline imports

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7 Although as their primary purpose is to explain (upstream/wholesale) natural gas prices they augment their model with additional variables, which they suggest may cause gas and oil prices to deviate, at least temporarily, from equilibrium. These are absolute (and relative to average) heating degree days, absolute (and relative to average) cooling degree days, the deviation of storage from seasonal averages and the amount of 'shut in' production.

8 We have experimented with alternative specifications using Brent crude oil as well as with heavy and light fuel oil (as these are often the reference prices used in the long-term gas contracts). Given the broad constancy of fuel oil refining margins the results are broadly similar, although the sharp increase in fuel oil refining margins in 2008 means that the regressions using fuel oil prices capture slightly better then sharp run up in border gas prices in the first half of 2008. However, given that Brent crude oil prices are the benchmark price for Europe and are the key energy price series used in the context of the Eurosystem projection exercises, here we focus on the results using Brent crude oil prices.

9 We use the adjustment coefficient of 5.45685 (taken from World Gas Intelligence) to convert crude oil prices per barrel to per MMBtu prices.

(84.6%) and for some countries (the UK - 95.0%; the Netherlands – 94.6%, and Germany – 93.9%); and is lower for LNG imports (38.8%) and some countries (most noticeably Spain – 49.7%). The degree of regular calendar adjustments is also much lower for oil prices (40.2% in USD terms) and for gas prices in spot markets (45.2% to 48.1%).

Table 1 - Calendar profile of upstream oil and gas prices

		Month1	Month2	Month3	Month4	M1-M4
oil	**usd**	Mar (10.5%)	Oct (10.2%)	Apr (10.1%)	Dec (9.5%)	40.2%
xchange	**usd:euro**	Dec (10.9%)	Oct (9.9%)	May (9.5%)	Aug (9.3%)	39.6%
oil	**euro**	Mar (10.4%)	Dec (10.1%)	Apr (9.9%)	Nov (9.4%)	39.8%
border gas	**belgium**	Jan (19.4%)	Oct (15.8%)	Apr (14.5%)	Jul (14.4%)	64.1%
	france	Jan (20.4%)	Oct (19.6%)	Apr (17.4%)	Jul (16.7%)	74.1%
	germany	Jan (27.5%)	Oct (24.2%)	Apr (21.8%)	Jul (20.4%)	93.9%
	italy	Jan (21.4%)	Oct (20.0%)	Apr (18.3%)	Jul (17.5%)	77.2%
	netherl.	Jan (27.4%)	Oct (23.9%)	Apr (22.2%)	Jul (21.2%)	94.6%
	spain	Jan (13.2%)	Oct (12.4%)	Apr (12.2%)	Jul (11.9%)	49.7%
	uk	Jan (27.9%)	Oct (24.4%)	Apr (22.5%)	Jul (20.1%)	95.0%
	euro area	Jan (21.7%)	Oct (20.0%)	Apr (18.1%)	Jul (17.4%)	77.1%
	pipeline	Jan (25.5%)	Oct (22.0%)	Apr (19.2%)	Jul (18.0%)	84.6%
	lng	Aug (10.2%)	Feb (9.7%)	Sep (9.5%)	Apr (9.4%)	38.8%
spot gas	**us**	Dec (15.2%)	Feb (12.2%)	Oct (9.7%)	Sep (9.0%)	46.2%
	belgium*	Nov (20.5%)	Jul (9.7%)	Mar (9.1%)	Jan (8.7%)	48.1%
	netherl.**	Mar (13.0%)	Jan (11.7%)	Nov (10.5%)	Sep (10.0%)	45.2%
	uk*	Nov (19.2%)	Oct (12.4%)	Dec (8.3%)	Feb (8.3%)	48.1%
	eu*	Nov (18.0%)	Oct (10.4%)	Mar (9.4%)	Feb (8.7%)	46.5%
Sources: DataStream, Energy Intelligence, Haver Analytics, ESCB staff calculations						
*Notes: * since 2001; ** since 2004*						

These regular calendar-based adjustments have implications for estimating the relationship between oil and gas prices. They cannot be treated as regular seasonal effects as (a) they depend on how far gas prices are away from the oil-based equilibrium, and (b) they may be upward or downward depending on whether gas prices are below or above the oil-based equilibrium. Simply ignoring the other months (and estimating a quarterly model based on the Jan, Apr, Jul and Oct data) is not satisfactory as this would imply 'throwing away' information on over 20% of price changes on average across the euro area. Therefore, our approach has been to estimate an error-correction model but to augment it with terms interacting the seasonally dummies and the error correction term. The results, which are summarised in Table A2 in the Appendix, illustrate a strong increase in the R^2 (from 0.60 to 0.76 – with a similar size increase in the adjusted R^2 statistic), as well as significant changes to the estimated error-correction adjustment term (which was -0.14 for the estimation without calendar effects), to around -0.20 in those months in which prices tend to be adjusted, but significantly lower (-0.04) in other months.

There are two main errors in the regression results allowing for calendar based adjustment - in February 2009 and April 2010. The first one, in February 2009, represents an unprecedented change in border gas prices of a magnitude that had never previously been observed outside the normal adjustment months (i.e. January, April, July and October).[10] This extraordinary change probably reflects the unprecedented sharp and large decline in oil prices in the preceding months since mid-2008. The other error relates to April 2010, where owing to high oil prices, the

[10] For this reason, and the significance of the coefficient on the 3rd autoregressive lag of border gas prices, that we insert a dummy variable (to switch off the adjustment in May 2009 that would otherwise be in the equation.

equation would have indicated an increase in border gas prices but they actually decreased. This decrease may owe to the growing emergence of the spot market for gas (the prices of which were below border prices in the beginning of 2010) and the consequent renegotiation of some long-term contracts. In this regard, a number of large European utility companies successfully sought to renegotiate their long-term contracts, in view of pressures faced by competitors who were sourcing gas from spot markets. In should also be noted that World Gas Intelligence (WGI) announced in 2010 a revision of the methodology used to calculate border prices "*to reflect increased spot trading and growing reliance on spot gas indexation in cross-border term contracts*".

This analysis thus far has abstracted from two issues. The first is cross-country differences in import gas prices. Although these tend to co-move closely over time, there are differences which have increased in more recent years both in absolute and percentage terms (see Chart 2). These differences may owe in part to different escalation factors applied to the index-linked contracts, but may also reflect other fundamental market factors such as the degree of competition from other sources, in particular spot gas markets and LNG markets. Second, Chart 3 illustrates that on average since 2001, spot market prices have been below border prices, although they have, upon occasion (in particular in 2006 and again in 2008) been above and also have been somewhat more volatile on average. Nonetheless, for a number of reasons, it might be expected that oil prices will continue to exert a strong impact on European gas import prices. One, many contracts are still explicitly linked to oil and have a long time to expire. The Energy Charter in a 2007 report on oil and gas pricing note that "*the prolongation (to between 2027 and 2036) of long-term contracts for Western Europe in the second half of 2006, the transition of supply arrangements in Eastern Europe from annually renewable gas-for-transit arrangements to long-term contracts, and the minor role that spot imports play so far, indicate that long-term import contracts will continue to play a predominant role in continental Europe in the future. This, however, does not mean that single elements that are still usual today, like pegging to fuel oil prices, will play the same role in the future*" (Energy Charter, 2007, pg 174). Two, although spot markets have increased in importance since 2006, economic factors, such as substitutability particularly for electricity generation, suggest some ongoing co-movement (see Box below, which shows that US and European spot markets tend to co-move relatively closely).

Chart 2 Gas import prices by country

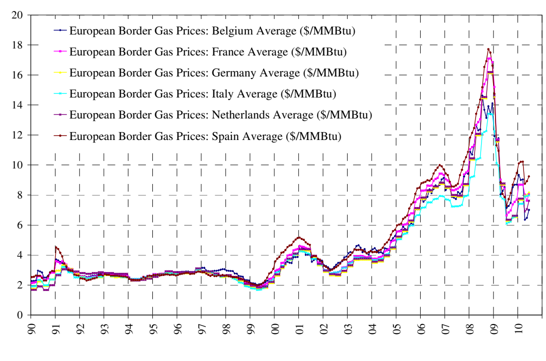
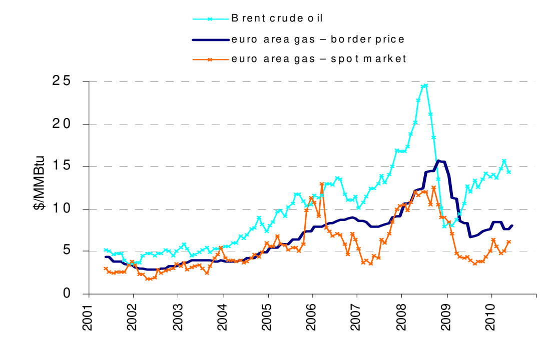


Chart 3 Border vs. spot market gas prices



Sources: DataStream, Energy Intelligence, Haver Analytics, ESCB staff calculations

Box – A brief comparison of US and European gas prices

In this box we briefly compare movements in US and European gas prices at the upstream (border – pipeline/LNG – and/or spot market hub) level. As discussed above the broad co-movement of oil and natural gas prices is a well-known and international phenomenon.

However, the extent to which the two co-move may vary across international markets as regional markets are still separated to some degree – this is because the cheapest way to transport gas is by pipeline, which implies most gas is consumed relatively close to where it is extracted.[11] Chart 4 shows that 'market' prices in all the main gas markets (euro area, Japan and the United States) co-move strongly with oil prices. However, the co-movement varies in terms of volatility and timing. Euro Area and Japanese 'market' gas prices are the smoothed and most formally linked to oil prices. Although US prices share the same broad upward and downward movements, from time to time they move in a much stronger and more volatile manner.

However, it is important to note that the euro area natural gas prices shown in Chart 4 are 'border' gas import prices (primarily pipeline but also LNG) and not spot market prices. The former are normally subject to long-term contract agreements and price adjustment formulas (usually based on oil prices).[12] In the United States spot market prices are generally the benchmark prices. In the euro area, however, the spot markets, though growing rapidly, still remain small relative to contracted gas.[13] Chart 5 shows that considering spot market prices in the euro area and in the United States, the co-movement is much stronger than is the case with border prices.[14] This would suggest that, in the absence of long-term contracts, regional gas markets could perhaps co-move more than frequently assumed.

Chart 4 – International market prices of natural gas

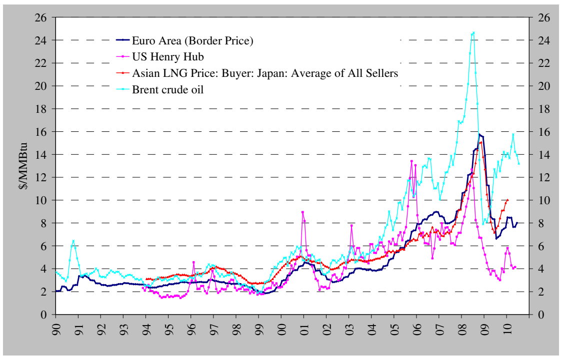
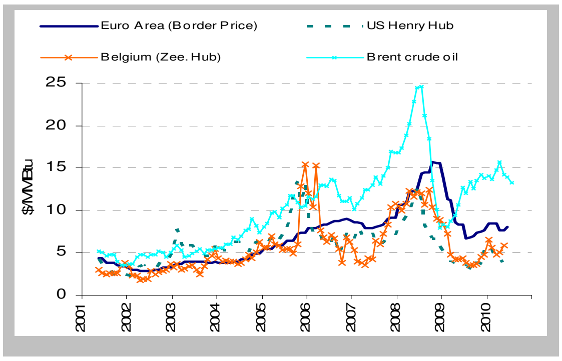


Chart 5 - Border vs. Spot Hub Price



Sources: DataStream, Energy Intelligence, Haver Analytics, ESCB staff calculations

3. Consumer gas prices

Consumer gas prices account for approximately 2% of the euro area Harmonised Index of Consumer Prices (HICP) and have increased at an annual average rate of 5.5% since 1996 (considerably above the average overall inflation rate of 2% - this equates to a higher rise of

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[11] Although liquefied natural gas (LNG) may be shipped, it is generally more expensive to do so and the volume traded (particularly freely) is low relative to the volume of gas piped.

[12] Japanese gas prices (generally LNG) are also linked by formula to oil prices, but this formula is generally non-linear (so-called 'S-curve'). This helps explain why Japanese gas import prices, which were historically higher than euro area and US as they imported LNG, did not rise by as much in recent years.

[13] Contracted border prices tend to be smoother than spot market prices. On the other hand, although spot prices have been more volatile over the period 2001-2009, they have also been somewhat lower on average by approximately 1$/MMBtu. There have been various arguments put forward in favour and against longer-term contracting and indexing of natural gas prices. Those in favour argue that given the large capital costs involved in building gas infrastructure, longer-term contracts help reduce uncertainty. On the other hand, those against argue that indexing on oil prices dulls the signal coming from relative supply and demand in gas markets. Ultimately, both set of prices should broadly co-move. However, this co-movement may vary over time reflecting market specific factors in both oil and gas markets.

[14] In the chart we show gas prices at the Zeebrugge Hub (Belgium). The picture remains the same for the Title Transfer Facility (TTF, the Netherlands) and National Balancing Point (NBP, the United Kingdom) hubs

around 80% in cumulative terms).[15] The volatility of consumer gas prices has also been quite high – the standard deviation of the annual rate of change in consumer gas prices was 8% on average over the period 1996-2009 compared to 0.8% for the overall inflation rate.

In this section we address in some detail the factors behind gas price levels and changes. However, to be able to address both the short-term dynamic impacts and level effects we need to combine two data sources - monthly HICP data and semi-annual information on gas price levels. Table 2 below provides a brief assessment of the relative advantages and disadvantages of these two sources of data. Gas price levels (with and without taxes, in Euros per gigajoule) are collated by Eurostat on a semi annual basis. Prices valid on the first January and the first July of each year were recorded until 2007, when the methodology was significantly changed. That change implied a new definition of the standard consumption[16] used and a focus on six month average prices, so that pre and post 2007 data are not directly comparable. HICP gas price indexes are also collated by Eurostat from national HICPs. These data are collected monthly, and made available approximately two weeks after the reference period. They are only available in index form (currently 2005 = 100) and including taxes but should reflect representative prices (i.e. a weighted average of different consumption groups).

Table 2 – Comparative advantages/disadvantages of HICP gas and gas price level data

	Advantages	**Disadvantages**
Price level	• Absolute prices (€ per GJ) since 1991 • Available exc. and inc. taxes • Different consumer types (albeit for more limited sample)	• Frequency (semi-annual) • Change in methodology (2007H2)
HICP	• Frequency (monthly) since 1995 • Timely – available within two weeks of reference month • Represents average price faced by consumers	• Index (2005 = 100) • Only available inc. taxes

Focusing on pre-2007 data allows a comparison with HICP data within a relatively large sample. A high degree of correlation can be seen between year-on-year price changes between the two datasets for the euro area as whole – see Chart 6a; suggesting that these data are representative of prices faced by 'typical' consumers. However, this is not systematically the case at the country level.[17] Chart 6b presents the price level data excluding taxes and the transformed HICP data (also without taxes); although there are some differences, the degree of correlation, at 0.98, is quite high. Therefore, in what follows we use the transformed HICP data as these data combined high frequency with information on absolute price levels.

15 The relative importance of gas ranges substantially across euro area countries from 4% in the Netherlands and Slovakia to no meaningful weight in Greece and Finland.

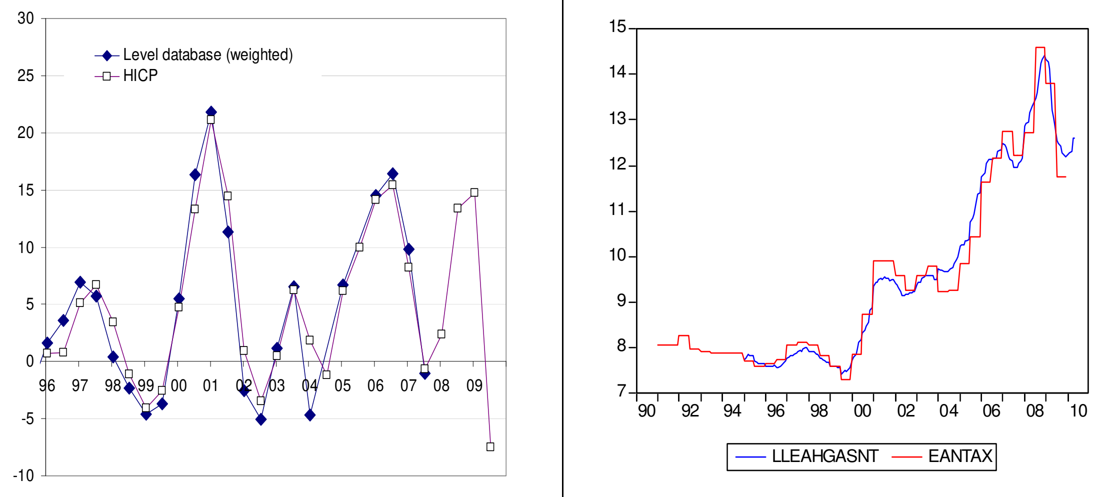
16 Definition of the standard consumptions (selected as structural or so-called Lisbon indicator) Gas: *Households* pre 2007: type D3 (annual consumption 83.70 GJ); post 2007: type band D2 (annual consumption between 20 and 200GJ).

17 For DE, SI, FR, IT, and LU a high correlation between the two data sources is found. In BE and ES, the correlation between HICP and level data is weaker because there is an additional lag in the HICP data compared to the level data. In ES it is so particularly in the period 2000-2005, but not thereafter. In BE no lag can be found after 2007: since then the HICP only reflects current price evolutions, whereas before 2007 prices were recorded as 12 months averages to reflect an annual bill approach, see Cornille (2009). For AT the HICP and level data are relatively weakly correlated. For PT and SK not enough data are available to make strong conclusions.

Chart 6 Euro area gas: comparison HICP and medium size households level data[1]
(annual rates of change on the 1st January and 1st July, %)

(a) Including taxes; annual rates of change

(b) Excluding taxes; €/gigajoule



Source: Eurostat, ESCB calculations.
[1] Level data according to the pre -2007 methodology: prices valid on the first January and the 1st July. The same standard medium size household is used for each country. Euro area: weighted according to 2009 HICP countries and items weights, for countries for which data are available. LLEAHGASNT denotes the monthly series derived from the HICP data; EANTAX denotes the original semi-annual series.

Chart 7 illustrates that consumer prices for gas have also increased rapidly since 1999 (from a level of around 10€/GJ), reaching a peak at the beginning of 2009 (at close to 20€/GJ) before declining somewhat during 2009.[18] Chart 7 also shows that the broad profile of consumer gas prices is similar to that of gas border (and crude oil) prices, although consumer gas prices tend to lag somewhat. For the euro area as a whole, the peak correlation of consumer gas prices with crude oil prices is at a lag of seven months in level (0.95) and eight months in year-on-year (0.77) terms and six months in terms of month-on-month changes (0.38). The peak correlation of consumer gas prices with gas border prices is at three months in level (0.97), year-on-year (0.91) and month-on-month (0.69) terms. This correlation structure is broadly shared across euro area countries.

The gap between the border and the consumer price excluding taxes (called the mark-up below) reflects the <u>costs</u> of processing, transmitting, storing and distributing gas to consumers as well as the <u>margins</u> of the various operators along the gas chain. Overall the mark-up has remained relatively stable, at around 5-6€/GJ, over the period since 1995. This suggests that movements in gas border prices are passed through fully into consumer prices, with a slight lag, and that as international gas prices have increased the share of consumer prices accounted for by raw inputs has increased. One implication of this is that as the price level increases, although the absolute pass through remains the same (i.e. complete), the percentage pass through (i.e. elasticity) increases – this issue is addressed in more detail below.

[18] Note that consumer prices are reported as € per gigajoule (GJ), whereas gas border prices are reported as €/MMBtu. To convert from prices per MMBtu to GJ we use a conversion factor of 1.055.

Chart 7 Decomposing euro area consumer gas prices (taxes, border prices and the 'mark-up')

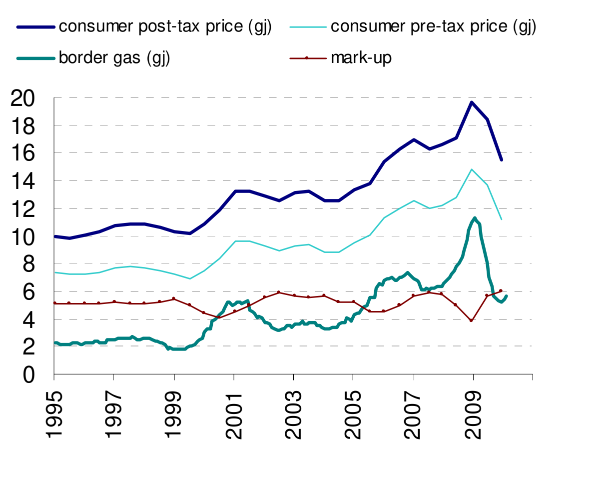
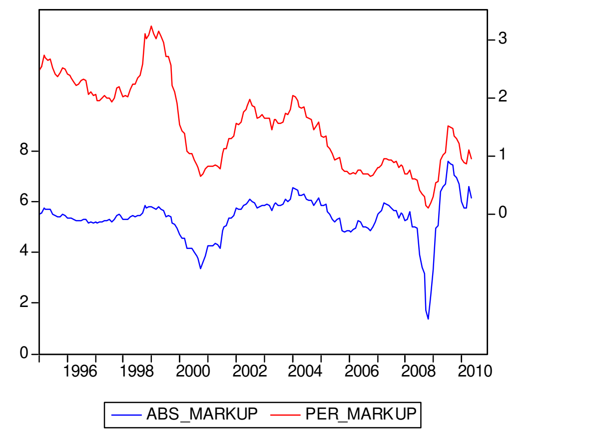


Chart 8 Gas mark-ups in absolute (left-hand scale) and percentage (right-hand scale) terms



Sources: Eurostat, Energy Intelligence, Haver Analytics and authors calculations

To arrive at our preferred estimation approach, we first carried out analyses of causality, stationarity and cointegration properties (see Table A1), as well as checking stability across different time periods. A general finding was that there is clear and robust evidence of causality from upstream prices to downstream prices. A graphical analysis of the data would suggest that upstream (crude oil and gas import prices) and downstream (consumer gas prices) have been non-stationary (both in terms of mean and variance) over the sample period. This is confirmed in Table A1 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 more than one shift in oil and gas price behaviour (around 1999, 2004 and 2008-2010) 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.[19]

The results of this analysis, which are available upon request, show that the cointegration properties (ADF Statistics) are stronger when the downstream prices are estimated in terms of raw levels rather than in terms of logarithms; suggesting, in line with the graphical evidence, that the former approach is to be preferred. In addition, although there is no statistically significant evidence of breakpoints in the relationship between upstream and downstream prices, there is some slight evidence of a break between crude oil prices and gas import prices around 1998/1999 when estimating in logs and in 2009 for both the log and absolute level specifications.

19 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 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".

However, as the latter possible breakpoint occurs towards the end of the available sample period it is too early to determine robustly whether it indeed represents a breakpoint. Regarding consumer gas prices, there is also some weak evidence of possible structural breaks around 2001 and again towards the end of the sample period.

Thus, following on from the analyses of causality, stationarity, cointegration and structural breaks, we estimate for consumer prices excluding taxes the following equation with two variants of upstream prices: (a) crude oil; (b) border gas import prices. The equation estimated is a standard single equation bivariate model with an error correction mechanism (see Equation 2). As energy prices have increased in level and volatility since 1999, we estimate the equations using Newey–West heteroskedacity and autocorrelation (HAC) consistent covariance estimates.

$$\Delta P_{i,t}^{CG} = c_{i,t} + \sum_{k=1}^{l} \alpha_{i,j,k} \Delta P_{i,t-k}^{CG} + \sum_{k=0}^{l} \beta_{i,j,k} \Delta P_{i,j,t-k}^{US} + \gamma_{i,j} \left(P_{i.t-1}^{CG} - \theta_{i,j} P_{j,t-1}^{US} \right) \qquad (2)$$

where, P_i^{CG} is the consumer gas price (excluding taxes) in country I, $P_{i,j}^{US}$ is the ‘upstream’ price (either crude oil or gas import prices). In addition, we allow for, and test, a time trend variable in the error correction term.

A key feature is that the pass-through estimation is carried out using absolute levels rather than logarithmic terms (see Meyler (2009) in this regard). The reason for this is that the gas mark-up appears to be broadly constant, on average, in absolute terms rather than being a constant percentage mark-up over input (wholesale) gas costs – see Chart 8. In any case, we test the results for this assumption.

Another fairly common feature across countries is that consumer gas prices, as is the case with gas import prices, tend to be ‘reset’ at a regular frequency. Table 3 reports which months tend to exhibit the most changes (calculated as the mean absolute change in that month as a percentage of the mean absolute change across all months). For consumer gas prices it is clear that most price changes tend to take place at the same regular quarterly frequency as was the case for gas import prices (i.e. generally in January, April, July and October). However, the extent to which changes are concentrated in these months is slightly lower for consumer gas prices, with 61.1% of euro area consumer gas price changes taking place during those four months compared to 77.1% of euro area border gas price changes. Price changes are most concentrated in specific calendar months in the Netherlands (with over 90% taking place in January and July) and in Ireland (79.7%). Consumer gas prices changes in Belgium (52.1%) and Italy (54.1%) are more evenly spread out. As was the case with border gas prices, these regular calendar-based adjustments may have implications for estimating the pass through from oil and gas import prices to consumer gas prices. Hence, our approach is again to estimate an error-correction model but to augment it with terms interacting the seasonally dummies and the error correction term. The results, which are summarised in Table A2 in the Appendix, illustrate a strong increase in the R^2 (from 0.55 to 0.75 – with a similar size increase in the adjusted R^2 statistic), as well as significant changes to the estimated error-correction adjustment term (which was -0.09 for the estimation without calendar effects), to around -0.18 in those months in which prices tend to be adjusted, but significantly lower (-0.04) in other months.

Table 3 - Calendar profile of downstream consumer gas prices

	Month1	Month2	Month3	Month4	M1-M4
euro area	Jan (23.9%)	Apr (14.3%)	Jul (12.2%)	Oct (10.7%)	61.1%
Be	Mar (15.9%)	Dec (12.7%)	Jun (12.7%)	Jan (10.8%)	52.1%
De	Jan (27.6%)	Oct (20.4%)	Apr (17.8%)	Jul (7.5%)	73.3%
Ie	Oct (50.6%)	Sep (13.7%)	Dec (8.3%)	Jun (7.1%)	79.7%
Es	Apr (22.2%)	Jan (18.4%)	Oct (18.1%)	Aug (11.0%)	69.7%
Fr	May (27.8%)	Nov (25.6%)	Apr (13.6%)	Jan (6.6%)	73.7%
It	Jan (16.7%)	Jul (14.9%)	Apr (12.3%)	Nov (10.3%)	54.1%
Lu	Jan (23.6%)	Oct (20.7%)	Jul (19.8%)	Apr (16.1%)	80.2%
Nl	Jan (56.9%)	Jul (38.2%)	Aug (1.3%)	Apr (0.9%)	97.3%
At	Jan (23.8%)	Nov (17.6%)	Jun (16.7%)	Oct (12.1%)	70.2%

Sources: Eurostat, ESCB staff calculations

Overall, it appears that movements in border gas prices are passed through fully into consumer prices albeit with some lag. Generally the test of the long-run coefficient being equal to unity is accepted for most countries (except for Spain and Luxembourg, where the coefficients are below/above unity respectively). Furthermore, when a unit coefficient is imposed, the resulting cointegrating is generally stationary, although in some cases there is then a significant coefficient on the trend (DE, IE, ES, IT, LU and AT).

An important result of our analysis is that, despite the substantial increase in upstream prices, for (pre-tax) consumer gas prices the distribution and retail costs and mark-up over wholesale (i.e. border) gas prices has remained broadly constant at around 5€/GJ (see Chart 7); although as there is some lag, mark-ups do buffer upstream price movements to some extent. An implication of this finding is that the relationship between upstream and downstream prices should be modelled in absolute level rather than logarithmic terms and that the elasticity of consumer gas prices with respect to oil prices is a function of the oil price level. Table 4 indicates that with crude oil prices around 20€/barrel (or 2.5€/MMBtu) the elasticity of consumer gas prices is around 20%, whereas at 50€/barrel (or 6.2€/MMBtu) the elasticity is close to 40%.

Table 4 Summary of consumer gas price elasticity with respect to oil and border gas prices

crude oil (*€per barrel*)	**natural gas (*€per MMBtu*)**	
20	**2.5**	20%
50	**6.2**	38%
100	**12.3**	55%

** based on median mark-ups observed over the period 1995-2010 and taxes (VAT, excise and others) as at May 2010*

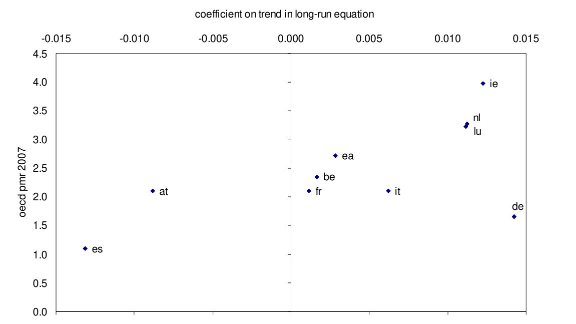
Another finding of note is that, with the exception of the Belgian equation, the R^2 is higher when using oil prices with a calendar effect than is the case when using gas border prices.[20] A priori, this is surprising given that it would normally be expected that the further one goes down the pricing change towards final consumer prices, the better the fit. However, it is possible that gas retailers when resetting their prices are already taking on board some information from oil prices at that time, which would not show up in border prices for 3-4 months.

[20] We experimented using the interactive seasonal terms with the border gas prices, but the results were generally negative. This may be because both the border and consumer prices share a broadly similar pattern in terms of which months shows the most changes.

4. Issues remaining

A number of issues remain to be teased out in more detail. First, whether most recent developments, specifically the growing evolution of LNG and European spot markets and the partial decoupling of gas import prices from oil prices, has impacted on consumer price developments. Although it may be that the impact will be strongest for utility and industrial customers. However, a definitive answer to this issue requires additional data. Second, we have not addressed the issue of a possible asymmetry in the response of consumer gas prices to increases and decreases in oil and gas import prices. Although the fact that margins have remained broadly constant on average would suggest that, if asymmetries are present, they relate primarily to short-run dynamics and not to the long-run co-movements. Lastly, we have not tried to explain cross-country differences in consumer gas price behaviour (either in terms of price levels, dynamics or pass through). Chart 9, which shows the coefficient on the time trend variable within the error correction term and the level of the OECD product market regulation for gas in 2007, provides some tentative evidence of the impact of market (de)regulation on pricing behaviour.[21]

Chart 9 – Link between OECD product market regulation indicator and trend in oil markups



Sources: OECD and ESCB calculations

21 See ECB (2010) and Gattini and Nardini (2010) for a more detailed discussion and analysis.

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Appendix – Summary of econometric analysis

Table A1 Summary of results from long-run analyses

			crude oil			**border gas**					
	ADF tests		cointeg. with oil	causality		coint with bgas	causality				
	tstat	prob.	yes/no		lr coef oil	yes/no		lr coef bgas	test $\theta_{i,j}$ = 1	ADF with $\theta_{i,j}$ = 1 imposed	coef. on trend
				oil to border gas							
oil	-1.90	0.33	–	–	–	–	–	–	–	–	–
border gas	-1.32	0.62	yes	0.00	0.67	–	–	–	–	–	–
	P_i^{CG}			oil to P_i^{CG}	$\theta_{i,j}$		border gas to P_i^{CG}	$\theta_{i,j}$			
ea	−0.80	0.82	yes	0.00	0.64	yes	0.00	0.88	0.14	0.00	0.003
be	−1.12	0.71	yes	0.00	0.65	no	0.00	1.00	0.97	0.01	0.002
de	−1.34	0.61	yes	0.00	0.85	yes	0.00	1.15	0.17	0.50	0.014
ie	−0.81	0.81	yes	0.00	0.81	yes	0.00	1.15	0.11	0.13	0.012
es	−0.82	0.81	yes	0.00	0.47	yes	0.00	0.57	0.00	0.01	-0.013
fr	0.17	0.97	yes	0.00	0.62	yes	0.00	0.77	0.01	0.00	0.001
it	0.07	0.96	yes	0.00	0.58	yes	0.07	0.95	0.60	0.00	0.006
lu	−1.06	0.73	yes	0.00	0.81	yes	0.04	1.13	0.25	0.08	0.011
nl	−1.05	0.73	yes	0.00	0.79	yes	0.00	1.07	0.47	0.06	0.011
at	−0.74	0.83	yes	0.00	0.43	yes	0.00	0.61	0.00	0.00	-0.009

Table A2 Summary of results from analyses of dynamics

	oil												border gas						
	no calendar terms						with calendar terms												
	$\theta_{i,j}$	t stat	$\gamma_{i,j}$	t stat	R^2		$\theta_{i,j}$	t stat	$\gamma_{i,j}$	t stat	R^2		$\theta_{i,j}$	t stat	test unity	$\gamma_{i,j}$	t stat	R^2	coef on trend
oil	–	–	–	–	–		–	–	–	–	–		–	–	–	–	–	–	–
border gas	0.64	17.0	-0.15	-4.8	0.60		0.66	14.74	-0.04 (-0.25)	-2.2 (-6.5)	0.76		–	–	–	–	–	–	–
ea	0.73	24.7	-0.09	-2.7	0.55		0.74	19.42	-0.04 (-0.18)	-2.0 (-3.9)	0.75		1.05	4.3	0.82	-0.02	-1.1	0.63	0.006
be	0.73	8.1	-0.08	-1.9	0.63		0.57	7.39	-0.07	-2.1	0.69		1.09	14.2	0.24	-0.08	-1.8	0.78	0.003
de	0.91	38.7	-0.17	-4.4	0.59		0.90	27.80	-0.10 (-0.32)	-3.7 (-4.4)	0.79		1.23	11.4	0.04	-0.05	-2.3	0.74	0.013
ie	0.93	9.3	-0.08	-3.0	0.27		0.90	8.96	-0.07 (-0.44)	-2.4 (-2.8)	0.41		1.35	6.6	0.09	-0.06	-1.8	0.22	0.017
es	0.50	26.6	-0.25	-4.4	0.37		0.52	30.45	-0.15 (-0.58)	-3.4 (-7.6)	0.59		0.63	11.4	0.00	-0.12	-3.0	0.35	-0.015
fr	0.75	19.7	-0.14	-4.3	0.44		0.75	16.95	-0.33 (-0.50)	-3.4 (-2.3)	0.55		1.02	7.8	0.91	-0.06	-2.4	0.38	0.004
it	0.73	9.7	-0.05	-1.7	0.20		1.10	5.83	–	–	0.42		1.55	2.2	0.44	-0.02	-0.8	0.24	0.016
lu	0.88	23.6	-0.21	-3.8	0.55		0.92	18.81	-0.07 (-0.49)	-2.4 (-10.7)	0.77		1.29	21.7	0.00	-0.16	-3.4	0.69	0.012
nl	0.88	10.9	-0.10	-2.4	0.28		0.65	10.38	– (-0.62)	– (-3.9)	0.65		0.56	0.4	0.75	-0.01	-0.7	0.59	0.007
at	0.59	8.5	-0.07	-2.2	0.28		0.62	8.86	-0.05 (-0.24)	-2.2 (-2.3)	0.37		0.82	12.8	0.00	-0.16	-3.4	0.28	-0.007