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At what cost price stability? New Evidence about the Phillips Curve in Europe and the United States

CEPS Working Document No. 302/September 2008

Andrea Beccarini and Daniel Gros

Abstract

With inflation increasing all over the world, central banks have to consider with some care how quickly to re-establish price stability. A key issue in this context is the short-run cost in terms of foregone output and higher unemployment. In other words, our aim in this paper was to find the 'sacrifice ratio' for the Euro Area and for the United States. Our main findings are:

The cost of reducing inflation is in most cases higher in the US than in the EA. For example, reducing (headline) inflation by 1% point requires a decline of output of 1.4% in the EU, but 2.3% for the US. Considering core inflation, the sacrifice ratio in terms of output is somewhat higher for the Euro Area (around 4) compared to 3.2 for the US. However, the sacrifice ratios in terms of unemployment are always much larger for the US. Reducing headline inflation by 1% requires an increase in unemployment of little more than 1% in the EA, compared to 8% in the US.

However, there is also a long-run 'hysterisis' cost that is specific to the Euro Area since the reaction of unemployment to output depends on the state of the economy. During downturns this relationship worsens. This implies that a recession engineered to combat inflation will have an additional cost in terms of lower unemployment later, even after the recovery of the economy.

ISBN-13: 978-92-9079-813-2
Available for free downloading from the CEPS website (http://www.ceps.eu)

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AT WHAT COST PRICE STABILITY?
NEW EVIDENCE ABOUT THE PHILLIPS CURVE IN EUROPE AND THE UNITED STATES

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ANDREA BECCARINI & DANIEL GROS*

Motivation

Understanding the main features of the Phillips-curve (PC) is crucial for the conduct of monetary policy in the short run, especially when a negative supply shock leads to higher inflation. A central bank that targets price stability must then implicitly accept the cost of short run output and employment losses against the social benefits of re-establishing price stability. The shape of the PC is also of interest to other policy-makers. They have to accept the policy set by an independent central bank, but they will need to understand the consequences for output and employment.

Given the recent period of low and stable inflation it has even been suggested that the Phillips curve has become so flat that it is irrelevant for policy purposes (see Borio and Filardo, 2007). Our results suggest, however, that this perception might have been due to the conjunction of two favourable circumstances: first, oil prices were, until recently, particularly low, and, second, structural changes and reform in many countries may have altered the old relationship. However, oil prices are now definitely much higher. Their increase, together with that of many other commodities, has led to an important term of trade shock to both the US and Europe. Moreover, the consequences of an oil price shock for inflation tend to have a quite specific time profile: upon impact, headline inflation jumps, but the core inflation tends to be little affected, at least in the short run. However, as more time passes the higher headline inflation might be feeding into the core inflation. All central banks are concerned with this danger, but for the ECB oil prices are also a more immediate cause for concern given its focus on headline inflation, even though for the ECB price stability is defined only as a medium-term objective.

Given this medium-term focus of the ECB, we also try to verify whether potential disinflation policies affect output and unemployment in the longer run and hence whether there is also a longer-run cost of the disinflation process.

Our results in the form of estimates of the shape of the PC in the Euro Area (EA) and in the US should thus be useful for policy-makers and financial market observers in order to ascertain the potential short- and long-run costs in terms either of the output or unemployment necessary to restore price stability.

1. Technical considerations

Our analysis proceeds in two steps:

First we estimate PCs for the EA and the US defined as the relationship between inflation (either headline or core) and the output gap.

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* Andrea Beccarini is at the Università dell'Aquila and at CEPS. Daniel Gros is Director at CEPS. They would like to thank Cecilia Frale for her valuable comments.

Second we estimate the Okun's law (see 2.4 below) for both economies.

Putting both results together we can calculate the sacrifice ratio (the cost to reduce inflation of 1%) in terms both of output (gap) and of employment.

At the technical level, one firstly needs to take into account that different functional forms of the PC may lead to different policy implications, since the decline of output (and employment) required to a unit-reduction of inflation may change according to the functional form of the PC. Hence, it is important to verify whether:

- the PC is linear, concave or convex;
- the slope is stable (in the case of linearity);
- the intercept is stable.

The instability of some parameters may also depend on the presence of instability in the stochastic process of the inflation rate (see Musso et al., 2007).

From a theoretical point of view, the shape and the slope of the PCs depends on the key features of the demand and supply of labour.[1] Understanding changes in both demand and supply of labour will help to correctly specify the functional form of the PCs and find movements of the equilibrium unemployment or NAIRU (Non Accelerating Inflation Rate of Unemployment). Note also that, labour and products market reforms are likely to shrink equilibrium unemployment; any increase in the effective labour force (as designed in the Lisbon agenda) should shift the (market) labour supply curve and may flatten it.

It has been also hypothesised that improvements in the conduct of the monetary policy, globalisation and a lesser dependency on oil can cause a flattening of the PC slope, see, for example, Blanchard and Galì (2007), Borio and Filardo, (2007) and Musso et al. (2007). However, these conclusions are mostly drawn from estimates that do not take some oil price related variables explicitly into account, which is clearly not appropriate after the recent oil price surge.[2] Nevertheless, after inserting the oil variables, one possible explanation remains about the flattening of the PC slope, especially for the analysed sample in this paper: it consists of the flattening of both the labour demand and supply curves (as the slope of the PC should reflect the steepness of both labour market curves).

So, it is likely that reforms performed in some EA countries such as Germany, France, Spain and Italy in the past years have shifted the labour supply curve rightwards as the Union coverage reduced and flexibility increased. In fact, the OECD (Economic Outlook No. 82) estimates a progressive reduction of NAIRU for these countries from 2003. For EA and the US, this outlook estimates pretty stable output gaps up to 2009 and as regards the NAIRUs it estimates a gradual decline for EA of 1% from 2003 (7.9%) to 2009. Meanwhile, for the US, it has been stable since 2005 at 4.6%.

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[1] For example, if the former is flat and the latter is linear, the slope of the PC is equal to the slope of the labour supply curve.

[2] In fact, the models in the quoted literature use data up to 2007 but we detect, using data up to 2008:1, that oil price rate of changes are not sufficient to explain the relationship between oil price and inflation. Furthermore, note that the output gap coefficient is a function of the covariance between inflation and output gap; at the same time, since an exogenous oil shock implies that oil price measures and the output gap are negatively correlated, excluding some oil price measures from the regression means that the expected value of the output gap estimated coefficient is the true parameter (PC slope) plus the regression coefficient of oil price measure on the output gap, hence biased downwards. So, these features may contribute to the perception of a flat PC.

Our estimation strategy proceeds as follows:

First of all we had to choose the relevant definition for inflation. For the Euro Area (EA) the choice was clear: the percentage variation of the average EA HICP (the harmonised index of consumer prices) is the reference inflation rate for the ECB. However, the US Federal Reserve is generally deemed to target the core CPI (consumer price index), i.e. an index that excludes volatile items like energy and food. As the two definitions of inflation (headline and core) show a very different time series profile this makes transatlantic comparisons difficult. In order to make our estimates comparable we thus used both definitions of inflation (headline and core CPI) for both the US and the EA.

Second, one has to choose the key relevant explanatory variables. The first one is, as usual, the output gap.[3] Moreover, as already argued above, given the large variations of the oil price in recent years the price of crude oil also needs to be considered as an important drive of inflation. The oil price stands in this context for the general level of commodity prices and captures an important source of supply shocks. Operationally we used the Brent price, in euro for the EA and the WTI price in dollars for the US.

Finally we had to verify the appropriate functional form.

(Log) linear is usually the default choice. However, we also evaluated several types of non-linearities. A first type includes non linear functions linking the inflation rate with the regressors (quadratic, cubic and exponential functions); a second type regards instability (breaks or changes in regimes) of the specified parameters either in the linear or in the non-linear functional form. The first kind of non-linearity should capture potential convexity or concavity between inflation and output gap;[4] if this feature is confirmed, the sacrifice-ratio[5] is not constant as in the case of linearity. The second kind of non-linearity should capture the structural changes in the parameters due, as stated above, to changes in monetary policy[6] or to changes in the inflation expectation formation or in changes in the institutions of the labour market. One way to verify these changes in the first instance is by introducing several dummies[7] to capture abrupt changes in the constant or in the other parameters.[8] A Time-Varying Smooth Transition model is also estimated (see van Dijk et al., 2002, for a recent survey).

After having looked at the empirical evidence as regards the existence of a stable PC (defined here as the relationship between inflation and the output gap) for the EA and for the US, we analyse the relationships between output and unemployment gaps, in order to find the sacrifice

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[3] The potential output has been calculated by the Hodrick-Prescott filter. The potential output has been also estimated by an unobserved component model (see Harvey 1989); however the use of the latter estimates does not change the regression results.

[4] Other non-linearities are evaluated. In particular, in order to capture a threshold effect of the oil price on inflation a term of the second and the fourth powers of the standardised oil price level is considered. When the standardised value of the oil price is less than one, the effect of the second and the fourth power terms on inflation rate is smaller than the linear effect; the reverse is also true. Hence, these variables capture the potential effect on inflation of very high values of the oil price.

[5] The reduction of output and employment required to a decline of 1% of the inflation rate.

[6] Which can influence the long-run inflation rate value by changing the inflation target.

[7] For the EA, the considered data are 1999 (entry of the euro), 2002 (physical entry of euro potentially increasing inflation through the conversion of national currencies), all data at which the 'euro-club' is changed that is 2000, 2006, 2007 and 2008. For the US the relevant dates to evaluate dummy variables are 2000 (change in the volatility of CPI; 2001:4 (the quarter after the terrorist attacks); 2004 (oil price surges and change in the Fed policy stance).

[8] By adding further regressors obtained by multiplying the initial regressors times the dummies.

ratios in term of unemployment rather than output. Okun's laws are estimated along with the unemployment rate equations; potential non linearities and asymmetries are investigated also by a Markov-switching regression with a time-varying transition probability matrix. In fact, some authors (Holmes and Silverstone, 2006) have found that the Okun coefficient may switch between regimes. If regime changes are due to the business cycles, then the sacrifice ratios (calculated in terms of unemployment) should change between regimes as well, hence different degrees of gradualism in the disinflation process may imply different impacts on unemployment for the same inflation reduction.

The period of observation is in all cases 1996:1 2008:1 (quarterly). The starting period is the earliest for which the HICP is available.

We proceed first with the estimates for the EA.

2. Results: EA estimates

All the macroeconomic data for the estimates of the EA are provided by Eurostat.[9] As mentioned above the period of observation is 1996:1 2008:1, as dictated by data availability.

2.1 EA PC with headline inflation

As regards the EA-PC specification, the estimated model for the Euro Area HICP headline is reported in Table 1 (all macroeconomic variables included in the model are stationary):[10]

Table 1. Estimates of the Euro Area Phillips curve, HICP headline

	D2003	K	HICP(-1)	HICP(-4)	OGAP	LOIL	LOIL(-3)	LOIL(-4)
P estimate	0.222**	0.414**	-0.389**	0.348**	0.185**	0.172**	0.109**	-0.099*

(*) and (**) refer to the 5% and the 1% significance levels, respectively.

Diagnostic tests: R^2=0.7; Std err. regress.=0.20; D-W=1.93; JB=0.75 (0.68); AIC=-0.25; LMSC(1)=0.07 (0.79); ARCH(1)=1.60 (0.21); RESET(1)=3.45 (0.07); SWC=0.07; LMSC(4)=0.40 (0.80); ARCH(4)=1.61 (0.19); WHITE=2.75 (0.01).

With the following specifications:

- Constant: K; dummy variable equals to 1 from 2003 on: D2003;
- HICP EA; first and fourth lag: HICP(-1), HICP(-4);
- Output gap: OGAP;
- Oil price in euro (Brent), percentage change on the previous period, standardised value; contemporaneous value, third and fourth lag: LOIL LOIL(-3) LOIL(-4).

Source: Own calculations

Apart from heteroschedasticity in the residuals, no other signs of misspecification show up in the above tests.[11] Therefore, standard errors are consistently estimated using the Newey-West method. All estimated parameters have the expected sign. In order to verify instability, a Time-

[9] Oil price is provided by the ECB.

[10] Usual unit root tests have been performed and the rejections of the null of a unit root in the levels have been made at 5% level of significance.

[11] LMSC is the Breusch-Godfrey Serial Correlation Lagrange Multiplier test; ARCH is the Engle Lagrange Multiplier test for Autoregressive Conditional Heteroschedasticity disturbances. JB is the Jarque-Bera test of normality of residuals. WHITE is the White's test for Heteroschedasticity disturbances. AIC is the Akaike Info Criterion and SWC is the Schwartz Info Criterion.

Varying Smooth-Transition model is estimated, however, the Maximum Likelihood criteria do not lead to prefer it at the place of the linear model. Since all oil-related regressors are measured as deviations from means, the long-run expected inflation (at a zero output gap) can be calculated from the constant (and the lagged coefficients). Before 2003 it equals 0.4 % per quarter, which, in annual terms, is 1.6% and after 2003 it is 0.61% or 2.44% on an annual basis. It is difficult to disentangle the factors that caused the long-run value of inflation to shift upwards in 2003. It may be due to a change in expectation formation perhaps meaning that the ECB is losing credibility. In this case the ECB should promptly intervene to restore price stability (see below for a more detailed discussion).

Another reason for the upward shift might be the house price bubble, which was also present in Europe (see Gros, 2008). The overall increase in commodity prices should in principle not be responsible for the upward shift in long-run inflation since it should have been captured by the oil price variable.

Alternative specifications for the PC with headline inflation are presented in Annex A (Tables 15 and 16). These alternative specifications model the relationship between oil price and inflation differently, however as they turned out not to be completely satisfactory they were not retained (see comments in Annex A).

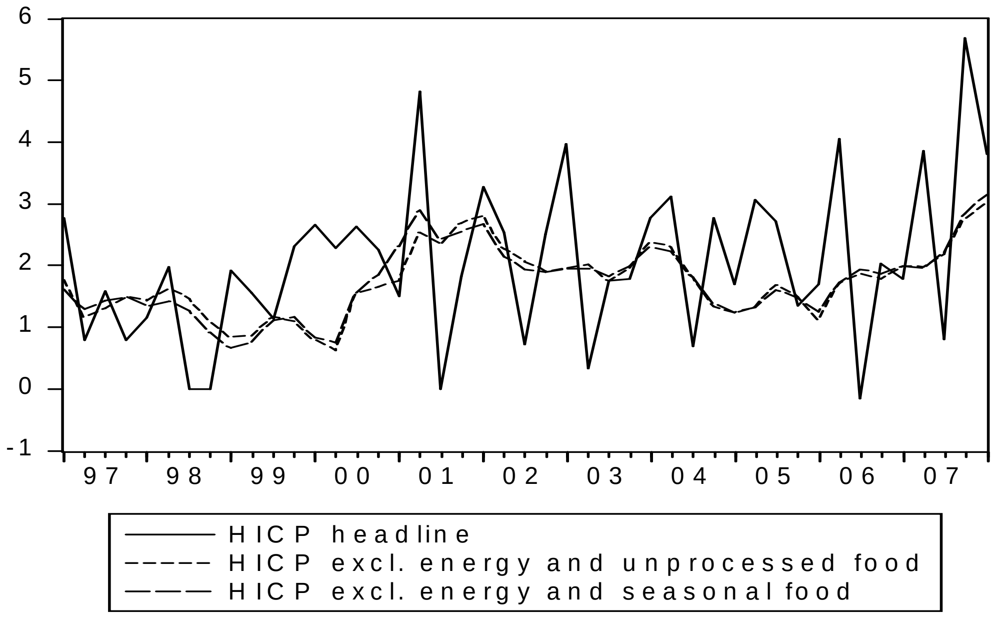
2.2 EA PC with 'core' inflation

As mentioned above, oil price shocks lead to large divergences between headline and core inflation. It thus is important to check whether one can identify a stable PC also in terms of core inflation and whether the latter is influenced by oil prices.

The difference in the time series behaviour of core and headline inflation is apparent at first sight.

Figure 1 depicts headline inflation and two definitions of EA core inflation, all quarterly on an annual basis.

Figure 1. EA inflation rates, annual basis



Source: Own calculations

There are many definitions of ‘core’ inflation. We used the overall HICP without two components: energy and unprocessed food. Annex A also provides estimates for the HICP core excluding energy and seasonal food (Table 17). As expected this yields essentially the same results.

Our estimate of the EA PC with our definition of the core HICP (HICPc) of the EA gave the following result:

Table 2. Estimates of EA Phillips curve HICPc (no energy and unprocessed food)

	D2003	K	HICPc(-1)	HICPc(-3)	HICPc(-4)	OGAP
P est	0.046*	0.107**	0.773**	-0.401*	0.359**	0.061**

(*) and (**) refer to the 5% and the 1% significance levels, respectively.

Diagnostic tests: R^2=0.77; Std err. regress.=0.07; D-W=1.98; JB=1.56 (0.45); AIC=-2.34; LMSC(1)=0.17 (0.68); ARCH(1)=2.03 (0.16); RESET(1)=1.56 (0.46); SWC=-2.10; LMSC(4)=1.60 (0.19); ARCH(4)=0.57 (0.68); WHITE=1.76 (0.11).

No sign of misspecification appears in the usual tests. The long run inflation rate changes, in 2003, from 1.58% to 2.27% on annual terms. Note that no oil variable is directly or indirectly significant in this regression; however, the fact that a dummy variable equalling 1 from 2003 is significant (implying a higher long run inflation rate from this date) might either represent a shift in monetary policy or a spurious result due to the fact that the oil price surge started roughly from that period. An alternative specification for HICPc consists of including, among regressors, the rate of change of oil price and the lagged differences between HICP and HICPc in order to capture the impact of energy and food price increases on the headline inflation. However, according to the maximum likelihood criteria (AIC and SWC), this alternative model is not preferable to the model of Table 2. At this junction it is worth anticipating that for the US, this latter model turns out to be preferable. One key reason why these regressors are not important in explaining the EA core rate might be the fact the ECB has a clear mandate to achieve price stability. Inflation expectations should thus be less susceptible to economic news (such as oil, energy and food prices)[12] since agents, in forming their expectations, discount the policy response to these news.

2.3 Dynamic consequences of different shocks

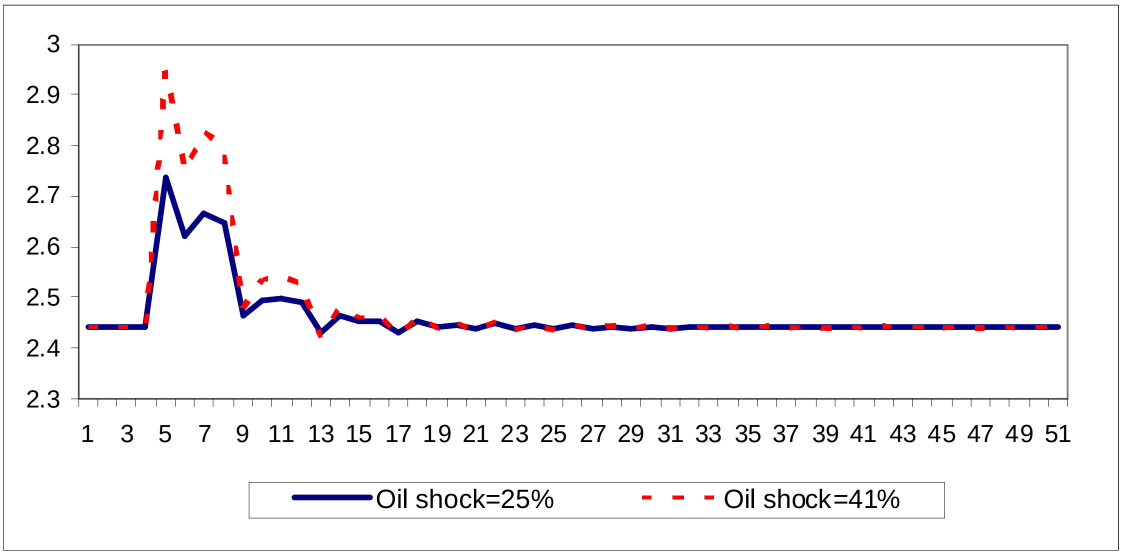
Let us focus on the impact of an oil shock and of an output gap shock for inflation in the Euro Area.

The reference regressions are that of Table 1 for the headline HICP and that of Table 2 and Table 17 in Annex A for the core HICPs. As regards the oil shock, the latest oil price of the sample is 64€/b (2008:1). Two scenarios are assumed, that is: the oil price reaches 80€/b (about 120$/b) and 90€/b (about 135$/b). This implies the following oil rates of change: 25% and 41%, respectively. After the shock, the oil price rate of change is assumed to come back to its (in sample) average level (which is 3% on a quarterly basis).

The next figure depicts the headline HICP rate dynamics in the two scenarios. The rate is calculated on the same quarter of the previous year. The shock occurs at time 4.

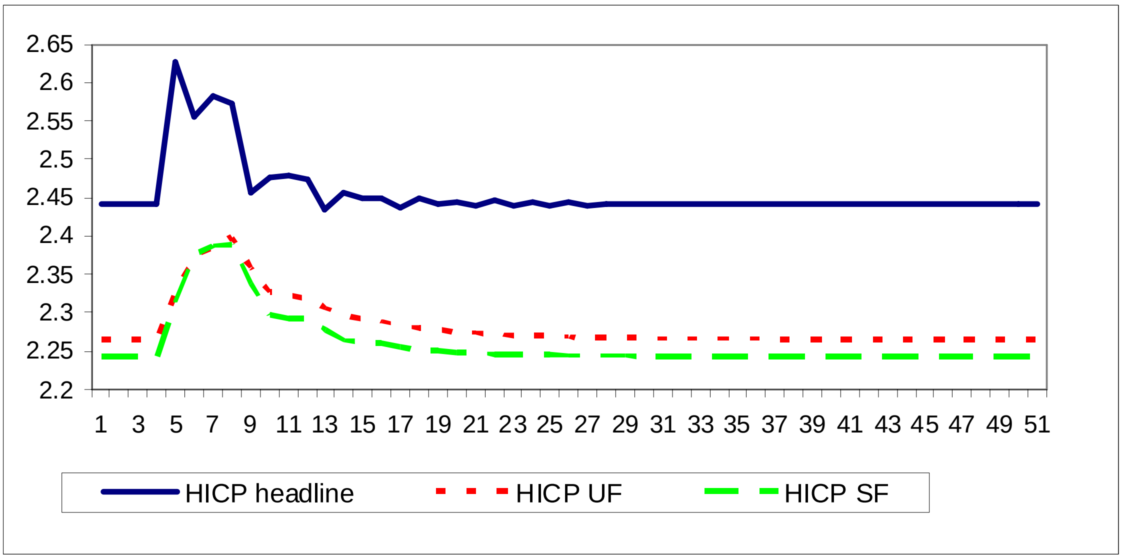
[12] See Ehrmann et al, (2007) and Beechey et al (2007)

Figure 2. EA headline inflation following the oil price shocks



As regards the output shock, it is assumed that the output gap increases 1% and then it immediately comes back to its long-run level (zero). The graph below depicts the HICP headline rate and the core rates after this shock. The rates are calculated on the same quarter of the previous year. The shock occurs at time 4.

Figure 3. EA headline and core inflations following the output gap shock



HICP UF refers to the core rate that excludes energy and unprocessed food and HICP SF excludes energy and seasonal food.

A key indicator for monetary policy is the sacrifice ratio; that is the amount of output (or employment) to give up in order to reduce inflation by 1%. It can be calculated with respect to both measures of inflation. Since 1% on an annual basis corresponds to 0.249% on a quarterly basis, the sacrifice ratio is the inverse of the PC slope, for the HICP headline, is 1/0.185=5.41%

times 0.249, which becomes 1.35. The other specifications of the EA PC considered in Annex A yield similar, but somewhat higher numbers. For example using the models of Tables 15 and 16 in Annex A, the sacrifice ratio becomes 1.82 and 1.92 respectively. These latter estimates are in line with the recent findings of Deutsche Bank (Economic Outlook, May 2008).

As regards the HICP core, the sacrifice ratio is 4.08 and 3.50 (for models of Tables 2 and 17 respectively). So, when the disinflation process focuses on the core inflation the sacrifice ratio is much higher. This is intuitive because the headline inflation includes the more volatile activities in the economy i.e. energy and food sectors; in fact, in these sectors, changes in the price levels do not provide information on the business profitability[13] hence, output does not change relatively; on the other side, in the sectors where prices are more stable a fall in prices implies a persistent revenue reduction and hence firms may find a decrease in output to be optimal.

2.4 Okun's law in Europe

We have so far established that a reasonably stable PC can be detected at the EU level, and that the dynamics and determinants of headline and core inflations measures may capture important effects of the pass-through of higher oil prices on core inflation.

However, what matters for politicians (not necessarily for the ECB) is the unemployment rate, rather than just the output gap. At this junction, it is important to clarify the relationship between the output gap and the unemployment gap (defined as the actual unemployment rate minus the NAIRU) both in percentage terms; this relationship is called the Okun law. In order to analyse this, we first describe the nature of the time series process driving unemployment rates, and then estimate the Okun law. This then allows us to find the sacrifice ratio in terms of unemployment, that is, the increase of the unemployment rate for a decline of 1% inflation rate.

As regards the stochastic process of the unemployment rate, the first point is to ascertain its stationarity property; that is whether there is a long-run value that the series goes to. Classical unit-root tests (ADF tests) may be not appropriate because of the presence of various regimes in the series; in fact, in this case, stationarity should be detected in the regimes and not on the overall series (see Ang and Bekaert, 2002a and 2002b). On the other side, the presence of regimes is due to labour market reforms that clearly can provoke large breaks in the series. However, in the case of the Euro Area as a whole any breaks should be gradual since the EA average is not strongly affected by single national labour market reforms.

The ADF tests for the EA unemployment rate lead to the conclusion that the level is not stationary but only its variation[14] (the first difference). Hence, the first difference equation of unemployment is:

Table 3. EA first diff. of unemployment equation estimate

	K	UN(-1)	UN(-3)	GDP
Par. Est.	0.156	0.36*	-0.37**	-0.06*

(*) and (**) refer to the 5% and the 1% significance levels, respectively.

Diagnostic tests: R^2=0.62; Std err. regress.=0.09; D-W=1.96; JB=1.81 (0.40); AIC=-1.90; LMSC(1)=0.02 (0.90); ARCH(1)=1.68 (0.20); RESET(1)=0.00 (0.96); SWC=-1.75; LMSC(4)=0.71 (0.58); ARCH(4)=1.02 (0.39); WHITE=0.59 (0.71).

[13] Since they are relatively frequent (because their variability is high).

[14] ADF test, on the level, with intercept and trend and two lags (selected by SBC); the p value is 0.26.

Where UN indicates the EA unemployment level and GDP is the EA GDP quarterly rate of change. Tests show no sign of misspecification. Under a different approach, looking at the Hodrick-Prescott (HP) filter, which should provide a measure of a time-varying NAIRU, a downward trend[15] is apparent; the Okun coefficient (change in unemployment gap on the change in the output gap) in the linear regression[16] is -0.134 but is not significant at the usual level of confidence (the p-value is 0.64). This evidence leads us to conclude that changes in cyclical output at the Euro Area scale do not affect unemployment. This may be possible if labour hoarding is dominant. But one must allow for other explanations before accepting this result. For example, it might be argued that the relationship implied by the Okun law is asymmetric (as in Holmes and Silverstone, 2006). In order to verify this possibility, a Markov-switching regression with a time-varying transition probability and related tests are performed.[17] The EA unemployment gap is regressed on a constant, on its first lag on the EA output gap. Estimates regard a two-regime and a three-regime specification to compare with the one-regime (OLS) specification.[18]

Table 4. The 2-regime Markov-switching estimates for the EA unemployment gap

	K	**Un. Gap, 1° lag**	**Output gap**	**Std err. regr**
Param. REGIME 1	0.85**	0.68**	-1.45**	0.60
Param. REGIME 2	-1.60**	0.81**	-1.02*	0.70

(*) and (**) refer to the 5% and the 1% significance levels, respectively.

Diagnostic tests: LL=-66.2; AIC=148.5; SWC=164.2; LMSC1= 2.3 (0.14); LMSC2=2.41 (0.13); ARCH=2.56 (0.11).

Table 5. The 3-regime Markov-switching estimates for the EA unemployment gap

	K	**Un. Gap, 1° lag**	**Output gap**	**Std err. regr**
Param. REGIME 1	1.31**	0.58**	-1.49**	0.50
Param. REGIME 2	-1.79**	0.81**	-0.27	0.68
Param. REGIME 3	0.02	0.75**	-0.82**	0.26

(*) and (**) refer to the 5% and the 1% significance levels, respectively.

Diagnostic tests: LL=-59.8; *AIC=149.7;* SWC=179.2.

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[15] Of course the HP filter does not say whether this is a stochastic or deterministic trend. The answer to this question is provided by the unit-root test (which implies a conclusion in favour of the former).

[16] Not reported, this estimate is obtained by having appropriately selected the other regressors according to the maximum likelihood criteria.

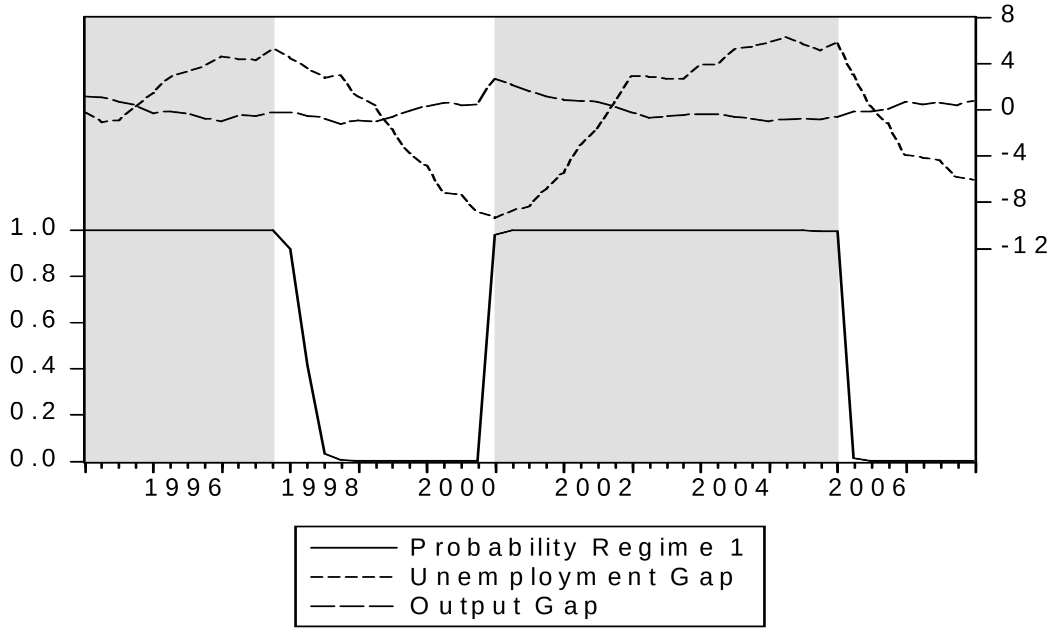
[17] In a Markov-switching model the dependent variable is supposed to change within regimes in the sample, this implies that the relationship with regressors changes according to the regime and hence the set of parameters varies according to the regimes. However, the process that governs the switches in regimes is not known and hence must be inferred. So, the outcomes of the M-S regression is *k* sets of parameters where *k* is the number of the postulated regimes and a transition probability matrix which serves as predicting the switches between regimes. See Hamilton 1989, 1990, 1996 and references therein. Moreover, the transition probability matrix can be parameterised as a function of some exogenous variables, see Diebold et al. (1994).

[18] The appropriate model is chosen on the basis of diagnostic tests and of maximum-likelihood criteria, which penalise the models according to the number of regressors and of regimes.

Diagnostic tests for both estimates show no sign of misspecification[19] and since the estimated parameter of the output gap in the 3-regimes model is significant only in two regimes wherein the estimates are similar to those of the 2-regimes model, it is convenient to consider the latter as the preferred specification (this choice is also consistent with the AIC and SWC criteria).[20]

Figure 4 exhibits the inferred probability that regime 1 occurs at each time along with the unemployment gap and the output gap. It is easy to see that regime 1 occurs[21] when the unemployment gap is trending upwards and when the output gap is (generally) trending downwards.[22] Hence, regime 1 resembles the recession status of the economy and regime 2 the expansion. More precisely, here recession is defined as a persistent upward trend of unemployment gap and a persistent downward trend of the output gap. The impact of the output gap is higher (-1.45 vs –1.02)[23] when the unemployment is moving upwards or when the output trends down, similar results are also obtained by Silvapulle et al. (2004). Note that the trend direction of unemployment and output gaps does not imply whether they are positive or negative.[24]

Figure 4. Unemployment and output gaps with the probability of regime 1



So, since the beginning of 2006 the EA economy is in regime 2, the regime with a positive business cycle and a minor sensitivity of unemployment to output. Since the model estimates a time-varying transition probability between the two regimes it is possible to forecast how the probability of each regime evolves as a function of some predetermined variables. In fact, it has

[19] LMSC1 and LMSC2 are Lagrange multiplier tests of serial correlation of first order within regime 1 and regime 2, respectively; ARCH is a LM test of arch residual in both regimes.

[20] The tests are constructed such that the preferred model is that with the lowest value.

[21] Of course, the probability for regime 2 to occur equals one minus the probability of regime 1.

[22] Within regime 1, the average increase of unemployment gap is 0.52 and the average decrease of output gap is –0.08; in regime 2, they are –1.33 and 0.12, respectively.

[23] A Wald test leads us to reject the null hypothesis that these two estimates are not significantly different.

[24] For example, from 2001:1 and 2005:4 the unemployment gap is trending upwards but only after 2002:3 the gap is positive.

been estimated that both the probability of remaining in regime 1 and the probability of switching to regime 1 from regime 2 depend negatively on the lagged first difference of the output gap.[25] The out-of-sample probability of the regime *j (j=1,2)* to occur (conditional on the information up to 2008:1) are obtained:

- firstly by forecasting the first difference of the output gap,
- secondly by forecasting the transition probabilities $j|j$ and $j|i$ ($i \neq j$) conditional on the output gap (lagged first difference) and
- finally, by summing up the transition probabilities $j|j$ and $j|i$ ($i \neq j$) weighted by the present probability of regime *j* and regime *i* (by the virtue of the total probabilities theorem).

The estimated parameters for the EA first difference of the output gap are reported in Table 6:

Table 6. Estimate for the EA output gap, first difference

	D2001_1	OGAP(-1)	OGAP(-3)
P estimate	2.374**	-0.077*	-0.141**

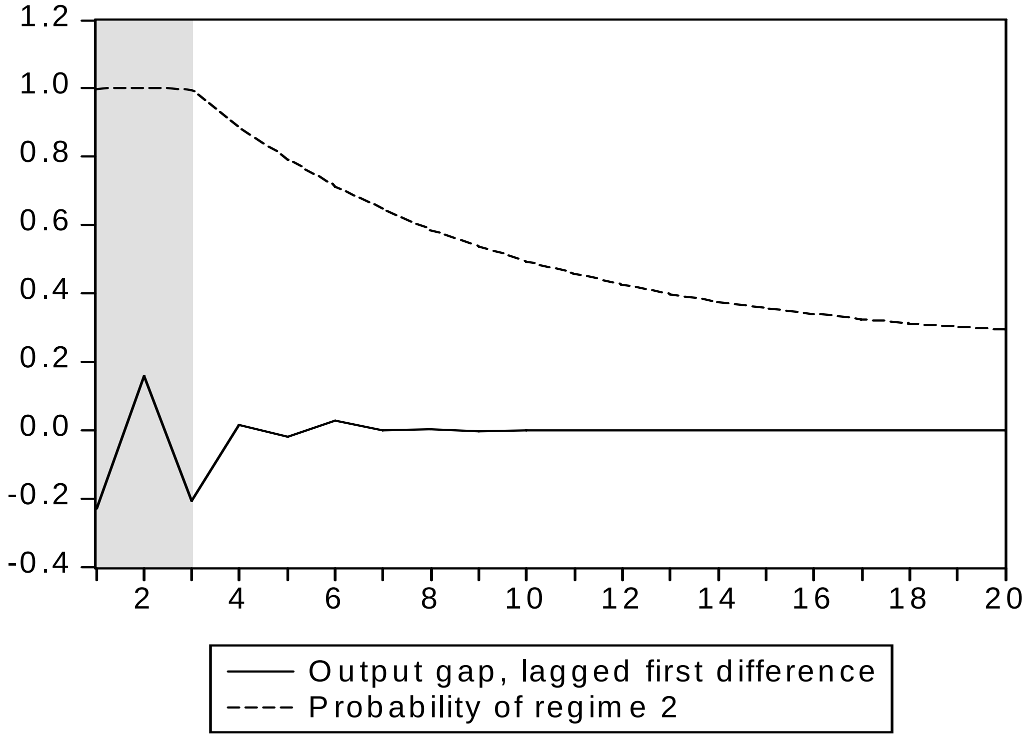
(*) and (**) refer to the 5% and the 1% significance levels, respectively.

With its latest values (up to 2008:1) it is possible to forecast the probability of regime 2. Figure 5 shows it along with the lagged first difference of output gap forecasts. The shaded line indicates the in-sample values.

[25] In particular, two transition probabilities of regime 1 conditional on regime 1 and that of regime 2 conditional on regime 2 are modelled as logistic functions of a constant and of the lagged first difference of the output gap. Their estimated parameters are 3.3 and –0.52 for Pr(regime=1|regime=1; output gap(-1)) respectively; for Pr(regime=2|regime=2; output gap(-1)) they are 2.09 and 0.14 respectively; note that the probability of switching to regime 1 from regime 2 is 1- Pr(regime=2|regime=2; output gap).

Note also that since the transition probability and the output gap difference are linked by a logistic function, the impact of the change of output gap on the transition probability depends on the magnitude of the output gap variation (for example it requires an output gap variation of 1% to obtain a probability of 10% to switch from regime 2 to 1 and a variation of -5% for the same probability of 20%).

Figure 5. Output gap (lagged first difference) and the probability of regime 2



In the out-of-sample forecasts, the probability for the EA to be in regime 2 (lower sensitivity of unemployment to the output gap) is calculated on the assumptions that the lagged difference of the output gap starts from the actual values (-0.22 in 2007:3, 0.16 in 2007:4 and -0.2 in 2008:1) and evolves according to the model of Table 6. Note that, when the output gap is zero (its long run value) the regime with higher sensitivity of unemployment to output is more likely.

The reason why for the asymmetric response of unemployment to the output is probably due to the different composition in the marginal labour in the two regimes. When unemployment increases (in recessions), the dismissed persons generally remain in the labour force at first hoping to find a new job, hence the labour force does not change (the 'discouraged' worker effect is small).[26]

On the contrary, when unemployment decreases (in expansions), the newly occupied persons are not only those stemming from the original labour force but they also come from outside the labour market, hence the unemployment rate is less respondent to expansions. This phenomenon implies hysteresis:[27] in fact, when a recession causes unemployment for some persons, the subsequent expansion does not imply that all of them will be able to find a job again since new and more competitive workers enter the labour market, hence they foster the long-term unemployment, which implies a deterioration of the NAIRU.

To further verify this asymmetry, one may regress the EA labour force on a constant, on lagged values of the dependent variable and on two series of output gap constructed so as the first series equals the output gap when it is positive and zero otherwise, the second series equals the output gap when it is negative and zero otherwise: the positive output gap, is significant and the

[26] The dismissed persons switch from the occupation status to the unemployment status.

[27] This is a damaging effect on the supply side of the economy, with a decrease in NAIRU, due to protracted negative unemployment and output gaps.

estimated parameter implies a 0,5% variation in the labour force for 1% variation in output gap meanwhile the negative output gap is not significant. This implies that in booms new workers enter the job market but those who are already there do not exit at the successive troughs. Furthermore, the EA long-term unemployment on total population significantly (and negatively) depends on output gap only when it is in regime 1; in fact, in recessions (regime 1) the long-term unemployment increases of 5 basis points for every 1% decrease of output gap. This means that there is a share of unemployed persons that increases during recessions but these same unemployed persons do not succeed in finding a job when the general market conditions become more favourable (in expansions).

All this implies that policy-makers should be aware that, in regime 1 the increase in unemployment will not be completely reabsorbed in the successive expansion (regime 2); hence, the sacrifice ratio, for regime 1, measures only a short run cost of the disinflation process since it does not take into account that a share of the newly unemployed will increase long-term unemployment.

With the Okun coefficients provided above it is possible to calculate the sacrifice ratios in terms of unemployment. Table 7 provides them by multiplying the sacrifice ratios in terms of output times the Okun coefficient, all for the headline and the core measures of inflation.

Table 7. Sacrifice ratios in terms of output and employment

Sacrifice Ratios in terms of	Output gap %	1° Unemployment gap % (regime 1)	2° Unemployment gap % (regime 2)
HICP headline	-1.35	1.96	1.38
HICP UF	-4.08	5.92	4.16
HICP SF	-3.50	5.08	3.57

As noted above the sacrifice ratios are only short-run costs of recessions implied by the disinflation process. For the EA, a present decline of the output gap of 1% implies an increase of unemployment rate of roughly 1% (in the current regime 2, the Okun coefficient is -1.02) which, in turn, implies an increase of the long-run unemployment rate (measured as the ratio on the total population) of 5 basis points. Moreover, the output gap reduction increases the probability for the economy to switch into regime 1 that is, when the sensitivity of unemployment rate is higher (-1.45). However, conditional on regime 2, the probability to switch in regime 1 should occur only for large swings of the output gap. Nevertheless, since the estimated PC is linear, the sacrifice ratios, in terms of output, do not depend on monetary policy preferences and hence, the degree of gradualism in the disinflation process would have no impact on output but it does impact unemployment. In fact, the central bank should also compare the probability of switching the economy in regime 1 (with higher sacrifice ratio), when taking a harsher approach (that is concentrating the output decline, say in one quarter rather than in many) with respect to a more gradualist approach. Annex B provides some clarification on this topic; it will also be dealt in paragraph 4.

As already stated, this asymmetry in Okun's coefficients implies hysteresis. Under the policy point of view, it would be not enough to stimulate the aggregate demand to alleviate such unemployment, rather it should be appropriate to implement particular labour market policies aiming at reconnecting the long-term unemployed with the labour market.

3. Results II: US estimates

For the US, data are provided by the IMF International Financial Statistics (on CD ROM). The data again covers the period 1996:1 to 2008:1.

3.1 US PC with headline inflation

The results of estimates of a standard PC with the headline consumer price index (CPI), quarterly rate of change, are shown in Table 8.

Table 8. US Phillips curve estimates with CPI headline

	K	CPI(-2)	CPI(-3)	LOIL	OGAP
Par. Estimates	0.787**	-O.470**	0.264**	0.205**	0.108

(*) and (**) refer to the 5% and the 1% significance levels, respectively.

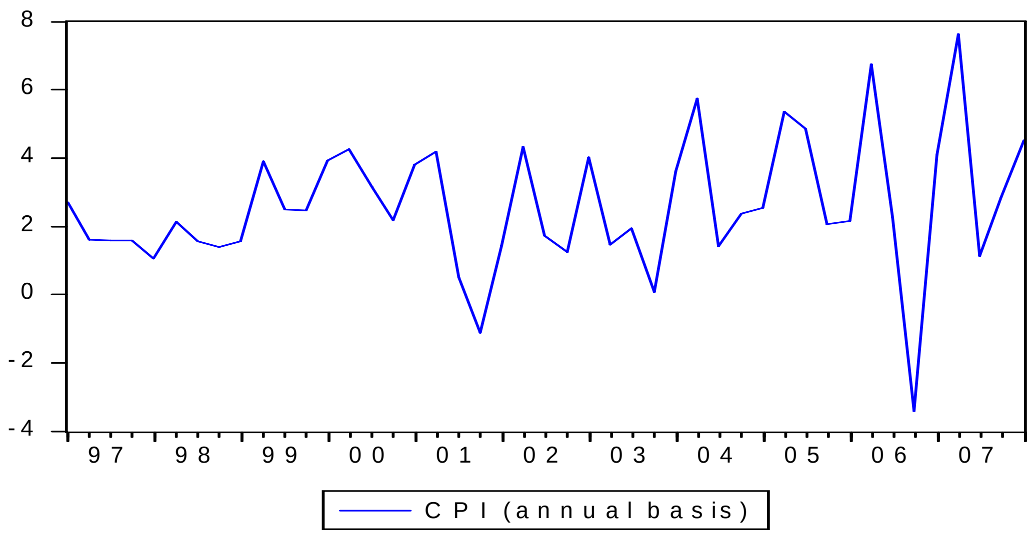
Diagnostic tests: R^2= 0.56; Std err. regress.=0.33; D-W=1.89; JB=1.66 (0.43); AIC=0.71; LMSC(1)=0.11 (0.73); ARCH(1)=1.13 (0.29); RESET(1)=0.91 (0.34); SWC=0.90; LMSC(4)=0.10 (0.98); ARCH(4)=0.69 (0.61); WHITE=0.75 (0.65).

LOIL is the rate of change of the oil price (in $US and using the average price of different types of crude oil, where WTI is predominant), which is again standardised.

OGAP is the output gap. One first important result is that in such a standard formulation the output gap is not significant. Different diagnostic tests lead to different results: AIC suggests including this variable, but SWC not.

These differing results (along with the inspection of the graph below) suggest performing regressions with breaks or changes in regimes. In fact, the variability of the CPI inflation rate (on an annual basis) increases from 2000 (see Figure 6 below):

Figure 6. US headline CPI rate, on an annual basis



This suggests that OGAP might have become significant after that date, in fact:

Table 9. US Phillips curve estimates with break in 2000. CPI headline

	K	CPI(-2)	CPI(-3)	LOIL	OGAP*D2000
Par. Estimates	0.813**	-O.488**	0.244**	0.207**	0.168**

(*) and (**) refer to the 5% and the 1% significance levels, respectively.

Diagnostic tests: R^2=0.59; Std err. regress.=0.32; D-W=2.08; JB=1.66 (0.43); AIC=0.63; LMSC(1)=0.08 (0.78); ARCH(1)=1.00 (0.32); RESET(1)=0.12 (0.72); SWC=0.81; LMSC(4)=0.16 (0.96); ARCH(4)=0.79 (0.54); WHITE=0.60 (0.77).

Where OGAP*D2000 is a dummy equal to output gap from 2000 and zero before. This regression shows no sign of misspecification. All estimates have the expected sign. The long run CPI rate is 2.61 on an annual basis given output gap equal to zero. In order to further verify the presence of breaks or regimes in the series a Markov-switching regression is performed. The results are:[28]

Table 10. US Phillips curve, regime-switching estimates of CPI headline

	K	CPI(-2)	CPI(-3)	LOIL	OGAP	Std err regr
Param. REGIME 1	0.883**	-0.231	-0.621**	0.131**	-0.023	0.10
Param. REGIME 2	0.979**	-0.601**	0.268**	0.246**	0.110*	0.25

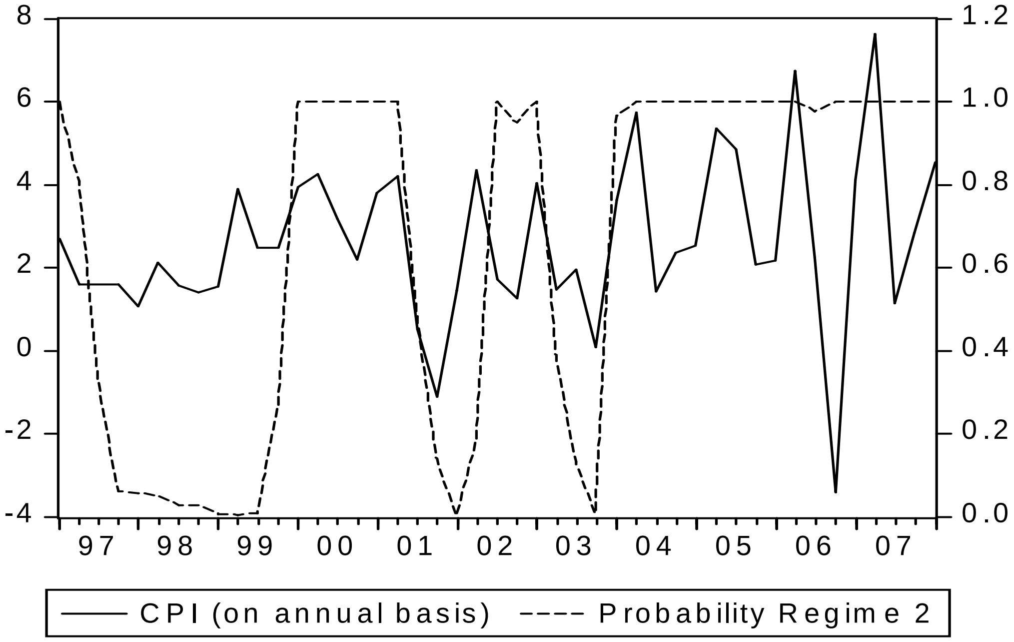
(*) and (**) refer to the 5% and the 1% significance levels, respectively.

Diagnostic tests: LL=5.26; AIC=0.27; SWC=0.73; LMSC1= 1.1 (0.30); LMSC2=4.4 (0.04); ARCH=1.07 (0.29).

According to AIC and SWC criteria, the latter model should be preferred to the 1-regime models (of Table 9). It can be easily seen that the long-run value of CPI in regime 1 is 1.91% and in regime 2 is 2.93% (both on an annual basis). You can see from Figure 7 that the current regime is regime 2, for which the long run value is high, the impact of oil (rate of change) is higher and the impact of the output gap is significant. The graph also shows that the break in 2000 detected in the above estimates (OLS) turns out to be a switching-point between regime 1 and regime 2.

[28] LMSC1 and LMSC2 are Lagrange multiplier tests of serial correlation within regime 1 and regime 2, respectively; ARCH is a LM test of arch residual in both regimes.

Figure 7. US headline CPI rate and the inferred probability of regime 2



Until now we have worked with the overall CPI (also called headline inflation) although it is widely assumed that the FED may focus on core inflation rather than headline inflation. We do not wish to take a stance on which measure of inflation is preferable. However, prominent US policy-makers seem to view the core CPI as a more reliable indicator for the monetary policy purposes since it[29]

> … provides some greater signal about persistent movements in inflation than does headline inflation itself… However, core measures have their limitations. A single core inflation measure cannot account for all types of shocks and can at times be misleading about what is happening to the underlying rate of *overall* inflation. And if increases in headline inflation prove more persistent than initially expected, central bankers must be vigilant to ensure that they do not become embedded into expectations and thereby generate substantial second-round effects on inflation. Finally, because price stability ultimately involves control of overall, headline inflation, which after all is the inflation measure that households really care about, central bankers should and do pay attention to headline inflation as well as to core inflation measures….

3.2 US PC with 'core' inflation

The entire sample regression of the CPI core rate on its lags, on the oil rate of change and on the output gap is not satisfactory (R-squared low at 0.41) and shows signs of instability.[30] This is what might have motivated some authors to argue that the US PC was 'dead'. However, estimates of the US PC with the CPI core rate that take into account a break in 2004 perform better, they are:

Table 11. US Phillips curve estimates with CPI core

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[29] Governor F.S. Mishkin, speech at the Business Cycles, International Transmission and Macroeconomic Policies Conference, HEC Montreal, Montreal, Canada. October 20, 2007.

[30] Cusumq and Chow (they are names) tests show a break in 2004:1 and there are signs of autocorrelation of residuals (LM(4)=2.35 (0.06)).

	CPIc(-1)	CPIc(-4)	LOIL	OGAP
Par. Est. up to 2004	0.191*	0.733**	-0.041**	0.075**

(*) and (**) refer to the 5% and the 1% significance levels, respectively.

	K	CPIc(-2)	CPIc(-3)	CPIc(-4)	CPFE(-3)	LOIL	OGAP
Par. E. from 2004	0.597**	-0.197	-0.169	0.295**	0.086**	-0.041**	0.075**

(*) and (**) refer to the 5% and the 1% significance levels, respectively.

Diagnostic tests: R^2=0.72; Std err. regress.=0.11; D-W=2.42; JB=4.44 (0.10); AIC=-1.48; LMSC(1)=2.17 (0.15); ARCH(1)=0.12 (0.73); RESET(1)=0.09 (0.77); SWC=-1.14; LMSC(4)=1.15 (0.35); ARCH(4)=1.14 (0.35); WHITE=0.84 (0.63).

Where:

- CPIc is the CPI core quarterly rate of change and
- CPFE is the difference between CPI and CPIc, in its standardized value.

This estimate shows no sign of misspecification; but it implies that from 2004 on, the process governing the core inflation rate changes considerably. This date coincides with the onset of the housing and related sub prime boom (whose bust is too recent to have had an impact on our estimates). After this date oil prices of course accelerate also their increase, but this should be accounted for by the LOIL variable. After this date the pass-through effect from the headline to the core rate becomes significant and the long run value of inflation increases considerably.

Note that the point estimates of the parameter concerning the impact of (the rate of change of) oil and the output gap are identical in the two sub-periods. But the long run inflation rate changes from 2004 on. Before that date, the core inflation goes to zero in the long run but, from 2004, the long run inflation becomes 2.23% on annual basis. There is an important pass-through effect captured by the standardised difference between the third lag headline inflation rate and the core rate (CPI-CPIc), however, this effect only occurs from 2004 on. The output gap significantly affects the inflation rate: an increase of 1% yields an increase in the core inflation of 8 basis points; this holds for the entire sample. Note that all variables in the right-hand sides of the equations are stationary. This means that, should an oil shock occur, the inflation rate does not require any adjustment in output to come back to their long run values. A fall movement in output would only fasten the process of adjusting to an oil price increase. This feature may be due to the fact that (in the sample) there has been no second-round effect triggered in the labour market, probably because of the particular features (i.e. flexibility and competition) of the US labour market.

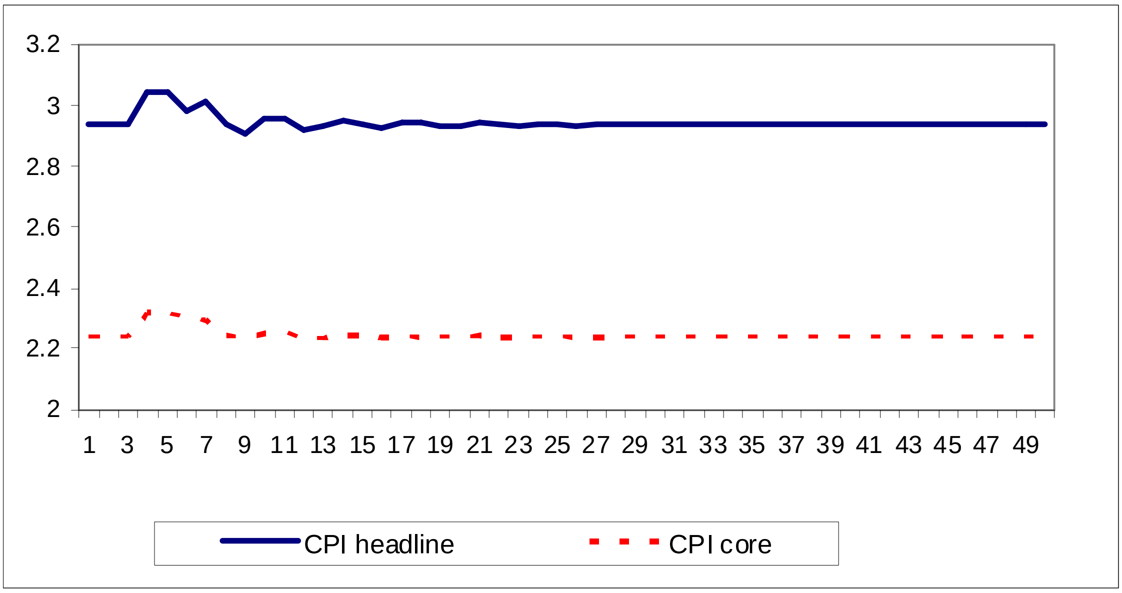
An interesting aspect of Table 11 is that the oil variable (the rate of change of oil price, standardised value) has a <u>negative</u> impact on the core inflation (it had a naturally positive impact on headline inflation). A straightforward explanation of this, at first sight, counter-intuitive result is that core prices have to decline if energy prices go up if price stability is to be maintained. However, this argument is difficult to make for the US where the FED does not try to stabilise the overall CPI (and in the EA, where the ECB does target the overall CPI, this negative effect does not appear). The gap between the headline and core inflation is also influenced by the oil price (which has a direct impact on headline inflation), this implies that the overall impact of LOIL on core inflation has two elements that partially offset each other.

Now, we focus on the impact on the US economy of an output gap shock and of a supply shock.

3.3 Dynamic consequences of different shocks

The reference regressions are that of Table 10 for the headline CPI and that of Table 11 for the core CPI. As regards the output shock, on may assume that the output gap increases 1% and then it immediately comes back to its long-run level (zero). Figure 8 depicts the CPI core and headline rates after this shock. Notice that the difference between the two inflation measures also affects the CPI core rate. The rates are calculated on the same quarter of the previous year.

Figure 8. US headline and core inflations following an output gap shock



As regards oil, for both inflation specifications, what matters is not the price level but its percentage change. At present (2008:1), the average oil price level amounts to 95$/b. Suppose a first scenario where oil price leaps to 130$/b and a second scenario where oil price becomes 150$/b. This implies that the rates of changes are 37% and 58%, respectively. Suppose also that the output gap is fixed at zero and the economy is in regime 2, whose parameters are exhibited in Table 10, then the dynamics of CPI headline rate, in the above scenarios is shown in Figure 9. The rates are calculated on the same quarter of the previous year.

Figure 9. US headline inflation following an oil shock

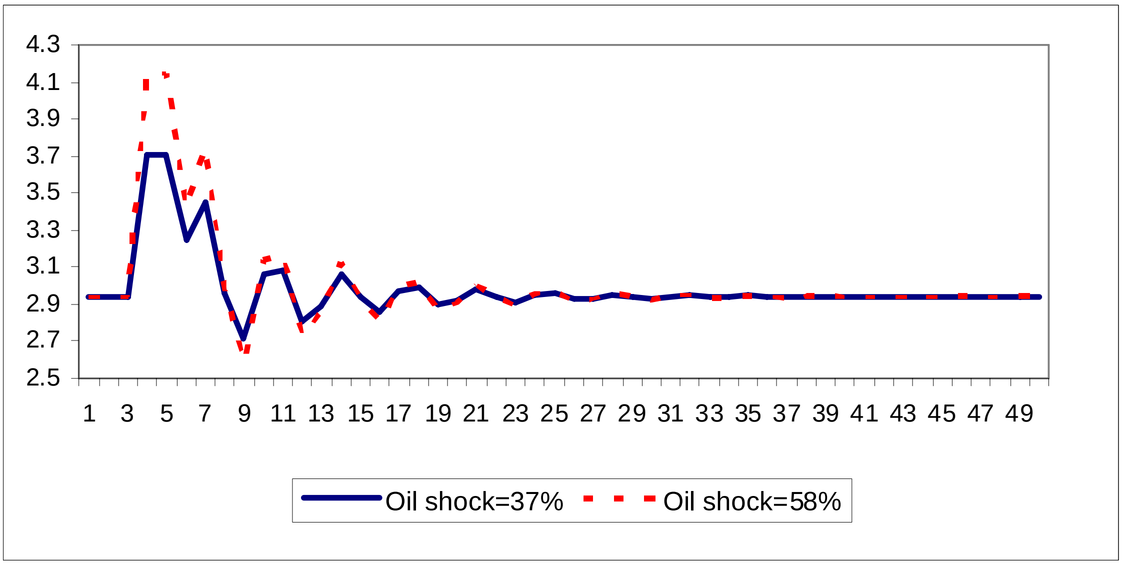
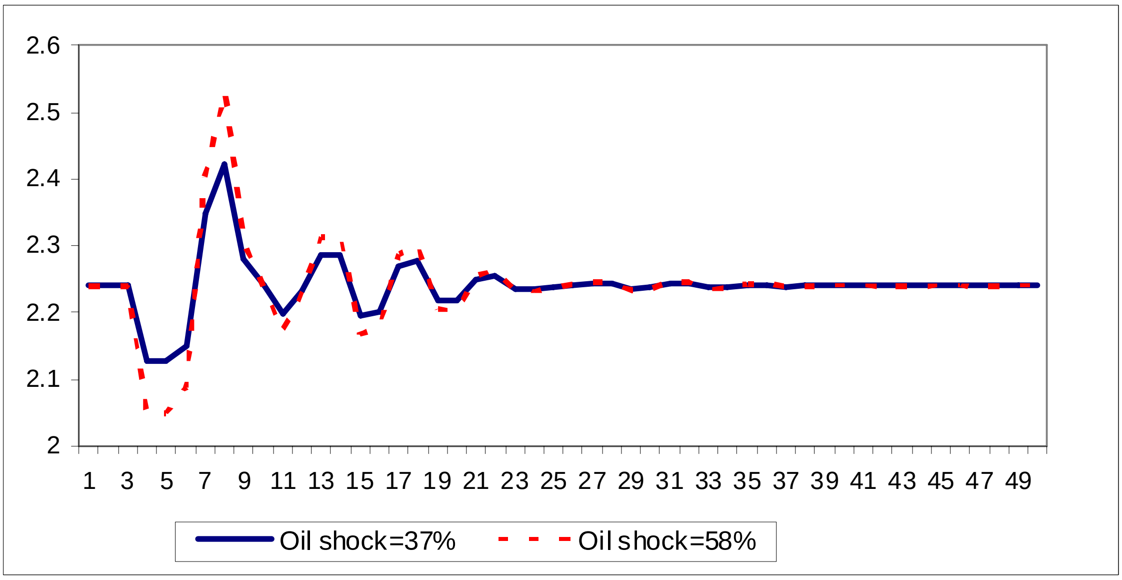


Figure 10 shows the CPI core rate dynamics in the above scenarios. Note that, the immediate effect of the oil shock is smaller in the CPI core rate. This shock occurs in time 4. After the oil shock, the core inflation is also affected by the energy and food inflations (difference between CPI headline and CPI core) hence the shock is more propagated in the core rate than in the headline rate because of the pass through effect that occurs three quarters after the time shock. The rates are calculated on the same quarter of the previous year.

Figure 10. US headline inflation following an oil shock



We now provide sacrifice ratios (here defined as the amount of output to give up in order to reduce inflation by 1% per year) calculated with respect to both measures of inflation. For the CPI headline rate, in regime 1, since the estimated coefficient cannot be considered different from zero, the sacrifice ratio does not exist meanwhile in the (present) second regime it is[31] 2.26. As regards the CPI core, the sacrifice ratio is 3.19. So, when the disinflation process focuses on the core inflation the sacrifice ratio is higher; this is intuitive because the headline inflation includes the more volatile activities in the economy i.e. energy and food sectors; in fact, in these sectors, changes in price levels do not provide information on the business profitability[32] hence, output does not change relatively; on the other hand, in the sectors where prices are more stable a fall in prices implies a persistent revenue reduction and hence firms may find a decrease in output optimal.

3.4 Okun's law in the United States

As regards the Okun law, one may assume that for the US the NAIRU and the GDP potential are constant (see OECD, Economic Outlook No. 82). If this is the case, the Okun law estimates correspond to the unemployment rate regression on GDP. Alternatively, one can estimate the potentials by the HP filter. However, one should firstly ascertain the stationarity property of the US unemployment rate (seasonal adjusted): according to the relevant ADF test, the probability of falsely rejecting the unit root hypothesis (the p-value of the test) is 0.2 in the sample 1996:1 2008:1. Hence, it is appropriate to estimate a first difference regression for the unemployment rate:

Table 12. US first difference of unemployment equation estimates

	K	D2001_4	UN(-1)	GDP	GDP(-2)	GDP(-4)
Par. Est.	0.618**	0.675**	-0.08*	-0.105**	-0.116*	-0.104*

(*) and (**) refer to the 5% and the 1% significance levels, respectively.

Diagnostic tests: R^2= 0.64; Std err. regress.=0.13; D-W=2.41; JB=0.54 (0.76); AIC=-1.14; LMSC(1)=2.11 (0.15); ARCH(1)=0.02 (0.89); RESET(1)=0.14 (0.71) SWC=-0.90; LMSC(4)=0.71 (0.58); ARCH(4)=0.54 (0.70); WHITE=0.41 (0.92).

Where GDP is measured in quarterly rate of change. Tests show no sign of misspecification. The Okun law with time-varying potential GDP and NAIRU is (by the HP filter):

Table 13. US Okun law estimates

	D2001_4	UNGAP(-1)	OGAP
Par. Estimates	9.707**	0.646**	-3.61**

(*) and (**) refer to the 5% and the 1% significance levels, respectively.

Diagnostic tests: R^2= 0.91; Std err. regress.=2.51; D-W=2.05; JB=0.50 (0.78); AIC=4.73; LMSC(1)=0.34 (0.57); ARCH(1)=0.54 (0.47); RESET(1)= 0.01 (0.,93); SWC=4.84; LMSC(4)=0.58 (0.68); ARCH(4)=0.29 (0.88); WHITE=0.39 (0.85).

UNGAP is the unemployment gap (dependent variable), OGAP is the US output gap. Tests show no sign of misspecification. As expected the US unemployment is more susceptible to business cycles than the EA unemployment. This is probably due to the greater resilience of the US economy with respect to the EA one. Furthermore, there is no evidence of instability of

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[31] Since 1% on an annual basis corresponds to 0.249% on a quarterly basis and the sacrifice ratio is the inverse of the PC slope, it yields: 1/0.11=7.69% times 0.249 which equals 2.26.

[32] Since they are relatively frequent (because their variability is high).

parameters, hence all implications of changes in the regime in the EA Okun law (hysteresis) do not hold for the US.

As regards the sacrifice ratios, one may calculate them also with respect unemployment. Table 14 reports them along with the ones calculated with respect to the output gap.

Table 14. Sacrifice ratios in terms of output and unemployment

Sacrifice Ratios in terms of	Output gap %	Unemployment gap %
CPI headline	-2.26	8.17
CPI core	-3.19	11.52

These relative high ratios (especially those related to unemployment) are due to the relative flat PC (with respect to the EA, for example) but also to the magnitude of the Okun coefficient. Indeed, these results are not surprising if one considers, from the one side, that higher flexibility of the US labour market with respect to the EA, implies higher employment rate (and hence a flatter labour supply curve) and, consequently a flatter PC curve and, from the other side, fewer legal protections for employment, which implies less labour hoarding and more unemployment sensitivity to output.

4. Policy implications

Our estimates of the Phillips curves and the Okun laws on both sides of the Atlantic clearly suggest that the economies of the EA and the US are different enough to motivate different monetary policies.

First of all, supply (oil price) shocks impact the economies in different ways. This may be due to several factors such as the Union power, the degree of competition in the products market and the central bank mandate. In the US economy the main threat to overall price stability from an oil price shock is the pass-through effect of higher energy (and food) prices through an increase of all input costs and hence the overall price level. By contrast, for the EA the main threat stems from potential second-round effects, that is, from the labour market. This can be ascertained by looking at the core inflation regressions for the two economies (Tables 2 and 11 respectively): in fact, the energy and food price increases (as the difference between headline and core inflations) are relevant only for the US economy, for the EA economy the oil price impact directly manifests itself on the core rate and not through the energy and food price. As noted in section 2, this may be due to the greater ability of the ECB to anchoring inflation expectations.

We also note that the slope of the PC (that is the output gap coefficients) is higher in the EA than in the US (all regressions confirm this feature).

The US and EA are also different from another important perspective: there is evidence of hysteresis only in the EA labour market. We find that in troughs the sensitivity of labour market to output is higher than in booms (the Okun coefficient is asymmetric), hence every trough causes long term unemployment. Thus, when initiating a disinflation process, one has to consider the deterioration of the supply side that the asymmetry of the Okun law implies for the EA.

From the beginning of 2008, the FED and ECB have been monitoring the oil price carefully. Whatever the cause of its surge, it is important to avoid the mistakes of the past that is: neglecting inflation expectations formation but, for the ECB the disinflation process should be performed more carefully since it may affect the probabilities of switching the EA economy in regime 1 (more sensitivity of unemployment to output).

From an operational point of view, assuming an HICP increase of 2% as the ECB inflation target, given the HICP inflation of 2008:1 of 3.8% on annual basis, it requires an output gap reduction of 1.8*1.35=2.43% and, given the regime 2 for the Okun law it implies an unemployment gap reduction of roughly the same amount. However, as already stressed, the current policy affects the probability of switching into regime 1 in the future (see Annex B); it can be shown that, for the two periods following the beginning of the disinflation process, the probabilities of regime 1 to occur are 15% and 24% if the planned reduction is exerted in 1 quarter, but if the reduction is performed in two times (say two output reductions of 1.2%) for these times the probability to switch in regime 1 will be 13% and 22%, respectively; thus a more gradual approach should be preferable. On the other side, however, if present inflation expectations (captured by the dummy variable, D2003 of table 1) do not change, the HICP tends to come back to the long-run value of inflation of 2.44%. At this point, further interventions aiming at decreasing the output gap will be necessary as far as inflation expectations are not centred on the inflation target. As regards the US economy, the CPI core at 2008:1 is roughly 3% on an annual basis, however, considering the model of Table 11, this value is likely to increase, given recent surges in the headline inflation. If the FED wants to bring this inflation back, say to 2%, it requires, according to Table 14, an output and unemployment gap reduction of 3.2% and 11.5% respectively and, since the US PCs are linear with respect to the output gap, these reductions are independent of the degree of gradualism the central bank wants to choose. However, a tightening monetary policy may be not consistent with the present situation of the US financial and credit markets.

Conclusions

Our results suggest that Phillips curves in the EA and in the US differ in many aspects but there are also some common features. Using headline inflation we find that the inflation process seems to have shifted upwards on both sides of the Atlantic since 2003/4, i.e. after the onset of the related real estate and credit booms, which led to the so-called ‘sub prime’ crisis of 2007/8.

For example, we find that, in the EA the long run value of inflation increases from approximately 2 to 2.4% from 2003 onwards. Around this date, the US inflation regime also changes, entering a regime with a higher long run value (2.93% per year) and with higher volatility. We also find that the impact of oil prices (or rather its rate of change) is more persistent on headline inflation of the EA than in the US. As regards the slope of the PC (the output gap coefficient) it is steeper for the EA than for the US (0.18 vs. 0.11), which implies that the sacrifice ratio is lower in the EA (–1.35 vs. -2.26). Thus, demand shocks affect EA inflation more but, for a given supply shock, the US economy requires a larger decline in output to restore initial inflation.

The PCs with core rates are also different; oil price increases affect the US core rate only after 2004. Furthermore, a pass-through effect from the headline to the core rate is present and it shows up with a lag of three quarters; in contrast, in the EA specification, the pass-through effect is not significant but the long-run value (of core inflation) increases after 2003 as in the headline specification.

Major differences between the two economies can be observed in their labour markets. The EA Okun law is asymmetric: if unemployment trends upwards (and output gap downwards) the sensitivity of unemployment to the output gap is higher (-1.45 vs. –1.02); this implies that the increase of unemployment in recessions is larger, in absolute value, than its decrease in expansions, given the same output gap percentage change in absolute terms. This phenomenon, called hysteresis, has important implications for monetary policy. In its strategy decisions, the ECB should take into account that each disinflation process implies a probability for the economy to switch in the regime with higher sensitivity of unemployment to output; at present, the ECB should perform a disinflation process amounting to roughly 2% (since the present inflation rate is at 3.8%, on an annual basis); we estimate that this probability is minimised when gradualism (that is in two quarters) is chosen with respect to a harsher approach (that is in one quarter). For the ECB it is also important to monitor inflation expectations carefully as in all PC specifications the long run value of inflation rates is above the 2 % target of the ECB.

As regards the US economy, the CPI core at 2008:1 is roughly 3% on an annual basis, but it is likely to increase in the short run (given the considerable gap between headline and core). Our estimates suggest that an output gap of 3.2 % and an increase in unemployment gaps over 10% would be needed to bring core inflation down to 2 %. (For the US the degree of gradualism does not matter). It is understandable that the FED is hesitating to pay this price.

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Annex A

Next tables show alternative models for HICP EA headline.

Table 15. EA Phillips curve estimates with HICP headline. Specification with DOIL2

	K	HICP(-1)	HICP(-4)	OGAP	LOIL(-3)	LOIL(-4)	DOIL2
P estimate	0.490**	-0.338**	0.403**	0.137**	0.129**	-0.121**	0.185**

(*) and (**) refer to the 5% and the 1% significance levels, respectively.

Diagnostic tests: R^2=0.73; Std err. regress.=0.18; D-W=2.29; JB=0.68 (0.71); AIC=-0.42; LMSC(1)=1.93 (0.17); ARCH(1)=0.04 (0.83); RESET(1)=0.39 (0.53); SWC=-0.14; LMSC(4)=1.11 (0.36); ARCH(4)=0.78 (0.54); WHITE=1.42 (0.21).

DOIL2 is the difference of the squared oil price level. All oil-related variables are in standardised values. The long-run inflation rate is 2.1%. Note however, that this model and that of Table 16 require strong assumptions (oil prices constant) in the out-of sample forecasts. In fact, in order for the inflation rate to converge in the long run, both the oil rate of change and the difference term should not converge to their in-sample mean values: if, for example, the oil rate of change converges to 3%, then the difference term diverges. On the contrary, only if oil prices are fixed (instead of increasing of 3%) do both quantities (the rate of change and the difference term) converge to zero and the inflation rate converges to a given value; this value is different from the one implied in the regressions' parameters, this difference is however negligible.

As regards the oil shock, the latest oil price of the sample is 64€/b (2008:1). Two scenarios are assumed, that is: the oil price becomes 80€/b and 90€/b. This implies the following rates of change: 25% and 41%, respectively. After the shock, the oil rate of change becomes zero (note that this implies that the long run inflation value decreases by a term equal to the average rate of change times the sum of the related parameters, however in this case the effect is negligible). The rates are calculated on the same quarter of the previous year.

Figure 11. EA headline inflation following the oil shocks, based on parameters of Table 15

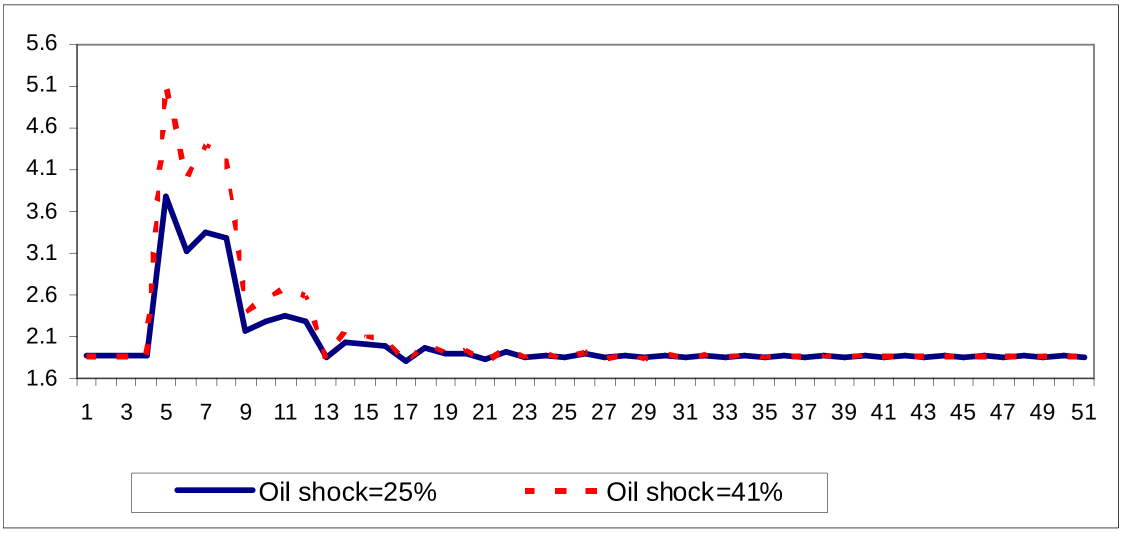


Table 16. EA Phillips curve estimates with HICP headline. Specification with DOIL4

	K	HICP(-1)	HICP(-4)	OGAP	LOIL	LOIL(-3)	LOIL(-4)	DOIL4
P estimate	0.485**	-0.368**	0.408**	0.130**	0.10**	0.129**	-0.103**	0.132**

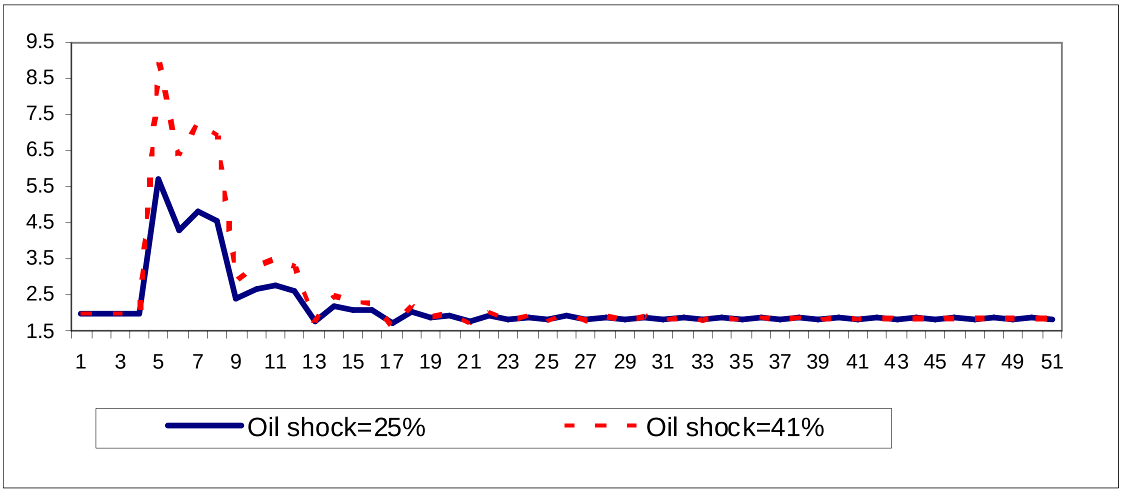
(*) and (**) refer to the 5% and the 1% significance levels, respectively.

Diagnostic tests: R^2=0.74; Std err. regress.=0.17; D-W=2.31; JB=0.75 (0.68); AIC=-0.42; LMSC(1)=1.99 (0.17); ARCH(1)=0.08 (0.77); RESET(1)=0.47 (0.49); SWC=-0.10; LMSC(4)=1.02 (0.40); ARCH(4)=0.87 (0.49); WHITE=1.21 (0.32).

All oil related variables are in standardised values. DOIL4 is the difference of the fourth power of the oil price level. The long-run inflation rate is 2.0%.

The same assumptions as above hold for the next simulation.

Figure 12. EA headline inflation following the oil shocks, based on parameters of Table 16



Next table shows the PC regression for the HICPc (less energy and seasonal food).

Table17. Estimates of EA Phillips curve HICPc (no energy and seasonal food)

	D2003	K	HICPc(-1)	HICPc(-2)	HICPc(-3)	OGAP
Par. estimates	0.057**	0.125**	0.871**	-0.592**	0.398**	0.071**

(*) and (**) refer to the 5% and the 1% significance levels, respectively.

Diagnostic tests: R^2=0.85; Std err. regress.=0.14; D-W=1.89; JB=0.84 (0.45); AIC=-2.69; LMSC(1)=0.03 (0.84); ARCH(1)=1.85 (0.18); RESET(1)=0.04 (0.84); SWC=-2.45; LMSC(4)=1.62 (0.18); ARCH(4)=0.73 (0.57); WHITE=2.22 (0.04).

Here HICPc is defined as the EA harmonised price index excluding energy and seasonal food. Due to the possible presence of heteroschedasticity (see White test) standard errors are estimated by the Newey-West method. Note that no oil variable is directly or indirectly significant in this regression but the presence of a dummy variable equalling 1 from 2003 (implying a higher long run inflation rate) is due to the oil price increase starting from that period.[33]

[33] Comments following Table 2 on this topic also hold for this regression.

Annex B

Suppose that the ECB faces a 4% headline inflation rate and wants to bring it back to 2%. According to Table 7, central bankers should raise interest rates such that the output gap decreases of 2*1.35=2.7%; as regards unemployment, however, the sacrifice ratio depends on the regime the economy lays which, in turn, also depends on the central bank's action. In fact, it has been estimated that the transition probabilities are logistic functions of a constant and of the lagged first difference of the output gap (which is affected by the monetary policy). For the transition probability Pr(regime=1|regime=1; output gap(-1)) their estimated parameters are 3.3 and –0.52 respectively; for Pr(regime=2|regime=2; output gap(-1)) they are 2.09 and 0.14 respectively (see also footnote 25). Now, suppose the economy is in regime 2 (as it is at 2008:1) and suppose that the central bank would perform the disinflation process (of 2%) either in one quarter or in two quarters.

Given the status of the economy and the parameter estimates the central bank, in t0, the central bank's policy can affect the probability of the economy to be in either regime in the two periods (say t1 and t2). In fact, since by assumption $\Pr[r(t_0)=2 \mid I(t_0)]=1$ (where $r(t_j)=i$, with *j=0,1,2.. i=1,2,* is the regime variable of time *j*, taking value 1 or 2 and *I(.)* is the available information at the specified time), future probabilities of the status of the economy are so calculated:

$$\begin{aligned} &\Pr[r(t_j)=2 \mid I(t_j)] = \\ &= \Pr[r(t_j)=2 \mid r(t_{j-1})=2; OGAP_{j-1}] \cdot \Pr[r(t_{j-1})=2 \mid I(t_{j-1})] + \\ &+ \Pr[r(t_j)=2 \mid r(t_{j-1})=1; OGAP_{j-1}] \cdot \Pr[r(t_{j-1})=1 \mid I(t_{j-1})] \end{aligned}$$

$$\Pr[r(t_j)=1 \mid I(t_j)] = 1 - \Pr[r(t_j)=2 \mid I(t_j)];$$

where *j=1,2*. So, by affecting OGAP (the output gap) the central bank can govern the probability of the future status of the economy. Next tables show these probabilities for the two supposed disinflation processes say 'cold turkey' and 'gradualism'.

Table 18. 'Cold Turkey' strategy and the probability of regime 1 to occur

Time *j*	J=0	J=1	J=2
OGAP	-2%	0%	0%
$\Pr[r(t_j)=1 \mid I(t_j)]$	0	0.99*0+0.14*1=0.14	0.97*0.14+0.11*(1-0.14) =0.23
$\Pr[r(t_{j+1})=1 \mid r(t_j)=1; OGAP_j]$	0.99	0.97	0.97
$\Pr[r(t_{j+1})=1 \mid r(t_j)=1; OGAP_j]$	0.14	0.11	0.11

Table 19. Gradualist strategy and the probability of regime 1 to occur

Time *j*	J=0	J=1	J=2
OGAP	-1%	-1%	0%
$\Pr[r(t_j)=1 \mid I(t_j)]$	0	0.98*0+0.12*1=0.12	0.98*0.12+0.12*(1-0.12)=0.22
$\Pr[r(t_{j+1})=1 \mid r(t_j)=1; OGAP_j]$	0.98	0.98	0.97
$\Pr[r(t_{j+1})=1 \mid r(t_j)=1; OGAP_j]$	0.12	0.12	0.11

Next table shows the probabilities for regime 1 to occur for different values of inflation to disinflate.

Table 20. Probabilities of regime 1 to occur for each disinflation value and strategy

Disinflation strategy		Cold turkey (one intervention)		Gradualism (two interventions)	
Time *J*		J=1	J=2	J=1	J=2
Disinflation value	2%	0.14	0.23	0.12	0.22
	4%	0.18	0.26	0.14	0.23
	6%	0.22	0.30	0.16	0.25
	8%	0.27	0.34	0.18	0.27

It is clear that gradualism it is the strategy that minimises the probability or regime 1 in each of the two periods given the disinflation value, hence the joint probability.

More formally, the central bank should choose the policy that maximises the probability of staying in regime 2 in the two periods in which it affects the economy. This means that the central bank maximises either:

- the joint probability that the economy is in regime 2 for both periods: $\Pr[r(t_2) = 2 \mid I(t_0)] \cdot \Pr[r(t_1) = 2 \mid I(t_0)]$ or,
- the joint probability that the economy is *not* in regime 1 for both periods which equals to: $\Pr[r(t_2) = 2 \mid I(t_0)] \cdot \Pr[r(t_1) = 2 \mid I(t_0)] + \Pr[r(t_2) = 1 \mid I(t_0)] \cdot \Pr[r(t_1) = 2 \mid I(t_0)] +$ $\Pr[r(t_2) = 2 \mid I(t_0)] \cdot \Pr[r(t_1) = 1 \mid I(t_0)]$.

However, given the probabilities of Table 20, gradualism should be always the preferred strategy.