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The Nonlinearity of the Phillips Curve and European Monetary Policy

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Abstract

This paper deals with the question of whether the euro area Phillips curve is nonlinear. There has recently been a great deal of discussion and studies concerning the same question in the US context. The data set includes most of the euro area countries, namely Austria, Germany, Finland, France, Italy, the Netherlands and Spain. Estimation is made both with pooled data and with country-specific models. The results give a clear indication of nonlinearity of the Phillips curve in many euro countries. The curve is asymmetric in the sense that, with a positive output gap (actual output is greater than potential output), its impact on inflation is positive, but, with a negative output gap, the deflationary impact is very small and not significant as a rule. The Phillips curve has been especially asymmetric in Germany, Finland, Italy, the Netherlands and Spain.

An important result of the study is the strong negative influence of inflation uncertainty on GDP in the euro countries during the estimation period, 1976–1997. This effect was very strong in pooled data but also at country level. This result is new in the sense that a Lucas-type supply function and especially nonlinear versions of it have not been estimated very often. Another interesting result is that Phillips curves can be estimated with good success using OECD Secretariat forecast data for inflation expectations.

A very important result for monetary policy are the large differences between countries as regards the slope and shape of the Phillips curve. The policy implication of nonlinearity is clear. The costs of unduly expansive monetary policy could be high in the euro area in the medium term. Nonlinearity also means that inflation pressure in the euro area is dependent not only on the average demand situation but also on how economic activity is distributed across the region.

Key words: Phillips curve, nonlinearity, monetary policy, uncertainty, euro area country differences

Phillips-käyrän epälineaarisuus ja Euroopan rahapolitiikka

Suomen Pankin keskustelualoitteita 17/99

Ilmo Pyyhtiä
Tutkimusosasto

Tiivistelmä

Tämä tutkimus käsittelee kysymystä, onko euroalueen Phillips-käyrä ei-lineaarinen. Asiaa on tarkasteltu runsaasti viime vuosina. Tutkimusaineisto käsittää useimmat euromaat eli Itävallan, Saksan, Suomen, Ranskan, Italian, Alankomaat ja Espanjan. Estimoinnit on tehty sekä paneeliaineistolla että maakohtaisilla malleilla. Estimointitulokset antavat selviä todisteita Phillips-käyrän ei-lineaarisuudesta monissa euromaissa. Käyrä on epäsymmetrinen siten, että positiivisen tuotantokuilun vallitessa (kun tuotanto on suurempaa kuin potentiaalinen tuotanto) inflaatiovaikutukset ovat positiivisia, mutta negatiivisen tuotantokuilun vallitessa inflaatiota hidastavat vaikutukset ovat pieniä eivätkä yleensä merkitseviä. Phillips-käyrä on ollut erityisen epäsymmetrinen Saksassa, Suomessa, Italiassa, Alankomaissa ja Espanjassa.

Toinen tutkimustulos oli inflaatioepävarmuuden suuri vaikutus kokonaistuotannon kasvuun euromaissa estimointiperiodin aikana eli 1976–1997. Tämä tulos oli hyvin selvä kaikki maat käsittävällä paneeliaineistolla mitattuna mutta myös maittain. Tulos on uusi siinä mielessä, että Lucaksen esittämää tarjontafunktiota ei ole estimoitu kovin usein eikä varsinkaan epälineaarisuuden sallivassa muodossa. Mielenkiintoinen tulos on myös se, että Phillips-käyrä onnistuttiin estimoimaan menestyksekkäästi käyttämällä inflaatio-odotusmuuttujana OECD:n sihteeristön inflaatioennusteita.

Tärkeä tutkimustulos rahapolitiikan kannalta on, että Phillips-käyrän kulmakertoimessa ja muodossa on suuria maidenvälisiä eroja. Politiikkajohtopäätös tästä on selkeä. Liian ekspansiivisen rahapolitiikan kustannukset voivat olla hyvin suuret euroalueella keskipitkällä aikavälillä. Phillips-relaation epälineaarisuuden vuoksi euroalueen inflaatiopaine ei riipu vain keskimääräisestä suhdannetilanteesta, vaan myös siitä,miten taloudellinen aktivisuus jakautuu talouden sisällä.

Asiasanat: Phillips-käyrä, ei-lineaarisuus, rahapolitiikka, epävarmuus, maittaiset erot euroalueella

Contents

1 Introduction

There has been a great deal of discussion and study recently of the possible nonlinearity of the Phillips curve. In the analytical sense the monetary policy implications of the nonlinear Phillips curve are fairly clear. Nonlinearity of the Phillips curve means that inflation and inflation expectations vary nonlinearly in relation to changes in acitivity. As a rule wages and prices are more rigid downwards than upwards. This increases the costs of disinflationary monetary policy and decreases the benefit of expansionary monetary policy as well. The policy lesson from this is that central banks have to react very fast and aggressively to first signs of acceleration of inflation expectations because killing inflation later can be very expensive. In addition the effects of uncertainty on inflation or output become very important if the Phillips relation is non-linear.

Recent empirical studies of the Phillips curve offer results which support the hypothesis of the nonlinearity of the relationship between unexpected increase in inflation and the output gap (see eg Clark, Laxton and Rose (1996)). However, the study methods differ a lot as do the results. A fairly common result has been that there is a difference between the USA and Europe in the form and curvature of the curve. The slope of the American Phillips curve is said to be steeper than the European one. Both curves are nonlinear and may be convex although a concave curve has also been noticed with the US data. There are also signs that the steepness of the curve has decreased in the nineties. For that reason and because the EMU is a new institutional development it is particularly important to study the euroarea Phillips curve.

The study of country level differences in the Phillips curve is especially important because the planning and decisions on monetary policy in Europe is based on aggregated economic figures of the euroarea. However it is known that the structure of industries differ among countries creating the risk of asymmetric shocks. Additionally many studies have found that the monetary policy transmission mechanism differs among countries due to structural differences in financial and labour markets. Also monetary policy has its own tradition in each euro country even though inflation convergence has been remarkable in the course of the 1990s. All these things together, not forgetting political pressures, make the common monetary policy of the ECB a very complicated task.

The goals of the ECB monetary policy are however clear because according to the Maastricht Treaty the maintenance of price stability is the primary objective of the European Central Bank. Price stability has been defined as a year-on-year increase in the Harmonised Index of Consumer Prices (HICP) for the euroarea of below 2 % which is to be maintained over the medium term. The ECB strategy consists of “two pillars”: first a prominent role for money as signalled by the quantitative reference value for the growth of a broad monetary aggregate, second a broadly based assessment of the outlook for future price developments and for the risks of price stability in the euro area as a whole (ECB Monthly Bulletin, Jan. 1999).

An important element in the ECBs monetary policy strategy is the statement that “price stability is to be maintained over the medium term” which reflects the need in monetary policy to have a forward-looking, medium-term orientation. It also acknowledges the existence of short-term volatility in prices, resulting from non-monetary shocks to the price level that cannot be controlled by monetary policy. The effects of indirect tax changes or variations in international commodity prices are good examples of this. The forward looking policy rule is also important in taking into account the normal lags in the transmission mechanism (Svensson, 1998).

It is important for the central bank to know the transmission mechanism of the monetary policy, how short-term nominal interest rates affect long-term rates and economic development via different channels and lags. In a closed economy, standard transmission channels include an aggregate demand channel and an expectations channel. In the aggregate demand channel, monetary policy affects aggregate demand, investment and consumption, via interest rate changes and availability of the credit. Finally aggregate demand influences inflation. In the expectations channel monetary policy affects inflation expectations which, in turn, have significant influences on inflation via wage- and price-setting behaviour. The expectations channel can be very effective if the credibility of the central bank is good. These two channels are explicitly modelled in the expectations-augmented form of the Phillips curve.

In an open economy, the exchange rate is an important additional transmission channel. The exchange rate is affected by the difference between domestic and foreign nominal interest rates and expected future exchange rates, via the interest rate parity condition. With sticky prices, the nominal exchange rate affects the real exchange rate. The real exchange rate will influence the relative prices of domestic and foreign goods.

The exchange rate can also influence domestic inflation directly, in that the exchange rate affects domestic currency prices of imported final goods, which enter the CPI figures. Typically, the lag in this direct exchange rate channel is shorter than that of the aggregate demand channel meaning that monetary policy can affect inflation with a shorter lag by inducing exchange rate movements. Finally, there is an additional exchange rate channel to inflation. The exchange rate affects the domestic currency prices of imported intermediate goods, which influence the domestic produce prices. Furthermost exchange rate movements can influence produce prices via direct CPI effects on wage setting.

However, the exchange rates are not independent on monetary policy inflation expectations and the real demand situation. In the end, the output-inflation trade off is mainly determined by the Phillips curve, or its equivalent.

2 Monetary policy and nonlinearity of the Phillips curve

The aggregate supply function is one of the main parts of the transmission mechanism of monetary policy. Its functional form has been studied extensively since Keynes (1936) suggested that downward rigidity of nominal wages meant that supply of output was completely inelastic for output prices above full employment but being elastic once the output level fell below full employment. The supply curve was thought to be backward-L shaped. Research in the relationship between inflation and output entered a new phase when Phillips (1958) pointed out from empirical evidence the inverse relationship between the rate of wage inflation and the unemployment rate prevailed. More importantly he found that the nominal wage unemployment function could be even convex in certain excess demand and supply situations.

The discussion about aggregate supply function changed markedly when Muth (1961) presented the idea of rational expectations and Friedman (1968) the concept of the natural rate of unemployment. This meant that incorporating and modelling inflation became a main focus in the study of the supply side of the economy. Phelps (1967) and Friedman (1968) presented a so called “expectations-augmented” Phillips curve, whereby inflation varied relative to its expected level in response to changes in activity. They assumed that for employees real wages and not nominal wages were relevant to decision making. For that reason inflation expectations became an important factor in studying wage formation. In their model the long-run aggregate supply curve is vertical when fully flexible wages and prices and rational expectations are assumed. This means that disturbances on the demand side of the economy or economic policy cannot increase the long-term economic growth rate. In the short-run economic policy can however influence growth and inflation throught the slow adjustment of prices and wages to economic shocks. On the other hand Phillips’ idea of a nonlinear wage unemployment curve was discarded as a long-run relationship on theoretical and empirical grounds in the 1960s and 1970s.

The Phillips relation is usually presented as a relationship between inflation, core inflation and output gap such as

$$\pi_t = \pi_t^* + \lambda\left(\ln Q_t - \ln Q_t^*\right) + \varepsilon_t^s, \qquad (2.1)$$

where π_t is the inflation rate. π^* is a core or underlying inflation rate which prevails when output Q equals to some natural rate of output, or potential or full-employment output denoted by Q*. The term ε^s captures supply shocks. The core inflation is a result of things like nominal contracts and other institutional arrangements reflecting prevailing inflation expectations (Friedman (1968)). So the core inflation is often replaced by inflation expectations in the function, giving it the form

$$\pi_t = \pi_t^e + \lambda\left(\ln Q_t - \ln Q_t^*\right) + \varepsilon_t^s \qquad (2.2)$$

where π_t^e is expected inflation. According to this equation, no policy can raise output permanently above its natural rate, since that requires workers’ and firms’ forecast of inflation to be perisistently too low.

The long-term aggregate supply curve is vertical when expectations and actual inflation are equal. The short-term supply curve is upward sloping (linear or nonlinear). A common idea of the nature of nonlinearity is that in the neighbourhood of potential output activity cannot increase very rapidly, regardless of the size of the demand shock, and any nominal stimulus beyond this point is translated directly into inflation. On the other hand inflation decreases very slowly when the output gap closes.

Most of the studies of the Phillips curve have been made following (2.1) and (2.2). However, Lucas (1973) presented his supply function in inverted form so that output is on the left hand side of the equation. He presumed that nominal output is determined on the aggregate demand side of the economy, with the division into real output and the price level primarily dependent on the behaviour of the suppliers of labour and goods. The partial “rigidities” which dominate short-run supply behaviour result from suppliers’ lack of information on some of the prices relevant to their decisions. He divided the markets into subsectors which each had its own cyclical variation in production and prices. Quantity supplied in each market is viewed as the product of a normal (or secular) component common to all markets and a cyclical component which varies from market to market. His aggregate supply function common to all markets is reached integrating over different markets. The Lucasion aggregate supply function has the form

$$Q_t = Q_t^n + \theta\gamma\left(\pi_t - \overline{\pi}_t\right) + \lambda\left(Q_{t-1} - Q_{t-1}^n\right), \tag{2.3}$$

where the slope of the supply curve depends on the relative price variance θ between markets and the aggregated price variance γ. Parameter λ is a partial adjustment factor of the lagged output gap variable.

Lucas estimation results show that in a stable price and production environment, policies which increase nominal income by surprise tend to have a large initial effect on real output, together with a small positive initial effect on the rate of inflation. Inflation stimulates real output if, and only if, it succeeds in “fooling” suppliers of labour and goods into thinking relative prices are moving in their favour.

Lucasian ideas have since been applied widely in simpler formulations. Mc Callum has recently (1997) presented his expectational Phillips curve in the inverted form where real output are explained by potential output and inflation bias

$$Q_t = \overline{Q} + \beta\left(\pi_t - \pi_t^e + u_t\right), \tag{2.4}$$

u_t reflects the discrepancies between the central bank’s instruments and the resulting inflation rate. This equation is of the same origin as Lucas’ supply function but here the public is more informed of the general price level. However it can be suggested that when prices rise very fast the uncertainty concerning general price level also increases, relative prices change and this influences output.

Natural rate or potential output is not stable over time. Investments in real capital increase potential output and bad recessions, demand and supply shocks can make vast amounts of capital obsolete. These things are difficult to estimate. Also, the structural unemployment rate can change and influence potential output. Gordon (1997) has recently revised his time-varying Nairu estimates and produced large changes in the Nairu with US data. A time varying Nairu and potential output has important policy implications but its forecasting is difficult.

The functional form of the relationship between inflation and output gap has as a rule been assumed linear in the expectations-augmented Phillips curve. The linear model ignores most of important policy conclusions already included in Keynesian economics: under conditions of full employment, inflation appeared to respond strongly to demand conditions, while in deep recessions, it was relative insensitive to changes in activity. Phillips especially emphasized an asymmetry between inflation and output by saying that excess demand had a much stronger effect in raising inflation than excess supply had in lowering it.

The functional form of the Phillips curve have been studied in the 1990s especially in the IMF and Bank of Canada. Laxton, Meredith and Rose (1995) discuss the policy implications of an asymmetric Phillips curve and estimate Phillips curves in a nonlinear functional form using quadratic and cubic forms of output gap as nonlinear proxy variables. They estimate inflation expectations from lagged inflation variables and find strong support for nonlinearity of the inflation – output gap relationship with G7 data. Clark, Laxton and Rose study asymmetry of the Phillips curve with a linear equation. They calculate an average output growth variable by the ordinary moving average method and estimate the difference between average and potential output. They add to the Phillips-curve equation a separate term for the gap when it is positive. They use Michigan survey results for inflation expectations data and also obtains very strong support for a nonlinear Phillips curve with US data.

A number of explanations have been offered for inflation's slow adjustment and the absence of costless disinflation (Cecchetti and Rich, 1999). First, inflation persistence may arise from the overlap and non-synchronization of wage and price contracts in the economy. Wages and prices adjust at different rates, and to each other, and so once one starts to rise, the other does too. Stopping the process takes time. Secondly, people's inflation expectations may adjust slowly over time, being based on a sort of adaptive mechanism. Because decisions about wages and prices depend on expectations of future changes, slow adaptation is self-fulfilling, creating inertia. And third, if people do not believe that the monetary authority is truly committed to reducing inflation, then inflation will not fall rapidly. That is, the credibility of the policymaker is important in determining the dynamics of inflation, with less credibility leading to more persistence.

Also past history over recent decades shows that deep and prolonged recessions have been required in industrialized countries to dampen inflation generated during periods of economic overheating. As a result of this experience, policymakers and especially central bankers in most of western countries have been very aware of the need to avoid excess demand pressures beforehand. This has been seen especially in the monetary policy of the Bundesbank and the inflation targets presented many central banks in recent years.

There are many interesting implications if the Phillips curve is nonlinear: in particular there is the result that the convex nature of the supply function makes it especially important to act quickly in the face of overheating of the economy, since an increase in inflation that results from excessively high activity today will need to be corrected by a correspondingly larger recession in the future if that extra inflation is to be squeezed out of the system (Bean, 1997). That phenomenon can also be measured by the so-called sacrifice ratio when the sacrifice is measured with output losses compared to change in trend inflation (Ball, 1994, in Mankiw). The sacrifice ratio with a convex Phillips curve is higher than with a linear Phillips curve.

Another important policy implication of a convex Phillips curve in an uncertain world is presented by Clark, Laxton and Rose (1995). They show that the presence of convexity in the response of inflation to output in an accelerationist (expectations-augmented with backward-looking expectations) Phillips curve implies that a high variability of output must be associated with a lower mean value of output. The result can be proved by Jensen's inequality when the Phillips curve is convex function. Thus, the mean level of output in a stochastic economy with a convex Phillips curve lies below the equilibrium of the economy without shocks to output. This is because the extra inflation brought about by a period of excess demand has to be compensated for by a period of greater excess supply in order to return the rate of inflation to its initial level. The basic policy lesson from a convex Phillips curve is that a forward looking monetary policy reaction function will lead to a smoother path of output and limit the cycles that result of an initial demand shock. By contrast, a myopic response to a demand shock results in cycles in output and in demand overshooting capacity output.

There is a planning and decision problem for ECB monetary policy if large differences in the transmission and symmetry are found because monetary policy is based on aggregate data of the euro area. In the earlier studies it is noticed that there are significant differences for instance in wage rigidities (Layard, Nickell and Jackman, 1991), sacrifice ratios (Mankiw, 1994, Ball, 1994) structure of industries and openess between euro countries (Mayes and Chapple, 1995). This result also confirms Cecchetti and Quiros (1999) paper where they compare the variability of the output and inflation in the euro countries and observe large differences both in the objectives and and economic structure. They also note large differences in transmission mechanisms across euro countries.

It must also be pointed out that under nonlinear Phillips curves, in each member country, inflationary pressure in Europe is not independent of the way economic activity is distributed over the eurozone.

3 Measurement problems and data

Expectations play a central role in estimating inflation equation for eurocountries because wage agreements are made as a rule forward looking one or two years ahead. Measuring expectations used in the wage negotiations is difficult because expectations are made as a rule with preliminary data which becomes firmer later afterwards. Orphanides (1998) has discussed in his paper problems of monetary policy making when information is as a rule noisy. Survey observations are not normally revized and that kind of data has been used in many Phillips curve studies. We have however chosen a different route and collected OECD secretariat’s price forecast data. This has a number of disadvantages, length, frequency, comparability but these data are in many respect however good expectations data. These are representative expectations data because OECD forecasts are made carefully using models and country specific information. These forecasts have also been very important information for wage negotiations in various OECD countries.

The GDP deflator is used as the price index here because it reflects market price developments more generally than consumer price indices and shock lags are shorter in producer price indices. Also, direct monetary and fiscal policy influences are small in the produce price index. The forecasts used in the study are spring forecasts for the current year. So the latest information set for the forecast is from the beginning of the realization year. Descriptive statistics of the forecast data are presented in the appendix (Chart 2). The standard deviation of the forecasts is as a rule about 0.5 percentage points except for Finland where the standard deviation is over 1 percentage point. Forecasts are as a rule largely normally distributed and the mean is reasonably near zero (Chart 3).

Measuring excess demand is one of the unsolved questions in estimating Phillips curves. Phillips used an unemployment rate in his study but recently an output gap has been frequently used because of problems in measuring NAIRU and natural rate of unemployment. The economic situation has very important role in wage settlements as a rule and the role of insiders has increased in wage negotiations. For these reasons the output gap also used in this study. There are many ways to measure potential output, surveys, structural estimation methods and into time series analysis based methods. This study uses time series methods because the main interest is in the functional form of the Phillips curve and differences between eurocountries. So it is useful to measure things in the same way in the different countries. To measure potential output a Hodrick-Prescott filter is used. Hodrick-Prescott trend components and real GDP-data are presented in the appendix (Chart 3). Differerences from similar data estimated by the OECD secretariat are small (Giorno, 1995).

Other things that influence to the development of inflation like import prices, different kind of supply and productivity shocks are not presented explicitly in the model to retain sufficient elasticity and simplicity in the estimate. These omissions in addition to measuring problems are retained to the error term of the equation. Also time dummies are used to measure common factors to all studied eurocountries.

4 Nonlinear expectation augmented Phillips curve

We test the non-linearity of the Phillips curve adding nonlinear variables to the linear equation. Clark and Laxton (1997) show that the Phillips curve is a reduced form equation derived from an ordinary inflation model. Clark and Laxton show that if real wages and unemployment have a negative relationship the inflation can be related in a nonlinear manner to the unemployment rate or output gap that is used in this study. In the absence of strong theoretical or empirical priors concerning the precise form of the non-linear Phillips curve we begin the testing by forming a general nonlinear price equation by a quadratic gap variable. Another test for nonlinearity is formed by estimating threshold models. The base equation we estimate is as follows:

$$\pi_t = \alpha\pi_t^e + \beta\left(\ln Q_t - \ln Q_t^{pot}\right) + \gamma\left(\ln Q_t - \ln Q_t^{pot}\right)^2 + \varepsilon_t, \tag{4.1}$$

where $\pi_t = \ln P_t - \ln P_{t-1}$ is inflation rate, $\pi_t^e = \ln P_t^e - \ln P_{t-1}^e$ is expected inflation rate, Q_t is output and Q_t^{pot} is potential output and their difference is the so called output gap. α and β are positive constant coefficients and $\varepsilon_t \in N\left(0, \sigma_\varepsilon^2\right)$ is a random variable which measures shocks. Larger values of α imply a greater nominal flexibility of prices compared to expectations; higher values of β imply greater price flexibility in that prices/wages respond to the level of excess demand/supply in the markets.

The second output gap in the quadratic functional form describes non-linearity of the Phillips curve. Parameter γ depends in a nonlinear fashion on the cyclical position in the economy. The quadratic functional form is a first approximation of the convex relationship. Higher values of γ imply greater convexity of the Phillips curve.

4.1 Estimation methods and results

This section presents the estimation results of Phillips curves and lines for Austria, Germany, Finland, France, Italy, Netherlands and Spain. Countries are selected by taking those with the longest data for the GDP deflator forecasts. Estimates are made both with pooled data and with country specific data. The basic estimation strategy followed in this paper is first to estimate the most parsimonius model for the Phillips curve that contains a quadratic gap term as a general approximation of nonlinearity. Second we apply different kinds of restrictions to the model and test these with the likelihood ratio. For all countries' common shocks we estimate with yearly time dummies. Finally nonlinear threshold models are estimated. In the models the output gap is divided into two samples – positive and negative gaps – which sum up to the original gap variable. The Phillips curve is estimated first with OLS, then with SURE method and finally with GMM.

The data are in difference form so that inflation and inflation expectations are differences in the price level. The output gap is a difference between logarithmic observed output and logarithmic potential output. In spite of that there is however a certain kind of unit root problem in the data. Explanation of this could be the structural change in the data set in the beginning of of the 1990s due to the collapse of the Soviet Union, Germany unification and the new inflation targets of the many European central banks. Perron (1989) has explained how to address the problem of the structural change in the small sample case. With long-sample this problem is not so large.

4.2 Phillips curve with quadratic output gap

OLS estimation results of the nonlinear Phillips curve with pooled data are presented in Table 1.A (columns 1–5). The general picture from the estimation results is that the hypothesis of nonlinearity does not reach very much support. The linear Phillips curve however works very well in this type of model where we have used expectional data from the forecasts published by the OECD secretariat. This means that we explain the inflation innovations (unexpected changes in the inflation expectations) by the output gap innovation.

The estimates of the parameter α, the coefficient of the GDP deflator forecast are as expected, α does not differ significantly from one. This can be seen from the value of the likelihood functions which have almost the same value in both equations when the coefficient of α is restricted to one (columns 1 and 2). This result is in line with descriptive statistics of the forecast figures (see appendix, chart 2). The coefficient of the output gap variable β deviate significantly from zero as measured with t-test when White's heteroscedasticity corrected standard errors are used. On the other hand the parameter estimate of the quadratic output gap term γ does not deviate significantly from zero. The sign is however positive in different estimates (columns 1–5).

Table 1.A **Phillips curve estimation results with quadratic output gap**

	(1) Linear model	(2) Unrestricted OLS	(3) H:0 α=1 (OLS)	(4) Dummies* (OLS)	(5) Dummies (OLS)	(6) SURE	(7) SURE	(8) GMM**
α	1.024	0.989	1	0.950	0.977	1.021	0.984	1.130
	(120.6)	(44.24)		(25.2)	(43.6)	(111.5)	(61.3)	(148.5)
β	0.063	0.072	0.039	0.102	0.076	0.063	0.061	0.365
	(2.15)	(1.86)	(1.79)	(1.95)	(2.06)	(2.18)	(2.12)	(10.65)
γ		0.882	0.915	1.308	0.932	0.739	1.444	5.861
		(0.79)	(0.82)	(1.10)	(0.85)	(0.89)	(1.61)	(7.12)
D78					0.005			
					(2.03)			
D92					–0.007			
					(–3.00)			
Adj R2	0.962	0.966	0.156	0.968	0.968	0.961	0.968	
DW	1.70	1.87	1.89	1.98	1.96	1.63	1.82	
LLF	612.5	628.5	628.2	647.8	632.5	613.0	629.0	J=0.307
Intercepts								
AT				0.002		0.002		
DE				–0.001		–0.001		
FI				–0.001		–0.003		
FR				0.001		0.000		
IT				0.010		0.008		
NL				–0.003		–0.003		
SP				0.007		0.005		

The estimating equation is

$$\pi_t = \alpha\pi_t^e + \beta\left(\ln Q_t - \ln Q_t^{pot}\right) + \gamma\left(\ln Q_t - \ln Q_t^{pot}\right)^2$$

$\pi_t = \ln P_t - \ln P_{t-1}$ = inflation rate

$\pi_t^e = \ln P_t^e - \ln P_{t-1}^e$ = expected inflation rate (OECD secretariat forecast data)

P_t = GDP deflator

Q_t = real GDP

Q_t^{pot} = potential output

Panel estimation (t-statistics in the parenthesis, White Heteroskedasticity-Consistent Standard-Errors & Covariance)

The data are annual data for 1976–1997

* Parameter estimates are displayed in chart 1 and appendix Table 1.A.1.

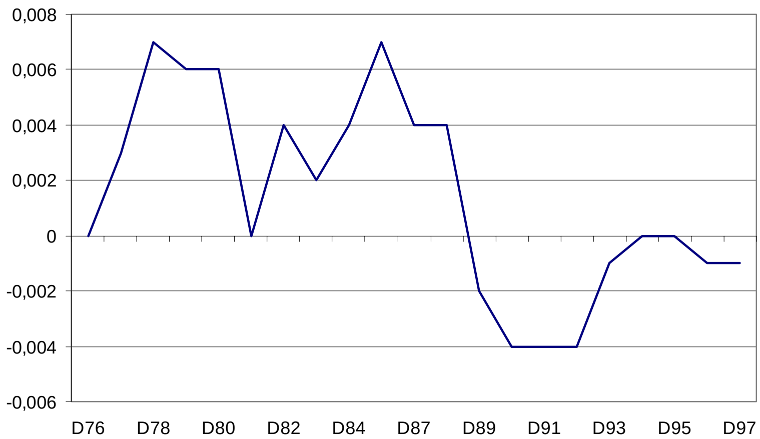
** Lagged output gap is used as an instrument

Laxton, Meredith and Rose (1995) and Clark, Laxton and Rose (1996) have used quadratic and cubic forms of the output gap in their estimates with G7 and US data. Their estimation results concerning the nonlinearity of the Phillips curve are more significant. They have however formed the inflation expectations in different way. They use model-generated forecasts which are in a sense onditional on past data. Our study used pure forecasts without any backward looking component. Naturally these forecasts are also in some sense model-consistent when the OECD forecasts are made using a macroeconomic model but adding national survey information to it.

Eliasson (1999) estimated Phillips-curves for Australia, Sweden and United States. She used in her estimations survey data and lagged inflation rates. Estimations were done using STR-models. She found that Phillips curve is nonlinear in Sweden and Australia but linear in the USA. The Swedish inflation expectations data worked very well in the models.

The common shocks of euro countries were studied first by using time dummies in the pooled estimation. Only two significant time dummies were found for the years 1978 and 1992. The sign of the first dummy was positive and second negative and the inflation influence was under one per cent in both cases. The method was to omit the dummies by beginning from the lowest t-value. This method can naturally lead to very different results depending on the ordering. There are not any easy explanations for both of the common inflation shocks. In 1992 there was however a general decrease in the world market prices of raw materials, which was due to the end of the Gulf war and could not be explained by the output gap development of the euro countries.

Chart 1. **Time dummies for the Phillips-curve (equation column 4, Table 1.A.1, appendix) SUR-estimation**



The correlation coefficients between the residuals are very high as can be seen from the Table 1.B in the appendix. For that reason the base equation (column 1–5) was estimated also by the SURE method. Estimation results (columns 6 and 7) show that the significance of the output gap variables increases with SURE and the parameter estimate of the quadratic term deviates from zero with 10 per cent probability. When country specific intercepts were used estimation results of the Phillips curve improved slightly. The size of the intercepts is however small.

The basic Phillips curve equation was also estimated with GMM to ensure the orthogonality conditions of the forecast of the GDP deflator. Different lagged instruments were used. Table 1.A (column 8) reports the estimation result with the lagged output gap as an instrument. The significance of the output gap variable parameter estimates increases in this case and the parameter estimate of the forecast bias variable is very near one. Also other variables of the equation were used in the lagged form as an instrument but the model was very sensitive to the selection of the instrument. The scarcity of the degrees of freedom limited also the use of many instruments. The fact that GMM gives much more significant coefficients β and γ suggests that there may be a errors-in-variables problem in the measure ot the output gap. If this is true, the use of instrument methods such as GMM should give more reliable results than OLS.

As mentioned earlier the cointegration relationships of the variables were tested by Johansen's method (Appendix, Table 3). Inflation and inflation expectations appear cointegrated.

Table 1.B **Phillips-curve, linear model, country estimates***

	AT	DE	FI	FR	IT	NL	SP
α	0.829	0.875	0.869	0.962	0.992	0.859	1.081
	(8.40)	(8.58)	(12.7)	(27.9)	(36.6)	(16.5)	(28.2)
β	0.110	0.053	0.062	0.026	0.274	0.055	0.084
	(1.13)	(0.88)	(1.17)	(0.30)	(3.38)	(0.75)	(1.22)
Intercepts	0.008	0.003	0.006	0.001	0.008	0.001	–0.002
R2	0.756	0.809	0.880	0.972	0.984	0.931	0.971
DW	1.66	1.24	1.59	1.47	2.86	2.23	2.41
LLF	642.3						

H:0 α and β are equal over countries
SUR estimates

Table 1.B presents the SURE estimation results of the linear model by country. The country differences are very large and the value of the likelihood function is clearly larger in the country estimation case than with the common coefficients which means that the restriction of the common coefficients by countries is not valid.

Nonlinear Phillips curve estimation results by country are presented in the Table 1.C. Estimates are made by SURE with country specific intercepts. There are some very large differences between countries in the results. Using the likelihood ratio test, twice the difference between the LLF gives a test statistic of 39, which is CHI-square distributed under the null hypothesis of a common coefficients. There are 21 restrictions which means that the common coefficient hypothesis is rejected at the 99 per cent confidence level.

The coefficient of the forecast variable is as a rule very near one. On the other hand the coefficients of the output gap term differ significantly from zero only in Italy. The coefficients are as a rule positive. The parameter estimates of the quadratic term looks again very poor. Only in the equations for Germany and Italy are the coefficients significant. Laxton, Rose and Tetlow (1993) also had difficulties in estimating a nonlinear Phillips curve with Canadian data. Results improved for the linear function when pooled estimation with several countries were used. It was difficult to find nonlinearity with a small sample.

Country level estimation results show how large the aggregation problem is in the eurocountries. Monetary policy is based on the aggregate data of the euroregion but there are however large differences by countries in the Phillips curves. Naturally the small sample problem affects the estimation results and may cause random variation in the estimates making the differences between countries in the Phillips curve appear larger than they really are. In any case the monetary policy planning must be based on the careful analysis of the whole dataset.

Table 1.C **Phillips curve (equation 4.1), nonlinear model, country estimates***

	AT	DE	FI	FR	IT	NL	SP
α	0.833	0.897	0.891	0.981	0.987	0.837	1.056
	(8.37)	(9.35)	(12.5)	(27.4)	(38.4)	(15.2)	(27.9)
β	0.065	–0.003	0.078	0.010	0.214	0.071	0.110
	(0.58)	(–0.04)	(1.46)	(0.12)	(2.53)	(0.99)	(1.61)
γ	4.838	5.058	0.735	6.197	10.81	5.333	4.512
	(0.68)	(1.79)	(0.77)	(1.06)	(2.15)	(1.33)	(1.31)
Intercepts	0.006	0.000	0.004	–0.001	0.006	0.001	–0.003
Adj R2	0.761	0.834	0.877	0.973	0.986	0.933	0.974
DW	1.74	1.42	1.47	1.54	2.88	2.05	2.51
LLF	648.5						

H:0 α, β and γ are equal over countries
SUR estimates

4.3 Asymmetric variables model

A further test of the nonlinearity of the Phillips curve is to estimate the curve in threshold model form. We take the output gap as a threshold variable which we divide into two samples – positive and negative output gaps. More subsamples in estimation because of the lack of degrees of freedom. The results are presented in Tables 1.D and 1.E. Estimates show quite a clear asymmetry when using pooled euro data.

The positive output gap variables have parameter estimates which deviate from zero very significantly. SUR estimation gives more precise parameter estimates but the models do not differ significantly from each other by the LR-test. The estimates of the negative output gap variables are not significant which means that a negative output gap does not influence the inflation rate. The signs of the coefficients are negative. We also include the time dummies for 1978 and 1992 used earlier in the model and these again show significant estimates but with effect of under one per cent on average in the whole panel. Looking at the loglikelihood functions, the change in estimation method or dummies do not influence the estimation results significantly.

Clark, Laxton and Rose (1995) estimated an asymmetric Phillips curve with US data using a variable for positive output gaps. Their results are similar to this study; the positive gap variable is more significant than the normal output gap variable, thus showing asymmetry in the Phillips curve. Virén and Mayes (1998) estimated threshold model for european data with positive and negative variables and got also very asymmetric results.

The finding of asymmetry is very important when monetary policy implications are considered. Laxton, Meredith and Rose (1995) simulated the effects of demand shocks in a small macroeconomic model, contrasting the results using a linear price adjustment equation with those using a nonlinear specification. They also studied how the results change for the two models as the response of monetary policy to demand shocks delayed. The simulations showed that, when the output-inflation trade-off is nonlinear, shocks creating excess demand lead to permanent output losses as the monetary authority responds to prevent an acceleration of inflation. The nonlinear economy also has the property that it is important for monetary policy to tighten quickly in the face of inflationary shocks. When the monetary response is delayed, output losses are larger, since a more severe tightening is required to combat higher inflation expectations.

Table 1.D **Asymmetric Phillips curve, panel estimation**

	OLS	SUR	Dummies
α	1.016	1.012	1.006
	(61.50)	(90.2)	(96.2)
τ	0.102	0.131	0.156
	(1.71)	(2.63)	(3.32)
ω	0.042	–0.000	–0.013
	(0.56)	(–0.01)	(–0.29)
Dummies			
D78			0.003
			(1.29)
D92			–0.006
			(–2.70)
Adj R2	0.962	0.962	0.964
DW	1.66	1.60	1.62
LLF	613.2	614.0	617.7

The estimating equation is

$$\pi_t = \alpha\pi_t^e + \tau \text{gappos} + \omega \text{gapneg}$$

gappos = positive values of the output gap variable (boom)
gapneg = negative values of the output gap variable (recession)

Panel estimation

We also estimate the threshold model by country. We again find fairly large differences between countries. The asymmetry of the Phillips curve is quite clear in half of the studied countries. The most asymmetric Phillips curves are in Italy, Germany, Netherlands and Spain. In Austria, Finland and France the output gap variables are not significant. Virén and Mayes (1998) have also reported asymmetric estimation results when using data from EU-countries. There results are very similar. The Phillips curve is clearly asymmetric and there are large differences between countries in the degree of asymmetry. Comparing the values of the likelihood functions it can be seen directly that the hypothesis of the common coefficients must be rejected because the value of the likelihood ratio test statistics is as large as 66.

Table 1.E **Asymmetric Phillips curve***

	AT	DE	FI	FR	IT	NL	SP
α	0.958	0.871	0.941	0.962	1.017	0.823	1.023
	(17.6)	(18.0)	(23.9)	(42.0)	(50.2)	(18.2)	(35.1)
τ	0.228	0.190	0.123	0.164	0.609	0.253	0.277
	(1.46)	(2.17)	(1.44)	(1.21)	(4.44)	(1.82)	(2.00)
ω	–0.179	–0.176	0.020	–0.127	–0.137	–0.104	–0.026
	(–0.88)	(–1.69)	(0.27)	(–0.95)	(–0.79)	(–0.99)	(–0.20)
Adj R2	0.759	0.840	0.873	0.972	0.985	0.938	0.973
DW	1.93	1.39	1.57	1.45	2.89	2.04	2.47
LLF	647.0						

H:0 α, τ and ω are equal over countries
Individual country estimates

5 Nonlinear Lucas supply function

As inflation expectations are one of the main exogenous variables the central bank looks at in deciding monetary policy we also estimate the Phillips curve in the inverted order compared to the expectations augmented Phillips curve. We explain output by potential output and inflation bias, which is realized inflation minus the inflation forecast. This equation is broadly in line with the supply curve presented by Lucas (1973). McCallum (1997) has also presented recently inverted Phillips curve in his paper concerning central bank independence.

We study the functional form of the Phillips curve by adding a quadratic inflation forecast error to the linear supply function. We write the supply function in the following form:

$$Q_t = Q_t^{pot} + \delta(\pi_t - \pi_t^e) + \lambda(\pi_t - \pi_t^e)^2. \tag{5.1}$$

where $\pi_t = \ln P_t - \ln P_{t-1}$ is the inflation rate, $\pi_t^e = \ln P_t^e - \ln P_{t-1}^e$ is the expected inflation rate, Q_t is output and Q_t^{pot} is potential output and their difference is the output gap. The equation entails that when inflation is as expected, production grows at its potential speed. On the other hand higher than expected inflation means higher growth. In practice there is uncertainty concerning inflation and potential output. Taking expectations of both sides of the equation (5.1) gives:

$$E[Q_t] = E[Q_t^{pot}] + \delta E[d_t] + \lambda E[(d_t)^2], \tag{5.2}$$

where $d_t = (\pi_t - \pi_t^e)$. Taking expectations of the quadratic form and making use of the definition of the variance, equation (5.2) can be expressed as:

$$E[Q_t] = E[Q_t^{pot}] + \delta[d_t] + \lambda[var(d_t) + E(d_t)^2]. \tag{5.3}$$

The important implication of the equation is that increases in the variance of the inflation bias influence output. It is a common theoretical result that increases in price uncertainty decrease output. What is the the direction of influence in this Lucas type supply function remains under empirical study?

Based on previous discussion we form the following estimating equation

$$Q_t = \mu Q_t^{pot} + \delta(d_t) + \lambda(d_t)^2 + \varepsilon_t, \tag{5.4}$$

where μ and δ are positive constant coefficients and $\varepsilon_t \in N(0, \sigma_\varepsilon^2)$ is a random variable which measures shocks. Larger values of μ imply a greater flexibility of production – higher values of δ imply greater influence of prices/wages to production. The parameter λ can have either negative or positive values and larger values means naturally more nonlinear Phillips curve.

5.1 Estimation results

The estimation results of the Lucas type supply function with pooled data are presented in the Table 2.A. Yearly time dummies are used for taking account of all common country effects which influence output in the estimation period. The unrestricted model is presented first (column 1). Only significant yearly dummies are included. Finally the parameter estimate of potential output, Hodrick – Prescott trend term, is restricted to one. This model is also estimated using SURE.

The estimation results with Lucas type supply model look very promising. The parameter estimate of potential output is as a rule very near one, although usually over one. The inflation bias variable, realized inflation minus OECD secretariat inflation forecast, is clearly significant in all equations. In addition to this, the quadratic form of the inflation forecast error also has very significant parameter estimates. The model shows very strong negative influences from the increase of the quadratic inflation bias to output with the pooled euro country data. The result coincides very well with the theory, an increase in inflation uncertainty decreases output. Limiting the potential output variable coefficient to one does not influence the parameter estimates very much. Using SUR estimation gives more precise parameter estimates.

Comparing the estimation results of the expectations augmented Phillips curve and the Lucas supply function it is found that the short-term is very flat as a rule with the expectations augmented Phillips curve and very steep with the Lucas supply function. This problem is discussed in the literature (Taylor, 1979) and the recommendation is to use some system estimation method (McCallum, 1976). The system estimation results were reported in the tables 1.A and 2.A. It can be noticed that when system estimation methods are used the expectations augmented Phillips curve and the Lucas supply function becomes more similar.

The dummy variable estimates show the common exogenous influences on eurocountries output clearly. Firstly, in the beginning of the 1980s, we see the influences of the second oil crisis. Secondly in the late 1980s we see the rapid growth of GDP which is due to the general liberalization of the financial markets. Thirdly in the beginning of the 1990s we see the negative influence of German unification coming from high market interest rates.

Table 2.A **Nonlinear Lucas supply function, panel estimation**

The estimating equation is

$$Q_t = \mu Q_t^{pot} + \delta(d_t) + \lambda(d_t)^2 + \varepsilon_t \quad *$$

The data are annual for 1976–1997

Parameter	(1) Linear model OLS	(2) OLS	(3) SURE	(4) H:0 μ=1, SURE	(5) Dummies SURE
μ	1.082	1.195	1.143	1	1.263
	(13.9)	(19.7)	(15.0)		(4.35)
δ	0.224	0.604	0.374	0.356	0.493
	(2.37)	(3.68)	(3.55)	(3.49)	(2.90)
λ		–53.7	–34.5	–26.3	–39.07
		(–4.05)	(–4.71)	(–3.77)	(–2.74)
Dummies					
D76					0.011
					(3.54)
D79					0.012
					(3.83)
D81					–0.016
					(–5.19)
D88					0.015
					(4.76)
D89					0.017
					(5.52)
D91					–0.014
					(–4.50)
D92					–0.011
					(–3.62)
D93					–0.027
					(–8.86)
D94					0.008
					(2.60)
D97					0.009
					(2.85)
Adj R2	0.207	0.363	0.335	0.159	0.565
DW	1.24	1.65	1.46	1.37	1.46
LLF	555.2	542.1	552.0	552.7	581.7

* In the equation d_t = inflation forecast error, the other notation is same as in the Table 1.

The Lucas supply function was also estimated by countries. We estimate the linear model and the nonlineary model and compare the results to the pooled estimation and between linear and nonlinear model (Tables 2.B and 2.C). The common coefficient restriction is valid neither in the linear model nor in the nonlinear model. The likelihood ratio test statistic has a value 30 in the linear model and a value 66.4 in the nonlinear model. It means again that the hypothesis of the common coefficient restrictions must be rejected.

The value of the loglikelihood function is larger in the nonlinear model than in the linear model and twice the difference of the log likelihood function is 36.4 which means that the linearity restriction is not valid and the test statistic is in favour of the nonlinear model. There are however quite large differences between countries in the nonlinear model. The quadratic inflation error has however a negative coefficient estimate in almost all country equations. The largest influence of the quadratic inflation error on output is in Germany, Finland and Netherlands. In spite of that the coefficient is positive and significant in the French equation, which is an interesting exception to the general result.

Table 2.B **Linear Lucas supply function, country estimates***

	AT	DE	FI	FR	IT	NL	SP
α	1.097	1.178	1.249	1.131	1.070	1.140	1.115
	(10.01)	(8.85)	(5.95)	(10.44)	(7.75)	(10.87)	(8.91)
β	–0.112	0.540	1.586	–0.167	0.353	0.194	–0.270
	(–0.41)	(1.69)	(4.93)	(–0.72)	(1.53)	(0.95)	(–1.13)
Adj R2	0.153	0.233	0.443	0.202	0.363	0.262	0.232
DW	1.97	1.44	2.00	1.46	1.53	1.36	0.94
LLF	567.0						

H:0 α and β are equal over countries
* SUR estimates

Table 2.C **Nonlinear Lucas supply function, country estimates***

	AT	DE	FI	FR	IT	NL	SP
μ	1.054	1.211	1.653	0.975	1.034	1.166	1.105
	(7.68)	(9.06)	(9.49)	(8.41)	(7.38)	(12.4)	(8.83)
δ	0.054	0.168	0.762	0.064	0.145	–0.517	0.244
	(0.19)	(0.36)	(2.90)	(0.24)	(0.30)	(–1.55)	(0.79)
λ	–4.848	–70.30	–98.02	54.66	10.75	–63.12	–32.43
	(–0.11)	(–1.86)	(–5.81)	(2.35)	(0.46)	(–2.64)	(–1.64)
Adj R2	0.133	0.322	0.657	0.138	0.344	0.414	0.348
DW	1.94	1.43	1.83	1.24	1.47	1.42	1.07
LLF	585.2						

H:0 μ, δ and λ are equal over countries
* SUR estimates

6 Policy implications

The main policy implications of the study are that there is strong evidence of the nonlinearity of the Phillips curve with pooled eurodata and at the country level. Country differences are however quite large depending on many country specific factors that cannot be studied here. The policy implication from this is strong. The costs of errors in monetary policy to the expansionary direction can be very high in the euro area in the medium term. The Phillips curve has been especially nonlinear in Germany, Finland, Netherlands and Spain.

Another implication of the nonlinearity (convexity) of Phillips curves is that the output-inflation tradeoff is conditional on the distribution of growth across countries. Any average dyclical position in Europe is the more inflationary the more asymmetry there is between countries. The influences of the inflation bias on the growth are presented in the Table 3. The results are based on the estimated parameters and the equation (5.3), the Lucas type supply function. The mean values, standard deviations and variances of the forecasts errors are calculated. The mean values of the forecasts are as a rule between 0.1 and 0.7 percentage points and the standard errors of the forecasts between 0.5–1.2. On the other hand the expected influences of the inflation biases on output differ a lot from country to country.

The influences of the inflation uncertainty, the variance component of the inflation forecast error, on growth vary also a lot from country to country. The influence is negative in most of the countries and largest in Finland, Spain, Netherlands and Germany. The inflation uncertainty has had its largest negative influence on output level on the estimation period in Finland 1.5 per cent on average in the year, in Spain and the Netherlands by 0.3 per cent and in Germany by 0.2 per cent. In the euro countries studied the increase in inflation uncertainty has decreased output yearly on average by 0.4 per cent.

The total effect of increase in inflation bias, quadratic inflation bias and variance of inflation bias on output level has between 1976–1997 been on average –0.4 per cent in the euro countries studied. The largest influence has been again in Finland –1.6 per cent, in Spain –0.3 per cent and in Germany –0.2 per cent.

Table 3. **Effect of inflation uncertainty on the mean of the output gap in the euro countries, per cent**

	Bias	Standard deviation	1 δ bias	2 λ bias2	3 λ var	Total 1+2+3
Austria	0.1266	0.7118	–0.001	–0.001	–0.025	–0.026
Germany	–0.1228	0.5318	–0.016	–0.011	–0.199	–0.225
Finland	–0.1800	1.2266	–0.107	–0.032	–1.475	–1.613
France	–0.0718	0.6253	0.013	0.003	0.214	0.230
Italy	0.7175	0.7940	0.670	0.055	0.068	0.793
Holland	–0.3122	0.6764	0.222	–0.062	–0.289	–0.128
Spain	0.4592	0.9544	0.111	–0.068	–0.295	–0.253
Euro	0.0881	0.7886	0.045	–0.068	–0.359	–0.382
Weighted Euro (GDP weights)	0.1026		0.052	–0.070	–0.360	–0.378

The calculations were made without weighting the countries by their size of economy. The weighting of the data did not influence the results very much because the larger countries (Spain and Germany) had large influences from inflation uncertainty to growth. The yearly average influence is surprisingly large and should be taken into account in the monetary policy planning of the ECB.

The nonlinearity of the Phillips curve has very important monetary policy implications. This has been studied recently by Schaling (1999), who has written a very interesting paper on the policy implications of the nonlinear supply function. According to his results, the optimal inflation target policy with a nonlinear output gap inflation relationship means higher interest rates than with a linear price function. In addition the level of inflation influences optimal policy. He gives a numerical example where he has the effects of a +0.50 % and –0.50 % output gap on the real interest rate penalty. Using parameter value of 0.7 for the output gap in the interest rate equation, he gets values 1.02 % and –0.75 % for the needed change in the interest rate when nonlinear Phillips curve is assumed. In the linear case (Taylor rule) the needed change in the interest rate is symmetric and has values 0.85 % and –0.85 % respectively. Extending the analysis with uncertainty about output gap he found that these results became even stronger. Uncertainty induced a further upward bias in nominal interest rates on top of the effect of the nonlinearity. In spite of that, it is important to react with monetary policy very rapidly when the inflation forecast is high because monetary policy has its inluence with a long lag to the future output gap and inflation.

Laxton, Meridith and Rose (1997) simulate the influence of the assymmetric Phillips curve to the inflation and interest rate and compare results to the linear case. In addition they compare results to the case where reaction of the monetary policy is delayed by one year. By the results the influence of the positive output shock to inflation and interest rate is stronger in the asymmetric Phillips curve case than with linear Phillips curve. Especially bad is the situation with the asymmetric Phillips curve when the response of monetary policy to the stock is delayed. The increase in inflation after the shock is twice the increase with linear Phillips curve which means also a strong response in the short-term interest rates.

7 Summary

The estimation results give a clear sign of nonlinearity in the Phillips curve in many euro countries. The curve is asymmetric in the sense that with a positive output gap (when the output is larger than the potential output) the influences on inflation are positive but with negative output gap the inflation influences are very small and as a rule not significant. The Phillips curve has been especially asymmetric in Germany, Finland, Italy, Netherlands and Spain.

Another empirical point which was found in the study is the strong negative influence of inflation uncertainty on GDP in the euro countries during the estimation period, 1976–1997. This result was very obvious with the pooled data but also on the country level. This result is new in the sense that Lucas type supply function has not been estimated very often recently.

The third interesting point obtained is the result that the Phillips curve can be estimated successfully by using OECD secretariat forecast data as inflation expectations. The output gap innovations have statistically significant parameter estimates with these expectations data. The forecast biases look fairly normally distributed and the mean is almost zero.

A very important result for ECB monetary policy is the large differences between countries in the Phillips curve in the slope of the curve and also in the curvature as well as the convesity itself.

In general, because of the convexity of the Phillips relationships, a given average level of activity will create the more of an inflation pressure the more unevenly it is distributed.

The study confirms the dangers of too expansive monetary policy because the nonlinearity of the Phillips curve means that the sacrifice costs of disinflationary monetary policy required to compensate for earlier expansion can be very high. This is because the costs of disinflation policy are higher with a nonlinear than with linear Phillips curve. In addition uncertainty concerning the future output gap requires a strong and fast reaction to inflation shocks. By the study's results we were also able to demonstrate that by decreasing inflation uncertainty it is possible to increase the average growth rate in the euro area.

Naturally the research concerns the past behaviour of the economic agents and there has been regime shift at the beginning of 1999. The result means however that when national exhange rate changes are impossible in the euroarea the national economies have to adjust in the wage and price determination to the general behaviour of the euroarea. Accordly to this study at least, downward adjustment appears very painful in real terms.

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Appendix

Table 1.A.1 **Parameter estimates of the time dummies (column 3)**

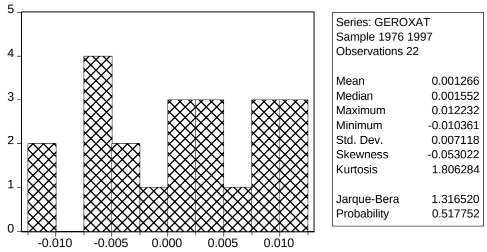
D76	–0.000 (–0.10)	D83	0.002 (0.63)	D91	–0.004 (–0.83)
D77	0.003 (0.73)	D84	0.004 (0.93)	D92	–0.004 (–0.83)
D78	0.007 (2.04)	D86	0.007 (1.69)	D93	–0.001 (–0.29)
D79	0.006 (1.62)	D87	0.004 (1.18)	D94	–0.000 (–0.12)
D80	0.006 (1.21)	D88	0.004 (1.23)	D95	0.000 (0.15)
D81	0.000 (0.03)	D89	–0.002 (–0.59)	D96	–0.001 (–0.41)
D82	0.004 (0.86)	D90	–0.004 (–0.10)	D97	–0.001 (–0.28)

Table 1.A.2 **Residual correlations coefficients of the base equation by countries (column 1)**

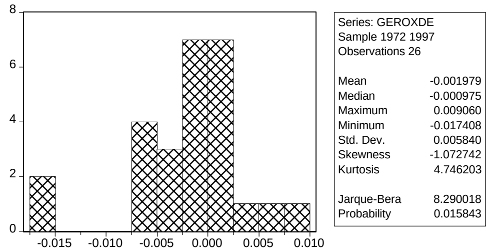
	AT	DE	FI	FR	IT	NL	SP
AT	1.00	0.87	0.81	0.83	0.87	0.84	0.87
DE	0.87	1.00	0.77	0.88	0.86	0.90	0.87
FI	0.81	0.77	1.00	0.92	0.91	0.87	0.92
FR	0.83	0.88	0.92	1.00	0.98	0.91	0.98
IT	0.87	0.86	0.92	0.98	1.00	0.93	0.98
NL	0.84	0.90	0.87	0.91	0.93	1.00	0.98
SP	0.87	0.87	0.92	0.98	0.98	0.88	1.00

Chart 2. **Descriptive statistics of the OECD secretariat forecasts concerning selected euro countries (GDP deflator forecast biases, one year ahead)**

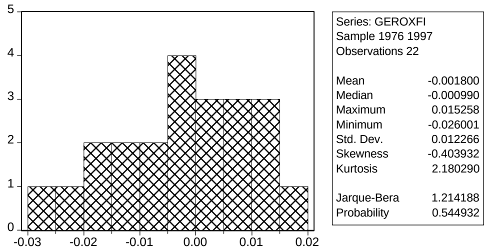
Austria



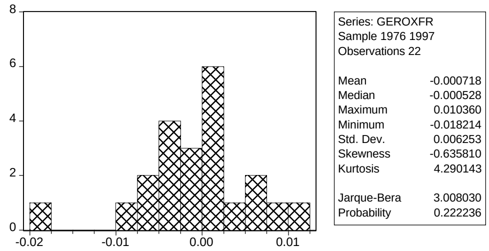
Germany



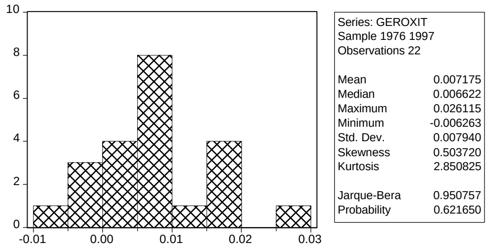
Finland



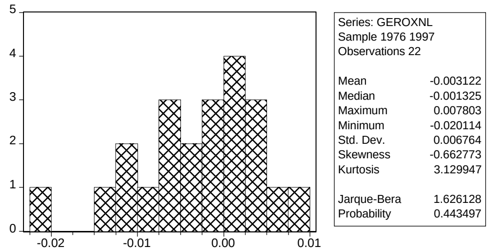
France



Italy



Netherlands



Spain

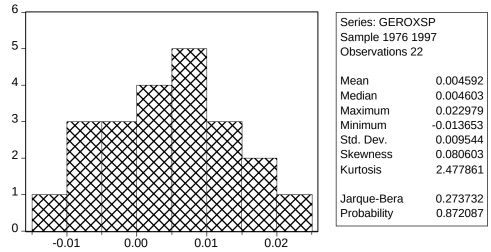
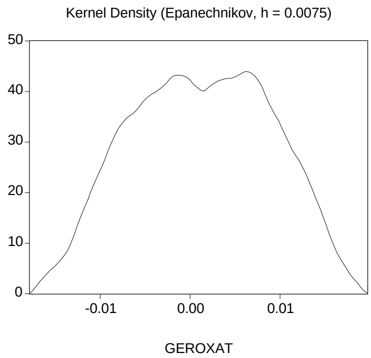
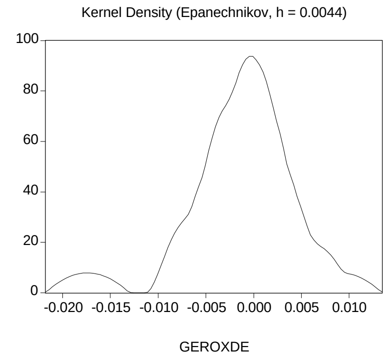
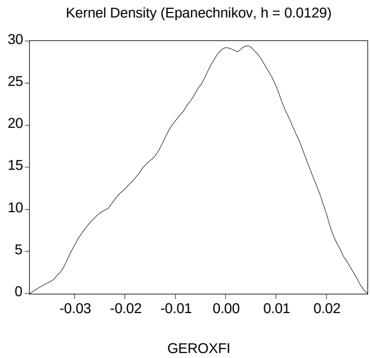
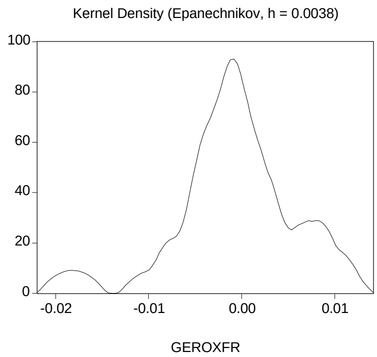


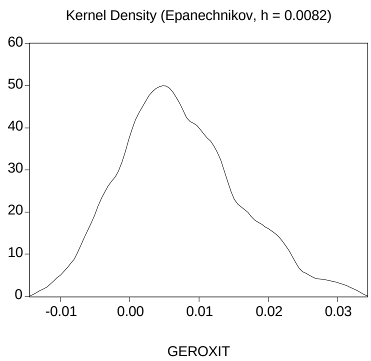
Chart 3. **Kernel Density of the OECD secretariat forecast biases (GDP deflator forecast biases, one year ahead)**

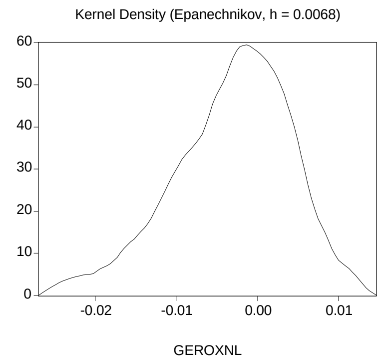












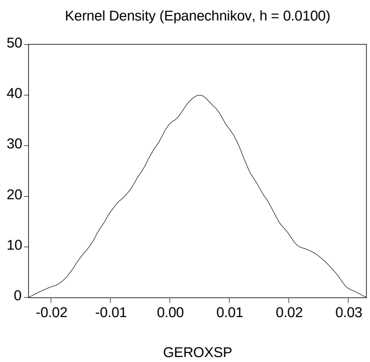
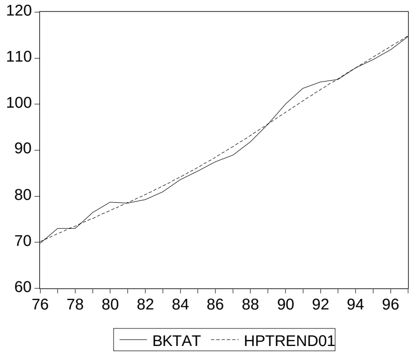
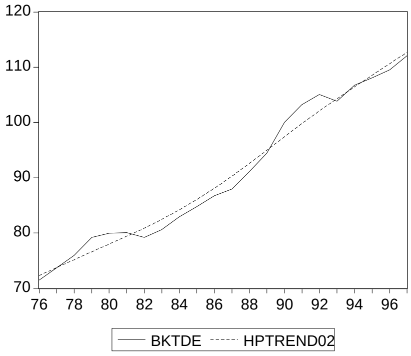


Chart 4. **Real GDP and potential output (HP-filter)**

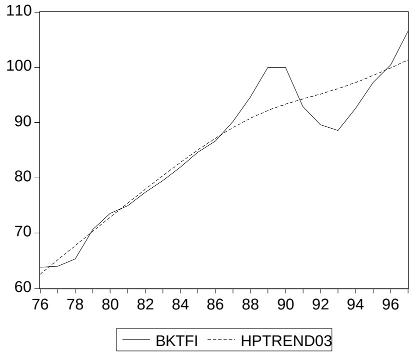
Austria



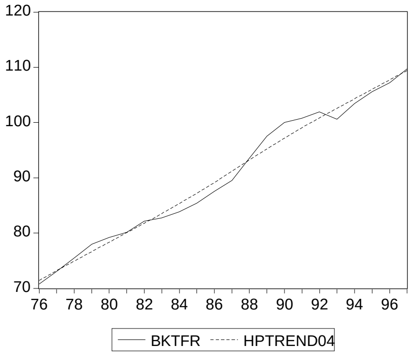
Germany



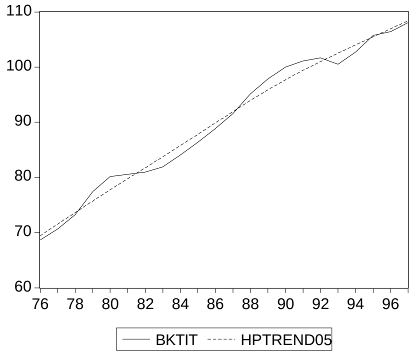
Finland



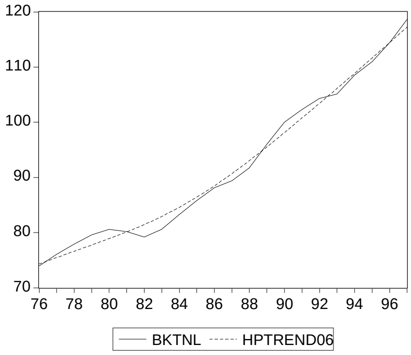
France



Italy



Netherlands



Spain

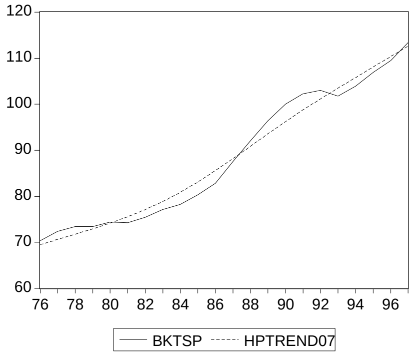
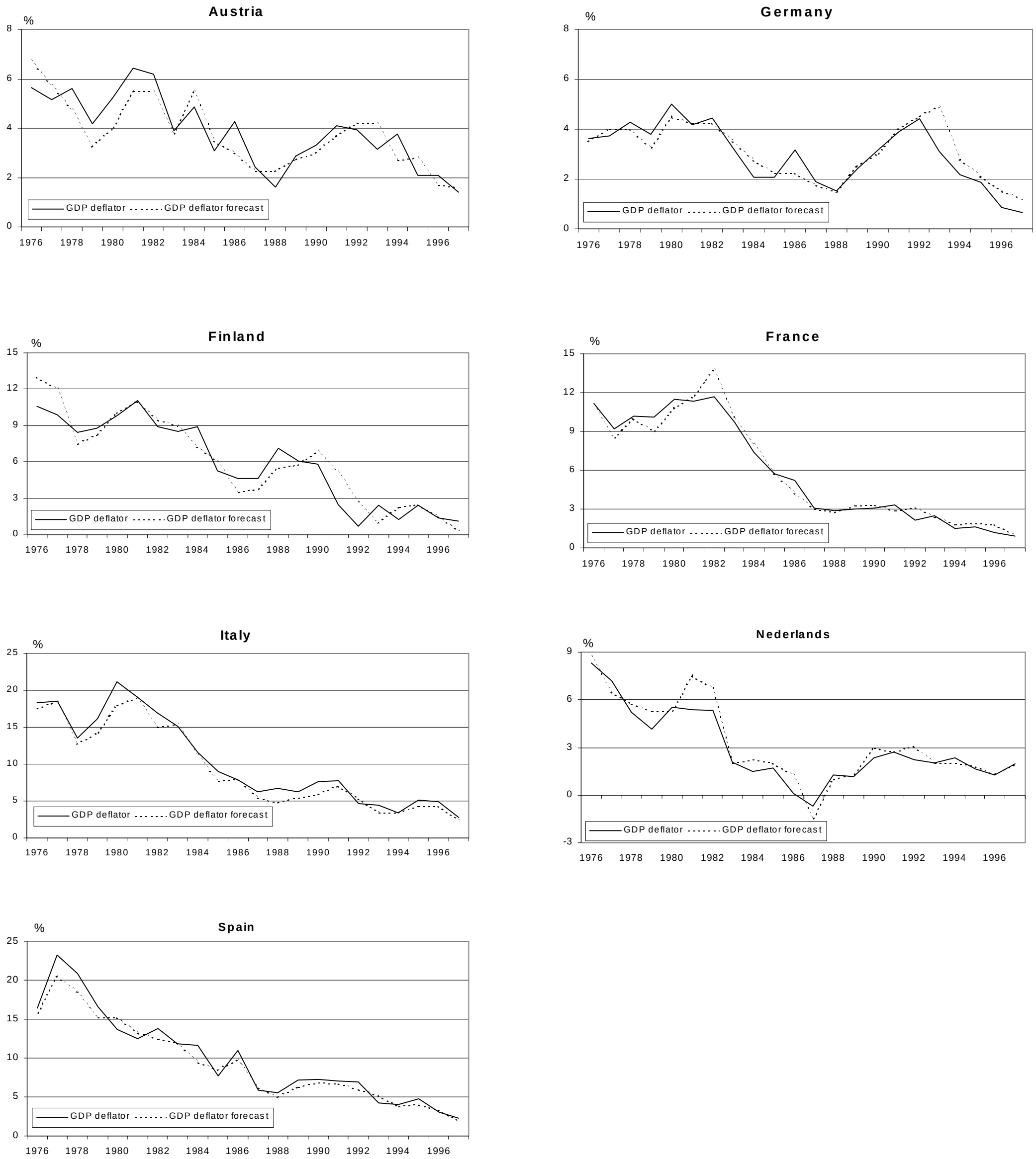


Chart 5. **GDP deflator**
GDP deflator forecast



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