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Günter Coenen, European Central Bank (ECB)
Volker Wieland, Goethe Universität Frankfurt and CEPR

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Centre for Economic Policy Research
90–98 Goswell Rd, London EC1V 7RR, UK
Tel: (44 20) 7878 2900, Fax: (44 20) 7878 2999
Email: cepr@cepr.org, Website: www.cepr.org

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ABSTRACT

A Small Estimated Euro Area Model with Rational Expectations and Nominal Rigidities*

In this Paper we estimate a small model of the Euro area to be used as a laboratory for evaluating the performance of alternative monetary policy strategies. We start with the relationship between output and inflation and investigate the fit of the nominal wage-contracting model due to Taylor (1980) and three different versions of the relative real wage-contracting model proposed by Buiter and Jewitt (1981) and estimated by Fuhrer and Moore (1995a) for the United States. While Fuhrer and Moore reject the nominal contracting model in favour of the relative contracting model, which induces more inflation persistence, we find that both models fit Euro area data reasonably well. When considering France, Germany and Italy separately, however, we find that the nominal contracting model fits German data better, while the relative contracting model does quite well in countries that transitioned out of a high inflation regime such as France and Italy. We close the model by estimating an aggregate demand relationship and investigate the consequences of the different wage contracting specifications for the inflation-output variability trade-off, when interest rates are set according to Taylor's rule.

JEL Classification: E31, E52, E58 and E61
Keywords: Euro area, European monetary union, inflation persistence, macroeconomic models, nominal rigidities and staggered contracts

Günter Coenen
Economic Research Department
European Central Bank
Kaiserstrasse 29
D-60311 Frankfurt am Main
GERMANY
Tel: (49 69) 1344 7887
Fax: (49 69) 1344 6575
Email: gunter.coenen@ecb.int

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Volker Wieland
Monetary Theory and Policy
Goethe Universität Frankfurt
PF 94 Mertonstrasse 17
D-60054 Frankfurt am Main
GERMANY
Tel: (49 69) 798 252 88
Fax: (49 69) 798 252 72
Email: wieland@wiwi.uni-frankfurt.de

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1 Introduction

With the formation of European Monetary Union (EMU) in 1999, the eleven countries that adopted the euro began to conduct a single monetary policy oriented towards union-wide objectives.[1] As prescribed by the Maastricht Treaty the primary goal of this policy is to maintain price stability within the euro area. The operational definition of this goal announced by the European Central Bank (ECB) is to aim for year-on-year increases in the euro area price level below 2 percent.[2] To evaluate alternative strategies for achieving such a euro-area-wide objective, it is essential to build empirical models that can be used to assess the area-wide impact of policy on key macroeconomic variables such as output and inflation. Thus, the objective of this paper is to construct a small model of the euro area, which may serve as a laboratory for evaluating the performance of alternative monetary policy strategies in the vein of recent studies for the United States.[3]

One possible approach would be to construct separate models of the member economies and link them to form a multi-country model of the euro area. The principal alternative is to start by aggregating the relevant macroeconomic time series across member economies and then estimate a model for the euro area as a whole. We pursue the latter approach, because the objectives and instruments of Eurosystem monetary policy are defined in terms of euro area aggregates. However, we are aware of its drawbacks such as the possibility of aggregation bias[4] and the fact that the available historical data originates from the time prior to EMU when the member economies experienced different monetary policy regimes. Therefore, we also estimate every specification of the model separately for the three largest

[1]Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain.

[2]A detailed discussion of the ECB's strategy can be found in Issing, Gaspar, Angeloni and Tristani (2001).

[3]The recent literature on policy rules for the U.S. economy has used a variety of models: (i) small-scale backward-looking models such as Rudebusch and Svensson (1999); (ii) large-scale backward-looking models such as Fair and Howrey (1996); (iii) small-scale models with rational expectations and nominal rigidities (cf. Fuhrer and Moore (1995a, 1995b), Fuhrer (1997), and Orphanides and Wieland (1998)); (iv) large-scale models of this type such as Taylor (1993a) and the Federal Reserve Board's FRB/US model (cf. Reifschneider et al. (1999)); and (v) small models with optimizing agents such as Rotemberg and Woodford (1999), Clarida, Galí and Gertler (1999) and McCallum and Nelson (1999). Recent comparative studies include Bryant, Hooper and Mann (1993) and Taylor (1999).

[4]See for example Beyer, Doornik and Hendry (2001).

member economies, France, Germany and Italy.[5] By comparing these estimates to those for the euro area, we can assess the influence of aggregation on the choice of model specification. Furthermore, by comparing France and Italy, which experienced a convergence process prior to EMU, to Germany, which enjoyed stable inflation, we can find out whether the empirical fit of alternative specifications depends on the monetary regime prior to EMU.

We start with the relationship between inflation and output and make two assumptions that are central to the key policy tradeoff between inflation and output variability. We assume that market participants form expectations in a forward-looking, rational manner and that monetary policy has short-run real effects due to the existence of overlapping wage contracts. In particular, we explore the empirical fit of the nominal wage contracting model due to Taylor (1980) as well as three different versions of the relative real wage contracting model first proposed by Buiter and Jewitt (1981) and estimated for the United States by Fuhrer and Moore (1995a). Fuhrer and Moore (1995a) have argued that the nominal contracting model cannot explain the degree of inflation persistence observed in U.S. data. Instead they found strong support for the relative real wage contracting model, which implies more inflation persistence and substantially higher output costs associated with stabilizing inflation.

For the euro area, however, we find that neither the nominal wage contracting model nor the relative real wage contracting model can be rejected, although the empirical fit of the latter model is somewhat better. Furthermore, it is noteworthy that the best fitting version of the relative real wage contracting model is one that is theoretically more plausible than the simplified specification preferred by Fuhrer and Moore. While this version of the relative wage contracting model also fits Italian and French data quite well, only the nominal contracting model has a shot at explaining German inflation data, which exhibits substantially less persistence.

Our findings with European data have implications for the ongoing debate on the sources of inflation persistence. A number of recent contributions to this debate have tried to show

[5] Together, these three economies comprise over 70% of economic activity in the euro area.

that Calvo(1983)- or Taylor-style contracting structures are consistent with the empirical evidence on inflation persistence if other sources of persistence such as backward-looking expectations and time-varying credibility or measures of marginal cost rather than the output gap are taken into account.[6] Thus, our diverging results for Italy and Germany may well be explained by the differences in the monetary policy regime prior to EMU rather than by structural differences in the wage-setting process. Imperfect credibility of the central bank's commitment to inflation convergence may have been the source of higher inflation persistence in Italy than in Germany, where inflation was rather stable and monetary policy fairly predictable.

Section 2 proceeds to review the overlapping contracts specifications. Empirical inflation and output dynamics are summarized in form of unconstrained VAR models in section 3, while estimates of the structural contracting models are presented in section 4. In section 5 we close the model with an aggregate demand equation, a term structure relationship and a policy rule, and discuss impulse responses and disinflation scenarios under the alternative contracting specifications. Section 6 concludes.

2 Modeling inflation dynamics with overlapping contracts

We consider four specifications of overlapping wage contracts, the nominal wage contracting model of Taylor (1980) and three variants of the relative real wage contracting model estimated by Fuhrer and Moore (1995a) for the United States. These models induce nominal rigidities, because workers negotiate long-term contracts and compare the contract wage to past contracts that are still in effect and future contracts that will be negotiated over the life of this contract. The distinction between nominal and relative real wage contracts concerns the definition of the wage indices that form the basis of this comparison and should not be confused with so-called real rigidities. In both cases the source of rigidity is nominal, that

[6]See for example Roberts (1997) on the role of adaptive expectations and Erceg and Levin (2001) on the role of imperfect credibility of the policymaker's inflation target in explaining U.S. inflation persistence. Also, Taylor (2000) shows that the level of inflation influences the pricing power of firms and that inflation persistence ought to be greater in a high inflation regime. Finally, Sbordone (2002) and Galí and Gertler (1999) provide evidence that Calvo-style sticky-price models fit the relationship between U.S. inflation and real unit labor cost.

Table 1: Alternative Staggered Contracts Models

(M-1) Price Level	$p_t = \sum_{i=0}^{3} f_i \, x_{t-i}$	where $f_i = .25 + (1.5 - i)\, s,\ s \in (\,0, 1/6\,]$
(M-2) NW	$x_t = \mathrm{E}_t\,[\bar{p}_t + \gamma\, \bar{q}_t] + \sigma_{\epsilon_x}\, \epsilon_{x,t}$	where $\bar{p}_t = \sum_{i=0}^{3} f_i \, p_{t+i}$, $\bar{q}_t = \sum_{i=0}^{3} f_i \, q_{t+i}$
(M-3) RW	$x_t - \mathrm{E}_t\,[\bar{p}_t] = \mathrm{E}_t \left[\sum_{i=0}^{3} f_i \, v_{t+i} + \gamma\, \bar{q}_t\right] + \sigma_{\epsilon_x}\, \epsilon_{x,t}$	where $v_t = \sum_{i=0}^{3} f_i (x_{t-i} - \mathrm{E}_t[\bar{p}_{t-i}])$
(M-4) RW-C	x_t set as in (M-3)	but $v_t = \sum_{i=0}^{3} f_i (x_{t-i} - \mathrm{E}_{t-i}[\bar{p}_{t-i}])$
(M-5) RW-S	x_t set as in (M-3)	but $\bar{p}_t = p_t$

Notes: p_t: aggregate price level; x_t: nominal contract wage; $\epsilon_{x,t}$: contract wage shock; q_t: output gap; $\bar{p}_t$: average price over the life of the contract; $\bar{q}_t$ average output gap; v_t: real contract wages in effect over the life of the contract.

is, at every point in time only a subset of nominal wage contracts are adjustable.

While the four specifications considered here emphasize wage contracting, the implications for price dynamics are essentially the same if prices are related to wages by a fixed markup. Thus, we follow Fuhrer and Moore (1995) in using price instead of wage data in estimation and use the terms “contract price” and “contract wage” interchangeably. In all specifications the log aggregate price index, p_t, is a weighted average of current and previously negotiated contract wages, x_{t-i} $(i = 0, 1, \dots)$ which are still in effect. Our benchmark case defined by equation (M-1) in **Table 1** is a one-year weighted average, which implies a maximum contract length of four quarters.[7] The weights f_i $(i = 0, 1, 2, 3)$ on contract wages from different periods are assumed to be non-negative and time-invariant and to sum to one. Rather than estimating each weight f_i separately, we follow Fuhrer and Moore and assume that they are a downward-sloping linear function of contract length that depends on the parameter s, as defined by model equation (M-1) in **Table 1**.

The determination of the nominal contract wage x_t for the different specifications is best

[7] Fuhrer and Moore (1995a) found this contract length sufficient to explain the degree of persistence in U.S. inflation. Similarly, Taylor (1993a) estimated the nominal contracting model for all G-7 countries with such a lag length.

explained starting with Taylor's nominal wage (NW) contracting model, which is defined by model equation (M-2). In this case, x_t is negotiated with reference to the price level that is expected to prevail over the life of the contract, $E_t[\bar{p}_t]$, as well as the expected deviation of output from its potential over this period, $E_t[\bar{q}_t]$. Since the price indices p_{t+i} reflect contemporaneous and preceding contract wages, (M-2) implies that wage setters look at an average of nominal contract wages negotiated in the recent past and expected to be negotiated in the near future when setting the current contract wage. In other words, they take into account nominal wages that apply to overlapping contracts. If they expect demand to exceed potential, $q_{t+i} > 0$, they adjust the current contract wage upwards relative to overlapping contracts. The sensitivity of contract wages to excess demand is measured by the parameter γ. The contract wage shock, $\epsilon_{x,t}$, which is assumed to be serially uncorrelated with zero mean and unit variance, is scaled by the parameter σ_{ϵ_x}.

The relative real wage (RW) contracting specification is defined by equation (M-3). In this case workers negotiating their nominal wage compare the implied real wage expected over the life of their contract with the real wages on overlapping contracts in the recent past and near future. For this comparison, it is helpful to define the index of real contract wages currently in effect, v_t. Using this index, (M-3) implies that the expected real wage under contracts signed in the current period is set with reference to the average real contract wage index expected to prevail over the current and the next three quarters. For the RW specification a subtle but important question arises with respect to the timing of the price expectations in the real contract wage indices v_{t+i}. For example, the current nominal contract wage x_t depends on the index of real contract wages currently in effect, v_t, which in turn is a function of the real contract wages from periods $t-1$, $t-2$ and $t-3$. One possibility is that the relevant reference points for the determination of the current contract wage are the *ex-post realized real contract wages* from these periods, which are now known to wage setters. This assumption underlies equation (M-3). The alternative is that current wage negotiations refer to the *ex-ante expected real contract wages*, which formed the basis of negotiations in earlier periods. We refer to this case as the RW-C specification in (M-4), because it implies that price expectations are *conditioned on historically available information.*

Fuhrer and Moore (1995a) discussed the RW and RW-C specification in the appendix of their paper. Their preferred specification for U.S. data, however, was a *simplified version* of the RW model (hereafter referred to as RW-S). The simplification concerned the definition of the real contract wage. Instead of using the average price level expected to prevail over the life of the contracts, they used the current price level, p_t, as denoted in equation (M-5). The index v_t then no longer uses price expectations. Since the RW, RW-C and RW-S specifications entail different degrees of forward-looking behavior when forming price expectations, they may have different implications for inflation persistence.[8]

Before turning to the empirical analysis, we note that the four specifications, which are written in terms of the price level and the nominal contract wage in **Table 1**, can be rewritten in terms of the quarterly inflation rate and the real contract wage. Thus, either price levels or inflation rates can be used in estimation. The contract wages, however, are unobservable. We also note that the contracting specifications only pin down the steady-state real contract wage as a function of steady-state inflation, which is ultimately determined by the central bank's inflation target, once we close the model.

3 Empirical inflation and output dynamics

Our empirical analysis of the alternative contracting specifications proceeds in two stages. In the first stage, we estimate an unconstrained bivariate VAR model to serve as an empirical summary of euro area output and inflation dynamics. In the second stage, which is discussed in the following section, we use the unconstrained VAR as auxiliary model in

[8]The equations summarized in Table 1 represent rules for contract wage and price setting that are not explicitly derived from a framework with optimizing agents. However, they need not necessarily be inconsistent with such a framework. More recently, Taylor-style fixed-duration contracts have been analyzed within optimizing dynamic general equilibrium models, for example by Chari, Kehoe and McGrattan (2000). However, their focus is on price rather than wage rigidity. Starting with a representative agent model with monopolistically competitive firms they add the constraint that firms set prices for a fixed number of periods and do so in a staggered fashion. In particular, each period, $1/N$ firms are assumed to choose new prices that are then fixed for N Periods. As shown by Chari et al. the contract wage equation (NW) in Table 1 coincides with the log-linear approximation of their contract price equation in a stripped-down version of their equilibrium model.

estimating the structural parameters of the contracting specifications by simulation-based indirect inference methods.

The data

The data we use in estimating the staggered contracts specifications comprise real GDP and the GDP deflator for France, Germany, Italy and weighted averages for the euro area as a whole.[9] The history of the euro area aggregates is depicted in **Figure 1**. As shown in the top-left panel euro area inflation steadily declined over the last 25 years. This downward trend is a special feature of euro area data, which complicates the empirical investigation of inflation dynamics relative to similar analyses for the United States.

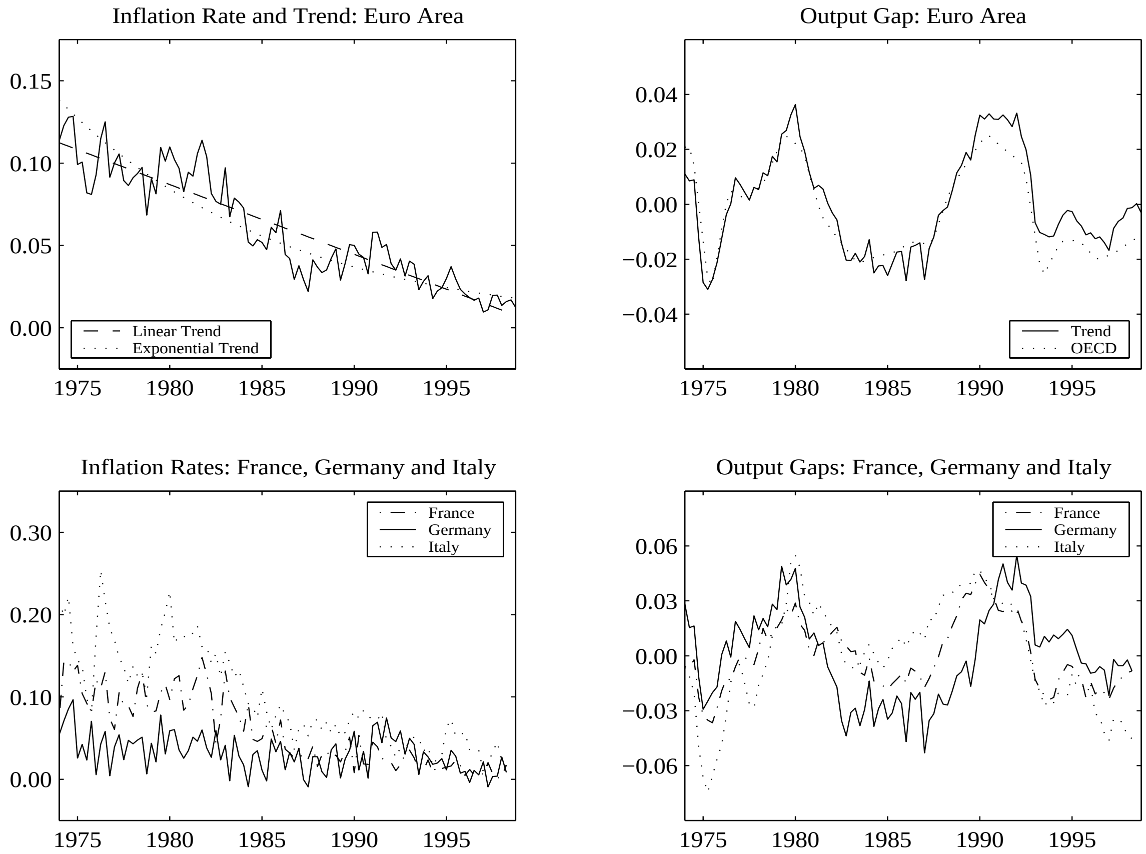
The source of the downward trend in euro area inflation was the protracted disinflation process undergone by some European economies. As shown in the bottom-left panel, inflation rates in France and Italy in the early 1970s were much higher than in Germany due to the combination of oil price shocks and accommodative monetary policy. It took 10 and 15 years, respectively, for French and Italian inflation rates to decline to German levels. This convergence process and the related role of the European Monetary System (EMS) have been widely discussed in the policy literature.[10] There is little doubt that it was largely due to the growing commitment on the part of European policymakers to achieve and maintain low inflation. The credibility of this commitment, however, varied over time.

In principle, a complete model of the European inflation process prior to EMU would need to account for both, the long-run convergence process as well as short-run variations around this trend. However, modeling the convergence process would require taking into account the varying degree of credibility of exchange rate pegs, the possibility of crises and realignments as well as learning by market participants about the long-run inflation objectives of European policymakers. Such an analysis is beyond the objective of this paper. Instead, we take a simpler approach by approximating the implicit time-varying

[9] The euro area data, which are averages of member country data using fixed GDP weights at PPP rates, have been obtained from the ECB area-wide model database (see Fagan et al. (2001)).

[10] See for example De Grauwe (1996) and Angeloni and Dedola (1999).

Figure 1: The Inflation and Output Gap Data



Source: ECB model databases. Aggregation over data for the member countries of the euro area using fixed 1995 GDP weights at PPP rates. The OECD output gap is obtained by interpolating the annual figures reported in OECD (1999).

inflation objective with a linear trend, and then estimate the contracting models using inflation deviations from this trend. Similar approaches have been implemented by Gerlach and Svensson (1999) and Cecchetti et al. (1999).[11] For robustness we also consider an exponential trend. Both trends are shown in the top left panel of **Figure 1**.

The wage contracting models we consider relate short-run inflation dynamics to the deviation of actual output from potential. Constructing a structural estimate of potential

[11] Gerlach and Svensson assume that an implicit euro area inflation objective converges exponentially to the Bundesbank's "price norm" in estimating a P-star model of inflation dynamics for the euro area. Cecchetti et al. construct inflation and output deviations from a 12-month moving average of actual values and estimate inflation-output tradeoffs for a number of euro area economies.

output for the euro area prior to EMU goes beyond the objective of this paper. Even for the individual member countries this would be rather difficult. A commonly used alternative is the log-linear trend (cf. Fuhrer and Moore (1995a) and Taylor (1993a)). The top right panel in **Figure 1** compares the euro area output gap based on a log-linear trend to the OECD's (1999) estimate. The surprising similarity provides at least some support for our use of output gaps based on log-linear trends in estimating the contracting models.[12] The resulting output gap estimates for France, Germany and Italy are shown in the bottom right-hand panel.

Unconstrained VAR estimation

To summarize inflation and output dynamics we estimate the following unconstrained VAR,

$$\begin{bmatrix} \pi_t \\ q_t \end{bmatrix} = A_1 \begin{bmatrix} \pi_{t-1} \\ q_{t-1} \end{bmatrix} + A_2 \begin{bmatrix} \pi_{t-2} \\ q_{t-2} \end{bmatrix} + A_3 \begin{bmatrix} \pi_{t-3} \\ q_{t-3} \end{bmatrix} + \begin{bmatrix} u_{\pi,t} \\ u_{q,t} \end{bmatrix}, \tag{1}$$

where q_t refers to the output gap and π_t to inflation. As discussed above, we use inflation deviations from trend rather than the actual inflation rate, except in the case of German data. We consider both a linear and an exponential trend in inflation for robustness. In estimation, we proceed by first de-trending the data and then estimating the VAR coefficients. The maximum lag order of the VAR is 3 since the reduced form of the contracting specifications discussed in section 2 corresponds to a constrained VAR of order 3 if the maximum contract length is one year.

The error terms $u_{\pi,t}$ and $u_{q,t}$ are assumed to be serially uncorrelated with mean zero and positive definite covariance matrix Σ_u. In fitting this VAR to euro area data, standard lag selection procedures based on the HQ and SC criteria suggest that a lag order of 2 would be sufficient to capture the empirical inflation and output dynamics.[13] However, we will consider both in the structural estimation. [14]

[12] Other alternatives include estimates based on the HP filter or unobserved components methods, which we have examined in some sensitivity studies.

[13] The Ljung-Box Q(12) statistic indicates serially uncorrelated residuals with a marginal probability value of 42.8%. Our point estimates imply that the smallest root of the characteristic equation $\det(I_2 - A_1\, z - A_2\, z^2) = 0$ is 1.2835, thereby suggesting that the inflation and output gaps are stationary. This conclusion is roughly supported by the results of standard univariate Dickey-Fuller tests for the presence of unit roots.

[14] Coefficient estimates of the VAR(2) and VAR(3) models are reported in Coenen and Wieland (2000).

So far we have omitted interest rates from the VAR even though the real interest rate is clearly a key determinant of aggregate demand and ultimately inflation. In fact, once we close our model in section 5 we will posit that the short-term nominal interest rate–the central bank's main policy instrument–influences aggregate demand and inflation through its effect on the long-term real interest rate. Nevertheless, we leave the interest rate out of the two-stage estimation of the overlapping contracts specification. Rather than being a preferred choice, this approach resulted from our inability to obtain reasonable parameter estimates for a tri-variate VAR of the euro area. Our lack of success in this regard, however, is not surprising given the following problems with European interest rates. First, it is unclear what would be the appropriate historical interest rate for the euro area. Historical GDP weighted averages of European interest rates need not have much relation to the actual cost of capital faced by European firms. While one could imagine using the relative weights in debt financing in order to aggregate national interest rates, these are not easily available. Secondly and perhaps more importantly, the varying degrees of commitment to EMS parities throughout the 1980s and early 90s implied instabilities in interest rate reaction functions at least for France and Italy. Thirdly, as convergence became more likely inflation risk premia embodied in the interest rates of those countries disappeared over time. Given these complications we prefer to rely on bivariate VARs in estimating the overlapping contracts specifications.

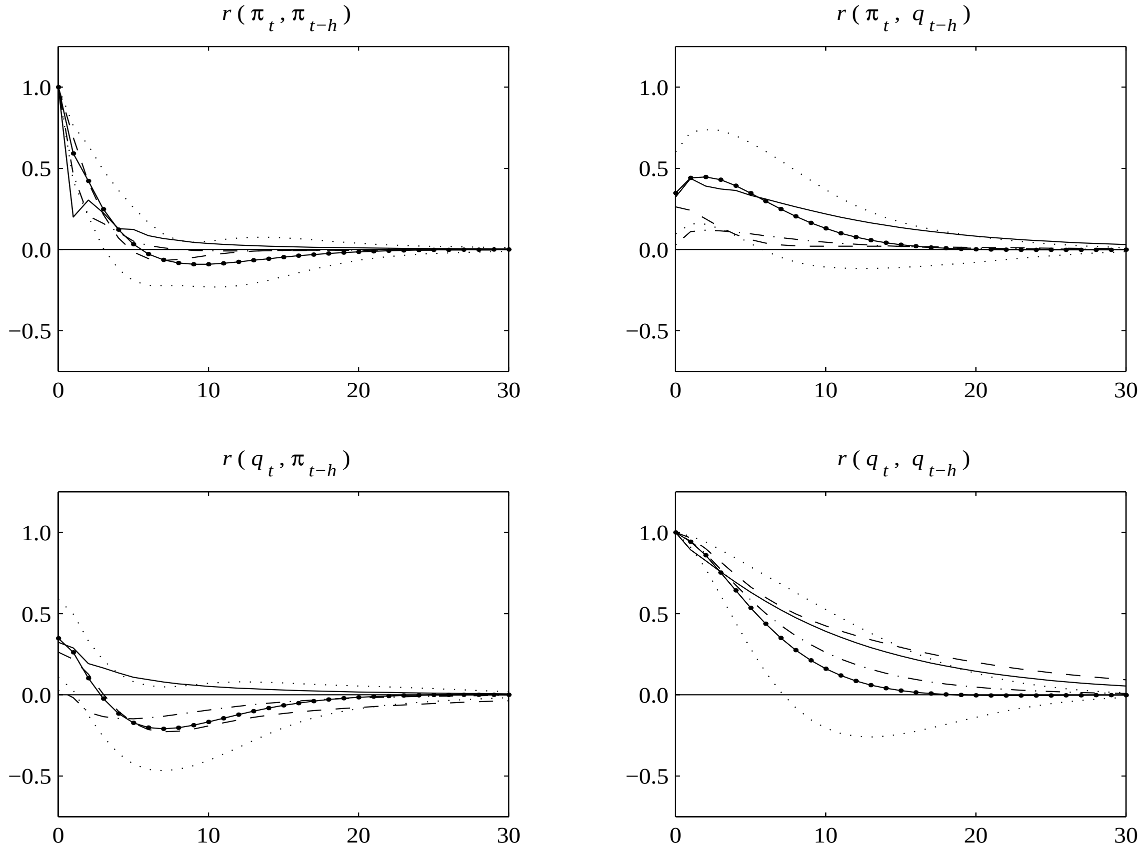
Empirical autocorrelation functions

We also compute the autocorrelation functions implied by the unconstrained VARs and the associated asymptotic confidence bands.[15] These autocorrelation functions provide a useful indication whether the lead-lag relationship between inflation and output is consistent with a short-run tradeoff, that is, with a short-run Phillips curve. Furthermore, they form an additional benchmark against which we can evaluate the ability of the alternative overlapping

Differences between the VAR(3) coefficients from the linear and exponential trend specifications are quite small, well below one standard deviation.

[15] For a detailed discussion of the methodology and the derivation of the asymptotic confidence bands for the estimated autocorrelation functions the reader is referred to Coenen (2000).

Figure 2: Estimated Autocorrelations of the Unconstrained VAR(3) Models



Notes:
Solid line with bold dots: Euro area autocorrelations.
Dash-dotted line: French autocorrelations.
Solid line: German autocorrelations.
Dashed line: Italian autocorrelations.
Dotted lines: Euro area autocorrelations plus/minus twice their estimated asymptotic standard errors.

contracts specifications to explain the dynamics of inflation in euro area data.[16]

The autocorrelation functions associated with the unconstrained VAR(3) model of the euro area are depicted by the solid lines with bold dots in **Figure 2**. The first and fourth panel (top left and bottom right) show the autocorrelations of inflation and output gaps, while the second and third panel show the lagged cross correlations. The thin dotted lines

[16]Such an approach has also been used by Fuhrer and Moore (1995a) and by McCallum (1999), who argued that autocovariance and autocorrelation functions are more appropriate for confronting macroeconomic models with the data than impulse response functions because of their purely descriptive nature.

indicate 95% confidence bands. Both, inflation and output gaps are quite persistent with positive, highly significant autocorrelations out to lags of about 5 and 8 quarters. The cross correlations in the second and third panel confirm much of conventional wisdom about inflation and output dynamics. For example, in the top-right panel, a high level of output is followed by a high level of inflation a year later and again these cross correlations are statistically significant. In the bottom-left panel a high level of inflation is followed by a low level of output a year later. These lead-lag interactions are indicative of the existence of a conventional short-run tradeoff between output and inflation. These correlations are stylized facts which any structural model of output and inflation dynamics ought to be able to explain.

The estimated autocorrelation functions of output and inflation in France, Germany and Italy correspond to the dash-dotted, solid and dashed lines in **Figure 2**, respectively. The autocorrelations for France (dash-dotted lines) and Italy (dotted lines) display qualitatively similar characteristics as for the euro area as a whole, in particular regarding the persistence in inflation and output variations. The cross correlations, however, are somewhat smaller. For Germany (solid lines) the degree of persistence in inflation is substantially lower. A further difference is that the correlations between current output and lagged inflation have the opposite sign, albeit statistically insignificant.

4 Estimating the overlapping contracts specifications

The reduced-form representation

Of course, the overlapping contracts specifications alone do not represent a complete model of inflation determination. Since the contract wage equations contain expected future output gaps, we need to specify how the output gap is determined in order to solve for the reduced-form representation of inflation and output dynamics for each contract specification. A full-information estimation approach would require a complete macroeconomic model to estimate the structural supply, demand and policy parameters jointly. While our ultimate objective is to build such a model, we take a less ambitious approach in estimating the contracting parameters and simply use the output gap equation from the unconstrained VAR (the second row in (1)) as an auxiliary equation for output determination.[17]

Using the output equation from the unconstrained VAR together with the wage-price block, we can solve for the reduced-form inflation and output dynamics under each of the four different contract specifications (RW, RW-C, RW-S and NW).[18] For this purpose it is convenient to rewrite the wage-price block in terms of the real contract wage $(x-p)_t$ and the annualized quarterly inflation rate π_t. This can be done for each of the four overlapping contracts models that we consider. The reduced-form of these models is a trivariate *constrained* VAR. While the quarterly inflation rate π_t and the output gap q_t are observable variables, the real contract wage $(x-p)_t$ is unobservable. Given a maximum contract length of one year this constrained VAR can be written as follows:

$$\begin{bmatrix} (x-p)_t \\ \pi_t \\ q_t \end{bmatrix} = B_1 \begin{bmatrix} (x-p)_{t-1} \\ \pi_{t-1} \\ q_{t-1} \end{bmatrix} + B_2 \begin{bmatrix} (x-p)_{t-2} \\ \pi_{t-2} \\ q_{t-2} \end{bmatrix} + B_3 \begin{bmatrix} (x-p)_{t-3} \\ \pi_{t-3} \\ q_{t-3} \end{bmatrix} + B_0\, \epsilon_t \tag{2}$$

where ϵ_t is a vector of serially uncorrelated error terms with mean zero and positive (semi-) definite covariance matrix, which is assumed to be diagonal with its non-zero elements normalized to unity. The coefficients in the bottom row of the B_i matrices $(i = 0, 1, 2, 3)$ coincide exactly with the coefficients of the output gap equation of the unconstrained VAR, with the B_0 coefficients obtained by means of a Choleski decomposition of the covariance matrix Σ_u. The reduced-form coefficients in the upper two rows of the B_i matrices, which are associated with the determination of the real contract wage and inflation, are functions of the structural parameters ($s, \gamma, \sigma_{\epsilon_x}$ as defined in **Table 2**) as well as the coefficients of the output gap equation of the unconstrained VAR.

Estimation method

We employ the indirect inference methods proposed by Smith (1993) and Gouriéroux, Monfort and Renault (1993) and developed further in Gouriéroux and Monfort (1996) to estimate

[17] This limited-information approach follows Taylor (1993a) and Fuhrer and Moore (1995a). Given the difficulties in measuring the appropriate real interest rate for the euro area discussed in the preceding section, this approach is likely to be more robust than a full-information approach.

[18] We employ the AIM algorithm of Anderson and Moore (1985), which uses the Blanchard and Kahn (1980) method for solving linear rational expecations models, to compute model-consistent expectations.

the structural parameters s, γ and σ_{ϵ_x}. Indirect inference is a simulation-based procedure that provides a precise way of comparing a model to the data by comparing key characteristics, which themselves are quantities that require estimation via an auxiliary model.[19] In our case, the aim of the estimation procedure is to find values of s, γ and σ_{ϵ_x} such that the degree of inflation persistence exhibited by the structural model matches the persistence in the data as summarized by an approximating statistical model. The latter model should fit inflation and output dynamics reasonably well, but need not necessarily nest the structural model. A natural candidate is the unconstrained VAR of section 3. In particular, the parameters of the inflation equation of the VAR constitute a convenient reference point for the degree of inflation persistence to be matched by the structural model.

An advantage of the unconstrained VAR is that it does not require controversial identifying assumptions. Furthermore, since the VAR parameters also determine the autocovariance functions of inflation and output, matching those parameters is essentially equivalent to matching the autocorrelations and cross-correlations discussed in section 3. In this sense, indirect inference based on the estimated parameters of the unconstrained VAR model is a robust and efficient way to make use of the relevant information contained in the data. By contrast, informal model calibration techniques, but also methods-of-moments based estimation, typically rely on a small set of often subjectively chosen standard deviations and autocorrelations directly inferred from the data.

Of course, one cannot directly match the parameters of the constrained VAR model (2) with the parameters of the unconstrained VAR model (1) because the constrained model also includes the real contract wage, which is unobservable. Instead, we first simulate the constrained VAR to generate "artificial" series for the real contract wage, the inflation rate and the output gap for given values of the structural parameters $(s, \gamma, \sigma_{\epsilon_x})$ and the parameters of the output gap equation. All that is needed for simulation are three initial

[19] Formally, indirect inference provides a rigorous statistical foundation for data-based calibration techniques, which have become increasingly popular in macroeconomic modelling in recent years. The procedure itself including its asymptotic properties, is discussed in detail in the appendix of the working paper version of this article (see Coenen and Wieland (2000)). There, we also provide a comparison to the maximum-likelihood methods used by Taylor (1993a) and Fuhrer and Moore (1995a).

values for each of these variables and a sequence of random shocks.[20] In a second step, we then fit the unconstrained VAR model to the inflation and output gap series generated in this manner and match the simulation-based estimates of the inflation equation as closely as possible with the empirical estimates by searching over the feasible space of the structural parameters.

Structural parameter estimates for the euro area

Euro area estimation results for the baseline version of the relative real wage contracting model (RW), the version with price expectations conditioned on historically available information (RW-C), the simplified version preferred by Fuhrer and Moore (RW-S) and the nominal wage contracting model (NW) are reported in **Table 2**. The estimation results indicate that all four contracting models fit the euro area inflation dynamics reasonably well when we allow for a maximum contract length of one year and thus three lags in the VAR. As can be seen from the standard errors given in parentheses, the estimates of the structural parameters are almost always statistically significant with the appropriate sign and economically significant magnitude. Although the parameter estimates of the different real wage contracting specifications are not directly comparable, since the specifications involve different degrees of forward-lookingness, it is interesting to note that the RW-S specification gives more weight to the higher lags than the RW and the RW-C specifications as implied by the smaller estimates of the slope parameter s.

We also compute the probability (P-) values of the test for the over-identifying restrictions that were imposed in estimating the structural parameters. According to this test, none of the four contracting specifications is rejected by the data. However, the RW specification implies a higher P-value than the NW specification.

We conducted a battery of sensitivity studies. First, we checked wether the results change if we use the VAR(2) model as approximating probability model. In this case, both, the RW-C and the RW-S specification can be rejected at convenient confidence levels, but

[20]In estimation we use steady-state values as initial conditions. We drop several years of data from the simulations so as to avoid an estimation bias due to these initial conditions.

Table 2: Estimates of the Staggered Contracts Models for the Euro Area

	Relative Real Wage Contracts			Nominal Wage Contracts (NW)
	RW	RW-C	RW-S	
B. VAR(3):				
s	.1276 (.0401)	.1372 (.0129)	.0742 (.0245)	.0456 (.0465)
γ	.0022 (.0011)	.0046 (.0008)	.0212 (.0048)	.0115 (.0053)
σ_{ϵ_x}	.0003 (.0001)	.0012 (.0002)	.0024 (.0003)	.0038 (.0005)
$P(\mathcal{Z} > z)$	.7993 [4]	.3326 [4]	.2602 [4]	.3186 [4]

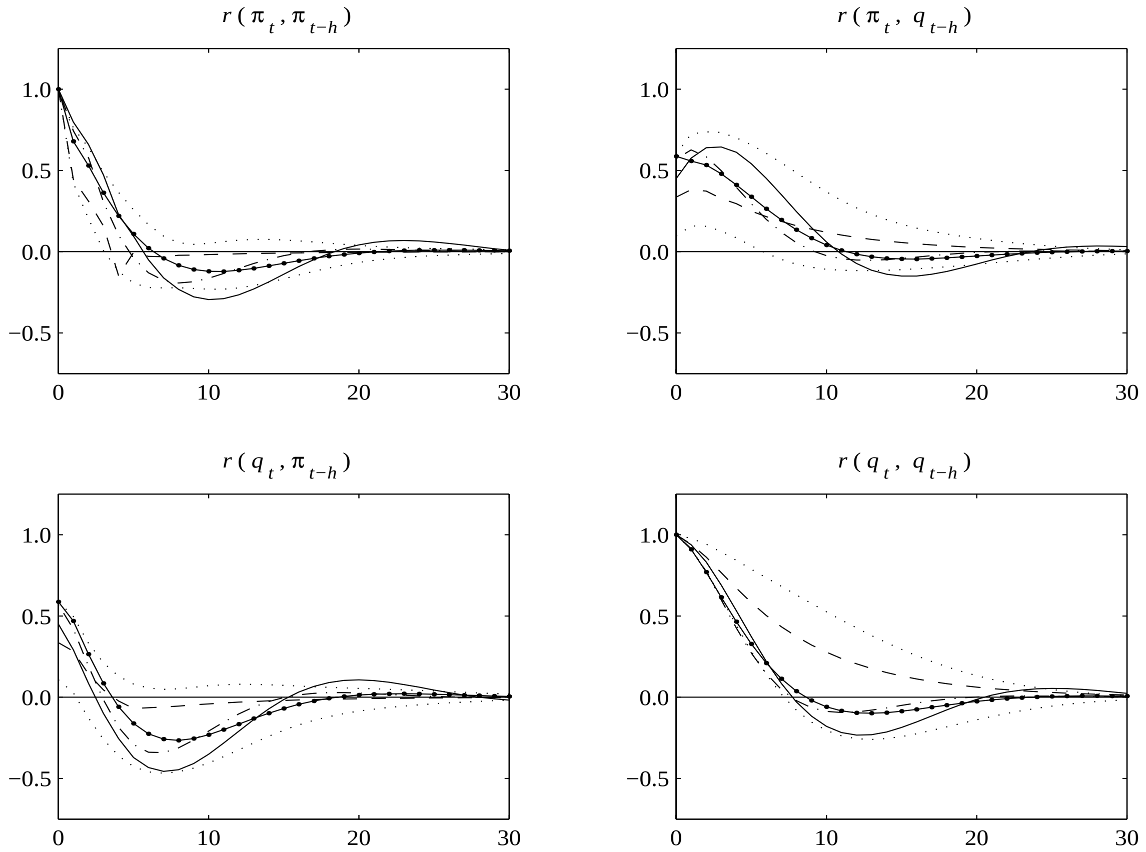
Notes: [a] Estimated standard errors in parantheses. [b] Estimate at the boundary of the parameter space. [c] Probability value of the test of overidentifying restrictions. Number of overidentifying restrictions in brackets.

not the RW or the NW specification, and the NW specification entails the highest P-value. Secondly, we investigated whether our findings are robust to using an exponential rather than linear trend in constructing inflation deviations. We find that the coefficient estimates based on inflation deviations from the exponential trend are with one exception within one standard error bounds of the estimates based on the linear trend. Based on the VAR(3) the RW specification implies a higher P-value than the NW specification whether we use inflation deviations from a linear or an exponential trend. Thirdly, we investigated whether de-trending the inflation series may have introduced a significant error in our estimation.[21] For further details regarding these sensitivity studies the reader is referred to Coenen and Wieland (2000).

To provide further insight regarding these estimation results, we compare the autocorrelation functions implied by the constrained VAR(3) representation of each of the four

[21] To this end we conducted a Monte Carlo study comparing the small-sample properties of the indirect estimation procedure when the downward trend is anticipated by wage and price setters and when it comes as a surprise. However, the outcome of the Monte Carlo study shows that the resulting error in estimation is rather small.

Figure 3: Estimated Autocorrelations of the Constrained VAR(3) Models for the Euro Area



Notes:
Solid line with bold dots: RW model.
Dash-dotted line: RW-C model.
Solid line: RW-S model.
Dashed line: NW model.
Dotted lines: Autocorrelations of the unconstrained VAR(3) model plus/minus twice their estimated asymptotic standard errors.

contracting models with the autocorrelation functions from the unconstrained VAR. As shown in **Figure 3**, the autocorrelation functions for all four models tend to remain inside the 95% confidence bands (dotted lines) associated with the autocorrelation functions of the unconstrained VAR. The three relative real wage contracting specifications (RW: solid line with bold dots, RW-C: dash-dotted line, RW-S: solid line) are rather similar. They exhibit substantial inflation persistence and quite pronounced cross correlations that are indicative of a short-run Phillips curve tradeoff. The second panel (top right) indicates that high levels of output are followed by high inflation, while the third panel (bottom left) shows that high levels of inflation are followed by low levels of output. The only noticeable difference to the unconstrained VAR is that the latter set of cross correlations are somewhat larger in absolute magnitude for the constrained VAR. The autocorrelations for the nominal contracting model (NW: dashed line) indicate a lower degree of inflation persistence and less pronounced cross correlations than for the different relative real wage contracting models.

We conclude that our findings for the euro area differ quite a bit from the results in Fuhrer and Moore (1995a), who reject the nominal wage contracting model for U.S. data and find that the RW-S specification fits U.S. inflation dynamics better than the theoretically more plausible RW specification.

Estimates for France, Germany and Italy

To investigate the validity of our results with respect to aggregation across euro area member economies, we estimate the different contracting models for France, Germany and Italy separately. The results based on VAR(3) models are summarized in **Table 3**. For France we reject the RW-C and the RW-S specifications, but not the RW and the NW specification. The NW model exhibits the highest P-value. However, in this case the parameter measuring the sensitivity to aggregate demand, γ, is statistically insignificant. The parameter estimates for the RW specification are significant and relatively close to the values obtained for the euro area. For Italy, which experienced the most dramatic transition process, the estimation of the NW model did not converge. Instead, the RW and the RW-C model fit Italian inflation data reasonably well and imply statistically significant parameter estimates. For Germany, where inflation exhibited no long-run trend, we find that all three relative real wage contracting models are strongly rejected by the data. While the nominal contracting model is also rejected, it does fit better in the sense of implying a higher P-value. The parameter estimates for the NW model with German data are surprisingly close to the NW estimates obtained with euro area data. For further insight regarding the empirical fit of the

Table 3: Estimates of the Staggered Contracts Models for France, Germany and Italy

VAR(3)	Relative Real Wage Contracts RW	RW-C	RW-S	Nominal Wage Contracts (NW)
A. France: [a]				
s	.1085 (.0500)	0 (—) [b]	.0564 (.0230)	.1189 (.0370)
γ	.0036 (.0020)	.0108 (.0000)	.0296 (.0066)	.0041 (.0041)
σ_{ϵ_x}	.0004 (.0001)	.0052 (.0000)	.0046 (.0005)	.0048 (.0010)
$P(\mathcal{Z} > z)$ [c]	.1156 [4]	.0073 [4]	.0002 [4]	.5435 [4]
B. Germany:				
s	.0487 (.0209)	.0376 (.0195)	0 (—)	.0501 (.0296)
γ	.0061 (.0017)	.0084 (.0013)	.0273 (.0064)	.0195 (.0057)
σ_{ϵ_x}	.0008 (.0001)	.0054 (.0007)	.0063 (.0003)	.0074 (.0007)
$P(\mathcal{Z} > z)$	$< 10^{-5}$ [4]	.0001 [4]	$< 10^{-7}$ [4]	.0026 [4]
C. Italy:				
s	1/6 (—)	.1244 (.0111)	.0970 (.0162)	n.c. [d]
γ	.0006 (.0003)	.0046 (.0010)	.0141 (.0043)	n.c.
σ_{ϵ_x}	.0002 (.0000)	.0023 (.0003)	.0038 (.0005)	n.c.
$P(\mathcal{Z} > z)$	.1575 [4]	.1574 [4]	.0709 [4]	

Notes: [a] Estimated standard errors in parantheses. [b] Estimate at the boundary of the parameter space. [c] Probability value of the test of overidentifying restrictions. Number of overidentifying restrictions in brackets. [d] No convergence.

different specifications from a comparison the autocorrelation functions of the constrained and unconstrained VAR models the reader is again referred to Coenen and Wieland (2000).

We conclude that, both, the RW and the NW specifications are plausible alternatives for the euro area. On the one hand, the estimation with aggregated euro area data indicates a slight preference for the relative wage contracting model. On the other hand, the comparison between France, Germany and Italy suggests that this preference may partly be due to the initial high-inflation regime in countries such as Italy and France and the fact that the subsequent disinflation was not fully anticipated. Thus, an optimist would conclude that the independent European Central Bank will likely face a similar environment in the future as the Bundesbank did in Germany or possibly the French central bank in the latter part of the EMS (the "Franc fort" period). In this case, the inflation-output relationship for the euro area would be best characterized by the nominal contracting specification. A skeptic, who suspects that stabilizing euro area inflation will require higher output losses, would instead prefer to use the RW specification for the euro area. A robust monetary policy strategy, however, should perform reasonably well under both specifications.

5 Closing the model: Output gaps and monetary policy

It remains to specify the determination of aggregate demand and the transmission of monetary policy. Equation (M-6) in **Table 4** relates the output gap q_t in a simple IS equation to two lags of itself and to the lagged long-term ex-ante real interest rate, r^l_{t-1}. The demand shock $\epsilon_{d,t}$ in equation (M-6), which is assumed to be serially uncorrelated with mean zero and unit variance, is scaled with the parameter σ_{ϵ_d}. The rationale for including lags of output is to account for habit persistence in consumption as well as adjustment costs and accelerator effects in investment. We use the lagged instead of the contemporaneous value of the real interest rate to allow for a transmission lag of monetary policy.[22]

Next we turn to the financial sector and relate the long-term real interest rate to the

[22] For now we neglect the possibility of effects of the real exchange rate. Fuhrer and Moore (1995b) found that a similar aggregate demand specification fits U.S. output dynamics quite well. Since the euro area is a large, relatively closed economy just like the United States, the exchange rate is likely to play a less important role than it did in the individual member economies prior to EMU.

Table 4: Aggregate Demand and Interest Rates

(M-6) Aggregate Demand	$q_t = \delta_0 + \delta_1\, q_{t-1} + \delta_2\, q_{t-2} + \delta_3\, r^l_{t-1} + \sigma_{\epsilon_d}\, \epsilon_{d,t}$
(M-7) Policy Rule	$i^s_t = r^* + \pi^{(4)}_t + \alpha_\pi(\pi^{(4)}_t - \pi^*) + \alpha_q\, q_t$, where $\pi^{(4)}_t = p_t - p_{t-4}$
(M-8) Term Structure	$i^l_t = \mathrm{E}_t\left[\frac{1}{8}\sum_{j=0}^{7} i^s_{t+j}\right]$
(M-9) Real Interest Rate	$r^l_t = i^l_t - \mathrm{E}_t\left[\frac{1}{2}(p_{t+8} - p_t)\right]$

Notes: q_t: output gap; r^l: long-term real interest rate; ϵ_d : demand shock; i^l: long-term nominal interest rate; i^s short-term nominal interest rate.

short-term nominal interest rate, which is the principal instrument of monetary policy. Three equations determine the various interest rates. The short-term nominal interest rate, i^s_t, is set according to a Taylor-type interest rate rule as defined by equation (M-7) in **Table 4**. According to this rule policymakers change the nominal interest rate in response to inflation deviations from the target π^* and output deviations from potential. The inflation measure is the year-on-year change in the aggregate price level and the interest rate is annualized. Furthermore, the real equilibrium rate r^* provides a reference point for the policy rule. As shown in Taylor (1993b), a rule with values of 0.5 for the two response parameters (α_π, α_q) and 2 percent for π^* and r^* fits U.S. federal funds rate behavior from 1987 to 1992 quite well. More recently, Gerlach and Schnabel (2000) have shown that average interest rates in the EMU countries in 1990-98, with the exception of the period of exchange market turmoil in 1992-93, moved very closely with average output gaps and inflation as implied by Taylor's rule.[23] As to the term structure that is defined in (M-8), we rely on the accumulated forecasts of the short rate over two years which, under the expectations hypothesis, will coincide with the long rate forecast for this horizon. The term

[23]Of related interest, work by Clarida, Galí and Gertler (1998) suggests that German interest rate policy since 1979 is summarized quite well by an interest rate rule that responds to a forecast of inflation and the current output gap and exhibits some degree of partial adjustment. Clarida et al. (1998) also argue that German monetary policy had a strong influence on interest rate policy in the U.K., France and Italy throughout this period and may have led to higher interest rates in those countries than warranted by domestic conditions at the time of the EMS crisis as suggested in Wieland (1996).

premium is assumed to be constant and equal to zero. We then obtain the ex-ante long-term real interest rate (defined in M-9) by subtracting inflation expectations over the following 8 quarters.

In the deterministic steady state of this model the output gap is zero and the long-term real interest rate equals its equilibrium value, r^*. This value is a function of the aggregate demand parameters, $r^* = -\delta_0/\delta_3$. Since the overlapping contracts specifications of the wage-price block do not impose any restriction on the steady-state inflation rate, it is determined by monetary policy alone and equals the target rate, π^*, in the policy rule.

To estimate the parameters of the aggregate demand equation (M-6) we first construct the ex-post long-term real rate by replacing expected future with realized values in equations (M-8) and (M-9). Then we estimate the parameters by means of Generalized Method of Moments (GMM) using lagged values of output, inflation and interest rates as instruments. The estimation results are reported in **Table 5**. The sample period for this estimation is 1974:Q4 to 1997:Q1.

Panel A refers to the estimates for the euro area. In the first row, the interest rate data are area-wide GDP-PPP-weighted averages of national money market rates. The coefficients on the two lags of the output gap are significant and exhibit an accelerator pattern. The interest rate sensitivity of aggregate demand has the expected negative sign, however the parameter estimate is only borderline significant and rather small. It is not clear however, what is the appropriate real interest rate measure for the euro area. For example, instead of GDP weights it may be more appropriate to use the relative weights in debt financing for aggregating national nominal interest rates. Or, one could make the argument that the relevant real rate for the euro area is the German one. After all, movements in German interest rates presumably had to be mirrored eventually by the other countries to the extent that they intended to maintain exchange rate parities within the EMS. For this reason we also use the German real interest rate to estimate the interest rate sensitivity of euro area aggregate demand. In this case, as shown in the second row, we find similar coefficients on the lags of the output gap, but the estimate of the interest

Table 5: Estimates of the IS Curve for the Euro Area, France, Germany and Italy

	δ_0	δ_1	δ_2	δ_3	σ_{ϵ_d}	$P(\mathcal{J} > j)^b$
A. Euro Area:[a]						
A.1 area-wide rate:	0.0012	1.2347	-0.2737	-0.0364	0.0056	0.1209 [5]
	(0.0007)	(0.0916)	(0.1004)	(0.0224)		
A.2 German rate:	0.0027	1.1807	-0.2045	-0.0947	0.0057	0.2307 [5]
	(0.0012)	(0.1006)	(0.1065)	(0.0333)		
B. France:	0.0024	1.2247	-0.2708	-0.0638	0.0060	0.1977 [5]
	(0.0008)	(0.1275)	(0.1284)	(0.0234)		
C. Germany:	0.0012	0.7865	0.1395	-0.0365	0.0112	0.2518 [5]
	(0.0027)	(0.0686)	(0.0825)	(0.0874)		
D. Italy:	0.0023	1.3524	-0.3852	-0.0544	0.0063	0.4210 [5]
	(0.0009)	(0.0845)	(0.0804)	(0.0236)		

Notes: [a] GMM estimates using a vector of ones and lagged values of the output gap (q_{t-1}, q_{t-2}), the quarterly inflation rate $(\pi_{t-1}, \pi_{t-2}, \pi_{t-3})$, and the short–term nominal interest rate $(i^s_{t-1}, i^s_{t-2}, i^s_{t-3})$ as instruments. The weighting matrix is estimated by means of the Newey-West (1987) estimator with the lag truncation parameter set equal to 7. Estimated standard errors in parantheses. [b] Probability value of the $\mathcal{J}$-test of overidentifying restrictions. Number of overidentifying restrictions in brackets.

rate sensitivity is highly significant and about three times as large.[24] For comparison, we have also estimated the same specification for France, Germany and Italy. In each case we use the domestic real interest rate. For France and Italy we obtain qualitatively similar estimates as for the euro area. For Germany however, the estimate of the interest rate sensitivity is not significant and the lags of output do not exhibit an accelerator-type pattern.

Dynamic Simulations

In the remainder of this section we use dynamic simulations to illustrate the implications

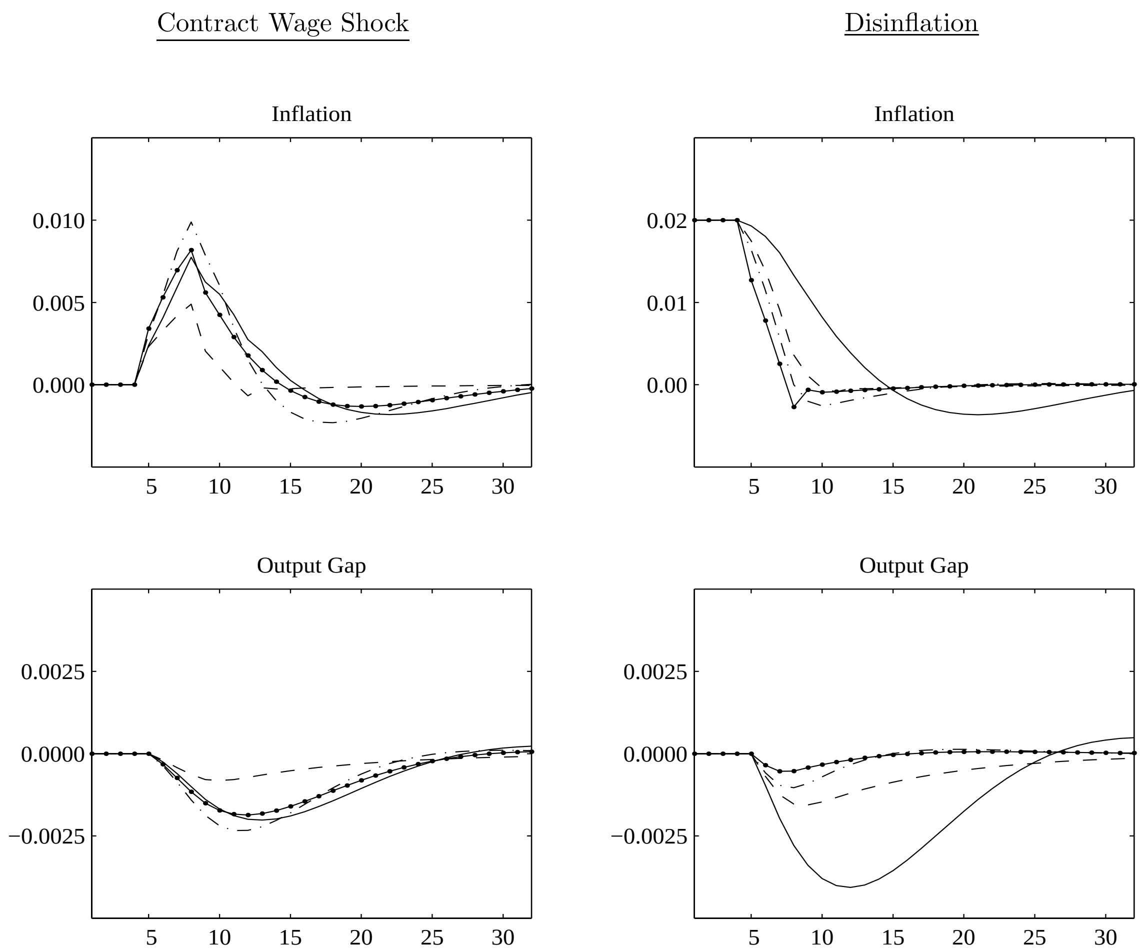
[24] We have subjected this specification of aggregate demand to a battery of sensitivity tests. For example, we have investigated alternative specifications of potential output, alternative horizons on the term structure equation, including the use of average long-term rates instead of a term structure based on short-term rates and we have varied the length of the sample period. At least qualitatively, the estimation results remain the same.

of the alternative wage contracting models for the inflation-output variability tradeoff faced by policymakers. To this end, we consider two different scenarios: an unexpected shock to the contract wage equation (a cost-push shock) and an unanticipated, credible disinflation. In both cases the coefficients in the policy rule are set equal to the value of 0.5 proposed in Taylor (1993b) that according to Gerlach and Schnabel (2000) coincides surprisingly well with average interest rate movements in the euro area throughout the 1990s. We compare the simulation outcomes under the RW, RW-S, RW-C and NW specifications of the staggered contracts model using the euro area estimates reported in **Table 2**. For euro area aggregate demand we use the estimates obtained with the German real interest rate as reported in the second row of **Table 5.**

We start with an unexpected shock to the contract wage equation, a short-run cost-push shock. Its effects on inflation and output under the four different contracting specifications are shown respectively in the top-left and bottom-left panel of **Figure 4**. The solid line with bold dots refers to the RW specification, which we found to have the best fit with euro area data. The RW-S and RW-C specifications correspond to the solid and dashed-dotted lines respectively. The response for the NW model is shown by the dashed line.

The shock occurs in the first quarter of the second year (period 5). As a result of this shock inflation increases over the next four quarters by almost a full percentage point. Monetary policy following Taylor's rule responds to this increase in inflation by raising short-term nominal interest rates sufficiently to drive up the long-term real interest rate. This policy tightening induces a slowdown in aggregate demand for about four years. Since future aggregate demand affects contract wages and through this channel the inflation rate, inflation returns to target after little more than two years, even undershooting for a few periods thereafter. The quantitative consequences of the contract wage shock are quite similar under the RW, RW-C and RW-S specification. In each case, policymakers face a substantive cost of stabilizing inflation in terms of a small recession. Qualitatively, the impact on output and inflation is the same under the NW specification, but it is smaller in size. Thus, the cost of stabilizing inflation in terms of reduced output is noticeably larger

Figure 4: Dynamic Simulations with the Euro Area Model



Notes:
Solid line with bold dots: RW model.
Solid line: RW-S model.
Dash-dotted line: RW-C model.
Dashed line: NW model.

under the relative real wage specifications.

While the costs of stabilizing inflation following an unexpected cost-push shock such as the contract wage shock above are noticeable and quite similar under the three relative wage contracting specifications, the output losses associated with an *unanticipated, perfectly credible* disinflation turn out to be quite different. As shown in the top-right and bottom-right panels of **Figure 4** an unanticipated change in the policymaker's inflation target,

π^* from 2 percent to 0 percent only results in significant output losses in the case of the RW-S specification preferred by Fuhrer and Moore. Also, inflation declines towards the new target rate much faster under the other contracting specifications. Clearly, in light of the discussion in Fuhrer and Moore (1995a) this finding is somewhat surprising. The reason for the lower output cost of the disinflation under the RW and RW-C setup compared to the RW-S specification is that wage setters negotiate contract wages with respect to the average price level expected to prevail over the life of the contract. In the RW-S model contract wages are instead negotiated with respect to the current price level. Thus, wage setters in the RW and RW-C models incorporate the anticipated disinflation more quickly in their decisions.

6 Conclusion

Contrary to Fuhrer and Moore (1995a), who reject the nominal contracting model for the United States and find strong evidence in favor of the relative contracting model which induces a higher degree of inflation persistence, we find that both types of contracting models fit euro area data reasonably well. The best fitting specification is a version of the relative contracting model, which is theoretically more plausible than the simplified version preferred by Fuhrer and Moore. To investigate the validity of our results for the euro area, we also estimated the contracting models for France, Germany and Italy separately. Our findings show that the relative contracting model does quite well in countries which transitioned out of a high inflation regime such as France and Italy, while only the nominal contracting model has a shot a fitting German data. One interpretation of these findings is that nominal rigidities in wage and price setting are more pronounced in Italy than in Germany. If so, one might expect that the euro area will also be characterized by a higher degree of nominal rigidity than Germany as suggested by our estimates based on euro area averages. Another interpretation would attribute the higher degree of inflation persistence in euro area, French and Italian data to expectations about imperfectly credible monetary policy and less than fully credible disinflation. In this case, the better fit of the relative wage contracting specification would be misleading. And consequently, the nominal wage contracting model may be viewed as a more accurate description of nominal rigidities in the euro area in the future. Dynamic simulations of the complete model's response to an unexpected cost-push shock indicate that stabilizing inflation in response to shocks is less costly under the nominal contracting model, and quite similar under the three relative real wage contracting models. More surprisingly, however, the only specification which implies substantive output costs of an unanticipated disinflation is the simplified relative-wage contracting model preferred by Fuhrer and Moore (1995a).

Comparing our results for the euro area with Fuhrer and Moore's estimates for the United States with maximum likelihood methods, the question arises whether the differences are due to the different estimation methodology or the data. Preliminary results based on the indirect inference methodology of this paper confirm Fuhrer and Moore's findings for U.S. data.[25] As in Fuhrer and Moore (1995a) the nominal contracting model tends to be rejected, while the RW-S specification obtains the best fit. However, along the lines of our discussion of Germany, France and Italy, we emphasize two alternative interpretations of this finding. On the one side this finding may represent evidence of more pronounced structural rigidities, but on the other side it may just pick up historical inflation persistence that was due to imperfect credibility of monetary policy.

As to future research two issues are of particular interest. First, in terms of evaluating policy rules for the euro area, it would be particularly important to identify robust rules that perform reasonably well under different types of nominal rigidities. Secondly, with regard to model estimation it would be of interest to explain the historical disinflation process in France, Italy and in the euro area as a whole within the model. One approach would be to incorporate a time-varying, imperfectly credible inflation target in the analysis. The moving target could capture the downward trend in inflation while market participants' beliefs regarding the target would constitute a source of inflation persistence. An alternative approach would be to consider changes in the inflation response of the

[25] These results form part of our ongoing effort to estimate a multi-country model with nominal rigidities due to overlapping contracts for the major industrial economies, the United States, Japan and the euro area.

policy rule as the source of inflation and disinflation. For example, a negative value of α_π in equation (M-7) would result in multiple equilibria with potentially self-fulfilling expectations. Thus, one could explore empirically whether a shift from negative to positive values of this parameter in France and Italy could explain the downward trend in euro area inflation over the 1980s and 1990s.[26]

References

Anderson, G. S. and G. R. Moore, 1985, A linear algebraic procedure for solving linear perfect foresight models, Economics Letters, 17, 247-252.

Angeloni, I. and L. Dedola, 1999, From the ERM to the euro: New evidence on economic and policy convergence among EU countries, European Central Bank, Working Paper No. 4, May.

Beyer, A., J. Doornik and D. Hendry, 2001, Constructing historical euro-zone data, Economic Journal, 111, 102-121.

Blanchard, O. J. and C. Kahn, 1980, The solution of linear difference models under rational expectations, Econometrica, 48, 1305-1311.

Bryant, R. C., P. Hooper and C. Mann (eds.), 1993, Evaluating policy regimes: New research in empirical macroeconomics, Washington DC: Brookings Institution.

Buiter, W. H. and I. Jewitt, 1981, Staggered wage setting with real wage relativities: Variations on a theme of Taylor, The Manchester School, 49, 211-228, reprinted in W. H. Buiter (ed.), 1989, Macroeconomic theory and stabilization policy, Manchester: Manchester University Press.

Calvo, G. A., 1983, Staggered prices in a utility-maximizing framework, Journal of Monetary Economics, 12, 3, 383-398.

Cecchetti, S., M. McConnell and G. Perez Quiros, 1999, Policymakers' revealed preferences and the output-inflation variability tradeoff: Implications for the European System of Central Banks, Manuscript.

Chari, V.V., P. Kehoe and E. McGrattan, 2000, Sticky price models of the business cycle: Can the contract multiplier solve the persistence problem ?, Econometrica, 68, 5, 1151-1180.

Clarida, R., J. Galí and M. Gertler, 1998, Monetary policy rules in practice: Some international evidence, European Economic Review, 42, 1033-1067.

Clarida, R., J. Galí and M. Gertler, 1999, The science of monetary policy: A new Keynesian perspective, Journal of Economic Literature, 37, 1661-1707.

[26]This intriguing explanation was suggested by one of our referees. It could be explored by estimating the respective interest rate rules over sub-samples. However, how to include such policy rules with breaks in the full-information estimation of the inflation process is an unresolved issue.

Coenen, G., 2000, Asymptotic confidence bands for the estimated autocovariance and autocorrelation functions of vector autoregressive models, European Central Bank, Working Paper No. 9, January.

Coenen, G. and V. Wieland, 2000, A small estimated euro area model with rational expectations and nominal rigidities, ECB Working Paper, No. 30, September.

De Grauwe, P., 1996, Inflation convergence during the transition to EMU, in P. De Grauwe, S. Micossi and G. Tullio (eds.), Inflation and wage behaviour in Europe, Oxford: Oxford University Press.

Erceg, C. and A. Levin, 2001, Imperfect credibility and inflation persistence, Finance and Economics Discussion Series, Federal Reserve Board, No. 2001-45.

Fagan, G., J. Henry and R. Mestre, 2001, An area-wide model (AWM) for the EU11, ECB Working Paper No. 42, January.

Fair, R. C. and E. P. Howrey, 1996, Evaluating alternative monetary policy rules, Journal of Monetary Economics, 38, 173-193.

Fuhrer, J. C., 1997, Inflation/output variance trade-offs and optimal monetary policy, Journal of Money, Credit, and Banking, 29, 214-234.

Fuhrer, J. C. and G. R. Moore, 1995a, Inflation persistence, Quarterly Journal of Economics, 110, 127-159.

Fuhrer, J. C. and G. R. Moore, 1995b, Monetary policy trade-offs and the correlation between nominal interest rates and real output, American Economic Review, 85, 219-239.

Galí, J. and M. Gertler, 1999, Inflation dynamics: A structural econometric analysis, Journal of Monetary Economics, 44, 195-222.

Gerlach, S. and L. E. O. Svensson, 1999, Money and inflation in the euro area: A case for monetary indicators?, Manuscript, July.

Gerlach, S. and G. Schnabel, 2000, The Taylor rule and interest rates in the EMU area, Economics Letters, 67, 165-171.

Gouriéroux, C. and A. Monfort, 1996, Simulation-based inference methods, Oxford: Oxford University Press.

Gouriéroux, C., A. Monfort and E. Renault, 1993, Indirect inference, Journal of Applied Econometrics, 8, Special issue: Econometric inference using simulation techniques, S85-S118.

Issing, O., V. Gaspar, I. Angeloni and O. Tristani, 2001, Monetary policy in the euro area, Cambridge: Cambridge University Press.

McCallum, B. T., 2001, Analysis of the monetary transmission mechanism: methodological Issues, in Deutsche Bundesbank (ed.), The monetary transmission process: Recent developments and lessons for Europe, Basingstoke: Palgrave.

McCallum, B. T. and E. Nelson, 1999, Performance of operational policy rules in an estimated semiclassical structural model, in Taylor, 1999.

Newey, W. K. and K. D. West, 1987, A simple, positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix, Econometrica, 55, 703-708.

OECD, 1999, OECD economic outlook No. 65, Organisation for Economic Co-Operation and Development, June.

Orphanides, A. and V. Wieland, 1998, Price stability and monetary policy effectiveness when nominal interest rates are bounded at zero, Finance and Economics Discussion Series, 98-35, Board of Governors of the Federal Reserve System, June.

Reifschneider, D., R. Tetlow and J. C. Williams, 1999, Aggregate disturbances, Monetary policy, and the macroeconomy: The FRB/US perspective, Federal Reserve Bulletin, 85, 1-19.

Roberts, J., 1997, Is inflation sticky?, Journal of Monetary Economics, 39, 173-196.

Rotemberg, J. and M Woodford, 1999, Interest-rate rules in an estimated sticky price model, in Taylor, 1999.

Rudebusch, G. and L. E. O. Svensson, 1999, Policy rules for inflation targeting, in Taylor, 1999.

Sbordone, A., 2002, Price and unit labor costs: A new test of price stickiness, Journal of Monetary Economics, 2002, vol. 49(2), pp. 265-292.

Smith, A. A., 1993, Estimating nonlinear time-series models using simulated vector autoregressions, Journal of Applied Econometrics, 8, Special issue: Econometric inference using simulation techniques, S63-S84.

Taylor, J. B., 1980, Aggregate dynamics and staggered contracts, Journal of Political Economy, 88, 1-24.

Taylor, J. B., 1993a, Macroeconomic policy in the world economy: From econometric design to practical operation, New York: W.W. Norton.

Taylor, J. B., 1993b, Discretion versus policy rules in practice, Carnegie-Rochester Conference Series on Public Policy, 39, 195-214.

Taylor, J. B. (ed.), 1999, Monetary policy rules, Chicago: NBER and University of Chicago Press.

Taylor, J. B., 2000, Low inflation, pass-through, and the pricing power of firms, European Economic Review,44 , 7, 1389-1408.

Wieland, V., 1996, Monetary policy targets and the stabilization objective: A source of tension in the EMS, Journal of International Money and Finance, 15, 95-116.