NOTES D'ÉTUDES

ET DE RECHERCHE

EVALUATING MONETARY POLICY RULES IN ESTIMATED FORWARD-LOOKING MODELS: A COMPARISON OF US AND GERMAN MONETARY POLICIES

Eric Jondeau and Hervé Le Bihan

October 2000

NER # 76

BANQUE DE FRANCE

DIRECTION GÉNÉRALE DES ÉTUDES ET DES RELATIONS INTERNATIONALES

Evaluating Monetary Policy Rules in Estimated Forward-Looking Models: A Comparison of US and German Monetary Policies

Eric Jondeau and Hervé Le Bihan*
Banque de France, Centre de recherche
31, rue Croix des Petits Champs, 75049 Paris, France.
eric.jondeau@banque-france.fr and herve.lebihan@banque-france.fr

December 1999

[Revised: September 2000]

Abstract

In this paper, we estimate two small, forward-looking, macroeconomic models for the US and Germany and we compare the implied optimal monetary policy rules. Both models have a standard structure: an I-S curve, a Phillips curve, a short term interest-rate rule and a long term interest rate determined by the Expectations Hypothesis. They are intended to fit the data while allowing for some forward-looking behavior. They are estimated from 1968 to 1998, using the full-information maximum-likelihood procedure, so that forward-looking expectations are fully model-consistent. In order to evaluate monetary policy, we compute optimal policy frontiers and we perform some simulations of the model. German optimal monetary policy is found to require a more persistent and slightly stronger response to inflation and output than the US optimal policy.

Résumé

Nous estimons dans ce papier deux petits modèles macroéconomiques, à anticipations *forward-looking*, pour les Etats-Unis et l'Allemagne, et nous comparons les règles de politique monétaire optimales induites par ces modèles. Les modèles sont constitués d'une courbe I-S, d'une courbe de Phillips, d'une règle de taux d'intérêt court, et d'un taux long déterminé par la théorie des anticipations. Ils sont estimés sur la période 1968-98, à l'aide d'une procédure du maximum de vraisemblance à information complète, de telle sorte que les anticipations *forward-looking* sont cohérentes avec le modèle. De façon à évaluer la politique monétaire, nous construisons des frontières de politique optimale et nous réalisons des simulations du modèle. Nous trouvons que la politique monétaire optimale allemande nécessite une réponse plus persistante et légèrement plus forte à l'inflation et à l'écart de production que la politique optimale américaine.

Keywords: Forward-looking model, monetary policy rules.
JEL classification: E52, E58, F41.

*We have benefited from the comments of Jean Cordier, Jeffrey Fuhrer, Heinz Herrmann, Jean-Pierre Laffargue, François Langot, Jean-Paul Pollin, Pierre Sicsic, participants at the Conference on the Econometrics of Policy Evaluation in Paris, January 2000 and at the workshop "Macroéconomie Monétaire" of the GDR "Monnaie et Financement" in Paris, March 2000. Any remaining errors are our own.

1 Introduction

In this paper, we estimate two small, forward-looking, macroeconomic models for the US and Germany, and we compare the associated optimal monetary policy rules. The models have the following common structure: inflation and output dynamics are described using a standard Phillips curve and an I-S curve respectively; the reaction function is a Taylor-type rule for the short-term interest rate; the long-term interest rate is consistent with the rational expectations hypothesis of the term structure of interest rate.

An abundant literature has investigated monetary policy and other macroeconomic topics using such models. The I-S curve / Phillips curve framework encompasses a wide range of macroeconomic models, especially since Kerr and King (1995) and McCallum and Nelson (1996) have included forward-looking features in the I-S curve. Such a theoretical framework can be associated with different empirical modelling strategies.

A first approach is to use fully calibrated models derived from optimization behaviors (King and Wolman, 1996, Rotemberg and Woodford, 1998, Yun, 1996). Haldane and Batini (1998), and Svensson (1998), while putting less emphasis on micro foundations, have also used a calibrated model to analyze monetary policy issues.

A contrasting strand of research has relied on VAR models to analyze monetary policy. The typical VAR model in this respect involves the inflation rate, the short-term interest rate and an output indicator (Sims, 1992, Gerlach and Smets, 1995, Bagliano and Favero, 1998). Interpreting impulse responses to a monetary policy shock involves implicit reference to the I-S curve/Phillips curve/reaction function structure. VAR models are an interesting benchmark, since they provide some guidelines as regards transmission lags of monetary policy and an agnostic encompassing specification against which structural models can be tested. However, they are less suited for studying monetary policy rules (see McCallum, 1999).

In order to evaluate monetary policy rules, a number of studies have estimated backward-looking versions of the I-S curve and Phillips curve model, which can be seen as constrained VARs (Rudebusch and Svensson, 1998, Fair and Howrey, 1996). Using European data, this approach has been adopted in particular by Taylor (1999a) and Artus, Penot, and Pollin (1999).

The aim of the present paper is to estimate such a small macroeconomic model, in order to reach a reasonable fit of the data, while including some forward-looking elements. Thus, our approach is related to the one developed by Fuhrer and Moore (1995a,b) and Fuhrer (1997a). Concerning the micro-foundations of the model, our strong prior is that adjustment is more sluggish on goods and labor markets than on financial assets markets. We allow for adjustment lags and backward-looking features in output and price behaviors. On the contrary, we regard long-term interest rates as more readily represented by forward-looking and rational expectations conditions. Thus, we use the expectations hypothesis of the term structure to model long rates.

Monetary policy is represented by a reaction function. This approach has proved to be an empirically successful characterization of central bank's behavior (Clarida and Gertler, 1997, Clarida, Gali, and Gertler, 1998a, Judd and Rudebusch, 1998). The short rate is assumed to depend on the inflation rate and an output-gap measure. An alternative approach is the optimal monetary policy approach, investigated thoroughly by Svensson (1997, 1998). However, a large number of studies (Taylor, 1999a, Williams, 1999, among others) have shown that a simple interest-rate rule is a fairly good approximation of an optimal rule.

The outline of the paper is as follows. Section 2 provides a description of the theoretical framework. Section 3 presents the full-information maximum-likelihood estimates of our structural model for the US and Germany over the 1968-98 period (the estimation method is described in Appendix 1.) To briefly summarize our results, we obtain for Germany an estimated model in which the economy is less reactive than the US economy. Over the recent period, the Bundesbank's monetary policy appears to have been more reactive to changes in the output gap than the Fed's, but also more smoothed. Weight on inflation in the reaction function are similar. In Section 4, we compute the optimal monetary frontiers for the US and Germany. We find that the Bundesbank's optimal response is more smoothed than the Fed's, which is consistent with the estimated rules. We find that for both countries the optimal monetary policy implies larger parameters than the estimated policy. In order to investigate the gap between estimated and optimal policy rules, we study the robustness of the computed German optimal policy frontier to parameter uncertainty. Section 5 presents our main conclusions.

2 The structural model

Investigating monetary policy requires to design a structural model including the instrument of policy and its targets. This model therefore includes a Phillips curve that relates inflation to the output gap, an I-S curve in which output gap is related to the long real rate, and a monetary-policy reaction function in which the short nominal rate depends on inflation and output gap.

Our model implicitly assumes that the inflation rate, the short nominal rate and the output gap are stationary variables. The overall structure of the model implies that the order of integration of inflation and nominal interest rate is determined by monetary policy. We assume here that the inflation target is constant (with a possible break in 1979) rather than a random walk. Moreover, assuming stationarity of the inflation rate, the short nominal rate and the output gap, we are able to compute steady-state values for the model variables. Furthermore, stability of the model crucially hinges on the degree of responsiveness of monetary policy. If the monetary authority has a sufficient response to deviations of inflation from its target, inflation and short nominal rate are stationary.

Our method for solving and estimating the model is presented in Appendix 1. It relies on putting the model under an autoregressive form for the predetermined variables. When some eigenvalues of the associated matrix are greater than 1, the algorithm does not converge, so that the method rules out non-stationary solutions.

2.1 The Phillips curve

Prices are set according to an augmented Phillips curve, which can be interpreted as an aggregate supply equation. Inflation is related to its own lagged value and to lagged output gap, y_t:

$$\pi_{t+1} = \alpha_\pi \pi_t + \alpha_y y_t + \alpha_0 + \varepsilon_{t+1} \tag{1}$$

where $\pi_t = 4\left(p_t - p_{t-1}\right)$ is the annualized quarter-on-quarter inflation rate at time t, with p_t the domestic (log) price index. The innovation ε_{t+1} is a zero-mean i.i.d cost-push supply shock. The parameter α_0 is a constant term. The output gap y_t is defined as

$$y_t = y_t^d - y_t^n,$$

where y_t^d is the (log) aggregate demand and y_t^n the (log) potential output. The above Phillips curve can be seen as a reduced form of many macroeconomic models. However, since it imposes a backward-looking behavior, it is somewhat restrictive. In the sticky-price models of Calvo (1983) and Rotemberg (1982), the Phillips curve is derived from an optimizing behavior, and is entirely forward looking. Fuhrer and Moore (1995a), building on Taylor (1979), put forward a more balanced model, which is able to replicate the observed inflation persistence. Their model is a version of the Taylor's staggered contracts model, in which employees are assumed to care about relative real wages rather than relative nominal wages. Fuhrer (1997b) shows however that empirical evidence in favor of the forward-looking component of the Phillips curve is rather 'unimportant' on US data. He finds that the part of the backward-looking component is systematically larger than 75 percent, and the null hypothesis of no forward-looking component is never rejected. We also tried to introduce in our model a forward-looking component to inflation. It failed to be significant. We then adopt a purely backward-looking inflation equation. This is consistent with the idea that good and labor markets have a more adaptive behavior than financial assets markets.

We constrain the sum of autoregressive parameters to equal one, in order to satisfy the 'natural rate' hypothesis. Moreover, we estimate a more general backward-looking specification of the form

$$\pi_{t+1} = \sum_{k=0}^{K} \alpha_{\pi k}\pi_{t-k} + \alpha_y y_t + \alpha_0 + \varepsilon_{t+1}$$

with $\alpha_\pi = \sum_{k=0}^{K} \alpha_{\pi k} = 1$. Imposing the sum of autoregressive parameter ($\alpha_\pi = \sum_{k=0}^{K} \alpha_{\pi k}$) to be equal to one does not contradict the stationarity hypothesis of the inflation rate. Stationarity has to be evaluated within the whole model. So, as long as the central bank overreacts to a shock on inflation, a negative effect of the long term real rate on the output gap will imply a stationary inflation through the effect of output gap on inflation, even though $\alpha_\pi = 1$.[1] Since we impose $\alpha_\pi = 1$, the constant term α_0 has to be set equal to 0. Indeed the long-run solution of eq. (1) is $\pi^{LR} = \pi^{LR} + \alpha_y y^{LR} + \alpha_0$. Since the output gap is null in the long run, we should have $\alpha_0 = 0$.

2.2 The I-S curve

The aggregate demand is described with an I-S curve, that relates the output gap to its own lagged values and to expected long real rate, $\rho_{t+1/t}$:

$$y_{t+1} = \beta_{y1} y_t + \beta_{y2} y_{t-1} - \beta_\rho \rho_{t+1/t} + \beta_0 + \eta_{t+1} \tag{2}$$

where η_{t+1} is a zero-mean demand shock. Throughout the paper, $x_{t+1/t}$ denotes the conditional expectation on date t of variable x_{t+1}. Forward-looking expectations

[1] Estimating this model freely yields $\sum_{k=0}^{K} \alpha_{\pi k} = 0.952$ (with t-stat $= 1.114$ for $(\alpha_\pi - 1)$) for US data and 0.761 (with t-stat $= 3.170$) for German data. Since we are interested in the long-run inflation / output-gap *volatility* trade-off, we constraint $\alpha_\pi = 1$ to avoid a long-run inflation / output gap *level* trade-off.

terms are model-consistent. The long real rate, ρ_t, is the yield to maturity on a hypothetical long-term real bond. The expectations hypothesis of the term structure implies that the expected holding-period return on a long-term real bond equals the short real rate, r_t:

$$\rho_t - D\left(\rho_{t+1/t} - \rho_t\right) = r_t. \tag{3}$$

The short real rate is defined as $r_t = i_t - \pi_{t+1/t}$, where the short nominal rate, i_t, is the monetary policy instrument. D is a constant approximation to Macaulay's duration.[2] Solving this equation recursively forward for ρ_t, we express the long real rate as an exponentially weighted moving average of the expected short real rates

$$\rho_t = \frac{1}{1+D}\sum_{\tau=0}^{\infty}\left(\frac{D}{1+D}\right)^{\tau} E_t r_{t+\tau/t}. \tag{4}$$

A time-varying risk premium may be introduced in this equation in order to take account of deviations from the expectations hypothesis. We do not consider this case in the following. Eq. (3) can also be expressed in the following way[3]

$$\rho_{t+1/t} = \frac{1+D}{D}\rho_t - \frac{1}{D}r_t = \frac{1+D}{D}\rho_t - \frac{1}{D}\left(i_t - \pi_{t+1/t}\right) \tag{5}$$

that is useful to write the model under state-space form.

The autoregressive term in eq. (2) is designed to capture persistence in the output gap and can be motivated by rule-of-thumb consumers or by habit formation (Fuhrer, 1998). The interest-rate elasticity in the I-S curve is crucial for the global dynamics of the model, since monetary policy affects inflation through the impact of the interest rate on the output gap. Note that the inclusion of the long real rate makes the I-S curve a forward-looking one. Future price developments do affect current output through their impact on expected future short term real rates. Since monetary policy and financial asset markets are themselves forward looking, this raises non-trivial estimation issues and cross-equation restrictions.

The long-run solution of eq. (2) implies that the steady-state value for the long real rate is constant: $\rho^{LR} = \frac{\beta_0}{\beta_\rho}$.

2.3 The monetary policy reaction function

Monetary policy rules have became a widely discussed topic (see Taylor, 1999b). The analysis has developed along two lines. The first approach consists in the empirical estimation of reaction functions (Taylor, 1993, Clarida, Gali, and Gertler, 1998a). A second strand of research has investigated the determination of the optimal monetary policy rule (Svensson, 1997, 1998). The optimal policy can generally be expressed as a feedback rule, but the rule depends on the parameters of the economy and on the parameters of the central bank's loss function. Optimal rules depend virtually on any

[2] In empirical application, we assume a constant duration. The average duration over the sample of the 10-year corporate bond is about 7 years for the US as well as for Germany. We therefore set $D = 28$ in the empirical estimates.

[3] Alternatively, eq. (3) states that the expected change in the long real rate is related to the real term spread, as:

$$\Delta\rho_{t+1/t} = \frac{1}{D}\left[\rho_t - \left(i_t + \pi_{t+1/t}\right)\right].$$

variable of the model. In the empirical estimation, we follow the first approach and estimate an instrument rule with a standard Taylor-rule type structure. Theoretically, we would be able to estimate the parameters of the central bank's loss function, but we do not assume that the monetary rule was optimal over the sample period.

In the original formulation of the Taylor rule, monetary policy is represented with a reaction function that relates the short nominal rate to current inflation and output gap:

$$i_{t+1} = \overline{r} + \overline{\pi} + 1.5\left(\pi_t - \overline{\pi}\right) + 0.5\left(y_t - \bar{y}\right) + u_{t+1}$$

where $\overline{\pi}$ and $\bar{y}$ are the central bank's inflation and output-gap targets; $\overline{r}$ is the equilibrium short real rate, assumed to be exogenous. We assume that the central bank does not have an inflation bias, so that the target for the output gap is set to zero ($\bar{y} = 0$).

Several extensions of this baseline specification have been proposed in the literature. Of particular interest in the context of rational expectations is the specification adopted by Clarida, Gali, and Gertler (1998a), which assume that the central bank does not react to observed inflation but to expected inflation. They estimate this equation on a single-equation basis using the Generalized-Method-of-Moments (GMM) approach. In the context of our simultaneous equation model, a more relevant approach is to use the model-consistent inflation expectation $\pi_{t+1/t} = \sum_{k=0}^{K} \alpha_\pi \pi_{t-k} + \alpha_y y_t$, which is available at date t.

Monetary policy is modelled by a partly forward-looking reaction function. The short nominal rate is related to its own lagged value, to expected and lagged inflation and to lagged output gap:

$$i_{t+1} = (1 - \delta_i)\left[\pi_{t+1/t} + (\delta_\pi - 1)\pi_t + \delta_y y_t\right] + \delta_i i_t + \delta_0 + u_{t+1}. \tag{6}$$

This specification includes a lag of the short rate, to capture the high degree of persistence in the interest-rate series. Sack and Wieland (1999) review motivations for smoothing interest rates. They mention measurement errors of macroeconomic variables as a possible explanation. In models with forward-looking expectations, inertial policy can also be optimal. This feature, as underlined by Levin, Wieland, and Williams (1998) and Williams (1999), derives from the forward-looking dynamics of interest rates. The same impact on the long real rate can be attained through a large but short-lived change in the short rate or through a small but expected to be persistent change in short rate. With the latter solution, the short-rate variability is kept moderate. (See for instance Williams, 1999, Woodford, 1999, and also section 4 of the present paper.)

Inflation and output gap are lagged to account for the delay in the observation of the data by the central bank. But we also introduce some forward-lookingness in the behavior of the central bank (see, e.g., Artus, Penot, and Pollin, 1999). The medium-run target is broken into two elements: the $\pi_{t+1/t}$ term implies that the central bank has a target for the short real rate $i_t - \pi_{t+1/t}$, while $(\delta_\pi - 1)\pi_t$ captures the reaction to deviation from the long-run inflation target. Thus, $\pi_{t+1/t} + (\delta_\pi - 1)\pi_t + \delta_y y_t$ can be seen as an error-correction term from the medium-run target for the nominal rate. Ensuring stability of the model implies $(\delta_\pi - 1)$ to be positive.[4]

[4] We therefore transform δ_π parameter into the authorized region $]a, b[$ using the transform $\delta_\pi = f\left(\tilde{\delta}_\pi, a, b\right)$ where $\tilde{\delta}_\pi$ is estimated freely, and the function $f(x, a, b) = a + (b - a)\frac{1}{1+\exp(-x)}$ maps $\mathbb{R}$ into $]a, b[$. Here we choose $a = 0.0001$ and $b = 0.9999$.

The long-run solution of eq. (6) for the short real rate is simply

$$(1-\delta_i)\, i^{LR} = (1-\delta_i)\left[\delta_\pi \pi^{LR} + \delta_y y^{LR}\right] + \delta_0$$

that is $i^{LR} = \delta_\pi \pi^{LR} + \frac{\delta_0}{1-\delta_i}$. Therefore, since $i^{LR} = \rho^{LR} + \pi^{LR}$, the steady-state value for the inflation rate is

$$\pi^{LR} = \frac{\rho^{LR}(1-\delta_i) - \delta_0}{(\delta_\pi - 1)(1-\delta_i)}$$

and the steady-state value for the nominal rate is

$$i^{LR} = \frac{\delta_\pi \beta_0}{\delta_\pi - 1} - \frac{\delta_0}{(\delta_\pi - 1)(1-\delta_i)}.$$

3 Empirical results

3.1 The data

The model is estimated for the US and Germany using quarterly data from 1968:Q1 to 1998:Q4. The data are mainly drawn from OECD databases (BSDB and MEI). Consistently with the quarterly frequency of the model, we use the three-month interest rate as a proxy for the central bank's intervention rate. The output gap is defined by the deviation of (log) real GDP from (log) potential GDP. Potential GDP is computed using a deterministic trend with a break in trend growth rate in 1974. The GDP deflator has been chosen as price indicator. Inflation is therefore defined as the annualized quarterly change in the GDP implicit deflator.

We deal with German reunification in the following way. There is some evidence that the Bundesbank has been focusing on West Germany developments in the first years of German unification. One important reason is that, in addition to the statistical break, inflation data have been distorted by several special factors such as price freeing in East Germany, or fiscal developments at that time (Reckwerth, 1997). Therefore, we use West Germany GDP data over the whole sample period. (West and overall output growth are very similar posterior to reunification.) Regarding the GDP deflator, we use West Germany data for the period up to 1994. Posterior to 1994, West Germany price data are not available and we use overall data. All data for West Germany are drawn from the BIS database. Fig. 1 displays the dynamics of inflation, output gap and short rate in the US as well as in Germany.

Our model has been estimated over a rather long period, in order to consistently estimate structural parameters. However over such a long period, some structural breaks may occur. More precisely, an abundant literature has highlighted that the period 1979-82 corresponds to a major break for the Fed reaction function. The change in the Fed operating procedures during this period (from targeting the Fed funds rate to the targeting of nonborrowed reserves) induced a large increase in both the level and the volatility of interest rates. Judd and Rudebusch (1998) estimate Fed reaction functions over the samples 1979:Q3-1987:Q2 and 1987:Q3-1997:Q4, corresponding to Volcker and Greenspan Fed Chairman tenures respectively. In estimating the Fed reaction function, Clarida, Gali, and Gertler (1998b) obtain substantial differences across periods in the sensitivity of interest rate to changes in expected inflation: during the pre-Volcker period, the Fed used to raise its nominal rate by less than the rise in expected inflation. By contrast, since 1979Q3, real rate has been raised in the wake of increase in expected inflation. Last, Fuhrer (1997a) breaks the 1966-93 sample into three subsamples corresponding to different monetary-policy regimes. Structural breaks are assumed to occur in 1979:Q3 and 1982:Q3. In the case of Germany, dating shifts in monetary policy is less uncontroversial. Clarida, and Gertler (1997) identify four episodes in the German monetary policy, with 1973, 1979, 1983 and 1990 as breaking dates. In particular, 1979 corresponds to a "shift to tightening". Clarida, Gali, and Gertler (1998b) estimate a Bundesbank reaction function over the period March 1979 to December 1993.

In this paper, we introduce a break in the reaction-function parameters between 1979:Q2 and 1979:Q3 for both countries, corresponding to the assumed shift in the monetary policy regime.[5] Reaction functions on each subsample are assumed to have the same explanatory variables (as in eq. (6)), but with possibly different parameter estimates.

3.2 FIML estimation of the two models

We turn now to the results of the FIML estimation of US and German models. Consistent but inefficient estimates of the parameters are obtained individually by OLS and used as starting values for the FIML estimation. The covariance matrix of parameters is computed as the inverse of the Hessian of the log-likelihood function. We freely estimate the covariance matrix of innovations.[6] Table 1 reports parameter estimates and residuals summary statistics for both US and German models. (Estimation is performed using GAUSS software.)

We begin with the US model (panel A). The estimated Phillips curve is fairly standard. We introduced four lags in the price inflation, with the sum of autoregressive terms being constrained to one. The sensitivity of inflation to movements in the output gap is rather large (0.18) and strongly significant, as in Rudebusch and Svensson (1998).

Regarding the I-S curve, the output gap displays the usual dynamics: the first lag on output gap is larger than one, but the second lag is negative, such that the sum of both parameters is lower than one (at about 0.95). The output-gap sensitivity to the long real rate is crucial in our model, since this is the way monetary policy affects the economy. As predicted by the theory, we obtain a negative parameter. Its magnitude (-0.35) is similar to the one obtained in the empirical literature. This is the order of magnitude found, for instance, by Fuhrer and Moore (1995b), and Rudebusch and Svensson (1998).

Concerning the Fed reaction function, two equations are actually estimated. For the 1968-79 subperiod, we find that the Fed reacts to an increase in inflation by an increase in short nominal rate of the same magnitude, since real rate remains unchanged. Since the monetary-policy reaction function determines the order of integration of inflation in the model, the result $\delta_\pi = 1$ (in fact, δ_π is constrained to be slightly larger than 1) implies that long-run inflation is almost unbounded over the first subperiod. In other words, the model is almost non-stationary for the first subperiod, since the largest eigenvalue is very close to one. This result is in line

[5] We also estimated a model with a break in 1982:Q3. However, we then obtained a unit root in the dynamics of the German short rate for the second subperiod.

[6] In a previous version of the paper, we assumed the covariance matrix of innovations to be diagonal, in order to interpret the innovations as structural shocks. Parameter estimates were broadly similar, but estimated standard errors were found to be somewhat larger.

with Clarida, Gali, and Gertler (1998b), who find that the estimated monetary policy rule for the pre-Volcker period permits greater macroeconomic instability than does the Volcker-Greenspan rule. Therefore, they find $\delta_\pi < 1$, which our estimation method rules out. In their calibrated forward-looking model, indeterminacy –rather than instability– may then arise. Indeed, following a rise in expected inflation, the Fed will let short real rates decline and the output gap will rise. The expected rise in inflation will then materialize self-fulfillingly. Note that since inflation is predetermined in our estimated Phillips curve, such an indeterminacy cannot occur. Besides, in the long run, a 1 percent increase in the output gap implies a 3.5 percentage point increase in the short nominal rate. For the second subperiod, corresponding to the post-1979 area, we find that parameters of the reaction function have significantly changed: the short real rate increases strongly after a shock on inflation ($\delta_\pi = 0.43$); but an increase in the output gap has no longer effect on interest rate. The estimated long-run value for the real rate, ρ^{LR}, is 3.4 percent, whereas we obtain 3.3 percent for the long-run inflation rate over the second subperiod. These values are consistent, for instance, with those obtained by Fuhrer (1997a).

Some serial correlation remains in the residuals of the Phillips curve and the monetary-policy reaction function. This result may be due to our choice to breakdown our sample into two subperiods only. Fuhrer (1997a) has highlighted that two structural breaks may be necessary to correctly specify the Fed reaction function. Another explanation may be the introduction of only one lagged value of interest rate in the reaction function. This may insufficiently smooth interest rate (as pointed out by Clarida, Gali, and Gertler, 1998a).

Results for Germany are reported in panel B of Table 1. Concerning the Phillips curve, three lags were introduced in the inflation dynamics. The effect of output gap on inflation is noticeably weaker in Germany (0.11) than in the US, but it is significantly positive.

The I-S curve is estimated with two lags on output gap. German output gap has a much stronger persistence than the US output gap, since we obtain $\beta_{y1} + \beta_{y2} = 0.98$. The effect of interest rate on output gap (β_ρ) is negative (to -0.51) and is larger than the US parameter.[7] In simulation experiment, this larger sensitivity is magnified by the strong persistence of the German output gap.

The Bundesbank's reaction function displays a very stable inflation parameter over the two subperiods under study, at $\delta_\pi = 0.45$. This estimate is very close to the basic Taylor-rule parameter. However, the Bundesbank's reaction to output gap displays very different patterns for the two subperiods. Over the 1965-79Q2 period, the Bundesbank strongly reacts to shocks on the output gap: the δ_y parameter is as high as 1.2. Over the second subperiod, the response to an output-gap shock is much weaker than previously, to only 0.3. Our results for the monetary-policy reaction function are close to those found by Clarida, Gali, and Gertler (1998a), although their results were obtained on monthly data with a different estimation method. To summarize, over the recent period, the Bundesbank has reacted more strongly to output gap than the Fed. The reaction to inflation is similar for both central banks.

[7] Note that, unlike this result, Taylor (1999a) finds that the elasticity of output gap to real interest rate is five times smaller for European countries than for the US. Differences in the data may explain such a difference: Taylor estimates an I-S curve for an aggregate of German, France and Italy from 1971:Q1 through 1994:Q4. Moreover, his output-gap measure is computed using the Hodrick-Prescott filter.

The steady-state value of the German real rate is very close to the US one (to 3.4 percent). Conversely, regarding long-run inflation, the German estimate is much lower (2 percent) than the US estimate. Last, residuals of the monetary-policy reaction function appear to be serially correlated and heteroskedastic.

4 Optimal policy frontiers

We are now interested in computing the optimal policy frontier in the class of Taylor-rule policies with interest-rate smoothing. While this class does not include the globally optimal rule, a large number of studies (Taylor, 1999a, Williams, 1999, among others) have shown that this kind of simple rules is a fairly good approximation of an optimal rule.[8] The optimal policy frontier is here defined as the set of efficient combinations of unconditional variances of the inflation rate, σ_π^2, the output gap, σ_y^2, and the interest rate, σ_i^2, attainable by the central bank. In other studies, the optimal policy frontier has been defined in the inflation/output-gap variance plane (see, for instance, Fuhrer and Moore, 1995b, Fuhrer, 1997a, Ball, 1997). However introducing interest rate in the central bank's loss function is a convenient way to rationalize the observed smoothing of interest rates.[9] In many models, when interest-rate variability is not taken into account, optimal rules generate implausibly large fluctuations in the interest rate (see, e.g., Artus, Penot, and Pollin, 1999). Another motivation for including interest-rate variability in the loss function is the central bank's concern for financial stability.

Two approaches can be implemented to compute efficiency frontiers, while taking into account interest-rate variability. The first one is to introduce interest-rate variability in the loss function. The optimal policy frontier is therefore computed by solving the following optimization program

$$\left\{ \begin{array}{l} \min\limits_{\{\theta\}} \mu_\pi \sigma_\pi^2 + \mu_y \sigma_y^2 + \left(1 - \mu_\pi - \mu_y\right) \sigma_i^2 \\ \text{s.t.} \qquad X_t = M(\theta) X_{t-1} + v_t \\ i_t = z_{t-1}\theta, \qquad z_{t-1} = (\pi_{t-1}, y_{t-1}, i_{t-1})' \end{array} \right. \tag{7}$$

where $\theta = \{\delta_\pi - 1, \delta_y, \delta_i\}$ denotes the parameters in the monetary-policy reaction function. Parameters μ_π and μ_y, such that μ_π, $\mu_y \in [0, 1]$ and $\mu_\pi + \mu_y \leq 1$, are the weights on inflation stabilization around the inflation target, and on output-gap stabilization, respectively. μ_π and μ_y therefore reflect the policymaker's preferences.

Another approach follows Levin, Wieland, and Williams (1998) and Williams (1999). Optimal policy frontiers are then defined as the set of efficient combinations of unconditional variances of the inflation rate and the output gap, subject to the constraint that the unconditional variance of the short rate should not exceed a given value k^2. The optimization program then becomes:

$$\left\{ \begin{array}{l} \min\limits_{\{\theta\}} \lambda \sigma_\pi^2 + (1 - \lambda) \sigma_y^2 \\ \text{s.t.} \qquad X_t = M(\theta) X_{t-1} + v_t \\ i_t = z_{t-1}\theta, \qquad z_{t-1} = (\pi_{t-1}, y_{t-1}, i_{t-1})' \\ \sigma_i^2 \leq k^2 \end{array} \right. \tag{8}$$

[8] See for instance Svensson (1998) for the analysis of more general monetary policy rules, in an open-economy framework.

[9] An alternative approach is to restrict the policy rule to an equation for the first-difference of the interest rate (e.g. Fuhrer and Moore, 1995).

where $\lambda \in [0, 1]$ is the weight on inflation stabilization around the inflation target.[10]

In the following, we will use both approaches in turn, because each one provides some insights. Program (8) appears to be best suited for the graphical representation of policy frontiers. Indeed, in the inflation / output-gap variance plane, each optimal frontier obtained for a given k corresponds actually to a contour line in the third interest-rate variance dimension. Another advantage of the second approach is that k^2 can be set equal to the interest-rate variance under the estimated policy rule. On the other hand, the approach defined by program (7) allows to compare policy rules in the two countries for the same preference parameters, regardless of the respective variances of the macroeconomic shocks in the two countries.

Since we are dealing with a small, linear model, we are able to evaluate an analytic expression for the unconditional variances of the model variables. This approach gives more accurate results than simulation-based methods. As shown in Appendix 1, the model can be written as

$$X_{t+1} = M(\theta) X_t + v_{t+1}$$

where X_t is the vector of all model variables, and v_t is a vector of serially uncorrelated disturbances with mean zero and finite diagonal variance matrix Ω. Then the unconditional contemporaneous covariance matrix of X_t, denoted by V, is given in vector form by

$$Vec(V) = [I - M \otimes M]^{-1} Vec(\Omega). \tag{9}$$

Unconditional variances for the inflation rate, the output gap and the interest rate are then obtained by selecting the appropriate component in $Vec(V)$. For a given interest-rate variability k, we determine the associated optimal-policy frontier as follows. For each value of λ varying from 0 to 1, we solve the optimization program in eq. (8): we start with an initial guess for the policy-rule parameters θ, obtain the reduced-form solution matrices M and Ω, compute the unconditional moments V and the value of the objective function. We then iteratively update the parameter vector θ until an optimum of the objective function is obtained.

Note that, since we solve the forward-looking model at each step, we choose the optimal policy rule among the stabilizing rules. (All variables must have a finite unconditional variance.) In particular, this rules out the case of a central bank under-reacting to the inflation rate.

In evaluating the optimal monetary policy, we only consider simple policy rules of the form given by eq. (6). Although it is a more general rule than the standard Taylor rule, since interest-rate smoothing is allowed, it remains a rather specific rule, because the optimal reaction function does not depend on all state variables. Furthermore, since we use a closed-economy framework, our model is not suited to evaluate the role of the exchange rate (or of foreign interest rates) in monetary-policy rules. As pointed out by Ball (1998) and Taylor (1999a), the exchange rate can be added to the policy rule either because the central bank uses a monetary condition index, defined as a weighted average of the interest rate and the exchange rate, or because the exchange rate is added as a variable to the policy rule.[11] Levin, Wieland, and Williams (1998) compare simple policy rules (based on the inflation rate, the output gap and the interest rate as instruments) and complex policy rules (incorporating all

[10] Williams (1999) reports that measuring interest-rate variability by the variance of the level of the interest rate or by the variance of the change in the interest rate gives similar optimal frontiers.

[11] Considering this type of monetary policy for the ECB, Taylor (1999a) finds no advantage for such a rule as compared to the standard Taylor rule.

available information in state variables). They conclude that complex rules slightly reduce inflation and output-gap variances, but that such benefits can be offset by the lower degree of transparency associated with complex rules.

4.1 Results for the US optimal monetary-policy frontier

Optimal policy rules for both the Fed and the Bundesbank are reported in Table 2. This table reports the optimal reaction-function parameters and the unconditional standard deviations computed for different values of the upper bound for σ_i: $k = 4.7$ (close to the interest-rate unconditional standard deviation under the last subsample estimated monetary policy), 5 and 6. Figures 2 display the associated optimal policy frontiers.

Regarding the US optimal monetary-policy frontier, the estimated values for unconditional standard deviations fall in the range of previous studies by Fuhrer (1997a), Levin, Wieland, and Williams (1998), Williams (1999), Rudebusch and Svensson (1999). Differences between unconditional standard deviations obtained in these various papers and our paper can be mainly explained by the sample used for the estimation and, to some extent, by the specification of the model. As in most papers, our estimated model tends to predict rather large values for unconditional variances. As it appears clearly in eq. (9), unconditional variances depend on both conditional variances and dominant roots in the system.[12] More precisely, the larger the conditional variances, and the larger the dominant roots, the larger are the unconditional variances of the variables in the system. In section 3, we have seen that the model dynamics is quite persistent. Thus lack of precision in estimating conditional variances is magnified in computing unconditional variances of the model variables. Furthermore, in computing efficient frontiers, we include the estimated conditional variance of the reaction function. We therefore consider 'monetary-policy shocks' to be a fully fledged source of variability. In practice however, removing the monetary-policy shock variance from the computation mainly reduces the interest-rate unconditional variance, but does not affect significantly the inflation / output-gap variance trade-off.

The estimated inflation and output-gap variances display some usual features. First, the Fed faces a clear inflation / output-gap variance trade-off, which would be all the more favorable if it would allows for a higher interest-rate volatility. The optimal frontier obtained for $k = 6$ corresponds, in the optimization program (7), to a very low weight on interest-rate smoothing (with $1-\mu_\pi-\mu_y < 0.1$). If we consider now decreasing upper bounds (or increasing weights on interest-rate smoothing), the set of attainable combinations of inflation / output-gap variance decreases. For instance, for $k = 4.7$, the inflation standard deviation is bounded by 2.6 percent, whereas the output-gap variance is bounded by 2.1 percent. This compares to minimal inflation and output-gap standard deviations of 2.2 percent and 1.7 percent in the case $k = 6$. Furthermore, it appears that, for the case $k = 6$, the optimal frontier implies very large output-gap variance penalties (in fact infinite penalties) for inflation standard deviations below 2 percent. Conversely, it implies very large inflation variance penalties for output-gap standard deviations below 1.9 percent. Above these bounds, we find rather balanced policies, with similar weights on inflation and output gap.

Fig. 2a also displays the estimated actual policy, summarized by the combination of unconditional variances at the parameter estimates. The estimated actual policy

[12] In a simple univariate framework, $x_t = ax_{t-1} + \varepsilon_t$, where ε_t is an error term with zero mean and σ_ε^2 variance, the unconditional variance for x is $\sigma_\varepsilon^2 / \left(1 - a^2\right)$.

is quite far from the computed frontier with no weight on interest-rate variability. But if we include some concern on interest rate, the actual policy appears far closer to an optimal one.

From Table 2, several results are worth noting. First, quite intuitively, when the weight of inflation in the loss function increases, the response of interest rate to inflation increases, while the parameter on output gap decreases. Yet, as Ball (1998), we find that it is always optimal to put a positive weight on output gap, whatever the central bank's preferences. The output-gap parameter, even for large interest-rate smoothing and large inflation preference parameters, is never smaller than 0.5.

Second, even when the weight on interest-rate smoothing is assumed to be very low, we obtain a large smoothing parameter δ_i, at about 0.7 in the US and 0.8 in Germany. This is consistent with the result highlighted by Levin, Wieland, and Williams (1998), deriving from the forward-lookingness of interest rates. Interest-rate smoothing helps to stabilize the economy by generating expectations of persistent rise (or decrease) in short term interest rates. This reduces the initial impact of shocks due to the forward-lookingness of aggregate demand, embodied here in long term interest rate.

While optimal policy rules have rather large parameters, they do imply a sensible dynamics when integrated in the model. We illustrate this issue by performing a simulation experiment, with a demand (I-S) shock on each model, for the estimated as well as the optimal policy rules. We retain balanced preferences, with parameters $1 - \mu_\pi - \mu_y = 0.3$, $\mu_\pi = \mu_y = 0.35$ in program (7), so that the reaction-function parameters are $(\delta_\pi - 1, \delta_y, \delta_i) = (0.9; 0.9; 0.7)$. To perform the simulation, we assume that the aggregate demand is not affected contemporaneously by price shocks or monetary-policy shocks, so that the shock on the I-S curve can be identified to a structural demand shock. As shown in Fig. 3, the adjustment is more rapid under the optimal rule: the output gap crosses zero on the third year of simulation. Moreover, the inflation peak is twice lower and inflation does not overshoot the target.

4.2 Results for the German optimal monetary-policy frontier

The results obtained for the German model are similar to those obtained for the US and we mainly emphasize the differences. Panel B of Table 2 reports the optimal reaction-function parameters and the unconditional standard deviations computed for different values of the upper bound for σ_i: $k = 4.7$, 5 (a value close to the interest-rate unconditional standard deviation under the last subperiod estimated monetary policy) and 6. Fig. 2b displays the corresponding optimal policy frontiers.

The first point to note is that the above feature concerning the level of unconditional variances is emphasized for the German optimal policy frontier. The German unconditional variances are larger than in the US. This result is mainly due to the large persistence in the model variables (in particular regarding the output-gap equation), rather than to large conditional error variances. If we consider first a given level of interest-rate variability, we find that inflation and output-gap unconditional standard deviations are systematically larger for Germany than for the US. Thus, to obtain a given level of inflation and output-gap variability, the Bundesbank has to accept a larger interest-rate variability than the US. We obtain such a feature whatever the level of interest-rate unconditional variance.

Our main result is that the German optimal policy is more persistent and slightly more aggressive in the long run than the US optimal policy. Consider the case of the same balanced preference set $1 - \mu_\pi - \mu_y = 0.3$, $\mu_\pi = \mu_y = 0.35$ (Table 3) for both countries. Then, the optimal reaction functions have the following parameter vectors $\theta = (\delta_\pi - 1, \delta_y, \delta_i) = (0.89; 0.87; 0.71)$ for the Fed and $\theta = (0.93; 0.94; 0.78)$ for the Bundesbank. In the German case, the optimal interest-rate smoothing parameter δ_i is between 0.75 and 0.80 for all policy rules. This result reflects the fact that the autoregressive parameter should be high, in order to make full use of the 'expectation channel' mentioned above. On the other hand, the value for δ_i is bounded by 1 and unconditional variances grow dramatically for large values of δ_i.[13] The benefits of interest-rate smoothing appear to be higher in Germany than in the US. This may stem from the strong effect of long real rate on the output-gap equation.

The estimated actual policy appears to be rather far from optimal policy frontiers, even from frontiers obtained with a large interest-rate smoothing (for instance, $k = 4.7$).

4.3 Estimated versus optimal policy rules

Given the gap between estimated and optimal policy rules, we cannot easily recover the preferences of the central bank from our exercise. Yet the results provide some indications. First, they indicate a strong degree of interest-rate stabilization. Second, both central banks appear to be inflation targeters in the sense of Rudebusch and Svensson (1998). Indeed with a high weight on inflation in the central bank's loss function, from Table 3, the reaction function parameter $\delta_\pi - 1$ is twice as large as δ_y. This is the case of the estimated rule of the Bundesbank. In the Fed case, no effect of the output gap was found empirically significant.

Still, the gap to the optimal rule may have several interpretations. First, one may note that, given the standard errors of the estimated parameters, some optimal policy rules actually fall in the range of the estimated rules. Alternatively, the assumed ability of committing to a rule could be questioned. Another possibility is that the estimated reaction function and the computed efficiency frontiers fail to include some relevant constraints in the central bank's loss function. For instance, our reaction function may be biased because of an omitted variable such as the exchange rate, or a constraint on the level of nominal interest rates.

A last interpretation relies on model uncertainty. Our results indicate that the optimal monetary policy would require larger reaction-function parameters than the estimated one. This may indicate that central banks have underestimated the degree of persistence of shocks over the sample period.[14]

4.4 The robustness of the German monetary-policy frontier

This section investigates the issue of robustness to parameter uncertainty, focusing on the German case. Computed optimal frontiers may be sensitive to different non-policy structural parameters, since our monetary policy evaluation is essentially model-specific: parameters may be imprecisely estimated and some model equations may

[13] We recall that the class of rules we evaluate is somewhat restrictive, since it does not include the first-difference rule studied by Fuhrer (1997a) or Williams (1999).

[14] Another approach to parameter uncertainty relies on defining a probability distribution over the model parameters. In such a context, a gradual monetary policy is shown to be optimal over all models under consideration (Sack and Wieland, 1999, and Rudebusch, 1999).

be inappropriate.[15] We therefore measure the robustness of the computed monetary-policy frontier with respect to key model parameters. Three key parameters for the design of monetary policy in a closed economy are the sensitivity of inflation to movements in the output gap (α_y), the interest-sensitivity of the I-S curve (β_ρ), and the persistence of the output-gap equation ($\beta_{y1} + \beta_{y2}$).

To measure the effect of parameter uncertainty in Germany, we vary each key parameter (α_y, β_ρ and $\beta_{y1} + \beta_{y2}$) in turn by $\pm$ one standard deviation, while all other model parameters and the error covariance matrix are left unchanged. We then compute the corresponding optimal policy frontier. In computing this optimal frontier, we use the optimization program (7), that includes explicitly interest-rate smoothing into the objective function. We set $1 - \mu_\pi - \mu_y = 0.3$, which yields an interest-rate unconditional standard deviation close to 4.9 percent, the interest-rate standard deviation obtained with the estimated monetary policy.[16] Notice that we vary β_{y1} and β_{y2} parameters, so that the sum $\beta_{y1} + \beta_{y2}$ varies by $\pm$ one standard deviation (yielding 0.91 and 1.05).[17] Tables 4 to 6 and Fig. 4 to 6 display the effect of a change in these parameters on the optimal policy frontier.

Increasing the α_y parameter (from 0.11 to 0.16) moves the optimal frontier inward toward to origin (Table 4, Fig. 4). Thus, for given weights μ_π and μ_y, unconditional variances for the inflation rate and the output gap are lowered, by about 5 percent and 15 percent, respectively. This is because the central bank is more aggressive in terms of δ_π and δ_y parameters. Raising these parameters allows to take advantage of the larger sensitivity of inflation to movements in the output gap. The overall result is a slight increase in the interest-rate unconditional variance. We note that an increase in the α_y parameter implies a flattening of the optimal frontier. Therefore, lowering inflation variance has a slightly smaller cost in terms of output-gap variance.

When the β_ρ parameter is increased in absolute value (from -0.51 to -0.84), we obtain a quite different pattern (Table 5, Fig. 5). As in the case of increasing α_y, the monetary policy gains a better control over the economy. But unlike the previous case, a large interest-sensitivity of the I-S curve allows the central bank to lower the inflation-rate and the output-gap parameters in the reaction function, while at the same time decreasing unconditional variances for the inflation rate and the output gap (by about 5 percent in most cases). Simultaneously, since output gap is more reactive to movement in the long real rate, the central bank is able to decrease its interest-rate smoothing and the unconditional variance of interest rate.

Let turn now to the case where persistence in the output gap is lowered (from 0.96 to 0.91). A strong decrease is obtained in both inflation and output-gap parameters in the reaction function, whereas unconditional variances on the inflation rate and the output gap remain basically unchanged (Table 6, Fig. 6). The central bank is thus able to obtain the same result in terms of unconditional variances with a much less aggressive monetary policy, allowing the interest-rate unconditional variance to

[15] A more in-depth sensitivity analysis should also review the issue of uncertainty in the measurement of the output gap.

[16] We prefer to use the optimization program (7) rather than program (8), because varying a structural parameter does not change the weight of interest rate in the central bank's objective function, whereas it affects the attainable interest-rate unconditional variances. Therefore, after a change in a structural parameter, the central bank adjusts reaction-function parameters to attain a new combination of unconditional variances of the inflation rate, the output gap and the short rate.

[17] We recall that values larger than 1 are admissible for the autoregressive sum ensuring stationnarity of the output gap.

decrease significantly. We therefore obtain a reaction function that is significantly closer to the empirical estimate. For large values of the weight on inflation in the loss function, the output-gap parameter falls below the empirical estimate of 0.27. So we may argue that the estimated reaction function is consistent with a lower degree of persistence in the demand shock.

5 Conclusion

This paper considers a structural model with model-consistent expectations designed to study US and German monetary policies. The model has a standard I-S curve / Phillips curve / interest-rate rule structure. We estimate this model on quarterly data from 1968 through 1998. Our results for the US economy are rather close to previous work (in particular, Fuhrer and Moore, 1995b, for the I-S curve, Rudebusch and Svensson, 1998, for the Phillips curve, and Clarida, Gali, and Gertler, 1998a, for the reaction function). Compared with the estimated US model, the German Phillips curve is found to be less sensitive to the output gap. Conversely, the output gap reacts to the long real rate more strongly. Over the recent period, the German reaction function put more emphasize on output-gap movements, but we also obtain a strong interest-rate smoothing.

Then, we compute optimal monetary rules and frontiers for both countries. We find that, consistently with the estimated reaction functions, optimal monetary policy implies a strong degree of interest-rate smoothing. This feature derives from the forward-looking dynamics of long real rates. As highlighted by Levin, Wieland, and Williams (1998) and Williams (1999), a small but expected to be persistent change in short rate allows to stabilize the economy while keeping the short-rate variability moderate. We find that the optimal degree of interest-rate smoothing is higher for the German economy than for the US. This rationalizes the higher degree of interest rate smoothing found in the estimated German reaction function.

Another main result is that optimal monetary policy implies a strong reaction to both the inflation rate and the output gap. In particular, optimal parameters on inflation and the output gap are larger than those implied by the Taylor rule. This result, obtained by Ball (1998) using a calibrated model, is confirmed for Germany as well as for the US. Thus, even with a low preference for output stabilization, the output gap should always matter in the reaction function. This finding supports the view that, in spite of the positive weight of the output gap in its estimated reaction function, the Bundesbank has been targeting inflation. Nevertheless, for both countries, estimated parameters for the inflation and output gap are lower than optimal parameters.

Several avenues can be explored to rationalize this result. First, uncertainty on the true model and on parameters of the economy may be an argument in favor of a more gradual response (Sack and Wieland, 1999). Performing sensitivity analysis demonstrates that the estimated policy rule for Germany is consistent with a lower than estimated persistence in the output gap. Second, our results may be due to the rather simple specification of the model, or to the restrictive form of the central bank's loss function. Last, our evaluation relies on the monetary authority committing to one simple rule. This might not be verified over the whole sample period.

6 Appendix: Estimating the model

The Appendix derives the state-space form of the model as well as the solution method, closely following Svensson (1998).

6.1 State-space form

Summarizing the structural model, the I-S curve, the Phillips curve and the monetary policy rule can be expressed as:

$$\pi_{t+1} = \sum_{k=0}^{K} \alpha_{\pi k} \pi_{t-k} + \alpha_y y_t + \varepsilon_{t+1} \quad (10)$$

$$y_{t+1} = \beta_{y1} y_t + \beta_{y2} y_{t-1} - \beta_\rho \rho_{t+1/t} + \beta_0 + \eta_{t+1} \quad (11)$$

$$i_{t+1} = (1-\delta_i)\left[\pi_{t+1/t} + (\delta_\pi - 1)\pi_t + \delta_y y_t\right] + \delta_i i_t + \delta_0 + u_{t+1}. \quad (12)$$

The dynamic of expected long real rate is as follows:

$$\rho_{t+1/t} = \frac{1+D}{D}\rho_t - \frac{1}{D}\left(i_t - \pi_{t+1/t}\right). \quad (13)$$

To set up the model in a state-space form, three types of variables have to be distinguished: the $(n_1, 1)$ vector of predetermined variables X_t, the $(n_2, 1)$ vector of forward-looking variables x_t and the $(n_3, 1)$ vector of measurement variables Y_t. This last vector is introduced in order to allow for some unobserved variables (some time-varying risk premia, for instance) and some additional lags. In the context of the present model, we do not introduce such unobserved variables, but we incorporate extra lags. Therefore, measurement variables Y_t are a subset of predetermined variables X_t. We have $n_1 = 7$, $n_2 = 1$ and $n_3 = 3$, and the three vectors are the following:

$$\begin{aligned} X_t &= (\pi_t, \pi_{t-1}, \pi_{t-2}, \pi_{t-3}, y_t, y_{t-1}, i_t)' \\ x_t &= (\rho_t)' \\ Y_t &= (\pi_t, y_t, i_t)'. \end{aligned}$$

We denote by $Z_t = (X_t', x_t')'$, of dimension $(n, 1)$, where $n = n_1 + n_2$, the vector of both predetermined variables and forward-looking variables. Innovations associated to the predetermined variables are $v_t = (\varepsilon_t, 0, 0, 0, \eta_t, 0, u_t)'$ with covariance matrix denoted Ω. We define Σ the covariance matrix of the true innovations $\tilde{v}_t = (\varepsilon_t, \eta_t, u_t)'$.

We can then collect equations (10) to (13) in the following state-space model:

$$\begin{aligned} \begin{pmatrix} X_{t+1} \\ x_{t+1/t} \end{pmatrix} &= AZ_t + \begin{pmatrix} v_{t+1} \\ 0 \end{pmatrix} \\ Y_t &= CX_t + e_t \end{aligned}$$

where A is the (n, n)-matrix of the model parameters and C is a (n_3, n_1) matrix with known elements. The error term e_t is introduced to achieve a general state-space formulation.

The definition of matrices A and C is straightforward from equations (10)-(13). To keep formulas more compact we report the row vectors of matrix A, with $A_{i.}$ denoting the ith row of matrix A. We use the notation e_i for the $(n, 1)$ vector whose ith element is unity and whose other elements are 0.

The dynamics of the Z_t variables can then be summarized in the following way:

$$A = \begin{pmatrix} \alpha_{\pi 1} e_1' + \alpha_{\pi 2} e_2' + \alpha_{\pi 3} e_3' + \alpha_{\pi 4} e_4' + \alpha_y e_5' \\ e_1' \\ e_2' \\ e_3' \\ \beta_{y1} e_5' + \beta_{y2} e_6' - \beta_\rho A_{8.} \\ e_5' \\ (1-\delta_i)\left[A_{1.} + (\delta_\pi - 1) e_1' + \delta_y e_5'\right] + \delta_i e_7' \\ e_8' - e_7' + A_{1.} \end{pmatrix}.$$

6.2 Autoregressive form of the model

To estimate the model, we begin with writing *forward-looking* variables x_t as a function of predetermined variables:

$$x_{t+1} = H X_{t+1} \tag{14}$$

where H has to be defined. We follow Svensson's (1998) iterative solution, starting from an arbitrary initial condition for H_{t+1}. The state-space model can then be written as:

$$\begin{pmatrix} X_{t+1} \\ x_{t+1/t} \end{pmatrix} = A Z_t + \begin{pmatrix} v_{t+1} \\ 0 \end{pmatrix} \tag{15}$$

where A is partitioned conformably with X_t and x_t

$$A = \begin{pmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{pmatrix}.$$

The first operation is to eliminate forward-looking variables of Z_t form the right-hand side of the system, so that current variables only depend on X_t variables. This is achieved by substracting H_{t+1} times the expectation at date t of the upward block of (15) from the inferior block of Z_t

$$x_{t+1/t} - H_{t+1} X_{t+1/t} = (A_{21} - H_{t+1} A_{11}) X_t + (A_{22} - H_{t+1} A_{12}) x_t.$$

Since the left-hand side part is zero according to eq. (14), it follows that:

$$x_t = -(A_{22} - H_{t+1} A_{12})^{-1} (A_{21} - H_{t+1} A_{11}) X_t$$

hence

$$H_t = -(A_{22} - H_{t+1} A_{12})^{-1} (A_{21} - H_{t+1} A_{11}).$$

Starting from an arbitrary initial value H_T, this equation is iterated backward, so that

$$H = \lim_{t \to -\infty} H_t.$$

Therefore, X_{t+1} can be expressed in an autoregressive form:

$$X_{t+1} = M X_t + v_{t+1} \qquad \text{with} \qquad M = A_{11} + A_{12} H. \tag{16}$$

Thus, the model can then be cast in a usual "backward-looking" state-space form, adding to eq. (16) the following measurement equation:

$$Y_t = C X_t + e_t. \tag{17}$$

Model (16)-(17) can be estimated using the full-information maximum likelihood approach. For this model, the measurement eq. (17) is useless here, since all X_t variables are observed. The log-likelihood is therefore written as

$$\log L = -\frac{n_1 T}{2} \log(2\pi) - \frac{1}{2}\sum_{t=1}^{T} \log|\Sigma_t| - \frac{1}{2}\sum_{t=1}^{T} \tilde{v}_t' \Sigma_t^{-1} \tilde{v}_t.$$

The estimation algorithm works in the following way. For each value of A and Σ, the resulting H and M matrices are computed. The log-likelihood function can then be evaluated and maximized over the parameters of matrices A and Σ.

References

[1] Artus, P., A. Penot, and J.P. Pollin (1999), "Quelle règle monétaire pour la Banque Centrale Européenne ?", *Revue d'Economie Politique*, 109(3), 309–385.

[2] Bagliano, F.C., and C.A. Favero (1998), "Measuring Monetary Policy with VAR Models: An Evaluation", *European Economic Review*, 42(6), 1069–1112.

[3] Ball, L. (1997), "Efficient Rules for Monetary Policy", NBER Working Paper 5952.

[4] Ball, L. (1998), "Policy Rules for Open Economy", NBER Working Paper 6760.

[5] Calvo, G. (1983), "Staggered Prices in a Utility-Maximizing Framework", *Journal of Monetary Economics*, 12(3), 383–398.

[6] Clarida, R., J. Gali, and M. Gertler (1998a), "Monetary Rules in Practice: Some International Evidence", *European Economic Review*, 42(6), 1033–1067.

[7] Clarida, R., J. Gali, and M. Gertler (1998b), "Monetary Policy Rules and Macroeconomic Stability: Evidence and some Theory", CEPR Discussion Paper 1908.

[8] Clarida, R., and M. Gertler (1997), "How the Bundesbank Conducts Monetary Policy", in Romer, C., and D. Romer (Eds.), *Reducing Inflation*, University of Chicago Press, Chicago.

[9] Fair, R.C., and E.P. Howrey (1996), "Evaluating Alternative Policy Rules", *Journal of Monetary Economics*, 38(2), 173–193.

[10] Fuhrer, J.C. (1997a), "Inflation/Output Variance Trade-Offs and Optimal Monetary Policy", *Journal of Money, Credit, and Banking*, 29(2), 214–234.

[11] Fuhrer, J.C. (1997b), "The (Un)importance of Forward Looking Behavior in Price Specifications", *Journal of Money, Credit, and Banking*, 29(3), 338–350.

[12] Fuhrer, J.C. (1998), "An Optimizing Model for Monetary Policy Analysis: Can Habit Formation Help?", Federal Bank of Boston Working Paper 98-1.

[13] Fuhrer, J.C., and G.R. Moore (1995a), "Inflation Persistence", *Quarterly Journal of Economics*, 110(1), 127–160.

[14] Fuhrer, J.C., and G.R. Moore (1995b), "Monetary Policy Trade-Off and the Correlation Between Nominal Interest Rates and Real Output", *American Economic Review*, 85(1), 219–239.

[15] Gerlach, S., and F. Smets (1995), "The Monetary Transmission Mechanism: Evidence from G7 Countries", CEPR Discussion Paper, 1219.

[16] Haldane, A., and N. Batini (1998), "Forward-Looking Rule for Monetary Policies", NBER Working Paper 6543.

[17] Judd, J.P., and G.D. Rudebusch (1998), "Taylor's Rule and the Fed: 1970-1997", *FRBSF Economic Review*, 3, 3–16.

[18] Kerr, W., and R.G. King (1995), "Limits on Interest Rate Rules in the IS Model", *Economic Quarterly*, 82(2), 47–75.

[19] King, R.G., and A.L. Wolman (1996), "Inflation Targeting in a St Louis Model of the 21th Century", *Federal Reserve Bank of Saint Louis Review*, May-June, 83–107.

[20] Levin, A., V. Wieland, and J.C. Williams (1998), "Robustness of Simple Monetary Policy Rules under Model Uncertainty", Board of Governors of the Federal Reserve System Working Paper, November.

[21] McCallum, B., and E. Nelson (1996), "An Optimizing IS-LM Specification for Monetary Policy and Business Cycle Analysis", *Journal of Money, Credit, and Banking*, 31(3), Pt. 1, 296–316.

[22] McCallum, B. (1999), "Analysis of the Monetary Transmission Mechanism: Methodological Issues", NBER Working Paper 7395.

[23] Reckwerth, J. (1998), "Inflation and Output in Germany: The Role of Inflation Expectations", Discussion Paper 1/98, Economic Research Group of the Deutsche Bundesbank.

[24] Rotemberg, J. (1982), "Monopolistic Price Adjustment and Aggregate Output", *Review of Economic Studies*, 49(4), 517–531.

[25] Rotemberg, J., and M. Woodford (1998), "An Optimization-Based Econometric Framework for the Evaluation of Monetary Policy", NBER Technical Working Paper 233.

[26] Rudebusch, G.D. (1999), "Is the Fed Too Timid? Monetary Policy in an Uncertain World", Federal Reserve Bank of San Francisco Working Paper 99-35.

[27] Rudebusch, G.D., and L.E.O. Svensson (1998), "Policy Rules for Inflation Targeting", NBER Working Paper 6512.

[28] Rudebusch, G.D., and L.E.O. Svensson (1999), "Eurosystem Monetary Targeting: Lessons from U.S. Data", mimeo.

[29] Sack, B., and V. Wieland (1999), "Interest-Rate Smoothing and Optimal Monetary Policy: a Review of Recent Empirical Evidence", Board of Governors of the Federal Reserve System. Finance and Economics Discussion Series 1999-39.

[30] Sims, C.A. (1992), "Interpreting the Macroeconomic Time Series Facts. The Effects of Monetary Policy.", *European Economic Review*, 36(5), 975–1011.

[31] Svensson, L.E.O. (1994), "Why Exchange Rate Bands? Monetary Independence in Spite of Fixed Exchange Rates", *Journal of Monetary Economics*, 33(1), 157–199.

[32] Svensson, L.E.O. (1997), "Inflation Forecast Targeting: Implementing and Monitoring Inflation Targets", *European Economic Review*, 41(6), 1111–1146.

[33] Svensson, L.E.O. (1998), "Open-Economy Inflation Targeting", CEPR Discussion Paper 1989.

[34] Taylor, J.B. (1979), "Staggered Price Setting in a Macro Model", *American Economic Review*, 69(2), 108–113.

[35] Taylor, J.B. (1993), "Discretion Versus Policy Rules in Practice", *Carnegie-Rochester Conference Series on Public Policy*, 39, 195–214.

[36] Taylor, J.B. (1999a), "The Robustness and Efficiency of Monetary Policy Rules as Guidelines for Interest Rate Setting by the European Central Bank", *Journal of Monetary Economics*, 43(3), 607–654.

[37] Taylor, J.B. (1999b), *Monetary Policy Rules*, University of Chicago Press, forthcoming.

[38] Williams, J.C. (1999), "Simple Rules for Monetary Policy", Federal Reserve Board Working Paper.

[39] Woodford , M. (1999), "Optimal Monetary Policy Inertia", NBER Working Paper 7261.

[40] Yun, T. (1996), "Nominal Price Rigidity, Money Supply Endogeneity and Business Cycles", *Journal of Monetary Economics*, 37(2), 345–370.

Table 1: FIML estimate of the econometric models

	Panel A: The US			**Panel B: Germany**		
Parameter	Estimate	Standard error	*t*-statistic	Estimate	Standard error	*t*-statistic
Phillips curve						
$\alpha_{\pi 1}$	0.597	0.093	6.450	0.287	0.090	3.188
$\alpha_{\pi 2}$	0.079	0.105	0.751	0.394	0.083	4.772
$\alpha_{\pi 3}$	0.208	0.105	1.983	0.319	–	–
$\alpha_{\pi 4}$	0.116	–	–	–	–	–
α_y	0.175	0.046	3.843	0.106	0.053	2.009
I-S curve						
β_0 (x100)	3.395	0.701	4.844	3.366	0.659	5.109
β_{y1}	1.150	0.085	13.483	0.666	0.092	7.224
β_{y2}	-0.200	0.086	-2.333	0.314	0.088	3.571
β_ρ	-0.348	0.215	-1.618	-0.508	0.335	-1.518
Reaction function						
1968-79:Q2						
δ_0 (x100)	0.268	0.163	1.639	-0.149	0.282	-0.527
$\delta_\pi - 1$	0.001	–	–	0.446	0.397	1.123
δ_y	3.545	5.349	0.663	1.210	0.646	1.873
δ_i	0.932	0.118	7.927	0.856	0.067	12.826
1979:Q3-98						
δ_0 (x100)	0.533	0.277	1.925	0.433	0.252	1.720
$\delta_\pi - 1$	0.435	0.171	2.536	0.436	0.315	1.384
δ_y	0.000	–	–	0.272	0.206	1.322
δ_i	0.725	0.057	12.621	0.827	0.064	12.837
Likelihood	-495.439			-562.386		
	Phillips curve	I-S curve	Reaction function	Phillips curve	I-S curve	Reaction function
LBc(12)	22.652	16.721	29.488	16.121	11.663	32.163
p-value	0.031	0.160	0.003	0.186	0.473	0.001
LB2(12)	9.074	15.598	13.728	8.890	16.444	25.271
p-value	0.697	0.210	0.318	0.712	0.172	0.014
	Real rate	Inflation (2^{nd} period)	Nominal rate	Real rate	Inflation (2^{nd} period)	Nominal rate
Steady-state values	3.395	3.350	6.745	3.366	1.971	5.337

Note: Standard errors are heteroscedasticity and autocorrelation consistent. LBc(12) is the Ljung-Box statistic, corrected for heteroskedasticity, obtained by regressing residuals on 12 lags. LB2(12) is the Engle statistic for heteroskedasticity obtained by regressing squared residuals on 12 lags. These statistics are distributed as $\chi^2(12)$. Steady-state values are defined in Section 2.

Table 2: Implied parameters for optimal monetary-policy rules using program (8)

Weights in the loss function	Optimal parameter values			Unconditional standard deviations		
$(\lambda;1-\lambda)$	$\delta_\pi-1$	δ_y	δ_i	σ_π	σ_y	$k=\sigma_i$
Panel A: The US						
(0.00;1.00)	0.63	2.96	0.68	3.68	1.66	6.00
(0.50;0.50)	2.25	2.49	0.71	2.26	2.01	6.00
(1.00;0.00)	2.61	1.47	0.75	2.13	2.38	6.00
(0.00;1.00)	0.63	1.55	0.71	3.21	1.93	5.00
(0.50;0.50)	1.26	1.33	0.73	2.53	2.15	5.00
(1.00;0.00)	1.38	0.86	0.73	2.44	2.39	5.00
(0.00;1.00)	0.60	1.00	0.70	3.10	2.12	4.70
(0.50;0.50)	0.90	0.88	0.72	2.72	2.26	4.70
(1.00;0.00)	0.97	0.64	0.72	2.65	2.42	4.70
Model estimate	0.43	0.00	0.72	3.40	3.10	4.75
Panel B: Germany						
(0.00;1.00)	0.67	2.43	0.76	4.66	1.98	6.00
(0.50;0.50)	2.43	2.59	0.77	2.94	2.61	6.00
(1.00;0.00)	2.55	1.08	0.81	2.59	3.59	6.00
(0.00;1.00)	0.63	1.25	0.77	3.87	2.40	5.00
(0.50;0.50)	1.26	1.33	0.79	3.13	2.75	5.00
(1.00;0.00)	1.32	0.72	0.79	2.89	3.39	5.00
(0.00;1.00)	0.60	0.84	0.77	3.62	2.70	4.70
(0.50;0.50)	0.85	0.85	0.78	3.27	2.89	4.70
(1.00;0.00)	0.91	0.59	0.78	3.11	3.29	4.70
Model estimate	0.43	0.27	0.82	3.80	4.00	4.90

Table 3: Implied parameters for optimal monetary-policy rules using program (7)

Weights in the loss function	Optimal parameter values			Unconditional standard deviations		
(μ_π ; μ_y ; $1-\mu_\pi-\mu_y$)	$\delta_\pi-1$	δ_y	δ_i	σ_π	σ_y	σ_i
Panel A: The US						
Inflation targeter (0.95;0.00;0.05)	2.98	1.63	0.74	2.08	2.38	6.31
Output-gap targeter (0.00;0.95;0.05)	0.63	2.85	0.69	3.64	1.67	5.91
Interest-rate targeter (0.00;0.00;1.00)	0.54	0.36	0.68	3.11	2.51	4.54
Balanced preferences (0.35;0.35;0.30)	0.89	0.87	0.71	2.72	2.26	4.71
Model estimate	0.43	0.00	0.72	3.40	3.10	4.75
Panel B: Germany						
Inflation targeter (0.95;0.00;0.05)	3.20	1.26	0.81	2.51	3.67	6.55
Output-gap targeter (0.00;0.95;0.05)	0.67	3.07	0.75	5.09	1.85	6.58
Interest-rate targeter (0.00;0.00;1.00)	0.56	0.47	0.76	3.46	3.20	4.61
Balanced preferences (0.35;0.35;0.30)	0.93	0.94	0.78	3.24	2.86	4.77
Model estimate	0.43	0.27	0.82	3.80	4.00	4.90

Table 4: Implied parameters for the German optimal monetary-policy rules for various values of α_y, using program (7)

Weights in the loss function	Optimal parameter values			Unconditional standard deviations		
(μ_π ; μ_y ; $1-\mu_\pi-\mu_y$)	$\delta_\pi-1$	δ_y	δ_i	σ_π	σ_y	σ_i
Model estimate	0.21	0.38	0.91	4.93	4.20	4.92
Optimal rule with estimated nonpolicy parameters (α_y=0.106)						
(0.00;0.70;0.30)	0.63	1.16	0.77	3.81	2.46	4.94
(0.35;0.35;0.30)	0.93	0.94	0.78	3.24	2.86	4.77
(0.70;0.00;0.30)	1.15	0.67	0.79	2.97	3.35	4.88
α_y=0.158						
(0.00;0.70;0.30)	0.64	1.30	0.77	3.59	2.24	4.98
(0.35;0.35;0.30)	0.96	1.13	0.78	3.12	2.49	4.92
(0.70;0.00;0.30)	1.20	0.94	0.78	2.92	2.75	5.05
α_y=0.054						
(0.00;0.70;0.30)	0.60	1.01	0.77	4.56	3.00	5.38
(0.35;0.35;0.30)	0.88	0.75	0.78	3.66	3.75	4.88
(0.70;0.00;0.30)	1.06	0.37	0.80	3.16	5.08	4.94

Table 5: Implied parameters for the German optimal monetary-policy rules for various values of β_ρ, using program (7)

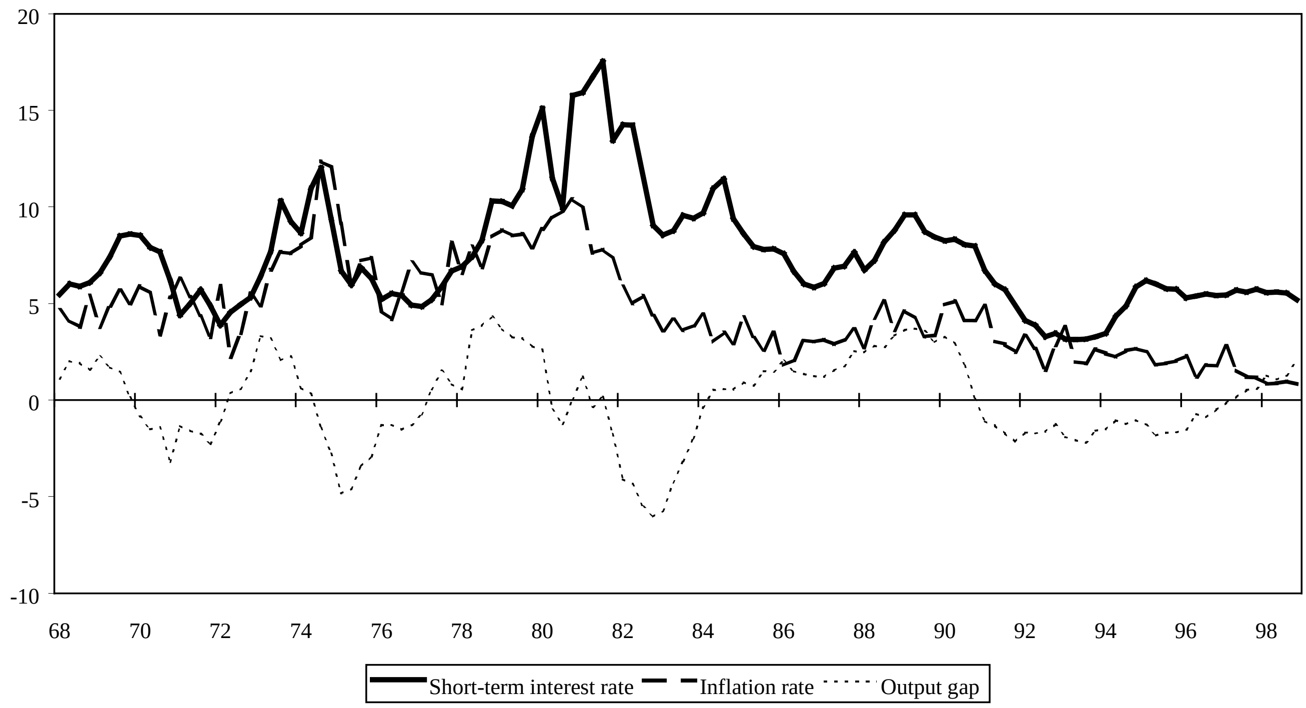
Weights in the loss function	Optimal parameter values			Unconditional standard deviations		
(μ_π ; μ_y ; 1– μ_π–μ_y)	δ_π–1	δ_y	δ_i	σ_π	σ_y	σ_i
Model estimate	0.21	0.38	0.91	4.93	4.20	4.92
Optimal rule with estimated nonpolicy parameters (β_ρ=–0.508)						
(0.00;0.70;0.30)	0.63	1.16	0.77	3.81	2.46	4.94
(0.35;0.35;0.30)	0.93	0.94	0.78	3.24	2.86	4.77
(0.70;0.00;0.30)	1.15	0.67	0.79	2.97	3.35	4.88
β_ρ=–0.84						
(0.00;0.70;0.30)	0.58	1.04	0.70	3.61	2.36	4.39
(0.35;0.35;0.30)	0.86	0.81	0.72	3.02	2.81	4.14
(0.70;0.00;0.30)	1.06	0.50	0.74	2.73	3.47	4.22
β_ρ=–0.17						
(0.00;0.70;0.30)	0.73	1.49	0.86	4.53	2.75	6.80
(0.35;0.35;0.30)	1.08	1.36	0.87	3.94	3.00	6.79
(0.70;0.00;0.30)	1.35	1.20	0.87	3.67	3.24	6.97

Table 6: Implied parameters for the German optimal monetary-policy rules for various values of $\beta_{y1}+\beta_{y2}$, using program (7)

Weights in the loss function	Optimal parameter values			Unconditional standard deviations		
$(\mu_\pi ; \mu_y ; 1-\mu_\pi-\mu_y)$	$\delta_\pi-1$	δ_y	δ_i	σ_π	σ_y	σ_i
Model estimate	0.21	0.38	0.91	4.93	4.20	4.92
Optimal rule with estimated nonpolicy parameters ($\beta_{y1}+\beta_{y2}$=0.98)						
(0.00;0.70;0.30)	0.63	1.16	0.77	3.81	2.46	4.94
(0.35;0.35;0.30)	0.93	0.94	0.78	3.24	2.86	4.77
(0.70;0.00;0.30)	1.15	0.67	0.79	2.97	3.35	4.88
$\beta_{y1}+\beta_{y2}$=1.05						
(0.00;0.70;0.30)	0.71	1.53	0.77	3.93	2.50	5.39
(0.35;0.35;0.30)	1.05	1.35	0.78	3.34	2.86	5.26
(0.70;0.00;0.30)	1.32	1.12	0.79	3.07	3.27	5.41
$\beta_{y1}+\beta_{y2}$=0.91						
(0.00;0.70;0.30)	0.51	0.71	0.75	3.72	2.40	4.60
(0.35;0.35;0.30)	0.72	0.46	0.76	3.15	2.83	4.38
(0.70;0.00;0.30)	0.84	0.14	0.76	2.89	3.37	4.47

Fig. 1: Inflation rate, output gap and short-term interest rate

The US



Germany

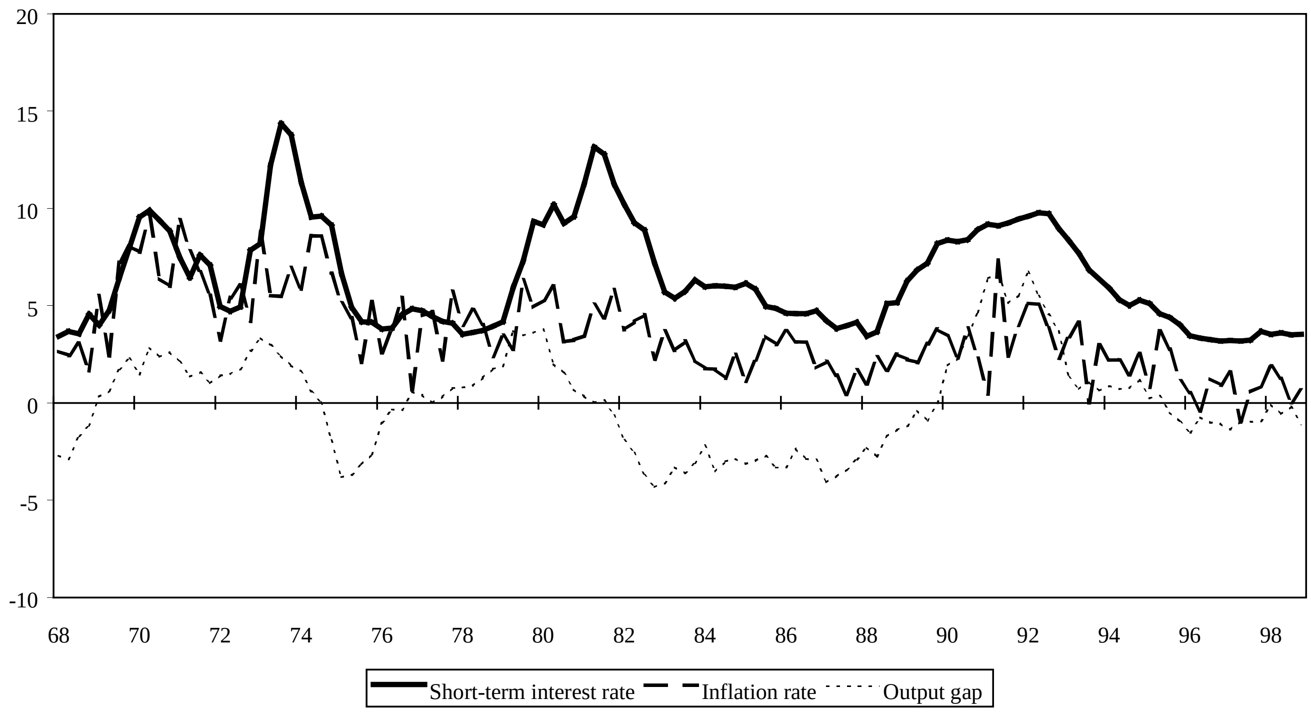


Fig. 2a: The US optimal policy frontier

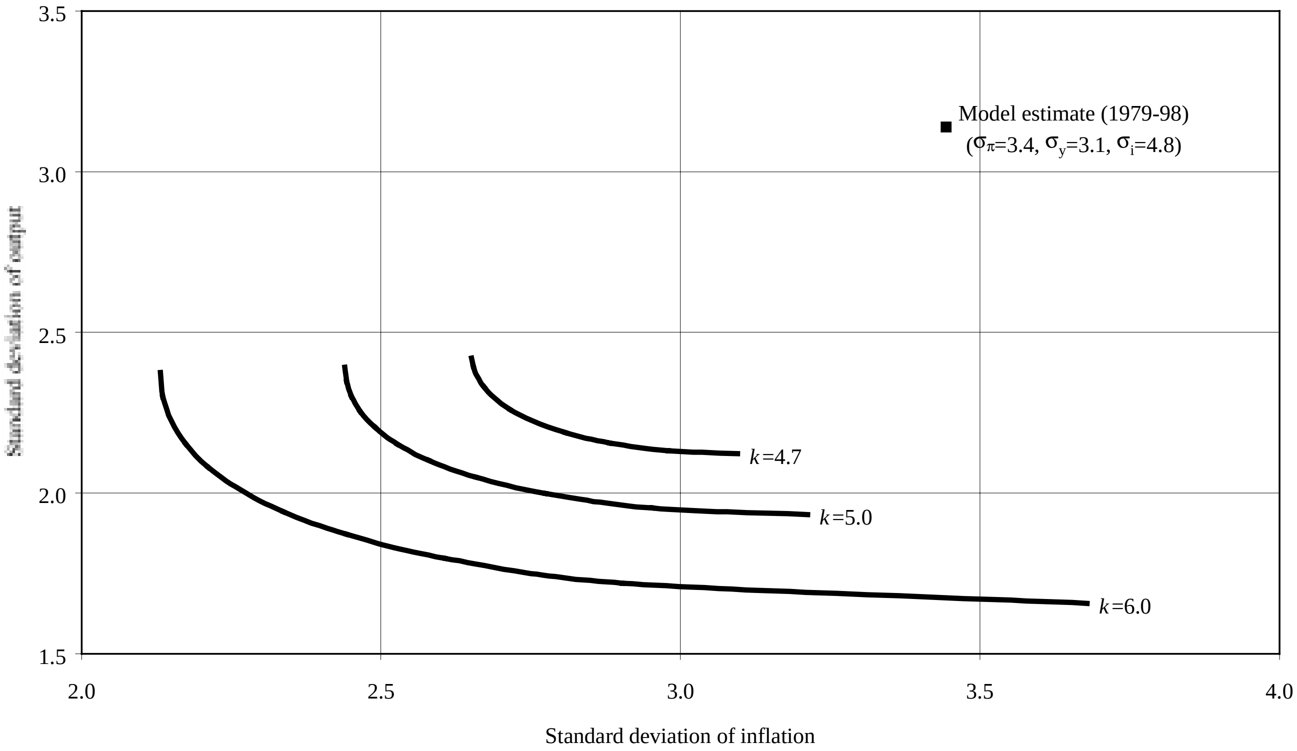


Fig. 2b: The German optimal policy frontier

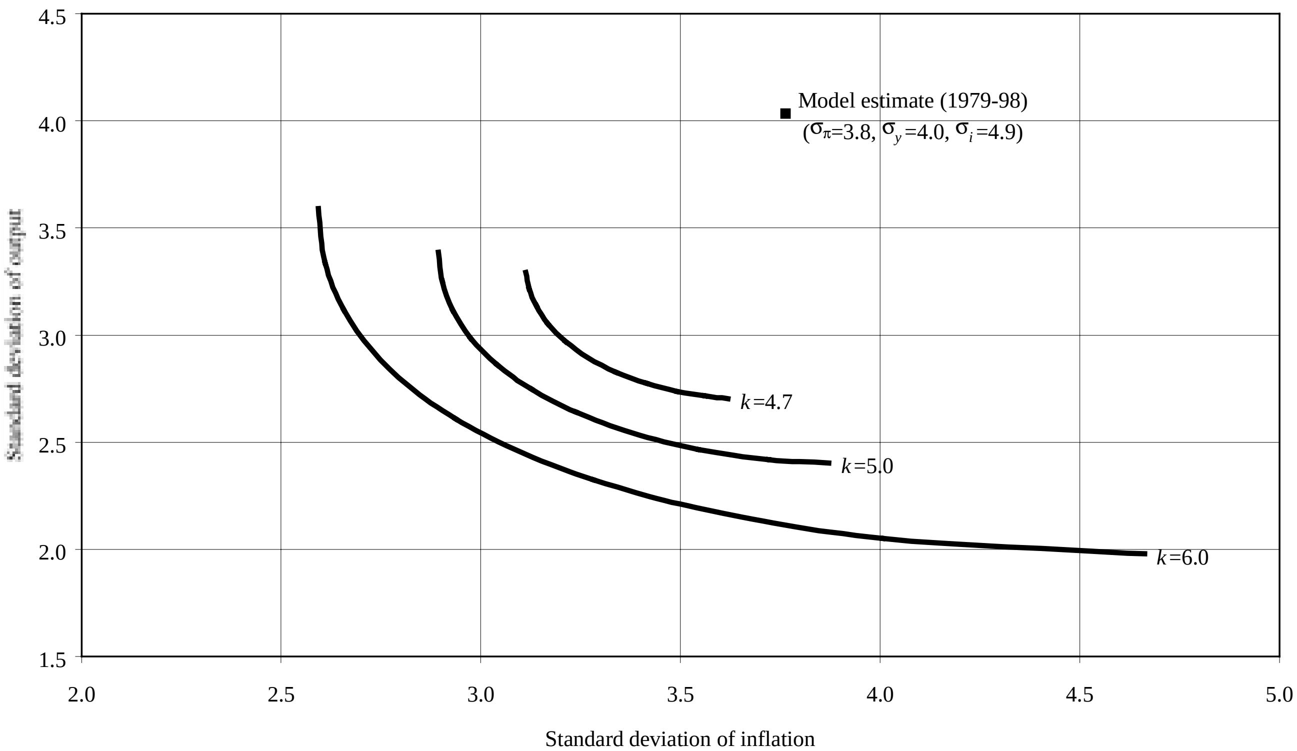
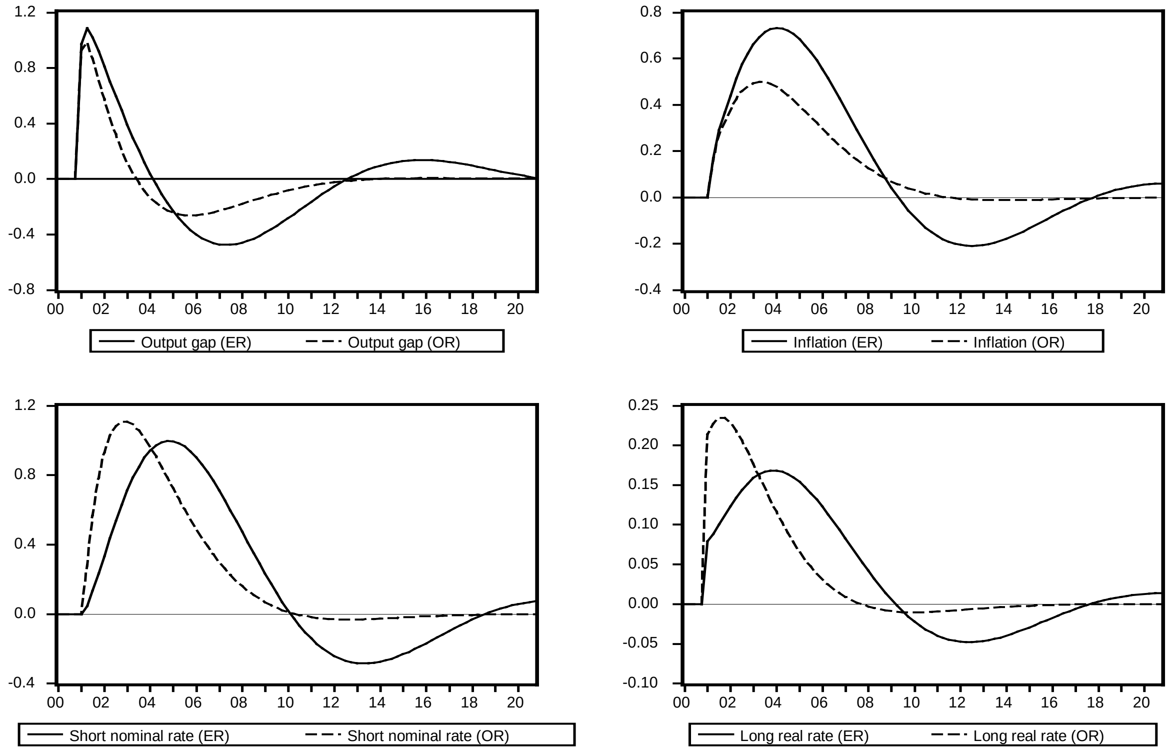


Fig. 3: Simulation of a temporary I-S shock under estimated rule (ER) and optimal rule (OR)

The US



Germany

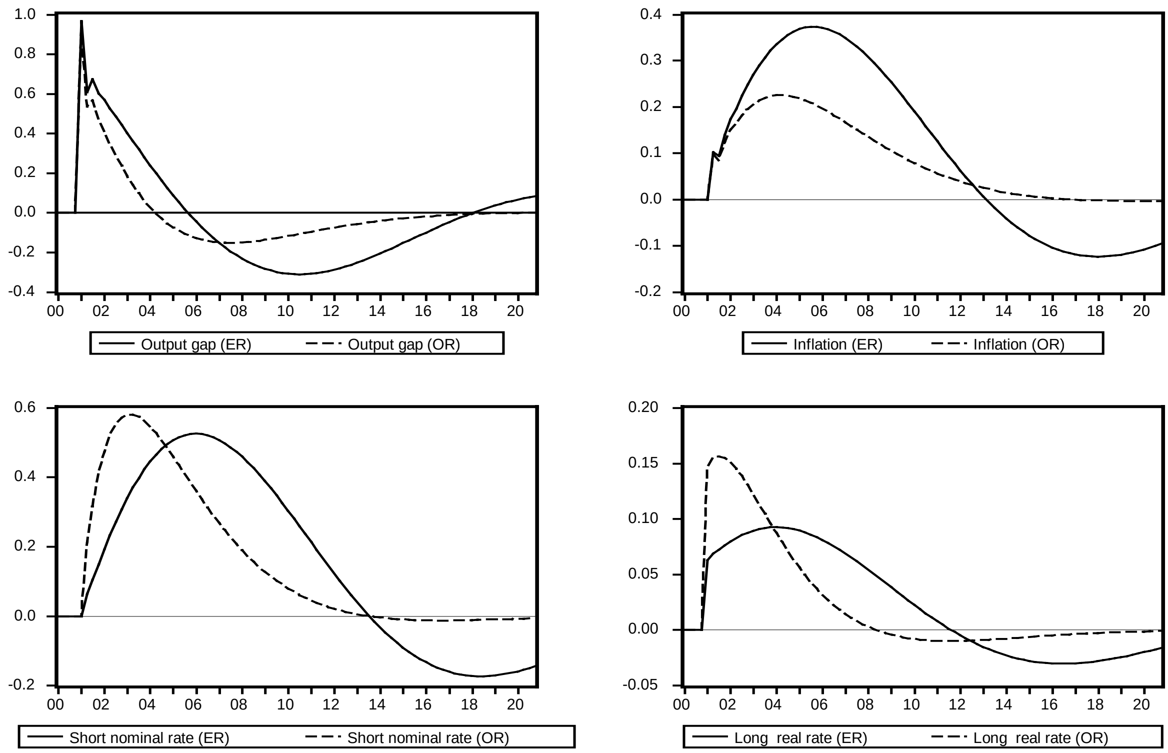


Fig. 4: Shifts in German optimal policy frontier (with μ_i=0.3) - Change in the sensitivity of inflation to movements in the output gap

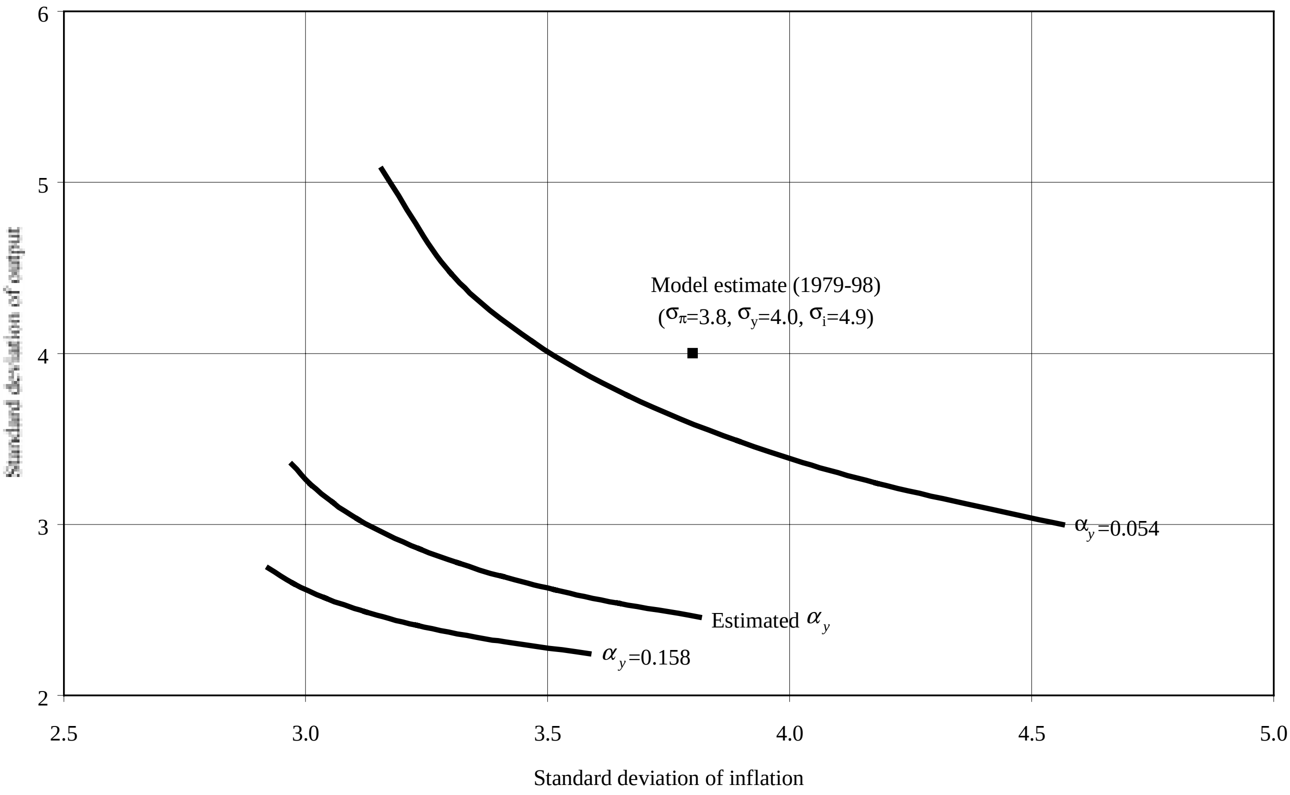


Fig. 5: Shifts in German optimal policy frontier (with μ_i=0.3) - Change in the interest-sensitivity of the I-S curve

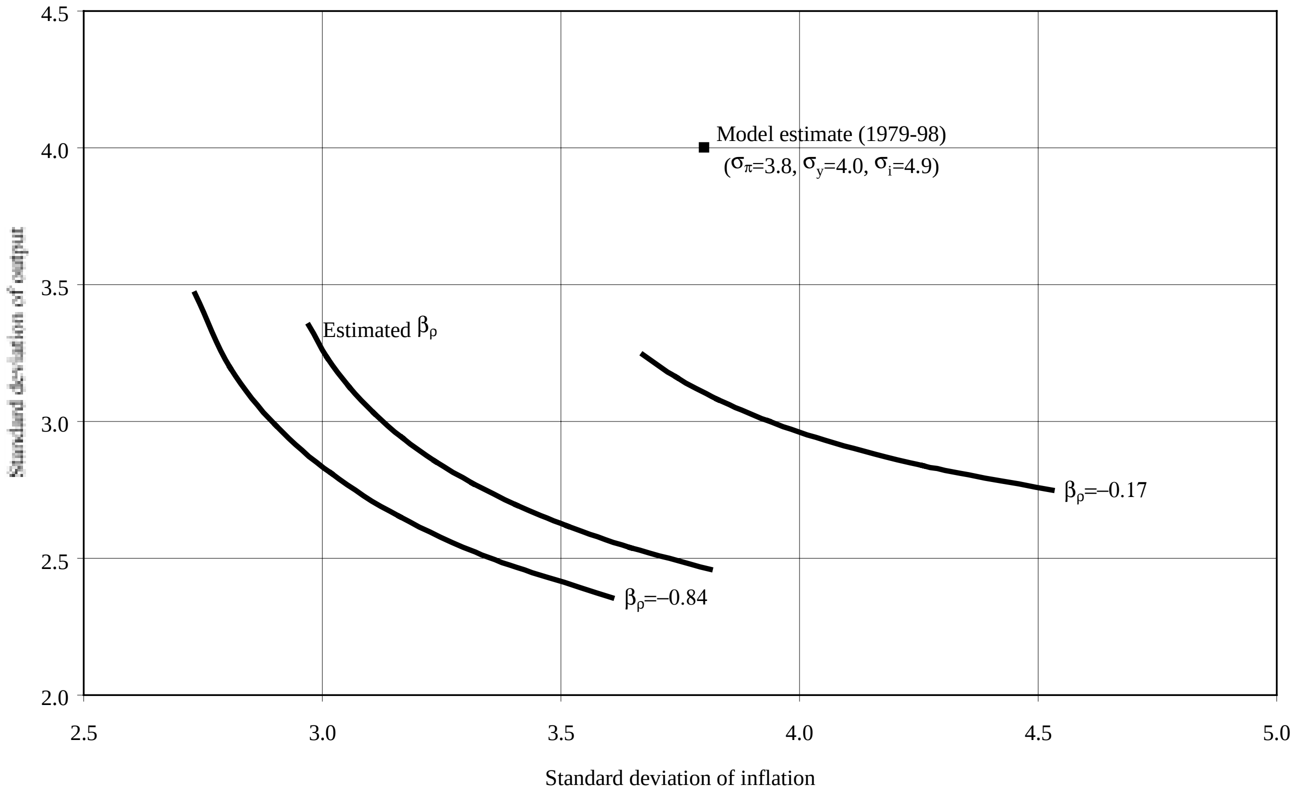
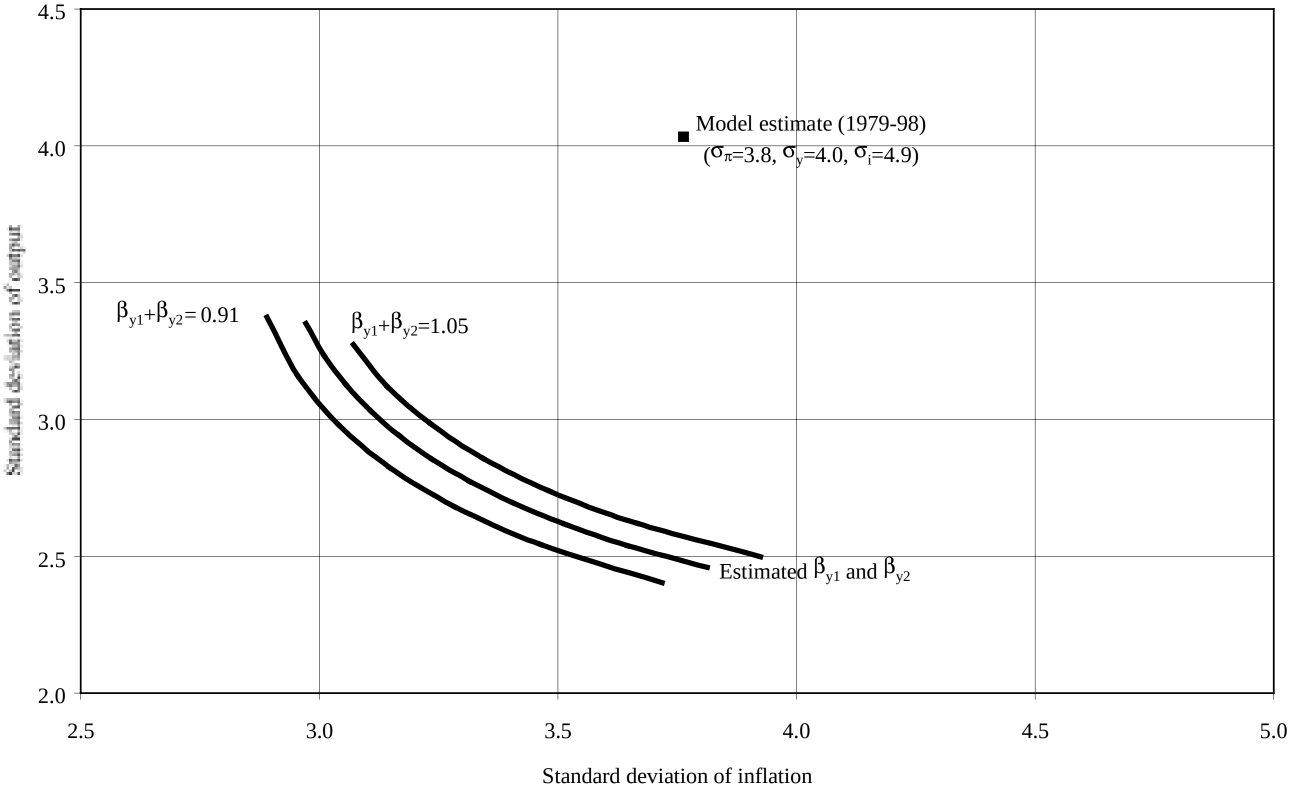


Fig. 6: Shifts in German optimal policy frontier (with μ_i=0.3) - Change in the persistence of the output-gap equation



Notes d'Études et de Recherche

1. C. Huang and H. Pagès, “Optimal Consumption and Portfolio Policies with an Infinite Horizon: Existence and Convergence,” May 1990.

2. C. Bordes, « Variabilité de la vitesse et volatilité de la croissance monétaire : le cas français », février 1989.

3. C. Bordes, M. Driscoll and A. Sauviat, “Interpreting the Money-Output Correlation: Money-Real or Real-Real?,” May 1989.

4. C. Bordes, D. Goyeau et A. Sauviat, « Taux d'intérêt, marge et rentabilité bancaires : le cas des pays de l'OCDE », mai 1989.

5. B. Bensaid, S. Federbusch et R. Gary-Bobo, « Sur quelques propriétés stratégiques de l’intéressement des salariés dans l'industrie », juin 1989.

6. O. De Bandt, « L'identification des chocs monétaires et financiers en France : une étude empirique », juin 1990.

7. M. Boutillier et S. Dérangère, « Le taux de crédit accordé aux entreprises françaises : coûts opératoires des banques et prime de risque de défaut », juin 1990.

8. M. Boutillier and B. Cabrillac, “Foreign Exchange Markets: Efficiency and Hierarchy,” October 1990.

9. O. De Bandt et P. Jacquinot, « Les choix de financement des entreprises en France : une modélisation économétrique », octobre 1990 (English version also available on request).

10. B. Bensaid and R. Gary-Bobo, “On Renegotiation of Profit-Sharing Contracts in Industry,” July 1989 (English version of NER n° 5).

11. P. G. Garella and Y. Richelle, “Cartel Formation and the Selection of Firms,” December 1990.

12. H. Pagès and H. He, “Consumption and Portfolio Decisions with Labor Income and Borrowing Constraints,” August 1990.

13. P. Sicsic, « Le franc Poincaré a-t-il été délibérément sous-évalué ? », octobre 1991.

14. B. Bensaid and R. Gary-Bobo, “On the Commitment Value of Contracts under Renegotiation Constraints,” January 1990 revised November 1990.

15. B. Bensaid, J.-P. Lesne, H. Pagès and J. Scheinkman, “Derivative Asset Pricing with Transaction Costs,” May 1991 revised November 1991.

16. C. Monticelli and M.-O. Strauss-Kahn, “European Integration and the Demand for Broad Money,” December 1991.

17. J. Henry and M. Phelipot, “The High and Low-Risk Asset Demand of French Households: A Multivariate Analysis,” November 1991 revised June 1992.

18. B. Bensaid and P. Garella, “Financing Takeovers under Asymetric Information,” September 1992.

19. A. de Palma and M. Uctum, “Financial Intermediation under Financial Integration and Deregulation,” September 1992.

20. A. de Palma, L. Leruth and P. Régibeau, “Partial Compatibility with Network Externalities and Double Purchase,” August 1992.

21. A. Frachot, D. Janci and V. Lacoste, “Factor Analysis of the Term Structure: a Probabilistic Approach,” November 1992.

22. P. Sicsic et B. Villeneuve, « L'Afflux d'or en France de 1928 à 1934 », janvier 1993.

23. M. Jeanblanc-Picqué and R. Avesani, “Impulse Control Method and Exchange Rate,” September 1993.

24. A. Frachot and J.-P. Lesne, “Expectations Hypothesis and Stochastic Volatilities,” July 1993 revised September 1993.

25. B. Bensaid and A. de Palma, “Spatial Multiproduct Oligopoly,” February 1993 revised October 1994.

26. A. de Palma and R. Gary-Bobo, “Credit Contraction in a Model of the Banking Industry,” October 1994.

27. P. Jacquinot et F. Mihoubi, « Dynamique et hétérogénéité de l'emploi en déséquilibre », septembre 1995.

28. G. Salmat, « Le retournement conjoncturel de 1992 et 1993 en France : une modélisation V.A.R. », octobre 1994.

29. J. Henry and J. Weidmann, “Asymmetry in the EMS Revisited: Evidence from the Causality Analysis of Daily Eurorates,” February 1994 revised October 1994.

30 O. De Bandt, “Competition Among Financial Intermediaries and the Risk of Contagious Failures,” September 1994 revised January 1995.

31. B. Bensaid et A. de Palma, « Politique monétaire et concurrence bancaire », janvier 1994 révisé en septembre 1995.

32. F. Rosenwald, « Coût du crédit et montant des prêts : une interprétation en terme de canal large du crédit », septembre 1995.

33. G. Cette et S. Mahfouz, « Le partage primaire du revenu : constat descriptif sur longue période », décembre 1995.

34. H. Pagès, “Is there a Premium for Currencies Correlated with Volatility ? Some Evidence from Risk Reversals,” January 1996.

35. E. Jondeau and R. Ricart, “The Expectations Theory : Tests on French, German and American Euro-rates,” June 1996.

36. B. Bensaid et O. De Bandt, « Les stratégies “stop-loss” : théorie et application au Contrat Notionnel du Matif », juin 1996.

37. C. Martin et F. Rosenwald, « Le marché des certificats de dépôts. Écarts de taux à l'émission : l'influence de la relation émetteurs-souscripteurs initiaux », avril 1996.

38. Banque de France - CEPREMAP - Direction de la Prévision - Erasme - INSEE - OFCE, « Structures et propriétés de cinq modèles macroéconomiques français », juin 1996.

39. F. Rosenwald, « L'influence des montants émis sur le taux des certificats de dépôts », octobre 1996.

40. L. Baumel, « Les crédits mis en place par les banques AFB de 1978 à 1992 : une évaluation des montants et des durées initiales », novembre 1996.

41. G. Cette et E. Kremp, « Le passage à une assiette valeur ajoutée pour les cotisations sociales : Une caractérisation des entreprises non financières “gagnantes” et “perdantes” », novembre 1996.

42. S. Avouyi-Dovi, E. Jondeau et C. Lai Tong, « Effets “volume”, volatilité et transmissions internationales sur les marchés boursiers dans le G5 », avril 1997.

43. E. Jondeau et R. Ricart, « Le contenu en information de la pente des taux : Application au cas des titres publics français », juin 1997.

44. B. Bensaid et M. Boutillier, « Le contrat notionnel : Efficience et efficacité », juillet 1997.

45. E. Jondeau et R. Ricart, « La théorie des anticipations de la structure par terme : test à partir des titres publics français », septembre 1997.

46. E. Jondeau, « Représentation VAR et test de la théorie des anticipations de la structure par terme », septembre 1997.

47. E. Jondeau et M. Rockinger, « Estimation et interprétation des densités neutres au risque : Une comparaison de méthodes », octobre 1997.

48. L. Baumel et P. Sevestre, « La relation entre le taux de crédits et le coût des ressources bancaires. Modélisation et estimation sur données individuelles de banques », octobre 1997.

49. P. Sevestre, “On the Use of Banks Balance Sheet Data in Loan Market Studies : A Note,” October 1997.

50. P.-C. Hautcoeur and P. Sicsic, “Threat of a Capital Levy, Expected Devaluation and Interest Rates in France during the Interwar Period,” January 1998.

51. P. Jacquinot, « L’inflation sous-jacente à partir d’une approche structurelle des VAR : une application à la France, à l’Allemagne et au Royaume-Uni », janvier 1998.

52. C. Bruneau et O. De Bandt, « La modélisation VAR structurel : application à la politique monétaire en France », janvier 1998.

53. C. Bruneau and E. Jondeau, “Long-Run Causality, with an Application to International Links between Long-Term Interest Rates,” June 1998.

54. S. Coutant, E. Jondeau and M. Rockinger, “Reading Interest Rate and Bond Futures Options’ Smiles: How PIBOR and Notional Operators Appreciated the 1997 French Snap Election,” June 1998.

55. E. Jondeau et F. Sédillot, « La prévision des taux longs français et allemands à partir d’un modèle à anticipations rationnelles », juin 1998.

56. E. Jondeau and M. Rockinger, “Estimating Gram-Charlier Expansions with Positivity Constraints,” January 1999.

57. S. Avouyi-Dovi and E. Jondeau, “Interest Rate Transmission and Volatility Transmission along the Yield Curve,” January 1999.

58. S. Avouyi-Dovi et E. Jondeau, « La modélisation de la volitilité des bourses asiatiques », janvier 1999.

59. E. Jondeau, « La mesure du ratio rendement-risque à partir du marché des euro-devises », janvier 1999.

60. C. Bruneau and O. De Bandt, “Fiscal policy in the transition to monetary union: a structural VAR model,” January 1999.

61. E. Jondeau and R. Ricart, “The Information Content of the French and German Government Bond Yield Curves: Why Such Differences?” February 1999.

62. J.-B. Chatelain et P. Sevestre, « Coûts et bénéfices du passage d’une faible inflation à la stabilité des prix », février 1999.

63. D. Irac et P. Jacquinot, « L’investissement en France depuis le début des années 1980 », Avril 1999.

64. F. Mihoubi, « Le partage de la valeur ajoutée en France et en Allemagne », mars 1999.

65. S. Avouyi-Dovi and E. Jondeau, “Modelling the French Swap Spread,” April 1999.

66. E. Jondeau and M. Rockinger, “The Tail Behavior of Stock Returns: Emerging Versus Mature Markets,” June 1999.

67. F. Sédillot, « La pente des taux contient-elle de l’information sur l’activité économique future ? », juin 1999.

68. E. Jondeau, H. Le Bihan et F. Sédillot, « Modélisation et prévision des indices de prix sectoriels », septembre 1999.

69. H. Le Bihan and F. Sédillot, “Implementing and Interpreting Indicators of Core Inflation : The French Case,” September 1999.

70 R. Lacroix, “Testing for Zeros in the Spectrum of an Univariate Stationary Process: Part I,” December 1999.

71 R. Lacroix, “Testing for Zeros in the Spectrum of an Univariate Stationary Process: Part II,” December 1999.

72 R. Lacroix, “Testing the Null Hypothesis of Stationarity in Fractionally Integrated Models,” December 1999.

73 F. Chesnay and E. Jondeau, “Does correlation between stock returns really increase during turbulent period?,” April 2000.

74 O. Burkart and V. Coudert, “Leading Indicators of Currency Crises in Emerging Economies,” May 2000.

75 D. Irac, “Estimation of a Time Varying NAIRU for France,” July 2000.

76 E. Jondeau and H. Le Bihan, "Evaluating Monetary Policy Rules in Estimated Forward-Looking Models: A Comparison of US and German Monetary Policy," October 2000.

Pour tous commentaires ou demandes sur les Notes d'Études et de Recherche, contacter la bibliothèque du Centre de recherche à l'adresse suivante :

For any comment or enquiries on the Notes d'Études et de Recherche, contact the library of the Centre de recherche at the following address :

BANQUE DE FRANCE
41.1391 - Centre de recherche
75 049 Paris CEDEX
tél : 01 42 92 49 55
fax :01 42 92 62 92
email : thierry.demoulin@banque-france.fr