Policymakers' Revealed Preferences and the Output-Inflation Variability Trade-off: Implications for the European System of Central Banks

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Abstract

This paper explores two aspects of the conduct of monetary policy under a monetary union. First, even if the preferences of policymakers over inflation and output variability are identical across member countries, differences in economic structure will mean different desired policy responses to even a common shock. Second, policymakers may be forced to make important concessions in their preferences over inflation and output variability. To examine these issues, this paper estimates the objective functions that the European national central banks were implicitly maximizing over the fifteen or so years prior to monetary union, as well as the slopes of the inflation-output variability trade-off in each country.

While the slopes of the trade-offs vary dramatically across countries, the objective functions are surprisingly similar, with most countries having weights in excess of three-quarters on inflation variability and less than one-quarter on output variability. Our findings suggest that while differences in economic structure across the Eurosystem countries might make it difficult to formulate a common policy even in the face of common goals, the concessions (in terms of preferences over output and inflation variability) that current inflation-targeting countries such as the U.K. and Sweden would have to make on accession to the EMU are likely to be minimal. (JEL E32, E58)

1 Introduction

The decision by a particular country to join a monetary union is shaped by a myriad of factors. The benefits of joining may include insulation from foreign exchange shocks with major trading partners, increased credibility inherited from union with historically successful central banks, forced fiscal discipline, and possible economies of scale in financial markets. Naturally, these and other benefits are likely to come with certain costs. First, even if the preferences of policymakers over inflation and output variability are identical across member countries, differences in economic structure will mean different desired policy responses to even a common shock. Second, the individual policymakers that comprise the decision-making body of the monetary union may at times be forced to make important concessions in their preferences over the relative stability of output and inflation.

This paper explores these issues using data from seven of the twelve countries currently participating in the European Monetary Union and three non-EMU countries. Our main contribution is to provide an estimate of the objective function that each of the national central banks was implicitly maximizing over the fifteen years or so prior to monetary union, thereby using the data to ascertain the degree to which the preferences over output and inflation variability differed between countries that were explicitly inflation targeting prior to joining the union (or not joining) and those that were not. Our analysis also allows us to gain some understanding of the differences in transmission mechanisms across each of these countries.

The logic of our analysis is as follows. Beginning with a simple quadratic loss function, policy can be viewed as the solution to an optimal control problem in which the interest rate path is chosen to minimize this loss subject to the constraints implied by the structure of the economy. We use the data to go backwards. That is to say, we estimate the structure of the economy and then, assuming actual policy was formed optimally, find the loss function that implies the policy path actually undertaken. While our parameterization of the loss function is very simple, it does allow us to estimate the relative weight national central banks were implicitly placing on output and inflation variability in the formulation of their policies.

We have a full set of results for Eurosystem member countries Belgium, France, Germany, Ireland, Italy, Portugal and Spain, as well as the remaining EU countries Denmark, Sweden, and the U.K.[1] While the slopes of the output-inflation variability trade-offs, which are largely functions of the relative impulse responses of output and inflation to policy innovations, vary quite dramatically across countries, the objective functions are not that different. We estimate that nearly all of the countries have weights at least as large as three-quarters on inflation variability and less than one-quarter on output variability.

Our findings suggest that the concessions (in terms of preferences over output and inflation variability) that current inflation-targeting countries such as the U.K. and Sweden would have to make on accession to the EMU are likely to be minimal. This conclusion is consistent with that of Cecchetti and Ehrmann (1999), who find that the reductions in both output and inflation variability experienced by inflation-targeting countries in recent years has been similar to that experienced by nontargeting European Union (EU) countries, for the likely reason that EU nontargeters increased their focus on inflation as they approached the start of the monetary union in 1999. It is important to emphasize however, that our conclusion that accession would impose little costs for inflation targeting countries in terms of preferences does not necessarily extend to other types of costs. In particular, if the economic structure of the U.K. or Sweden, for example, differed substantially from the average or sum of the economic structures of the current EMU countries, then joining the EMU and surrendering an independent monetary policy will be costly regardless of how similar the average inflation aversion of the EMU central banks is to that of policymakers in the U.K. or Sweden.

Our work is closely related to several previous papers. Rudebusch and Svensson (1998), for example, estimate output-inflation variability frontiers and then, assuming a particular structure for policymakers' preferences, use their estimated frontiers

[1]We present results for as many countries as data and our structural estimation allows.

to examine the relative efficiency of different simple policy rules. Using a similar methodological framework, Rudebusch (1998) explicitly incorporates uncertainty into the analysis in order to understand why Taylor-type rules estimated from historical data imply more cautious monetary policy than does an optimal rule. Our work departs from these two papers in that we infer the parameters of the objective function rather than assume them.

Favero and Rovelli (2001) use a different methodology to estimate the relative importance of output and inflation variability in policymakers' objective functions, and conclude that output stabilization does not enter independently in the U.S. Federal Reserve's objective function. While our purpose lines up closely with that of Favero and Rovelli, we not only use a different methodological approach, but also apply our technique to a wider range of countries. Our analysis leads us to conclude that output stabilization has entered as an independent argument in the objective functions of each of the central banks we consider, though for many countries the weight on output stabilization has been quite small.

The remainder of the paper contains five sections. In Section 2, we present price and output data for the countries of the European Community. The main purpose here is to compare the cyclical behavior of inflation and output across these countries. Section 3 describes the simple optimal control problem that we assume is the basis for policy. Using an instrument such as an interest rate, together with knowledge of the evolution of the economy (aggregate output and the price level), the policymaker is assumed to minimize some combination of the future variability in output and prices. This results in a rule for adjusting the control variable as a function of previous values of the state variable and of the control variable itself. Our goal of recovering the objective function requires that we estimate a model of the economy. This is the task in Section 4 where we describe and report the estimation of a set of structural vector autoregressions that give us the necessary information. Section 5 reports and discusses the major results in the paper: the estimate of the objective function as derived from both a simple static version of our model and a more complex dynamic version. We also include an examination of a term in the loss function that penalizes movements in the policy instrument, thus creating an incentive to smooth interest rates. The final section concludes.

2 Inflation and the Business Cycle Across EMU Countries

As noted in the introduction, the ability of the Eurosystem to implement an effective monetary policy depends on the extent to which movements in output and inflation are correlated across participating countries, as well as on the degree to which there is accordance in the timing and response to monetary shocks and the preferences of monetary policymakers over output and inflation variability. This section takes a broad look at the former issue, while the next three sections explore the latter.

Does it appear that output cycles moved closely across the group of countries in the European Monetary Union prior to the start of the EMU? To provide evidence on this, we apply the Baxter and King (1999) filter to individual country industrial production data in order to construct the business cycle component for each country. The Baxter-King procedure, as we have implemented it, removes all fluctuations shorter than eighteen months or longer than eight years.[2] The left panel of Table 1 reports the correlation coefficients for each of these countries against Germany, France and Italy. While the bulk of the correlations are above 0.6, there are some notable exceptions. In particular, Finland, Portugal and Ireland seem to have relatively independent cycles, differing markedly from at least one of the larger countries.

Figures 1 and 2 provide examples of some of the differences across countries. In Figure 1 we plot the cyclical component of industrial production for Germany, Ireland, Luxembourg, Portugal and Spain. While Germany and Luxembourg appear to track each other quite closely, Portugal and Ireland seem out of phase both with one another and with Germany. Throughout the 1980s, Spain and Germany appear to move in

[2]The use of alternative filters for extracting a business cycle component does not qualitatively affect our results.

virtually opposite directions. Figure 2 plots the filtered ip series for Germany and the four EU countries that weren't part of the first round of EMU participants. Here again, one is struck by the asynchronous cycles across countries.

Overall these results highlight two important aspects of the differences in cyclical fluctuations across these countries. First, there is little to suggest a history of close correspondence in cyclical turning points. In fact, it is easy to pick out differences as large as two or three years in each of these pictures. Abstracting from the fact that these relationships are likely to change in response to the formation of a common central bank and monetary policy, the degree of disparity in cyclical movements depicted above may present substantial difficulties for policymakers, as a policy intended to slow growth in a group of accelerating economies may have the side effect of plunging others, or even one other, further into recession. Second, and quite importantly, however, there seems to have been nearly uniform timing of the turning point in the early 1990's, with the exceptions to this being the U.K. and Greece (and Finland, though this is not shown in the figures). This suggests the possibility that there has been some convergence in cyclical fluctuations across these countries in recent years, and while it is clearly too early to tell with any certainty, one would expect increasingly more synchronization of output movements.

Recent inflation experience for the Eurosystem countries (excluding Ireland) is summarized the right panel of Table 1, which reports the correlations of monthly consumer price inflation. Here we look at the raw, unfiltered, inflation data. As a result, the correlations are substantially lower. The one thing that is unambiguously clear is that the correlation of inflation rates with France and Italy is higher than the correlation with Germany. Though not captured in these correlations, another striking feature of the inflation data is the remarkable convergence in inflation rates across these countries over our sample (with the notable exception being Greece).

3 A Simple Model

Following Cecchetti (1998) we note that central bank policy can viewed as the solution to an optimal control problem. A truly complete description of the policymaker's problem begins with an intertemporal general equilibrium model based on a social welfare function (tastes), production functions (technology), and market imperfections that cause nominal shocks to have real effects (nominal rigidities). The goal would be welfare maximization.

We do not propose to delineate the fully specified problem. Instead, we begin with a commonly used quadratic loss function that might be a second-order approximation to the objective function in this more detailed problem.[3] The policymaker seeks to minimize the discounted sum of squared deviations of output and prices from their target paths. The general form of such a loss function can be written as

$$\mathcal{L} = E_t \left(\sum_{i=0}^{h} \beta^i \left\{ \alpha [p_{t+i} - p^*_{t+i}]^2 + (1-\alpha)[y_{t+i} - y^*_{t+i}]^2 \right\} \right) \ , \qquad (1)$$

where p_t is the (log) aggregate price level, y_t is the (log) aggregate output, p^* and y^* are the desired levels for p and y, β is the discount factor, h is the horizon, α is the relative weight given to squared price deviations from their desired paths and $(1-\alpha)$ is the weight given to squared output deviations, and E_t is the expectation conditional on information at time t.[4] The loss function provides the policymaker with information about preferences over different paths for the variance of output and prices.

The policymaker's loss is a function of the vector $\theta = (\alpha, \beta, h, \pi^*, y^*)$. The values of each of these will depend on the underlying economic structure, that is, tastes and

[3] Throughout the discussion in this section, we assume that the there is no dynamic consistency problem, and so policymakers can credibly commit to whatever rule they choose.

[4] In Section 5.3 we generalize the loss function 1 to include a term that penalizes changes in the control, making changes in interest rates explicitly costly. One could also write down a specification for the loss function in which the exchange rate enters explicitly. We exclude the exchange rate on the grounds that we view it as an intermediate target that is chosen ultimately for its effects on output and inflation, rather than as an objective in and of itself.

technology. The preference over different paths for inflation and output variability, as embodied in the loss function, depends on the fundamental reason that these things are costly. The same is true of the desired steady level of inflation, π^*.

The policymaker's problem cannot be solved without knowledge of the dynamics of the state variables y_t and p_t as functions of the policy control variable and the stochastic forcing process driving the economy. These relations, which are taken as constraints in the optimization problem, describe the structure of the economy. For the purposes of the current discussion, we assume that central bank policy is carried out in terms of an interest rate, r_t, and that the innovations to the economy come from an n-variate process $\{\epsilon_t\}$, with expectation zero and variance-covariance matrix Σ.[5] The reduced form for the evolution of the output and prices can then be written as

$$\begin{bmatrix} y_t \\ p_t \end{bmatrix} = A(L) \begin{bmatrix} \epsilon_t \\ r_t \end{bmatrix} , \tag{2}$$

where $A(L)$ is an $(n+1)$x2 matrix of (possibly infinite-order) lag polynomials in the lag operator L.[6] The coefficients in $A(L)$ describe a reduced form of the economy.

We can now characterize the policymaker's problem as choosing a path for r_t that minimizes Equation (1), subject to (2). The result is the optimal interest rate rule that specifies responses to the innovations to the economy. We write this as

$$r_t^* = \phi(L)\epsilon_t , \tag{3}$$

where $\phi(L)$ is a (possibly infinite-order) lag polynomial.[7] This optimal path for

[5]The use of an interest rate is not necessary. The control variable could be any quantity that is directly governed by the central bank. For example, the monetary base or some measure of reserves could be used as the control.

[6]Equation (2) is the vector moving-average form. The more common vector autoregressive (VAR) form is equivalent.

[7]The linear-quadratic structure of the problem described here gives rise to a linear policy rule. In general, this would not be the case. For example, if the loss function included cubic terms, or if there were some nonlinear constraints on the policymaker's behavior not considered here, then the policy rule would be nonlinear as well.

interest rates as a function of the innovations to the economy (which could be written as differences in the observable quantities) is the policy rule. Importantly, $\phi(L)$ is a function of the parameters θ, as well as the coefficients in $A(L)$ and the covariance matrix of ϵ, Σ.

The goal of our analysis is to recover the parameters of the loss function. Primarily, we are interested in an estimate of α, the relative weight that the policymaker places on inflation and output variability. Our strategy for recovering an estimate of α is straightforward. Assuming that the policymaker is solving this optimization problem, and that we know the structure of the economy as embodied in $A(L)$ and the path of exogenous shocks to the economy, then we can find the α that gives a reaction function $\phi(L)$ that is the closest to that in the data. Put differently, we will find the loss function that implies interest rate movements closest to those actually observed.

We solve this problem in two steps. In the next section we describe how to construct estimates of a structural model linking monetary policy to output and prices for each country in our sample. Then, in Section 5 we proceed to derive estimates of α.

4 Measuring the Monetary Transmission Mechanism

The next task is to uncover a measure of the monetary transmission mechanism for each of the countries participating in the EMU. For our purposes, estimates of the impulse response functions of output and prices to a monetary shock allow us to infer the trade-off policymakers face in the short run when pursuing the potentially disparate goals of output and price stability.

We use a structural vector autoregression (SVAR) approach to quantify the monetary transmission mechanism. That is, we are interested a structural representation of a set of endogenous economic variables (Z_t), including output and inflation, as arising from dynamic responses ($C(L)$) to a set of exogenous economic shocks (ϵ_t)).

We write the model as a vector moving average process

$$Z_t = C(L)\epsilon_t \ , \tag{4}$$

where Z is a vector of variables the must include output, inflation and the policy instruments, and may include other variables as well.

There is a large literature associated with the use of SVARs in the context of identifying the effects of monetary policy. While we make no attempt to review that literature here, we note that much of it is concerned with isolating the effects of monetary policy in the U.S., a country which is both large and closed relative to the economies considered here and thus while the strategies outlined there are appropriate for an economy such as the U.S., they are less well suited for the smaller and considerably more open economies of Europe.

Ideally, we are interested in extracting a measure of preferences from a model that employs an identical set of identifying restrictions for each country (i.e., assumes the same basic structure but allows the parameter estimates to differ) and which yields a complete set of impulse response functions that conform with our priors with regard to the type of shock being identified.[8] In practice, this is extremely difficult. While there are numerous methodologies (for example Cushman and Zha (1997), Jacobson et al. (1999)) that are able to successfully identify at least a monetary policy shock for some of the countries in which we are interested, we know of no study that can do so for all the European countries over our sample.

In order to analyze as large a set of countries as possible, we follow Ehrmann (1998) and use the methodology set forth in King, Plosser, Stock and Watson (KPSW) (1991). The KPSW identification strategy is based on the implications of the cointegrating relations in a multivariate system. Complete identification of an n-variable system structural system requires $\left[\frac{n(n-1)}{2}\right]$ restrictions. In a system with r cointegrating relations there will be k common trends, where $k = n - r$ and thus k shocks that

[8] In particular, it is important for our purposes that all shocks in the system, not just the money shock, produce plausible impulse response functions.

are assumed to have long-term effects on the variables in the system (and are therefore interpretable as supply shocks). This structural assumption imposes $k * r$ of the necessary restrictions. For complete identification of the effects of supply shocks we need $\left[\frac{k(k-1)}{2}\right]$ additional restrictions. The King, Plosser, Stock and Watson methodology employs a triangular specification, allowing the first shock to have an effect on all the dependent variables, the second on the last n-1, and so on. In order to identify the transitory shocks (interpretable as demand shocks), we need a set of additional $\left[\frac{(n-k)(n-k-1)}{2}\right]$ restrictions. Again, we use a triangular specification.

For each country, the model has either four or five variables, including output, inflation, and an interest rate, and, with the exception of Germany, an exchange rate. When a fifth variable is present, it is either a second interest rate or a commodity price index.[9]

Figure 3 plots the responses of output and inflation to a 100 basis point interest rate movement for ten EU countries.[10] As is clear from these plots, the point estimates of the impulse response functions vary dramatically across countries. Looking at the impact of interest rate movements on output, note that for France and Germany, the peak impact is nearly twice what it is in the other countries. The impact of policy on inflation also varies substantially.

5 Policymakers' Objectives and The Variability Trade-off

Our primary interest in this paper is in assessing the differences across countries in the loss function policymakers are minimizing, and in particular in obtaining a measure of α, the weight placed on deviations of prices from their target value. As we show, this entails estimating the output-inflation variability trade-off faced in each country, as well determining where on their respective frontiers these countries have located

[9]See Appendix A for a list of the variables and sample period used for each country. Each regression also contains a set of dummy variables to account for significant historical episodes such as tax changes and exchange rate crises. See Ehrmann (1998) for additional details.

[10]These ten countries are the ones for which the Ehrmann model (1998) is able to generate consistent and plausible results.

in recent years.[11] These exercises give us a sense of the disparities in the trade-offs faced by these countries as well as the differences in the underlying preferences, or relative costs, of output versus inflation variability. As stated in the introduction, we do not view the estimated trade-off as a menu of possible combinations from which policymakers can choose. Clearly the shape of the frontier depends on the degree and source of nominal rigidity in the economy, the credibility of the central bank, and ultimately the preferences of the policymakers themselves. Instead, we look at this as an exercise in estimating the revealed preferences of the national central banks over a particular, and important, recent historical period.

5.1 The Static Model

Conceptually, it is straightforward to take the estimated models from the previous section, both the point estimates of impulse responses and their associated covariance matrices, and estimate the relative weight α, the horizon h and the discount factor β from Equation 1. But we begin with something much simpler. In particular, we construct estimates of α by considering a simple static model that is meant to represent the medium run response and trade-off. In this model, we assume the policymaker's horizon, h, is zero (and thus the discount factor, β, is irrelevant) and that the target levels of prices (π^*) and output (y^*) are both zero. This simple model is as follows

$$y_t = \gamma(r_t - d_t) + s_t, \gamma < 0 \tag{5}$$

$$\pi_t = -(r_t - d_t) - \omega s_t \tag{6}$$

where d_t and s_t are aggregate demand and aggregate supply shocks. We assume that the variance of demand shocks is normalized to one and thus the variance of supply shocks, given by σ_s^2, is interpreted as the variance of supply shocks relative to demand shocks. The parameter γ gives the ratio of the responses of output and inflation to a

[11] For more on the importance of the tradeoffs policymakers make when choosing policy rules see Taylor (1979, 1994).

policy shock, and can be thought of as the inverse of the slope of the aggregate supply curve. The parameter ω is the slope of aggregate demand. Given our quadratic loss specification, we can write the policy rule as

$$r_t = ad_t + bs_t. \tag{7}$$

Substituting equation 7 into equations 5 and 6 and taking the variance of these expressions we obtain

$$\sigma_y^2 = (a-1)^2\gamma^2 + (1+\gamma b)^2\sigma_s^2 \tag{8}$$

and

$$\sigma_\pi^2 = (1-a)^2 + (\omega + b)^2\sigma_s^2. \tag{9}$$

Choosing the coefficients a and b of the policy rule to minimize the loss function

$$L = \alpha\sigma_\pi^2 + (1-\alpha)\sigma_y^2, \tag{10}$$

yields

$$a = 1 \tag{11}$$

and

$$b = \frac{\alpha(\gamma - \omega) - \gamma}{\alpha(1-\gamma^2) + \gamma^2} \tag{12}$$

In this simple static model, the result that $a = 1$ has a clear interpretation–policymakers completely offset the effects of demand shocks on both output and inflation since demand shocks do not cause policymakers to have to choose between output and inflation variability. We can substitute the expressions for a and b into the expressions for σ_y^2 and σ_π^2, and in turn substitute these expressions into equation 10. This gives us the loss function in terms of the preference parameter (α) and the ratio of the mean responses of output and prices to a monetary shock (γ). We can now use the actual values of σ_y^2, σ_π^2 and the estimated value of γ to infer both the α for the period of estimation and the shape of the output-inflation volatility frontier.

Given the following expression for the ratio of output to price variability

$$\frac{\sigma_y^2}{\sigma_\pi^2} = \left[\frac{\alpha}{\gamma(\alpha - 1)}\right]^2 \tag{13}$$

we choose the α for each country to be the value that equates this ratio to the actual output inflation variability ratio we observe in the data. Equation 13 has the property that for $\alpha = 0$, $\sigma_y^2/\sigma_\pi^2 = 0$ and likewise for $\alpha = 1$, that $\sigma_y^2/\sigma_\pi^2 = \infty$. Values of α between zero and one trace out the entire frontier, the shape of which is related to the slope of the aggregate supply curve and is unaffected by the slope of the aggregate demand curve.

Once we have estimates of the ratio of the variance of output and inflation, measured as deviations from their desired levels, and an estimate of γ, we can use equation 13 to compute the implied value of α. Following the logic that this is meant as a model of the medium run, we compute an estimate of $\frac{\sigma_y^2}{\sigma_p^2}$ as the ratio of variance of the deviations of output and inflation from their 12 quarter moving averages[12]. Analogously, we use the impulse response functions plotted in Figure 3 to calculate an estimate of γ as the ratio of the mean output response to the mean price response, over a 12 quarter horizon.

Table 2 reports the results of this exercise. The top panel of the table includes estimates for seven of the eleven member countries of the Eurosystem. The lower section of the table reports the results for Denmark, Sweden, and the UK for comparison. The second column of Table 2 gives the ratio of the variance of deviations of output from its 12-quarter moving average to the variance of deviations of inflation from its 12-quarter moving average. The next column reports the estimate of γ, computed as the mean output response to a monetary shock divided by the mean price response over a three year period. The fifth column reports the implied value of α.

[12]Our measure of potential GDP and target inflation in this exercise is therefore given by a 12-month moving average of actual values. This assumes that output and inflation were on average close to their target levels. Our results are likely to be sensitive the definition of potential output and target inflation.

The first thing to notice about the results is that most of the α's are quite large, indicating that many of these countries seem to have taken the goal of inflation stability very seriously over this period. Only Portugal seems to place approximately equal weight on the objectives of output stability and inflation stability. The U.K. and Spain have the next smallest estimated values of α, though each of these is in excess of a three-quarter weight on inflation variability. Each of the remaining countries reveal an α larger than 0.90.

It is important to note that our analysis is likely to produce values of α for these countries that are upper bounds on the true value. The reason for this is our use of industrial production (IP) rather than GDP data in the structural estimation. Since GDP is less volatile than IP and is likely less sensitive to changes in policy, the use of IP rather than GDP should raise both our estimate of σ_y^2/σ_π^2 and our estimate of the absolute value of γ. For any given value of σ_y^2/σ_π^2, a higher γ will imply a higher value of α since the slope of the output inflation-variability frontier at that point will be steeper. Thus both of these effects serve to raise the value of α we obtain relative to what we would obtain using GDP.[13]

The next interesting aspect of the results is the fact that these α's, with the exception of Portugal, are clustered so close to one another. This suggests that there was not much dispersion across countries in their relative preferences for output and inflation variability over the fifteen or so years prior to the EMU.

To see more clearly what we can learn from this exercise, begin by comparing the results for Portugal and Sweden. We see that both countries experienced a similar degree of output variability relative to price variability over the sample we consider. Portugal, however, has an estimated γ that is smaller than Sweden's. Since $1/\gamma$ in our model is interpreted as the slope of the aggregate supply curve, this implies that Portugal's estimated aggregate supply curve is steeper than Sweden's.[14] In this simple

[13]Indeed, when we redo our estimation for both France and Germany using real GDP rather than industrial production, our estimates of γ, σ_y^2/σ_p^2 and α for these countries all decline.

[14]For the present purposes, we are using the responses of output and inflation to a monetary shock only to infer the slope of the supply curve. In the dynamic model presented below, we include all the

model, our result translates into the fact that Portugal faced a flatter output-inflation variability frontier than did Sweden. For the purpose of illustration we plot these two frontiers in Figure 4 (constructed by varying α in Equation 13 from zero to one and tracing out the implied ratio of output to inflation variability).

For a supply shock of a given size, the implication of a flatter frontier (or a steeper aggregate supply curve) is that it is relatively inexpensive in terms of output to stabilize prices. In other words, relative to Sweden, Portugal should have found it easy to be an inflation fighter. Given the roughly comparable ratio of output to inflation variability actually observed in these two economies, our model concludes that Portugal must have placed relatively more weight on output stability more heavily than did Sweden and hence assigns it a lower α.

Likewise, while Denmark and Ireland have similar ratios of output to price variability, Denmark faces a flatter frontier than does Ireland. Thus, despite its relative advantage at reducing inflation variability, Denmark tolerated a similar ratio of output to inflation variability and hence it is assigned a smaller α.

We can make the same type of comparisons using countries for which we estimate similar structures but different actual values of relative output to inflation variability. For example, Germany and Sweden have similar estimated output-inflation variability frontiers (this can be seen either by comparing the estimates of γ across these countries or by looking at the frontiers plotted in Figure 5). The ratio of output to inflation variability in Germany, however, was more than twice that of Sweden. Given the similarities of their frontiers, this suggests a greater distaste for inflation on the part of German policymakers and hence a larger α.

While the tradeoffs between output and inflation variability are relatively similar in Denmark and Spain, output variability relative to inflation variability in Spain was actually only slightly more than half that of Denmark. We therefore find a lower α for Spain relative to Denmark. For countries such as Belgium and France, for which

estimated responses from the structural model and thus are less restrictive about our characterization of the 'supply' curve.

the estimate of γ is large (and hence the tradeoff is steep) and the ratio of output to price variability is large, we find very large values of α.

Finally, it is interesting to note that Germany, Ireland and Italy all have similar estimated α's. In the context of our simple model, does this imply that they would all implement the same policy in response to a shock of the same sign and magnitude? The answer is to this question is clearly no. Germany and Italy might implement a similar policy, but Ireland faces a flatter variability tradeoff (Figure 6) and hence would need to respond less aggressively than would Germany or Italy. Clearly, the formation of a common monetary policy is made more difficult to the extent that such differences in the underlying structure of the economy persist even under monetary union.[15]

5.2 The Dynamic Model

The static model simplifies our analysis by allowing us to look only at medium horizon averages and by allowing us to use only the responses to monetary shocks to trace out the slope of the aggregate supply curve. Given that our structural estimation provides a characterization of the full dynamic structure of the economy, we can examine the robustness of the results of the static analysis to the more complete specification of the economy.

Our strategy is to find the value of α for which the optimal interest rate path, implied by the control problem, is closest to the actual path in the data. That is,

$$\min_{\alpha} \mathcal{M} = \sum_{t} [r_t^*(\alpha) - r_t]^2 \ , \tag{14}$$

where $r_t^*(\alpha)$ is the optimal path from equation 3, for a given value of α, and r_t is the actual observed path of interest rates.[16]

[15] One obvious and important objection to our analysis is the fact that the slope of the supply curve is not likely to be invariant to the α of the policymakers. We discuss this issue further below.

[16] The procedure we implement is actually based on the deviations from the optimal impulse response functions associated with each α. To understand our procedure, assume that the central

The results of this exercise are summarized in Table 3. For each country, we present a range of values for α. This range reflects the values of the loss function that fall within 5% of either side of the minimum value. These results confirm the basic message of the static model. Namely, that there appears to be little dispersion across policymakers' in terms of their preferences over output and inflation variability and that the estimate of α, the weight on inflation variability in the policymaker's objective function, is high in all of these countries.

The rank ordering of the countries in terms of α changes slightly when we move from the static to the dynamic model. In particular, Italy is now the country with the lowest weight on inflation variability. However, we still find that Denmark, Portugal, Spain and the UK all have low α's relative to Belgium, France, Germany, Ireland and Sweden.

5.3 Interest Rate Smoothing

It is common to presume that the policymaker's explicitly smooth interest rates when making their decisions. Following Rudebusch and Svensson (1998) and Rudebusch (1998), we can introduce smoothing into the objective function, and rewrite the loss function to be minimized as

$$\mathcal{L}' = E_t \left(\sum_{i=0}^{h} \beta^i \left\{ \alpha [p_{t+i} - p^*_{t+i}]^2 + (1-\alpha)[y_{t+i} - y^*_{t+i}]^2 + \delta [r_t - r_{t-1}]^2 \right\} \right) \quad (1')$$

bank only cares about maintaining a stable inflation level (α=1). If this is the case, the central bank's reaction to shocks yields impulse response functions for inflation that die out very quickly and have extremely small coefficients. In the same way, if the monetary authority wants to maintain a constant output level (α=0), it would react systematically to shocks in accordance with that goal. That systematic reaction would imply that the coefficients reflecting the transmission of shocks in the output equation would be small and die out quickly. We therefore create a loss function as a function of the coefficients of the impulse responses. In particular, calling $c_{\pi i} = (c_{1\pi i}, c_{2\pi i} \ldots)$ the coefficients of the impulse response function of shock i into the inflation level and calling $c_{yi} = (c_{1yi}, c_{2yi} \ldots)$ the coefficients of the impulse response function of shock i into the output level, we define the loss function and minimize this function with respect to α.

where δ is a penalty associated with moving the control r_t. Minimization of $\mathcal{L}'$ will result in smoother interest rate paths the higher is the parameter δ.

We have studied optimal policy using the dynamic model of Section 5.2 for various values of δ. The general methods for computation of the α, given a value of the smoothing parameter δ, are the same. That is, for a given value of δ, we find the weight on inflation variability in the policymaker's loss function that minimizes the distance between the actual interest rate path and the one implied by the optimal policy response function (equation 14).

Table 4 reports the results of an exercise where $\delta = 0.01$, as well as the results for the case in which $\delta = 0$, as reported in Table 3 . Included is the ratio of the distance function minimized to compute α as δ increases from zero to 0.01. There are two interesting characteristics of these estimates. First, smoothing implies unambiguously lower levels of α. That is, we are finding that making interest rate moves explicitly costly is tantamount to placing a higher weight on output variability, and so it is equivalent to moving down the output-inflation variability frontier and increasing the variance of inflation relative to the variance of output. This follows naturally from the fact that our estimated frontiers and aggregate supply curves are quite steep: In an environment in which interest rate moves have a larger impact on output than inflation, a policymaker that dislikes large interest rate moves will also appear to care less about stabilizing inflation relative to a policymaker that does not smooth interest rates.

Second, increasing δ from zero substantially increases the distance of the optimal from the observed interest rate rule. In other words, when we look for the optimal policy response that is closest to that we observe in the data by adjusting both α and δ, we find that preferences always imply $\delta = 0$. This seems very intuitive, as one would expect that an unconstrained choice of an interest rate rule, one in which $\delta = 0$, would give policymakers the option to smooth interest rates as much as they would like. Forcing them to smooth must force the optimal rule away from observed behavior.

Before we conclude, it is important to note several limitations of our analysis. First, while we do provide estimates of the recent output-inflation variability trade-off for each country in our sample, we do not view this as a menu for policy choice. There is no assurance whatsoever that if the national central banks had chosen different policy paths that they would have simply moved to another point on the trade-off. Second, in order to compute the implied loss function from the actual historical data, we must assume that policymakers are behaving optimally. That is to say, we find the problem to which the observed interest rate path is the optimal solution. Clearly, policymakers could have had something completely different in mind when they made their decisions. Finally, there is the obvious point that the actual implementation and operation of policies by the European Central Bank and the twelve national central banks that compose the Eurosystem is likely to change the mechanisms that governed output and price fluctuations in these countries, and indeed, even the preferences of individual policymakers.

6 Interpretation and Conclusions

What does this all mean for the Eurosystem? Given that each of the NCB governors votes in the ECB Council, the differences we observe in economic structure across countries (if they persist) could present serious challenges to the implementation of a common policy. For example, a common policy objective such as inflation for the Euro-12 in the zero to two percent range could in practice require the implementation of very different policies for different countries. Thus, one of the basic messages of this analysis is that differences in the structure of the economy could imply that inflation stability, at least in the short-run, may come at a much greater cost for some countries than for others, a result that should hold true even if these countries have synchronized cycles. Clearly those countries participating in the European Monetary Union implicitly view such costs as being smaller than the benefits of the union.

On the other hand, our analysis does suggest that despite small differences across countries in the estimated objective functions, all of the EU countries considered here seem to have located on the high, rather than the low, end of the inflation-stability spectrum. This result suggests that there were not marked differences in preferences across the EU central banks prior to the start of the monetary union, regardless of whether a particular country was operating under an explicit inflation-targeting regime. Thus one might conclude that the current central bankers from each of these countries, including those from inflation targeting countries such as the U.K. and Sweden, is unlikely to differ markedly in their views on the appropriateness of a particular policy.

Appendix[17]

Data

Note: All data is taken from Datastream

Belgium: 3 month t-bill rate, industrial production, CPI-inflation, Franc/DM exchange rate, German short interest rate, sample: 84:3-97.4

Denmark: 3 month interbank rate, industrial production (sa), CPI-inflation, Krone/DM exchange rate, long term interest rate (10 year govmnt bonds), sample: 84:1-97.3

Finland: call money rate, industrial production, CPI-inflation, Markka/US$ exchange rate, sample: 84:1-97.4

France: 3 month money market rate, industrial production, CPI-inflation, French Franc/DM exchange rate, long term interest rate on gov't bonds, sample: 85:3-97.4

Germany: 3 month money market rate, industrial production (sa), CPI-inflation, DM/US$ exchange rate, IMF Commodity price index, sample: 79:3-97.4

Ireland: 3 month t-bill rate, industrial production, CPI-inflation, Punt/DM exchange rate, Punt/Sterling exchange rate, sample: 84.1-97.3

Italy: 3 month t-bill rate, industrial production, CPI-inflation, Lir/DM exchange rate, IMF Commodity price index, sample: 84.1-97.4

Portugal: 5 day money market rate, industrial production, CPI-inflation, Escudo/DM exchange rate, German short interest rate, sample: 84:1-97.2

Spain: 3 month money market rate, industrial production, CPI-inflation, Peseta/DM exchange rate, real ALP (ALP is a monetary measure of active liquidity in private hands, broader than the M3 aggregate. Real ALP is constructed as the difference between the natural logarithm of ALP and the CPI), sample: 84:1-97.4

[17] The information contained in this Appendix is taken from the Appendix in Ehrmann (1998).

Cointegration Rank of System

Belgium: 2

Denmark: 2

France: 2

Germany: 3

Ireland: 3

Italy: 3

Portugal: 3

Spain: 2

Sweden: 2

United Kingdom: 3

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Figure 1: Band-Pass Filtered IP: Germany, Ireland, Spain, Portugal, Luxembourg

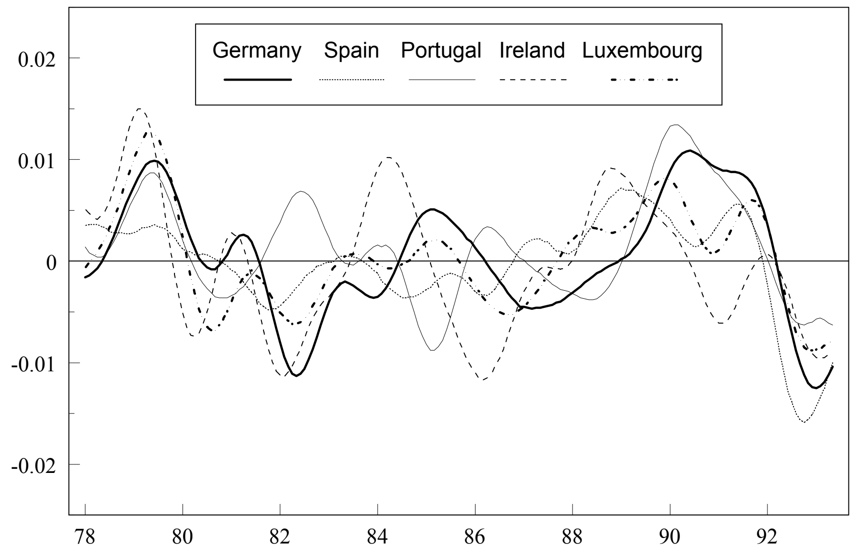

Figure 2: Band-Pass Filtered IP: Denmark, Germany, Greece, Sweden, UK

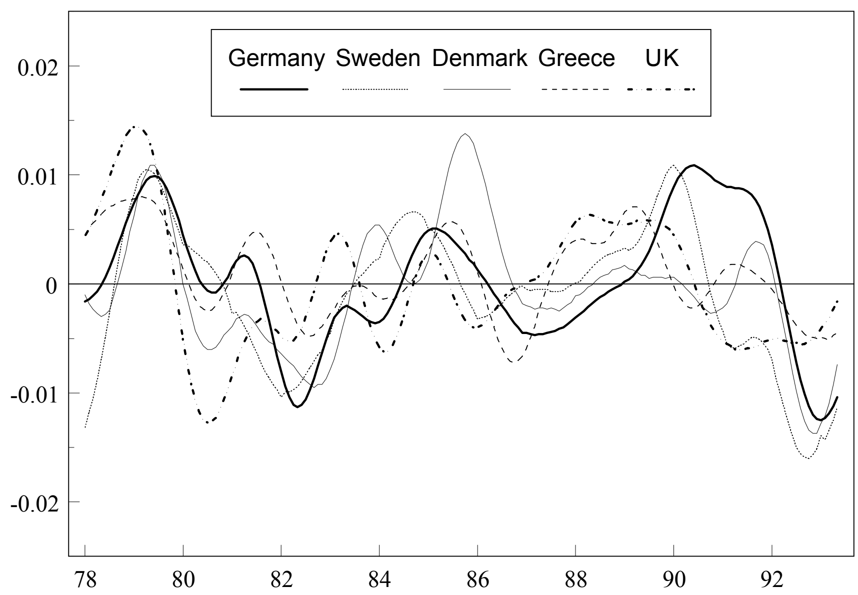

Figure 3: Response of Output (solid line) and Prices (dotted line) to Policy Shocks

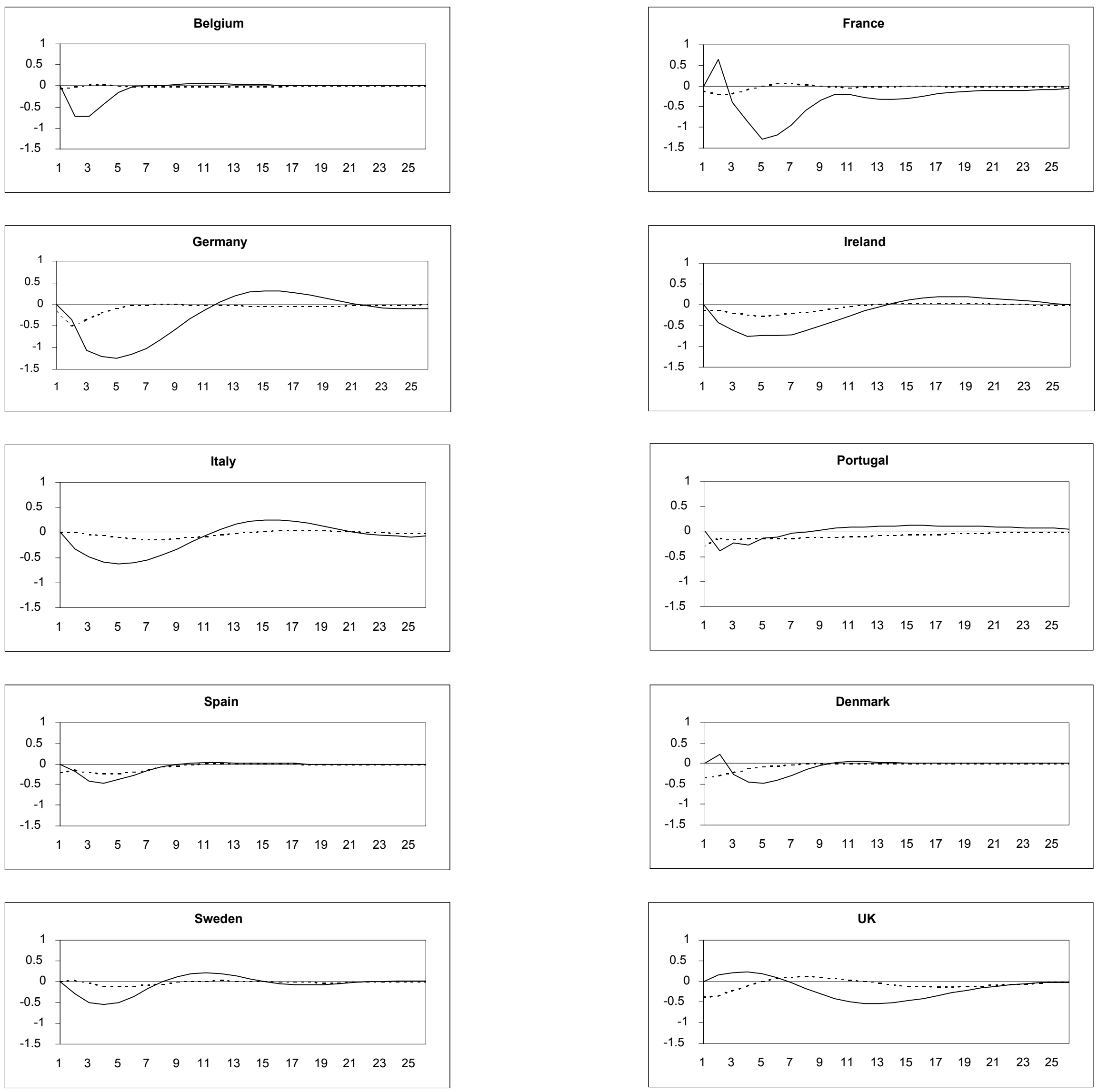

Figure 4: Implied Output-Inflation Variability Frontiers

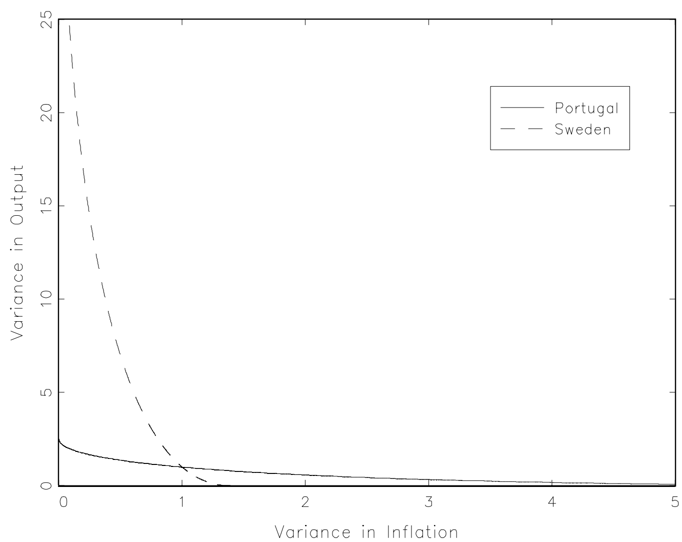

Figure 5: Implied Output-Inflation Variability Frontiers

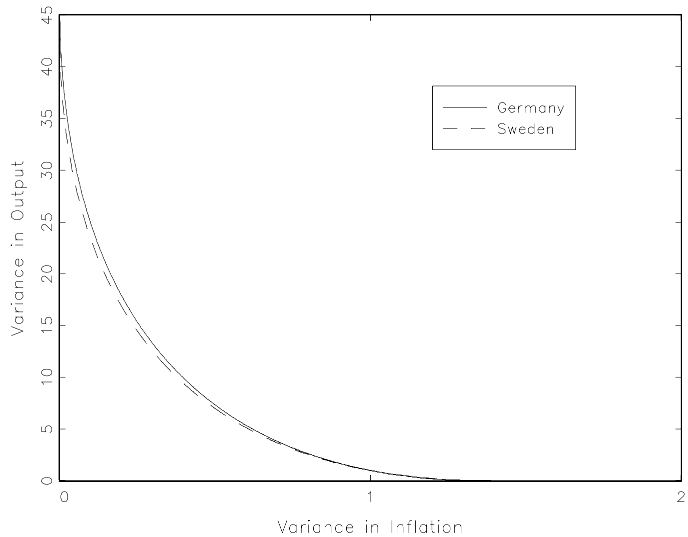

Figure 6: Implied Output-Inflation Variability Frontiers

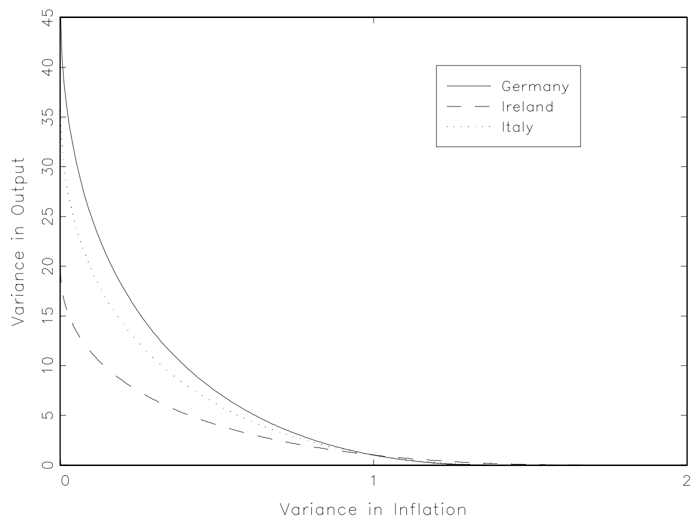

Table 1: Cross Country Correlations of Business Cycle and Inflation Indicators

	Band-Pass Filtered IP 1978:07 to 1993:11			Monthly CPI Inflation 1977:02 to 1997:08		
	Germany	France	Italy	Germany	France	Italy
Austria	0.94	0.79	0.72	0.16	0.55	0.53
Belgium	0.79	0.93	0.68	0.47	0.51	0.52
Finland	0.19	0.47	0.68	0.17	0.57	0.48
France	0.79	1.00	0.81	0.31	1.00	0.75
Greece	0.52	0.78	0.63	0.17	0.31	0.30
Ireland	0.38	0.68	0.52	na	na	na
Italy	0.63	0.81	1.00	0.28	0.75	1.00
Luxembourg	0.79	0.93	0.68	0.20	0.29	0.33
Netherlands	0.82	0.63	0.58	0.34	0.48	0.40
Portugal	0.50	0.50	0.30	0.12	0.46	0.39
Spain	0.59	0.80	0.68	0.17	0.61	0.56
Denmark	0.61	0.55	0.51	0.18	0.55	0.51
Sweden	0.64	0.73	0.72	0.15	0.45	0.41
UK	0.23	0.58	0.28	0.26	0.61	0.49

Table 2: Results of Static Model

Country	$\frac{\sigma_y^2}{\sigma_\pi^2}$	γ	α
Belgium	46.78	-45.29	1.00
France	36.39	-12.07	0.99
Germany	7.86	-5.83	0.94
Ireland	17.39	-3.45	0.94
Italy	8.54	-5.01	0.95
Portugal	3.70	-0.58	0.53
Spain	9.14	-1.34	0.80
Denmark	17.88	-1.69	0.88
Sweden	3.03	-5.61	0.91
UK	2.02	-2.57	0.79

Note: $\frac{\sigma_y^2}{\sigma_p^2}$ is the ratio of the variance of deviations of output from its 12-quarter moving average to the variance of deviations of inflation from its 12-quarter moving average, computed over the sample indicated. The estimate of γ is the mean output response to a policy supply shock over the mean price response over a 12-quarter horizon, where the impulse responses are computed from the structural estimation described in Section 4 over the samples indicated in footnote **??**.

Table 3: Results of Dynamic Model

Country	α	Range
Belgium	0.97	(0.93–1.00)
France	1.00	(0.99–1.00)
Germany	1.00	(0.98–1.00)
Ireland	0.99	(0.97–1.00)
Italy	0.72	(0.65–0.77)
Portugal	0.82	(0.73–0.90)
Spain	0.92	(0.89–0.95)
Denmark	0.85	(0.80–0.88)
Sweden	0.97	(0.85–1.00)
UK	0.75	(0.70–0.78)

Note: Estimated α's are the weight on inflation variability in the objective function that minimizes the distance between the estimated and optimal interest rate response to structural economic shocks, assuming the horizon in the objective function, h, is 12 quarters.

Table 4: The Dynamic Model with Interest Rate Smoothing

Country	α ($\delta = 0$)	α ($\delta = 0.01$)	Ratio of Distances $\frac{\mathcal{M}(\alpha,\delta=0.01)}{\mathcal{M}(\alpha,\delta=0)}$
Belgium	0.97	0.95	5.96
France	1.00	0.84	4.71
Germany	1.00	1.00	8.50
Ireland	0.99	0.95	8.55
Italy	0.72	0.42	4.87
Portugal	0.82	0.77	2.85
Spain	0.92	0.90	7.71
Denmark	0.85	0.73	1.43
Sweden	0.97	0.86	2.32
UK	0.75	0.63	4.86

Note: Estimated α's are the weight on inflation variability in the objective function that minimizes the distance between the estimated and optimal interest rate response to structural economic shocks, assuming the horizon in the objective function, h, is 12 quarters. δ is the weight on interest rate changes in the objective function. The ratio of the distance is the distance function minimized to choose α, given δ, at $\delta = 0.01$ divided by its minimum value at $\delta = 0$.