INFLATION PERSISTENCE AND OPTIMAL MONETARY POLICY IN THE EURO AREA

Pierpaolo Benigno and J. David López-Salido

Banco de España

Banco de España — Servicio de Estudios
Documento de Trabajo n.º 0215

Inflation Persistence and Optimal Monetary Policy in the Euro Area*

Pierpaolo Benigno† and J. David López-Salido‡

July 2002
First draft (October 2001)

Abstract

In this paper we first present supporting evidence of the existence of heterogeneity in inflation dynamics across euro area countries. Based on the estimation of *New Phillips Curves* for five major countries of the euro area, we find that there is significant *inertial (backward looking)* behavior in inflation in four of them, while inflation in Germany has a dominant *forward looking* component. In the second part of the paper we present an optimizing agent model for the euro area emphasizing the heterogeneity in inflation persistence across regions. Allowing for such a backward looking component will affect the evaluation of the degree of nominal rigidities relevant for the monetary policy design. We explore the welfare implications of this circumstance by comparing the adjustment of the economies and the area as a whole in response to terms-of-trade shocks under four monetary policy rules: fully optimal, optimal inflation targeting, HICP targeting and output gap stabilization.

*We thank the useful comments of the participants in the *First International Research Forum on Monetary Policy*, July 5-6, 2002, at the ECB in Frankfurt, and specially those of Andy Levin and Ilian Mihov, as well as the detailed discussion provided by Nicoleta Batini and Robert Tetlow. We also thanks the continuous feedback provided by Jordi Galí and Fernando Restoy to earlier versions of the project, as well as participants in seminars at UPF and the Bank of Spain. The views expressed in this paper are those of the authors and do not represent those of the *Banco de España*.

†*New York University and CEPR*

‡*Banco de España, Research Department and CEPR*

1 Introduction

In this paper we examine the idea that in the euro area monetary policy should be conducted so as to eliminate, or at least mitigate, the distortions in relative prices arising from the differences in the degree of adjustment of inflation rates to terms of trade shocks (i.e. asymmetric shocks). This broad statement is close to the principle under which a mandate of price stability has been delegated to the ECB. In fact, as stressed in the 1999 Bulletin of the ECB (January 1999), the main argument for price stability is that it improves the transparency of the relative price mechanism, thereby avoiding distortions and helping to ensure that the market allocates real resources efficiently both across uses and over time. In this paper, we will present an empirical and theoretical framework where we can explicitly address such an issue.

To do this we proceed in two steps. First, we estimate the main parameters driving the degree of price stickiness in five major countries of the euro area. We mostly focus on the implications, for the design of the optimal monetary policy, of the existence of a different nature and degree of inflation persistence across countries belonging to the European Monetary Union. The first part of the paper concludes pointing out the existence of two different zones inside the euro area. There is one country (Germany) where we cannot reject that inflation has a significant forward looking component. This country represents around 35 percent of the GDP of the area. The other group of countries is formed by France, Italy, Spain and to a lesser extent the Netherlands, where inflation dynamics are mixed by a forward and a backward looking component. These four countries represent around 53 of the GDP of the area.

In the second part of the paper we exploit these results with the aim of addressing some normative issues, as the optimal inflation-targeting policy and the optimal policy in the euro area. We formulate a two-region optimizing-agent model: in one region sellers evidence *forward-looking behavior in setting prices;* while in the other, past inflation plays also a crucial role in understanding inflation persistence, through what we call the *hybrid* model. We then exploit the micro-foundations of our framework in order to provide a welfare criterion for the Central Bank in terms of the utility of the consumers. The policymaker seeks to stabilize the output gap as well as a weighted average of inflation rates in the area. Moreover, importance should be given to the deviation of the relative price between regions with respect to the natural level. Finally, given the role of past inflation in understanding inflation persistence in the area, monetary policymakers should also stabilize the change in inflation in the region characterized by the hybrid model. Within this framework we will analyze both the dynamic adjustment of the driving macroeconomic variables in the regions and area to terms-of-trade shocks, as well as the welfare implications of alternative monetary policy rules. We focus on four alternative policy rules: (i) *fully optimal policy*, (ii) *optimal inflation targeting policy*, (iii) *Harmonized Index of Consumer Prices (HICP)-targeting*, and (iv) *stabilization of the area output gap.*

According to the criterion of efficiency followed by the ECB, we are able to show within our framework that, *in principle*, a quantitative target in terms of stabilization of the *HICP* does not succeed in eliminating the distortions in the relative price mechanism. We have proposed two policies that may perform better: the *optimal inflation targeting* policy (the inflation rate in the region with higher degree of rigidity should receive higher weight), which generalizes that outlined in Benigno (2001a), and the *output-gap stabilization* policy. Nevertheless, we will show that the applicability of these policies has *pros* and *cons*, making it not so straightforward to move from HICP-targeting to other forms of targets. In particular, the architects of the ECB have specified a broad target, HICP inflation less than 2 percent, so as to give flexibility to the monetary policymakers in conducting their policy. Around this target, policymakers can have the discretion that allows them to evaluate in an appropriate way the different sources of rigidity of the inflation rate, without necessarily disclosing them to the public. In addition, as our analysis shows, in cases where inertia in the terms of trade is high, monitoring the area output gap can also provide the right information on the final goal.

The rest of the paper is structured as follows. In Section 2 we present the empirical estimates of the New Phillips Curve for five major countries of the euro area. This will allow us to identify the degree of price rigidity and so how the degree of inflation inertia varies across regions of the euro area. In Section 3 we present our theoretical model and we accordingly calculate the welfare function that policymakers seek to maximize. We will emphasize how the existence of backward looking price-setters will affect this welfare. In Section 4 we present a correspondence between the rigidity intrinsic in the backward looking region and that of the forward-looking region within the class of inflation targeting policies described above. In Section 5 we analyze the dynamic adjustment of both the area and the regions within the area to terms-of-trade shocks, as well as the welfare implications of alternative monetary policy rules. Section 6 concludes.

2 Differences in Price Rigidity in Euro-Area Countries: Empirical Evidence

The aim of this section is the estimation of some of the main parameters driving the degree of price stickiness in the five major countries of the euro area. Our empirical strategy follows recent empirical work by Sbordone (2002, 2001), Galí and Gertler (1999), and Galí, Gertler and López-Salido (2001) that has recently shown that the *New Phillips Curve* (NPC) based on real marginal cost does a reasonably good job in accounting for inflation in the U.S and in the euro area. Here, we pay special attention to the main countries participating in EMU in order to draw similitudes and differences in their inflation dynamics. We view this empirical evidence, as a first step in constructing a monetary model for the euro area, to which we will devote the following sections. In particular we mostly focus on the implications, for the design of the (optimal) monetary policy, of the existence of a different nature and degree of inflation persistence across EMU member states.

2.1 Basic Set up

Our theoretical approach will be based on staggered nominal price setting, in the spirit of subsequent works by Taylor (1980), Calvo (1983) and Yun (1996). In particular, firms choose prices optimally subject to constraints on the frequency of price adjustment. The aggregation of the decision rules of firms leads to an aggregate Phillips curve equation that relates inflation to cyclical activity. As explicitly suggested by the underlying theory, our measure of cyclical activity will be a measure of real marginal costs.

In Calvo's model, each seller faces a fixed probability, $1-\alpha$, of changing its price. This probability is independent of the length of time since the last adjustment occurred. In this event, the price is chosen to maximize the expected discounted profits under the circumstance that the decision on the price is maintained. In this setup the degree of rigidity can be described in terms of the duration of prices being fixed, which is given by the expression: $D^F = \frac{1}{1-\alpha}$. Thus, when α increases, the degree of nominal rigidity is higher.

Some authors argue that the previous set up should be extended to explain the persistence of inflation that we observe in both the US and Europe (see, for instance, Fuhrer and Moore (1995) and Coenen and Wieland (2000)). As shown by Galí and Gertler (1999), the previous model can be extended by allowing for a fraction of firms, ω, that act as backward looking price setters. Aggregating across the price-setting behavior of individual firms yields the following relationship between inflation, expected future inflation, past inflation, and real marginal cost:

$$\widehat{\pi}_t = \gamma_b \widehat{\pi}_{t-1} + \gamma_f \; E_t\{\widehat{\pi}_{t+1}\} + \widetilde{\lambda} \; \widehat{mc}_t \tag{1}$$

where $\widehat{mc}_t$ is the log deviation of the average real marginal cost at time t from its steady state, and π_t is the inflation rate at time t, and $\widetilde{\lambda} \equiv \frac{(1-\omega)\lambda\alpha}{\phi}$; $\gamma_b \equiv \omega\phi^{-1}$; $\gamma_f \equiv \beta\alpha\phi^{-1}$; and $\phi \equiv \alpha + \omega[1-\alpha(1-\beta)]$. The parameter β is the subjective discount factor in consumer preferences, and the slope coefficient $\widetilde{\lambda}$ is a function of $\lambda \equiv \frac{(1-\alpha)(1-\beta\alpha)}{\alpha}\frac{1}{1+\eta\sigma}$ that depends on the degree of price rigidity through the parameter of the model, α. As we will show, the parameter η is the inverse of the elasticity with respect to output of the disutility of supplying production, and σ is the elasticity of demand across the differentiated goods that can be related with the steady state markup as follows: $\mu \equiv \frac{\sigma}{\sigma-1}$.

Notice that the coefficients γ_f and γ_b are the same as in the hybrid model of Galí and Gertler (1999), so when $\beta = 1$, then $\gamma_f + \gamma_b = 1$. In addition, the *hybrid model* nests the baseline *forward looking* model in the limiting case of non backward looking firms (i.e., $\omega = 0$). We will refer to equation (1) as the *hybrid* formulation of the NPC, which will constitute the reference model of our empirical estimates.

Notice that, in this framework, the average duration of prices that are set in a forward-looking manner is again $1/(1-\alpha)$. However, it is not that obvious to conclude that the average duration of prices in the hybrid model is only captured by the parameter $1/(1-\alpha)$. Indeed, there is another source of inertia linked to the proportion of firms that set prices in a backward looking manner. In this paper, we try to characterize a new index of nominal rigidity that will depend upon both parameters $(\alpha,\, \omega)$. This new index will be of crucial importance for characterizing the optimal inflation targeting policy and in fact the comparison between the average price rigidity in a forward-looking model and the average price rigidity implicit in a hybrid model will be performed according to an appropriate utility-based welfare criterion. Hence, as we will show in section 4, under this hybrid formulation an index of nominal rigidity (i.e. the equivalent to the duration) is given by the following expression: $D^H = \frac{1}{1-\alpha}\frac{1}{1-\omega} = D^F\frac{1}{1-\omega}$. We can distinguish two components: the first part is related to the forward looking character of inflation (D^F), the other is related to the existence of backward looking price-setters $(\frac{1}{1-\omega})$. This latter component reinforces in a highly non-linear way the degree of nominal rigidities related only to the forward looking component. Intuitively, this expression reflects the fact that the fraction of firms which keeps prices constant in each period is not α, but is given by: $\alpha(1-\omega)+\omega$. However, it is worth noting that there might be other criteria of equivalence between the two models that might give different answer. As it will be clearer later in the text, and equivalence in terms of utlity-based criterion is appropriate in our context.

2.2 Results and Implications

In this section, we use quarterly time series data for the five major countries in EMU (Germany, France, Italy, Spain and the Netherlands) over the period 1970:I-1997:I. All the data are from the OECD Business Sector Database and are available upon request. Our measure of output is real GDP, prices are measured using GDP deflator, nominal wages are measured using total compensation, and employment is total employment.

In Figure 1 we plot, for each country in our sample and for the euro area, annual inflation as well as our measure of average real marginal cost, i.e. the log of real unit labor costs.[1] As is clear from the figure, both variables move closely together, at least at medium frequencies in all the countries, and so in the euro area. In general, our measure of real marginal costs matches the high inflation of the 1970s and early 1980s, and the long disinflationary period of the late 1980s and the 1990's. This is particularly true in the case of France, where it is easy to see that inflation anticipates future movements in marginal costs, as the model predicts.

In order to estimate the structural parameters we follow Galí and Gertler (1999), and Galí, Gertler and López-Salido (2000). We use expression (1) as orthogonality condition, so that we can estimate the model using generalized method of moments

[1] The data for the euro area are from Galí, Gertler and López-Salido (2000).

(GMM). Let $\mathbf{z}_t$ denote a vector of variables observed at time t. Then, under rational expectations, these equations define the following set of orthogonality conditions:[2]

$$E_t\{(\pi_t - \omega\ \pi_{t-1} - \beta\alpha\pi_{t+1} - \lambda\ \widehat{mc}_t)\ \mathbf{z}_t\} = 0$$

which corresponds to expression (1). Our set of instruments, $\mathbf{z}_t$, includes four lags of inflation, the real marginal cost (i.e. real unit labor costs), detrended output, and wage inflation.[3] We also check the robustness of our results to changes in the instruments set, in particular we will also estimate the model using four lags on inflation and only two lags of wage inflation, output and marginal cost. [4]

In Table 1 we present the results for the hybrid model over the period 1970:1 1997:1, which allows us to test directly against the hypothesis of backward-looking inflation inertia. The first three columns report the estimates of the two primitive parameters, ω, α, and the discount factor β; while the fourth to sixth columns report the reduced form coefficients γ_b and γ_f , and the slope coefficient on real marginal cost $\widetilde{\lambda}$. Finally, in the last two columns we display the index of price rigidity and the Hansen test of overidentifying restrictions.

The parameter β is rather low in most of the countries excepts for the Netherlands, although it is in a reasonable range once we take into account the uncertainty surrounding the estimates. The degree of price stickiness is well estimated in all countries. The most striking feature that can be elicited from this Table is that two different groups of countries emerge. The first group is basically represented by Germany (and to a lesser extent the Netherlands), for which we find no evidence of backward lookingness in the inflation equation, and so the degree of price stickiness is quite similar to that obtained in the forward-looking specification. The rest of the countries (France, Italy, Spain) form a more compact group in which, although the forward-looking component is slightly more relevant, the backward-looking component plays a significant role. In addition, the rest of the parameters of the model are quite well estimated and in line with the previous results by Galí, Gertler and López-Salido (2000). As noted above, allowing for a fraction of backward-looking firms will affect the average duration that prices are kept constant. Thus, in that case the average duration in the backward-looking group of countries rises to between 6 and 12 quarters for the Netherlands and Spain, respectively. Finally, in row (2) of Table 1 we show that the results are robust to a different instruments set. In particular, we use four lags of inflation byut only two lags of output, wage inflation and marginal

[2]Notice that λ also corresponds to the reduced form estimates (see e.g. Galí and Gertler (1999) and Sbordone (2002)).

[3]In the following analysis, the standard errors are robust to the presence of correlation up to order eight (Newey-West correction). As stressed by Galí, Gertler and López-Salido (2000), this will allow to control for the presence of measurement error in our measure of real marginal costs.

[4]In order to estimate the model we calibrate the parameters η, and σ. We set $\eta = 0.6$ and $\sigma = 6$. As it will be clear in the theoretical section, these values are compatible with a steady state labor income share of 0.75 and a steady state markup $\mu = 1.2$.

cost.

We view this evidence as supporting the existence of two different zones inside the euro area. There is one country (Germany) where we cannot reject that inflation has a dominant forward-looking character. This country represents around 35 percent of the GDP of the area. The other group of countries is formed by France, Italy, Spain and to a lesser extent the Netherlands and inflation dynamics are mixed by a forward and a backward-looking component. These four countries represent around 53 percent of the GDP of the area.[5]

We evaluate the implicit average duration in the group of countries where the backward looking component is a significant determinant of inflation persistence, by using the following weighted average: $AD = \prod_{i=1}^{4} (D_i)^{w_i}$, where i represents the country and w_i is the consumption weight of country i in total consumption in the area. Using the results in Table 1, the corresponding average duration in this backward-looking area is slightly lower than two years (7.8 quarters). This value contrasts with the estimates for Germany, which were slightly more than one year (around 5 quarters). Finally, we try to evaluate the uncertainty surrounding these estimates proceeding in the following way. We calculate, for each country, two durations that bound 95 percent of the empirical estimates (i.e. $D \pm 2$ se, where se are the corresponding standard errors - see Table 1-). Using these values we can obtain an upper and a lower value of the average duration in the group of backward-looking countries, which can be thought as a measure of the uncertainty surrounding the degree of inflation persistence in this group of countries. This exercise yields a duration of between 7 and 8.3 quarters for that set of countries. In the case of Germany, the forward-looking region of the area, the duration varies between 4.6 and 5.3 quarters.

Finally, given the changes that have taken place in European monetary policy, in Figure 2 we present the structural estimates, resulting from a rolling regression starting at the beginning of the nineties, of the degree of price stickiness (i.e. α and ω, respectively) for each country. As can be seen, our estimates of α are fairly stable, showing that by using the model we are able to identify this coefficient as a fairly structural one. A similar conclusion arises for the estimated backward looking parameter (ω) with a small symptom of instability in the case of Germany. In this country we find limited evidence of backward lookingness at the beginning of the nineties, but the parameter progressively diminishes to nil at the end of the sample period.

3 The Model

In this section, we exploit the results of the previous section to address some normative issues, such as the optimal inflation-targeting policy and the fully optimal policy in

[5]The weights are the following: France, 22.3; Italy, 15.5; Spain, 8.5; and the Netherlands, 5.7, respectively.

the euro area. In keeping with the empirical section, we model the euro area as a currency area made up of two regions labeled H and F. In region F sellers show only *forward-looking behavior*, instead region H is characterized by the *hybrid* model where past inflation plays also a crucial role for understanding inflation persistence. The whole area is populated by a continuum of agents on the interval $[0,1]$. There is no possibility of migration across regions. A generic agent, belonging to the area, is both producer and consumer: a producer of a single differentiated product and a consumer of all the goods produced in both regions. Households maximize the expected discounted value of the utility flow. Preferences of the generic household j are given by

$$U_t^j = \mathrm{E}_t \left\{ \sum_{k=t}^{\infty} \beta^{k-t} \left[U(C_k^j, \xi_{D,k}^i) - \widetilde{V}(N_k^j, \widetilde{\xi}_{S,k}^i) \right] \right\},$$

where the upper index j denotes a variable that is specific to agent j, while the upper index i denotes a variable that is specific to region i. We have that $i = H$ if $j \in [0, n)$, while $i = F$ if $j \in [n, 1]$. E_t denotes the expectation conditional on the information set at date t, while β is the intertemporal discount factor, with $0 < \beta < 1$.

Agents obtain utility from consumption C (through the function U), while they derive disutility from supplying hours, N, to the production of the differentiated product j (through the function $\widetilde{V}$). The utility function is separable into these two arguments. With ξ_D^i and $\widetilde{\xi}_S^i$ we denote region-specific demand and supply shocks, respectively. The consumption index C is a Cobb-Douglas function of the consumption bundles of home and foreign goods, irrespective of the region of residence of the consumer.[6]

We assume that the asset markets are complete both at a regional and international level and that the law of one price holds without any segmentation in the goods market across different regions. These assumptions imply that the marginal utilities of nominal and real incomes are equated across regions. Thus, asymmetric demand shocks are properly offset by appropriate movements in the consumption level of both regions. Moreover, given that the consumption index is common across regions, it follows that the consumption-based price index P is equal across regions.

As it is common in the recent literature on monetary policy evaluation, we exploit the micro-foundations of our framework in order to provide a welfare criterion for the Central Bank based on the utility of the consumers.[7] This criterion allows for a direct evaluation of the deadweight losses implied by the distortions included in the model. As welfare criterion, we assume the discounted sum of the utility flows of the

[6]The framework can be readily extended to analyze the general case with a CES consumption index, as shown in Benigno (2001b).

[7]See, for instance, Rotemberg and Woodford (1997), Woodford (1999b) and Erceg, Henderson and Levin (2000).

household belonging to the whole union. The average utility flow is defined as

$$w_t \equiv \int_0^1 [U(C_t^j, \xi_{D,t}^i) - \widetilde{V}(N_t^j, \widetilde{\xi}_{S,t}^i)]dj,$$

at each date t, where it has been implicitly assumed that each region has a weight equal to its economic and population size. The welfare criterion of the whole union is then defined as

$$W = \mathrm{E}_0 \left\{ \sum_{t=0}^{+\infty} \beta^t w_t \right\}.$$

Following Rotemberg and Woodford (1997), Woodford (1999b), Amato and Laubach (2001), Benigno (2001a) and Steinsson (2000), we compute a second-order Taylor series expansion of W around the deterministic steady state where all the shocks are zero. Our second-order approximation delivers an intuitive representation of the welfare function:

$$W = -\Omega \mathrm{E}_0 \left\{ \sum_{t=0}^{+\infty} \beta^t L_t \right\}, \tag{2}$$

$$L_t = \Lambda[\widehat{Y}_t^W - \widetilde{Y}_t^W]^2 + n(1-n)\Gamma[\widehat{T}_t - \widetilde{T}_t]^2 + (1-\theta)(\pi_t^F)^2 + \theta(\pi_t^H)^2 + \theta\psi(\Delta\pi_t^H)^2,$$

where Ω, Λ, Γ, θ, ψ are functions of the structural parameters of the model.[8]

Note that a cap-variable ($\widehat{\ }$) represents the deviations of that variable from the steady state under the sticky-price equilibrium, while a tilde-variable ($\widetilde{\ }$) represents the deviations from the steady state under the flexible-price equilibrium.

From (2), it follows that monetary policymakers should stabilize the output gap, $y_t^W = \widehat{Y}_t^W - \widetilde{Y}_t^W$, i.e. the deviations of area output from its natural rate, as well as the deviations of the terms of trade $\widehat{T}_t$ from their natural rate $\widetilde{T}_t$. Indeed, following an asymmetric shock, efficiency requires that relative prices should be moved in order to shift the burden of adjustment "equally" across regions. Monetary policymakers

[8] Where the relationship among the structural parameters of the model, and the welfare coefficients is given by:

$$\begin{aligned}
\Omega &\equiv \frac{1}{2} U_C \overline{C}(nd^H + (1-n)d^F)\sigma(1+\sigma\eta) \\
\Lambda &\equiv \frac{1}{\sigma}\frac{\rho+\eta}{1+\sigma\eta}\frac{1}{nd^H+(1-n)d^F},\ d^i = \frac{\alpha^i}{(1-\alpha^i)(1-\alpha^i\beta)},\ i = H, F \\
\Gamma &\equiv \frac{1}{\sigma}\frac{1+\eta}{1+\sigma\eta}\frac{1}{nd^H+(1-n)d^F}, \\
\theta &\equiv \frac{nd^H}{nd^H+(1-n)d^F}. \\
\psi &\equiv \frac{\omega^H}{\alpha^H(1-\omega^H)},
\end{aligned}$$

An appendix on the details of the derivation is available online.

should also stabilize a weighted average of the squares of the producer inflation rates in each region. However, there is a trade-off between stabilizing inflation in both regions and stabilizing relative prices to their natural level, in fact as prices are stable within a region, the terms of trade cannot be moved to offset asymmetric shocks. This trade-off is further amplified by the last term in the loss function. Given the importance of past inflation for understanding inflation persistence in the area, as in Amato and Laubach (2001) and Steinsson (2000), we obtain that monetary policymakers should also stabilize the growth of inflation in the hybrid region H. This term follows from the presence in this region of backward-looking agents that behave according to the rule of thumb. In the case in which the fraction of backward-looking agents becomes zero, the last term disappears and the welfare criterion collapses to the one in Benigno (2001a).

As noted in our empirical section, here we recall the aggregate supply specifications in the log-linear form. For the F and H regions, we obtain respectively:

$$\pi_{F,t} = \lambda^F \ \widehat{mc}_t^F + \beta \ E_t\{\pi_{F,t+1}\}, \tag{3}$$

$$\pi_{H,t} = \gamma_b^H \pi_{H,t-1} + \lambda^H \ \widehat{mc}_t^H + \gamma_f^H \ E_t\{\pi_{H,t+1}\}, \tag{4}$$

where the coefficients λ^F, λ^H, γ_b^H and γ_f^H correspond to the parameters defined in the empirical section, with the appropriate upper script. For each region, we can further decompose the real marginal costs by using the structure implied by the consumer's optimizing behavior. In deriving (3) and (4), we have assumed that each differentiated good j is produced according to the production function $y^j = A^i f(N^j)$ where A^i is a region-specific productivity shock. Given this assumption, the average real marginal cost in region F can be related to

$$mc_t^F = \frac{MC_t^F}{P_{F,t}} = \frac{w_t^F}{P_t}\frac{P_t}{P_{F,t}}\frac{1}{A_t^F f'(f^{-1}(Y_t^F/A_t^F)},$$

where the foreign nominal marginal costs, MC_t^F, has been deflated by the appropriate foreign producer price index P_F and the average real wage is determined by the marginal rate of substitution between labor and consumption as in

$$\frac{\widetilde{V}_N(N_t^F, \widetilde{\xi}_{S,t}^F)}{U_C(C_t^F, \xi_{D,t}^F)} = \frac{w_t^F}{P_t}. \tag{5}$$

We can then substitute and obtain

$$mc_t^F = \frac{\widetilde{V}_N(f^{-1}(Y_t^F/A_t^F), \widetilde{\xi}_{S,t}^F)}{U_C(C_t^F, \xi_{D,t}^F)}\frac{P_t}{P_{F,t}}\frac{1}{A_t^F f'(f^{-1}(Y_t^F/A_t^F))}.$$

Following Woodford (2000), we define

$$V(y^j, \xi^i_{S,t}) \equiv \widetilde{V}(f^{-1}(y^j/A^i_t), \widetilde{\xi}^i_{S,t}),$$

where the vector ξ^i_S has been appropriately modified. We can then write the average real marginal costs as

$$mc^F_t = \frac{V_y(C^W_t T^{-n}_t, \xi^F_{S,t})}{U_C(C^F_t, \xi^F_{D,t})} T^{-n}_t.$$

where foreign output has been written as $Y^F = C^W T^{-n}$, with the world consumption denoted by C^W. Taking a log-linear approximation of the above equation, we obtain that the deviations of the average real marginal costs from the steady state are

$$\widehat{mc}^F_t = (\rho + \eta)(\widehat{Y}^W_t - \widetilde{Y}^W_t) - n(1+\eta)(\widehat{T}_t - \widetilde{T}_t),$$

in which we have defined the inverse of the elasticity of the disutility of supply goods and of the elasticity of substitution in consumption as $\eta \equiv V_{yy}\overline{Y}^F/V_y$ and $\rho = -U_{CC}\overline{C}^F/U_C$ respectively. Following the same steps, we get the log-linear approximation of the average marginal costs for the hybrid country H as

$$\widehat{mc}^H_t = (\rho + \eta)(\widehat{Y}^W_t - \widetilde{Y}^W_t) + (1-n)(1+\eta)(\widehat{T}_t - \widetilde{T}_t).$$

Finally we can write the aggregate supply equation for the region F as

$$\pi_{F,t} = k^F_C(\widehat{Y}^W_t - \widetilde{Y}^W_t) - nk^F_T(\widehat{T}_t - \widetilde{T}) + \beta E_t\{\pi_{F,t+1}\} \tag{6}$$

where

$$k^F_C \equiv \frac{(1-\alpha^F\beta)(1-\alpha^F)}{\alpha^H}\frac{\rho+\eta}{1+\sigma\eta} \quad \text{and} \quad k^F_T = k^F_C\frac{1+\eta}{\rho+\eta}.$$

As in the corresponding closed-economy version, inflation depends on present and expected future values of the real marginal costs. However, in an open-economy framework, the real marginal costs are not proportional to the output gap, as a consequence of the interdependence induced by the international relative prices. This result has been firstly shown by Svensson (2000). The smaller and more open the country is, the more relative prices influence the real marginal costs and thus inflation rates. In the same way, the aggregate supply equation for region H is

$$\pi_{H,t} = \gamma^H_b\pi_{H,t-1} + k^H_C(\widehat{Y}^W_t - \widetilde{Y}^W_t) + (1-n)k^H_T(\widehat{T}_t - \widetilde{T}_t) + \gamma^H_f \mathrm{E}_t\{\pi_{H,t+1}\} \tag{7}$$

where

$$\gamma^H_b \equiv \frac{w^H}{w^H(1-\alpha^H+\alpha^H\beta)+\alpha^H} \quad \text{and} \quad \gamma^H_f \equiv \frac{\gamma^H_b\alpha^H\beta}{w^H},$$

$$k^H_C \equiv \frac{\rho+\eta}{1+\sigma\eta}\frac{(1-\omega^H)(1-\alpha^H)(1-\alpha^H\beta)}{[w^H(1-\alpha^H+\alpha^H\beta)+\alpha^H]}, \quad \text{and} \quad k^H_T \equiv \frac{1+\eta}{\rho+\eta}k^H_C.$$

The model is closed with the terms-of-trade identity which in a log-linear approximation, can be written as

$$\widehat{T}_t = \widehat{T}_{t-1} + \pi_t^F - \pi_t^H. \tag{8}$$

In the optimal plan monetary policymakers are committed to maximize the welfare function (2) under the constraints given by the structural equations (6), (7) and (8). Because of the existing trade-off, the optimal plan is highly complicated. We do not go into the details of the characterization of the optimal plan. Instead we look at simpler rules.

In the analysis that follows, in keeping with the empirical section, we 'calibrate' the parameter σ equal to 6, which corresponds to a steady-state mark-up of 1.2. We set the inverse of the elasticity of substitution in consumption, ρ, equal to $1/6$ as in the recent work of Rotemberg and Woodford (1997). The elasticity of the disutility of producing the differentiated goods is set equal to 0.6. Considering a reasonable value of the share of labor in total output of 0.75, then the implied Frisch elasticity of labor supply is equal to 5.[9] Moreover, the empirical analysis of the previous section has suggested a possible partition of the countries analyzed in two groups. Accordingly, we can then calibrate the size of region H to $n = 0.6$ while the size of region F will be $(1 - n) = 0.4$. Finally, we consider that the economy is subject to terms of trade shocks following a Markovian process of the kind:

$$\widetilde{T}_t = \tau \widetilde{T}_{t-1} + \varepsilon_t,$$

where we set $\tau = 0.9$. As results from the micro-foundation of the model, these terms-of-trade shocks originate from asymmetric supply shocks. The value chosen for τ is consistent with the calibration used in the international business cycle literature, e.g. Backus et al. (1992) and Kehoe and Perri (2000).

4 Inflation Targeting and Nominal Rigidities in the Presence of Backward Looking Price-setters

As already described in section 1, the hybrid model can sometimes offer a complementary explanation of the persistence in inflation that is currently observed (see Galí, Gertler and López-Salido (2001)). Still, one open issue is to address the evaluation of the degree of nominal rigidity implicit in such a *hybrid* formulation. In the *forward looking model*, we already know the answer. For a given fraction α^F of agents that in each period are constrained to keep their prices constant, an indicator of the degree

[9] This value is in line with most of the authors in the RBC literature. Actually, our value of 5 is lower than the value used by Christiano and Eichenbaum (1992), and it is clearly lower than infinite which is the value that corresponds to Hansen's model of indivisibilities (1985). Nevertheless, these values are higher than the ones emerging from the microeconometric estimates of the labor supply literature (e.g., see Killingsworth and Heckman, 1986).

of nominal rigidity is given by the average length or duration of contracts in units of time represented by $D^F = 1/(1-\alpha^F)$. However, in the hybrid model, there is no direct answer.

To deal with this issue we note that there are two components affecting the degree of rigidity. The first is given by the fraction of agents that cannot adjust their prices but that behave in a forward-looking manner, formally: $(1-\omega^H)\alpha^H$. The second is given by the fraction of agents that behave according to the rule of thumb (ω^H). Our aim is to map the pair of parameters (α^H, ω^H) into an equivalent value of α^F.

The aim of this section is to find a correspondence between the nominal rigidity intrinsic in the hybrid model and that of the forward-looking model within the class of inflation targeting policies described above. Hence, as a criterion for such an evaluation we choose the class of optimal inflation-targeting policies, i.e. the weight ξ in the class of inflation-targeting policies

$$\xi\pi_t^H + (1-\xi)\pi_t^F = 0, \tag{9}$$

where ξ is chosen to maximize the welfare criterion (2) subject to the structural equations of the model ((6), (7) and (8)). Why do we proceed in such a way? In fact, as shown in Benigno (2001a), in a model with only forward-looking agents, in the event the degrees of rigidity are the same across the two regions, the optimal choice of ξ will be equal to n, which is the size of region H. Each region's inflation rate receives a weight equal to its economic size (i.e. this coincides with HICP targeting). But, for values of the degrees of rigidity in region H higher than region F, a weight bigger than n will be given to region H (and viceversa in the opposite case). Hence, a pair (α^H, ω^H) will be equivalent to α^F if the optimal weight ξ coincides with n. This equivalency has a natural interpretation in the case where ω^H is equal to zero, because it directly relates the inflation weights to the duration and so to the parameters $\alpha's$. But, what is the relevant measure of nominal rigidities in the hybrid country? Or, in other words, how does the existence of backward-looking firms affect the weights of the optimal inflation targeting policy? Formally, in the case where ω^H is different from zero, we will look for the pair (α^H, ω^H) that is equivalent in terms of implied nominal rigidity to the single value α^F in the optimal inflation targeting policy, if each region's inflation rate receives a weight equal to its economic size. Table 2 summarizes some of the results.[10]

For any given duration implicit in the forward-looking supply equation (the columns in the table), and for any given fraction of backward-looking agents (the rows in the table) each cell represents the value of α^H consistent with that duration according to our mapping criterion. As the fraction of backward looking agents increases, a lower value of α^H is needed to match the implicit duration (i.e. the degree of stickiness) of the forward-looking model. Likewise, Figure 3 shows the same results for a broader grid of parameters. An interesting observation that we can derive from this figure is

[10] The model is calibrated according to the parameters of the previous section.

that, for reasonable values of duration (usually slightly higher than 3 or 4 quarters), a good approximation of the duration in the hybrid model is given by the following expression:

$$D^H = \frac{1}{1-\alpha^H}\frac{1}{1-\omega^H},$$

which is the duration that could be derived by observing that the total fraction of agents that have prices fixed or that behave according to the rule of thumb is given by $\omega^H + (1-\omega^H)\alpha^H$.

Hence, we have found the correspondence between the rigidity intrinsic in the hybrid model and that of the forward-looking model within the class of inflation-targeting policies described above. When the two rigidities are the same, the optimal inflation-targeting policy requires that each region receives a weight equal to its economic size. If region H has a higher degree of rigidity, a weight higher than n should be given to inflation in this region.

The empirical section has provided an estimation of the parameters α^H,α^F and ω^H. At the estimated point, we obtain that the rigidity implicit in the forward-looking countries is around 5 quarters, while in the hybrid model it is around 8 quarters, according to the rough measure of rigidity D^H. This suggests that in the optimal inflation-targeting policy a higher weight, greater than size n, should be given to region H. In fact, by simulating for the optimal weight, we find that $\widehat{\xi} = 0.797$, well above the value of HICP-targeting (0.60).

Given the uncertainty surrounding our estimates, in Tables 3 we provide a sensitivity analysis on how alternative degrees of stickiness in both areas would affect the optimal $\widehat{\xi}$. In particular, in the forward looking area, we consider that the degree of rigidity can vary between 3 and 6 quarters, while in the hybrid region the degree of uncertainty of our estimates is somewhat higher, so we consider that this rigidity is between 7 and 12 quarters. In particular, in the hybrid region, we fix the parameter ω^H and let the parameter α^H vary so as to obtain the degrees of rigidity in the range between 7 and 12 quarters. In Table 3a we set ω^H equal to the point estimate 0.48, while in Tables 3b and 3c it assumes the lower and the upper bound on the 95% confidence interval, 0.34 and 0.61, respectively. In the intervals considered the optimal choice of $\widehat{\xi}$ varies between 0.7 to 0.95, reaching the smallest value when the difference in the durations across regions is small, while the largest value is obtained when the difference is large. Indeed, in this experiment, we have considered that the difference in durations ranges from 1 quarter to 9 quarters. However, for the central parts of the intervals considered, the optimal choice of $\widehat{\xi}$ is stable around 0.8-0.85. Most interestingly, the optimal $\widehat{\xi}$ is robust across different sources of rigidity, whether from the backward-looking component or the forward-looking one. This is consistent with our previous findings which emphasize that what matters for evaluating the degree of rigidity in the hybrid region is the composite duration, given by the index D^H instead of D^F.

5 Terms-of-Trade Shocks and Monetary Policy

In this section, we compare the adjustment of the economies in responses to terms-of-trade shocks under different monetary policies from both positive and normative viewpoints. In particular, we focus on four alternative policy rules. The first policy under consideration is the *fully optimal policy.* Formally, this implies that monetary policymakers are committed to maximizing the welfare function (2) under the constraints given by the structural equations (6), (7) and (8). The second class is the *optimal inflation targeting policy* in which policymakers are committed to the class of policies given by the previous expression (9) and they choose optimally ξ. The third class is *HICP targeting* which belongs to the previous class; but, unlike the previous case, the parameter ξ is set to be equal to the size of the H country, say n.[11] It is always the case that optimal policy performs at least as well as the optimal inflation targeting policy, while the latter is always at least as good as HICP-targeting. Finally, we further analyze a policy aimed at *stabilizing the output gap* of the area, i.e. setting $y_t^W = 0$ at all dates t.

5.1 Output Gap Targeting

Why do we focus on the latter policy? Notice that within the theoretical framework described above this policy can be easily ranked in terms of the previous ones when both regions have only forward-looking agents. To see this let us consider conditions (6), (7) under the assumption that $\omega^H = 0$. It can be shown that, in this case, the policy that stabilizes the output gap coincides with a policy *within the class of the inflation-targeting policies* where the weight ξ is chosen to be:

$$\xi = \frac{nk_T^F}{(1-n)k_T^H + nk_T^F}. \qquad (10)$$

Thus, it is then the case that by stabilizing the area output gap, policymakers are implicitly pursuing an inflation-targeting policy, not an optimal one, although the performance of this output-gap targeting policy is nested in that of the optimal inflation-targeting policy. In fact, we will show that the stabilization of the output gap in the area performs at least as well as HICP-targeting, given that the weights to the inflation rates are adjusted as to weight more the region with higher degree of rigidity in the area (see expression (10)). In particular, the weight given to region H is higher the greater is the size of this economy (higher n), and the higher the degree of flexibility of region F in response to terms-of-trade shocks (i.e. higher

[11] A kind of *HICP targeting* can be seen as the policy followed by the European Central Bank (Alesina *et al.* (2001)). HICP stands for Harmonized Index of Consumer Prices. The HICP inflation of the whole euro area is constructed as a weighted average of the HICP of the single countries belonging to the union, with weights equal to the share of the country's consumption in the consumption of the area.

k_T^F).Things are more complicated when ω^H is different from zero. Under such circumstances, the output-gap stabilization policy is no longer nested in the class of the inflation-targeting policy.

5.2 Welfare Comparisons

A numerical quantification appears in Table 4, where we present the welfare comparisons among all the above-mentioned policies. We summarize the comparisons in terms of the variability of the variables that are relevant for the computation of welfare, using the statistic $v(.)$. This operator, $v(.)$, applied to the generic variable x, is defined as follows:

$$v(x) = E[E_0(1-\beta)\sum_{t=0}^{+\infty}\beta^t x_t^2].$$

where, as in Woodford (1999a), the unconditional expectations E are taken over the possible initial states of the economy $\widetilde{T}_0$. By using this operator, it is possible to analyze welfare, W, as a composite of the operator $v(.)$ applied to the relevant variables. Thus, we are able to understand the contribution of the relative volatilities of inflation and output to welfare under alternative policy rules. In particular, we can decompose welfare in five components: first, the output gap of the area $v(y^W)$; second, the output-gap differential or the terms of trade gap $v(\widehat{T}-\widetilde{T})$[12]; third and fourth, the contributions of inflation in both areas, i.e. $v(\pi^F)$ and $v(\pi^H)$, respectively; and finally the changes in inflation in the sticky inflation area (i.e. the area where the hybrid model applies) $v(\Delta\pi^H)$. As shown in Table 4 we have ranked welfare starting from the worst policy, HICP-targeting, and ending with the fully optimal one. In particular, we provide a measure of the losses in terms of permanent percentage shift in steady-state consumption. To this end, we define the index δ as

$$\delta^j \equiv -(1-\beta)\cdot\left[\frac{W^j - W^E}{U_C\overline{C}}\right],$$

where W^E is welfare under the efficient policy, which is not feasible; W^j is welfare indexed by the four policies that are considered in this experiment, while U_C is the marginal utility of consumption and $\overline{C}$ is the steady-state level of consumption. Thus δ^j measures the permanent percentage shift in steady-state consumption that is lost under the policy j with respect to the efficient level.

Table 4 summarizes the comparisons, where the variance of the shock ε has been normalized to one. However, the variance of ε is crucial for evaluating the magnitude

[12] Notice that the output gap differential is proportional to the terms-of-trade gap, i.e. formally the following relationship holds:

$$y_t^H - y_t^F = \widehat{T}_t - \widetilde{T}_t.$$

of the costs in terms of a permanent shift in steady-state consumption. In keeping with the international real business cycle literature, we calibrate the variance of ε to be 0.01^2. Using the measure δ, we have then evaluated the costs of the fully optimal policy to be around 0.0148 percent of a permanent shift in steady-state consumption.[13] Output-gap stabilization approximates the welfare that would be achieved under the optimal policy. The optimal inflation-targeting policy performs considerably better than HICP-targeting but less than the optimal policy and output-gap stabilization policy. Indeed, the costs of the HICP targeting and the optimal inflation targeting policies are of the order of 0.023 and 0.020 percent, respectively. The output stabilization policy is quite close to the fully optimal one since many of the welfare gains in the fully optimal policy arises from the fact that the output gap is almost fully stabilized in the area. Notice also that in the fully optimal policy the output gap of the area is not fully stabilized but the relative output gaps or the terms of trade are much more stabilized than in the case of the output gap stabilization policy. Inflation-targeting policies are far enough from the previous two policies, because they imply that the output gap of the area is far from stabilized.

An interesting observation is that all the policies under consideration perform equally in terms of the variance of the terms-of-trade gap. Given the high degree of price rigidity, and the persistence of the relative price shock, the terms of trade can adjust only slowly. Hence, monetary policy cannot efficiently shift the unfavorable shocks in region H to region F. In terms of the welfare function (2), it can only control the area output gap and, marginally, the inflation rates in each region. However, for this calibrated example, the weights on the inflation rates are of an order of magnitude *100 times* larger than the weights on the output gap, thus they matter far more for the maximization of welfare. Interestingly, in our case, the output gap policy is then also able not to destabilize the inflation rates.

5.3 Dynamic Adjustments

To gain intuition on the previous results, in Figures 4 and 5 we plot the impulse response functions of the variables that are relevant for the computation of welfare following a negative shock to the terms of trade, namely an unexpected transitory drop in $\widetilde{T}$. This shock can be interpreted as a decrease in productivity in country H relative to country F. Efficiency would require that terms-of-trade changes offset completely terms of trade shocks, without any movements in domestic inflation rates and output gaps. However, in a currency area, such efficient equilibrium is not feasible. After the unfavorable terms-of-trade shocks, inflation in region H increases, while it decreases in region F. Under the HICP-targeting regime, inflation increases more in region H and decreases less in region F than under the optimal plan. In fact, HICP targeting does not adjust for the differences in the degrees of rigidity across countries.

[13] Lucas (1988) has evaluated the costs of the business cycle to be around 0.05 percent of a permanent shift in steady-state consumption.

On the other hand, the optimal inflation-targeting policy gives a higher weight to the inflation rate in region H, which has a higher degree of rigidity. Hence, it succeeds in stabilizing more the inflation in that region. However, it fails in stabilizing the area output gap. HICP-targeting further exacerbates fluctuations in the area output gap. It so happens that, in our calibrated-estimated economy, the fully optimal plan requires quasi-stabilization of the output-gap at the area wide level. It is then the case that the policy of stabilizing the area output-gap completely can approximate the optimal plan well. By stabilizing the area output-gap, it is also possible to reach the right inertia in inflation rates that the commitment to the optimal policy requires, so the path of the inflation rates is also stabilized.

5.4 Sensitivity Analysis

In Figures 6 and 7, we compare the different policies under a broad range of parameters. First, in Figure 6, we fix the average duration at the area level at 6 quarters, and we let the relative duration across the regions vary (for different values of ω^H). The average duration is defined as $D^W = (D^H)^n(D^F)^{1-n}$, while the relative duration is $D^R = D^H/D^F$. As the fraction of backward-looking agents increase, output-gap stabilization performs well compared to the optimal inflation-targeting policy. But this depends on relative duration. Not surprisingly, area output targeting is a symmetric policy in a world in which there are big asymmetries. It works well when the duration of the hybrid model exceeds that of forward-looking model. It does not work when, notwithstanding the backward-looking component, the hybrid-model region is less rigid than the forward-looking region. Figure 7 performs the same analysis for an average duration of 3 quarters. In particular, Figures 8 and 9 show a case in which output-gap targeting is destabilizing. In these figures, we have assumed that the forward-looking component in the hybrid region is such that $\alpha^H = 0.5$, while we have kept $\omega^H = 0.5$ and $\alpha^F = 0.785$.

There is some intuition as to why, under some parametrization, the stabilization of the output gap can approximate the optimal policy. In fact, the example in Figures 8 and 9 differs from Figures 4 and 5 because the main factor of rigidity in the hybrid region is given by the backward-looking (ω^H). Looking back to the AS equation in the hybrid region

$$\pi_{H,t} = \gamma_b^H \pi_{H,t-1} + k_C^H(\widehat{Y}_t^W - \widetilde{Y}_t^W) + (1-n)k_T^H(\widehat{T}_t - \widetilde{T}_t) + \gamma_f^H \mathrm{E}_t\{\pi_{H,t+1}\}, \qquad (11)$$

when the rigidity in the forward-looking component (α^H) decreases, for a given ω^H , all the coefficients γ_b^H, k_C^H, k_T^H and γ_f^H increase. Indeed, past inflation becomes more important, and the short-run reaction to real marginal costs increase. Given that the terms of trade move very slowly, under the policy of stabilization of the output-gap, the terms of trade shock has a bigger impact on inflation rates. Given the importance of the backward-looking component, this effect is transmitted also in the future periods. Alternatively, when α^H is higher, the impact of the terms-of-trade shocks on inflation is smaller, as is their persistence and volatility.

6 Conclusions

We have shown that there are sizeable differences in rigidities across the countries belonging to the European Monetary Union. In particular, as a criterion for evaluation, we rely on a microfounded welfare function which, in the spirit of King and Wolman (1998) and Woodford (1999b), allows for an evaluation of the deadweight losses existing in the model. The idea that monetary policy should be geared to eliminating the distortions in the relative price mechanism is close to the principle under which a mandate of price stability has been delegated to the ECB. In fact, as stressed in the 1999 Bulletin of the ECB (January 1999), the main argument for price stability is that it improves the transparency of the relative price mechanism thereby avoiding distortions and helping to ensure that the market allocates real resources efficiently both across uses and over time. According to the criterion of efficiency followed by the ECB, our framework has shown that the quantitative target in terms of stabilization of the HICP does not fully succeed in eliminating the distortions in the relative price mechanism.

We have proposed two policies that may perform better: the *optimal inflation targeting* policy, which implies that the inflation rate in the region with higher degree of rigidity should receive a higher weight; and the *output-gap stabilization* policy.

An inflation targeting policy that assigns higher weight to countries with higher degrees of inflation persistence benefits those countries since once the policy of the central bank is credible, it produces lower inflation rates for them simply because it cares more about those inflation rates. Notwithstanding, such a rigidity-adjusted inflation-targeting policy may create the wrong incentives for the adoptions by the countries of structural changes that reduce their goods and labor market rigidities. This concern does not consider that once there are rigidities in the price mechanism, relative prices move also sluggishly, so asymmetric shocks would require enough flexibility in the adjustment of relative prices.

The policy of stabilizing the output gap is immune to this adverse-incentive criticism as it gives a weight to each country similar to its economic size as in the HICP-targeting policy. Our analysis shows that, in cases where the inertia in the terms of trade is high and there are important backward looking components in inflation in some zones of the area, monitoring the output gap can give the right information on the final goal. However, as we have shown, it is less robust across different parametrizations, and in some cases may perform worse than HICP targeting. Moreover, it is more difficult to implement since it involves the unobservability of the natural level of output. While, in our context, the natural level indicates the flexible-price equilibrium, there are several other concepts of the natural rate as well as several ways to measure it, as outlined also in McCallum (2001). Thus, a policy of stabilization of the output gap is neither easy to implement nor to communicate to private agents.

These arguments suggest that it may not be desirable to abandon HICP-targeting for optimal inflation targeting as defined in this paper. Nevertheless, it also emphasizes that inflation differentials are not irrelevant for monetary policy. First we have to be conscious of the welfare costs associated to the distribution of inflation across countries; and second, cross country inflation information can provide useful information as far as the degree of inertia differs across countries.

References

[1] Alesina, Alberto; Olivier Blanchard; Jordi Galí, Francesco Giavazzi and Harald Uhlig (2001), *Defining a Macroeconomic Framework for the Euro Area*, in *Monitoring the European Central Bank 3*, CEPR 90-98, London.

[2] Amato, Jeffrey and Thomas Laubach (2001), "Rule-of-Thumb Behaviour and Monetary Policy," Finance and Economics Discussion Series no.2002-5, Board of Governors Federal Reserve System.

[3] Backus, David K., Kehoe, Patrick and Finn Kydland (1992), "International Real Business Cycles," *Journal of Political Economy* 100, 745-775.

[4] Batini, Nicoletta, Brian Jackson and Stephen Nickell (2000), "Inflation and the Labour Share in the UK," unpublished manuscript, Bank of England.

[5] Benigno, P. (2001a), "Optimal Monetary Policy in a Currency Area," CEPR Discussion Paper No. 2755.

[6] Benigno, P. (2001b), "Price Stability with Imperfect Financial Integration," unpublished manuscript, New York University.

[7] Calvo, Guillermo A. (1983), "Staggered Prices in a Utility Maximizing Framework", *Journal of Monetary Economics*, 12, 383-398.

[8] Christiano, Lawrence, Martin Eichenbaum, (1992), "Current Real Business Cycle Theories and Aggregate Labor Market Fluctuations" *American Economic Review,* 82 (3), 430-450.

[9] Coenen, Gunter and Volker Wieland (2000), "A Small Estimated Euro-Area Model with Rational Expectations and Nominal Rigidities", ECB Working Paper N^{o}30.

[10] Erceg C., Dale Henderson, and Andrew Levin, (2000), "Optimal Monetary Policy with Staggered Wage and Price Contracts," *Journal of Monetary Economics*

[11] Fuhrer, Jeffrey, Geoffrey Moore (1995), "Inflation Persistence", *Quarterly Journal of Economics*, 110(1), 127-159.

[12] Galí, J. and Mark Gertler (1999), "Inflation Dynamics: A Structural Econometric Analysis", *Journal of Monetary Economics,* 44, 195-222.

[13] Galí, J., Mark Gertler and J. David López-Salido (2000), "European Inflation Dynamics", *European Economic Review,* forthcoming.

[14] Hansen, G. (1985), "Indivisible Labor and the Business Cycle", *Journal of Monetary Economics,* 16, 309-327.

[15] Kehoe, Patrick and Fabrizio Perri (2000), "International Business Cycles With Endogenous Incomplete Markets," unpublished manuscript, Federal Reserve Bank of Minneapolis, Staff Report 265.

[16] Killingsworth, M. and Heckman, J. (1986), "Female Labor Supply: A Survey", in: O. Ashenfelter and R. Layard (eds), *Handbook of Labor Economics*, Vol.1 103-204, Elsevier Science B.V. Amsterdam.

[17] King, Robert G. and Alexander L. Wolman (1998), "What Should Monetary Authority Do When Prices are Sticky?" in J.B.Taylor (ed.), *Monetary Policy Rules*. University of Chicago Press for NBER.

[18] Lucas, Robert (1987), *Models of Business Cycles,* Blackwell, Oxford.

[19] McCallum, Bennett (2001), "Should Monetary Policy Respond Strongly to Output Gaps?," unpublished manuscript, Carnegie Mellon University.

[20] Rotemberg, Julio, and Michael Woodford (1997), "An optimization-based Econometric Framework for the Evaluation of Monetary Policy", in *NBER Macroeconomic Annual 1997*, Ben Bernanke and Julio Rotemberg, eds., 297-346, MIT Press.

[21] Rotemberg, Julio, and Michael Woodford (1999), "The Cyclical Behavior of Prices and Costs", in J. Taylor and M. Woodford (eds.) *Handbook of Macroeconomics*, Vol. 1B, 1050-1135.

[22] Sbordone, Argia, M. (2002), "Prices and Unit Labor Costs: A New Test of Price Stickiness," *Journal of Monetary Economics*, 49(2), 265-292.

[23] Sbordone, Argia (2001), "An Optimizing Model of U.S. Wage and Price Dynamics", unpublished manuscript, Rutgers University.

[24] Steinsson, (2000), "Optimal Monetary Policy in an Economy with Inflation Persistence," unpublished manuscript, Princeton University.

[25] Svensson, Lars E. (2000), "Open Economy Inflation Targeting", *Journal of International Economics*, 50, 155-183.

[26] Taylor, John B. (1980), "Aggregate Dynamics and Staggered Contracts," *Journal of Political Economy*, 88, 1-23.

[27] Woodford, Michael (1999a), "Optimal Monetary Policy Inertia,", NBER Working Paper No. 7261.

[28] Woodford, Michael (1999b), "Inflation Stabilization and Welfare," unpublished manuscript, Princeton University.

[29] Woodford, Michael (2000), "Optimal Models with Nominal Rigidities," unpublished manuscript, Princeton University.

[30] Yun, Tack (1996), "Nominal Price Rigidity, Money Supply Endogeneity, and Business Cycles", *Journal of Monetary Economics* 37, 345-370.

Table 1. Price Stickiness in Euro Area Countries

Hybrid Model

		ω	α	β	γ_b	γ_f	$\widetilde{\lambda}$	D	$J\ Test$
Germany	(1)	0.075	0.785	0.757	0.089	0.702	0.096	5.0	9.538
		(0.049)	(0.033)	(0.076)	(0.055)	(0.073)	(0.028)	(0.19)	(0.731)
	(2)	0.026	0.743	0.790	0.035	0.767	0.135	4.0	8.523
		(0.057)	(0.032)	(0.098)	(0.073)	(0.108)	(0.038)	(0.21)	(0.482)
France	(1)	0.326	0.784	0.903	0.300	0.653	0.040	6.8	7.761
		(0.073)	(0.061)	(0.059)	(0.043)	(0.041)	(0.030)	(0.16)	(0.859)
	(2)	0.331	0.771	0.884	0.308	0.635	0.046	6.5	7.413
		(0.066)	(0.059)	(0.069)	(0.040)	(0.048)	(0.032)	(0.13)	(0.594)
Italy	(1)	0.594	0.682	0.691	0.516	0.409	0.059	7.6	10.98
		(0.052)	(0.042)	(0.091)	(0.032)	(0.047)	(0.023)	(0.03)	(0.613)
	(2)	0.660	0.709	0.619	0.554	0.368	0.047	10.1	6.924
		(0.053)	(0.058)	(0.163)	(0.053)	(0.084)	(0.027)	(0.03)	(0.645)
Spain	(1)	0.667	0.769	0.841	0.495	0.477	0.020	12.9	7.739
		(0.090)	(0.044)	(0.131)	(0.019)	(0.052)	(0.018)	(0.05)	(0.860)
	(2)	0.724	0.797	0.890	0.497	0.486	0.011	17.8	4.620
		(0.147)	(0.075)	(0.171)	(0.021)	(0.067)	(0.019)	(0.07)	(0.866)
Netherlands	(1)	0.371	0.638	0.993	0.368	0.629	0.083	4.4	7.069
		(0.057)	(0.063)	(0.137)	(0.041)	(0.048)	(0.029)	(0.06)	(0.898)
	(2)	0.358	0.643	1.060	0.353	0.671	0.72	4.4	5.174
		(0.063)	(0.075)	(0.168)	(0.044)	(0.067)	(0.040)	(0.07)	(0.819)

Note: Sample period 70-98. The average labor income shares are set to be equal to 0.75, and the steady-state markup is $\mu = 1.20$. Column D corresponds to price duration, and $J\ Test$ to the Hansen test of the overidentifying restrictions (below in brackets we report the p-value). Estimates in row (1) use as instruments are: inflation, detrended output, real unit labor costs and wage inflation from t-1 to t-4; while in row (2) we use five lags of inflation and two lags of the rest of variables. In the estimates of the Netherlands we include a dummy variable taking the value of 1 after 1982:1.

Table 2

ω^H	α^H	α^F (*Duration in quarters*) 0.500 (2)	0.660 (3)	0.750 (4)	0.830 (6)	0.875 (8)	0.937 (16)
	0.0	0.500	0.660	0.750	0.830	0.875	0.937
	0.1	0.440	0.625	0.725	0.810	0.865	0.930
	0.2	0.365	0.580	0.695	0.790	0.845	0.925
	0.3	0.250	0.525	0.650	0.760	0.825	0.907
	0.4	0.010	0.430	0.595	0.725	0.790	0.890
	0.5	-	0.265	0.500	0.675	0.750	0.875
	0.6	-	-	0.335	0.575	0.600	0.830
	0.7	-	-	0.020	0.425	0.595	0.810
	0.8	-	-	-	0.105	0.410	0.720
	0.9	-	-	-	-	0.050	0.570

Note: Duration corresponds to the expression $D^F = (1-\alpha^F)^{-1}$. Each cell, corresponding to a pair α^F (in the columns) and ω^H (in the rows), represents the value of α^H such that the rigidity implied by (α^H, ω^H), in the hybrid region, is equivalent to the rigidity implied by α^F, in the forward-looking region.

Table 3(a). Optimal Weights to Region *H* under Inflation Targeting (ξ)

Duration (*Backward Looking Region*)	*Duration (Forward Looking Region)* 3	4	5	6
7	0.882	0.815	0.752	0.697
8	0.905	0.850	0.797	0.752
9	0.922	0.877	0.835	0.795
10	0.935	0.897	0.860	0.827
12	0.957	0.932	0.907	0.882

Note: The duration in the hybrid region is computed by varying the parameter α^H, maintaining the parameter ω^H=0.48.

Table 3(b). Optimal Weights to Region *H* under Inflation Targeting (ξ)

Duration (*Backward Looking Region*)	*Duration (Forward Looking Region)* 3	4	5	6
7	0.867	0.790	0.722	0.665
8	0.892	0.827	0.767	0.720
9	0.910	0.855	0.805	0.760
10	0.925	0.877	0.832	0.795
12	0.945	0.910	0.875	0.845

Note: The duration in the hybrid region is computed by varying the parameter α^H, maintaining the parameter ω^H=0.34.

Table 3(c). Optimal Weights to Region *H* under Inflation Targeting (ξ)

Duration (*Backward Looking Region*)	*Duration (Forward Looking Region)* 3	4	5	6
7	0.900	0.837	0.777	0.725
8	0.920	0.872	0.825	0.780
9	0.937	0.897	0.857	0.822
10	0.947	0.915	0.882	0.852
12	0.962	0.940	0.928	0.895

Note: The duration in the hybrid region is computed by varying the parameter α^H, maintaining the parameter ω^H=0.61.

Table 4: Welfare and Variability Comparisons

	$v(y^W)$	$v(\widehat{T}-\widetilde{T})$	$v(\pi^H)$	$v(\pi^F)$	$v(\Delta\pi^H)$	δ
HICP-targeting	2.1253	2.4923	0.0494	0.1112	0.0008	2.31
Optimal Inflation Targeting	1.0165	2.5210	0.0109	0.1884	0.0002	2.03
Output-Gap Stabilization	0.0000	2.5119	0.0840	0.0800	0.0007	1.52
Optimal Policy	0.0221	2.5094	0.0566	0.1041	0.0005	1.48

Note: σ_{ε}^2 has been normalized to 1%.

Figure 1. Inflation and Marginal Cost in Euro area countries

Inflation (Continuous) Marginal cost (dotted)

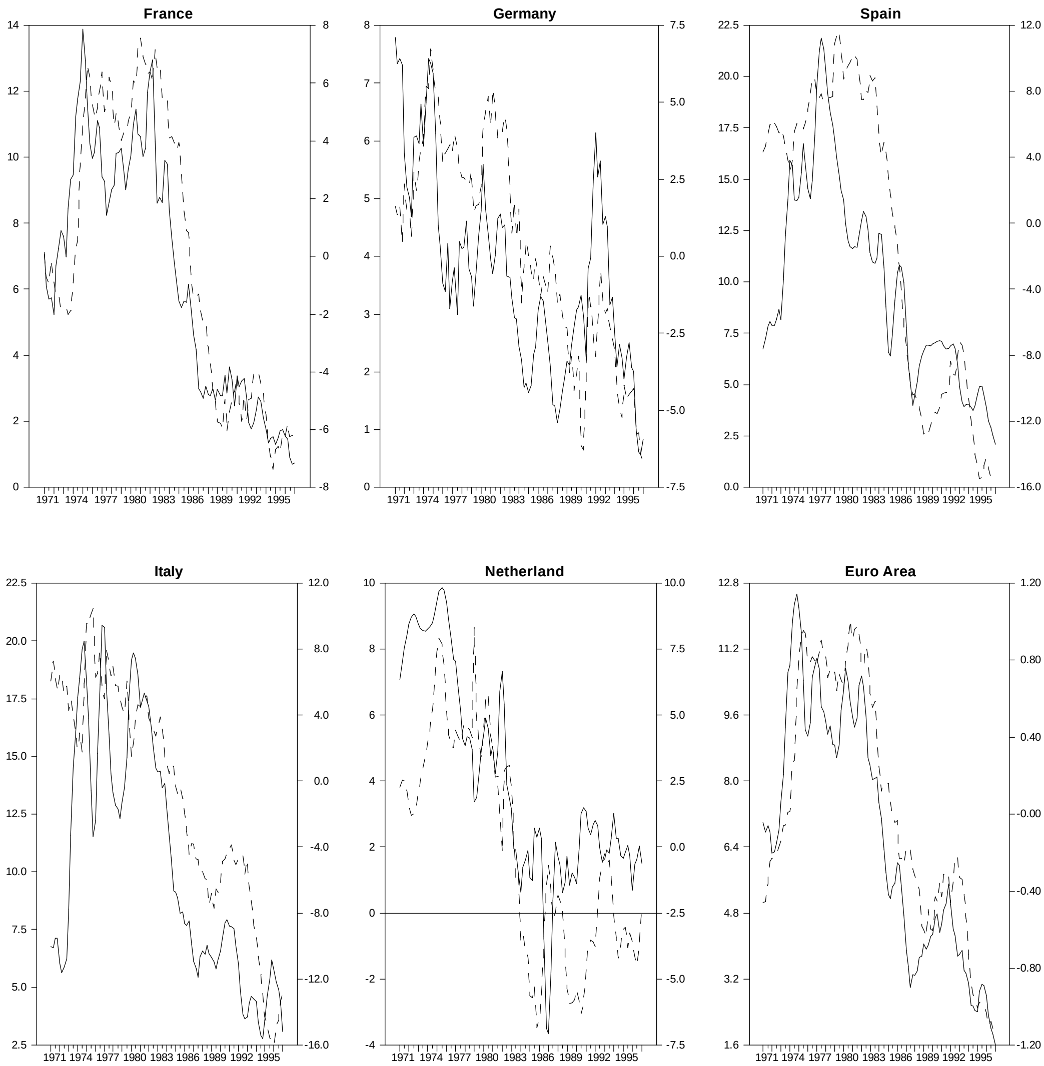

Figure 2. Stability Analysis

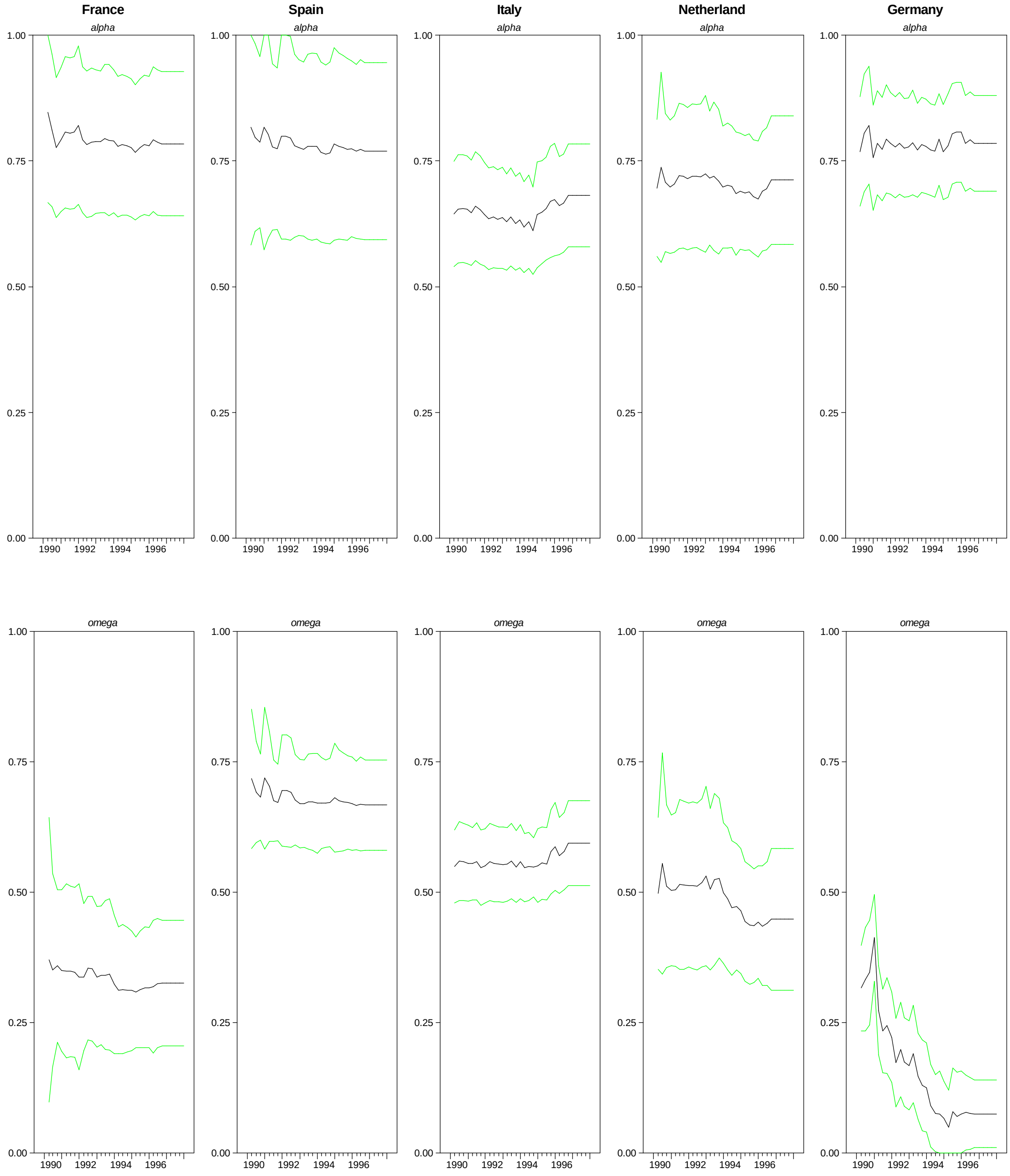

Figure 3: Lines of equivalence between the forward looking components (α^H,α^F), by varying the backward looking component (ω^H)

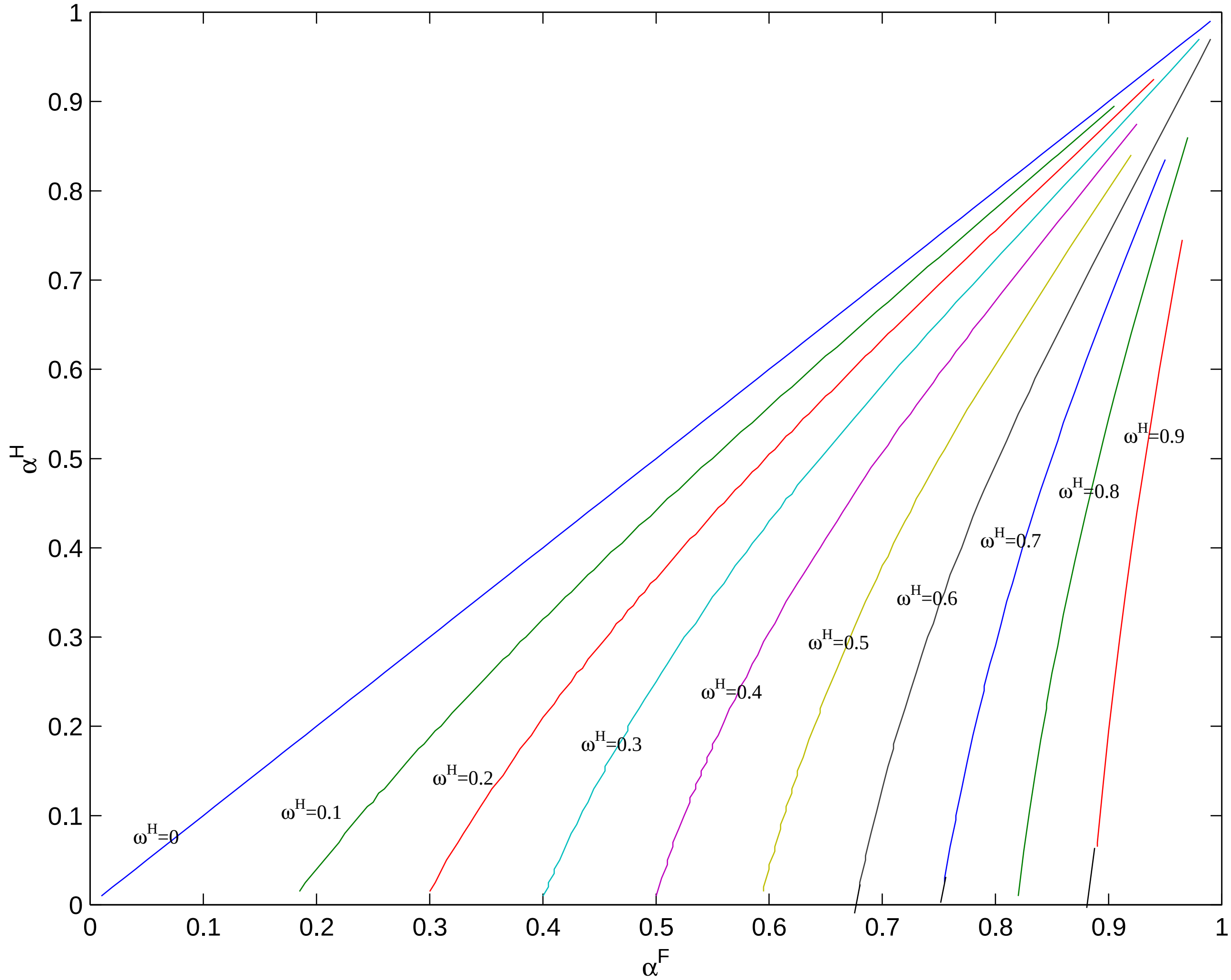

Figure 4: Impulse Response Functions, α_H=0.75, ω_H=0.48, α_F=0.785

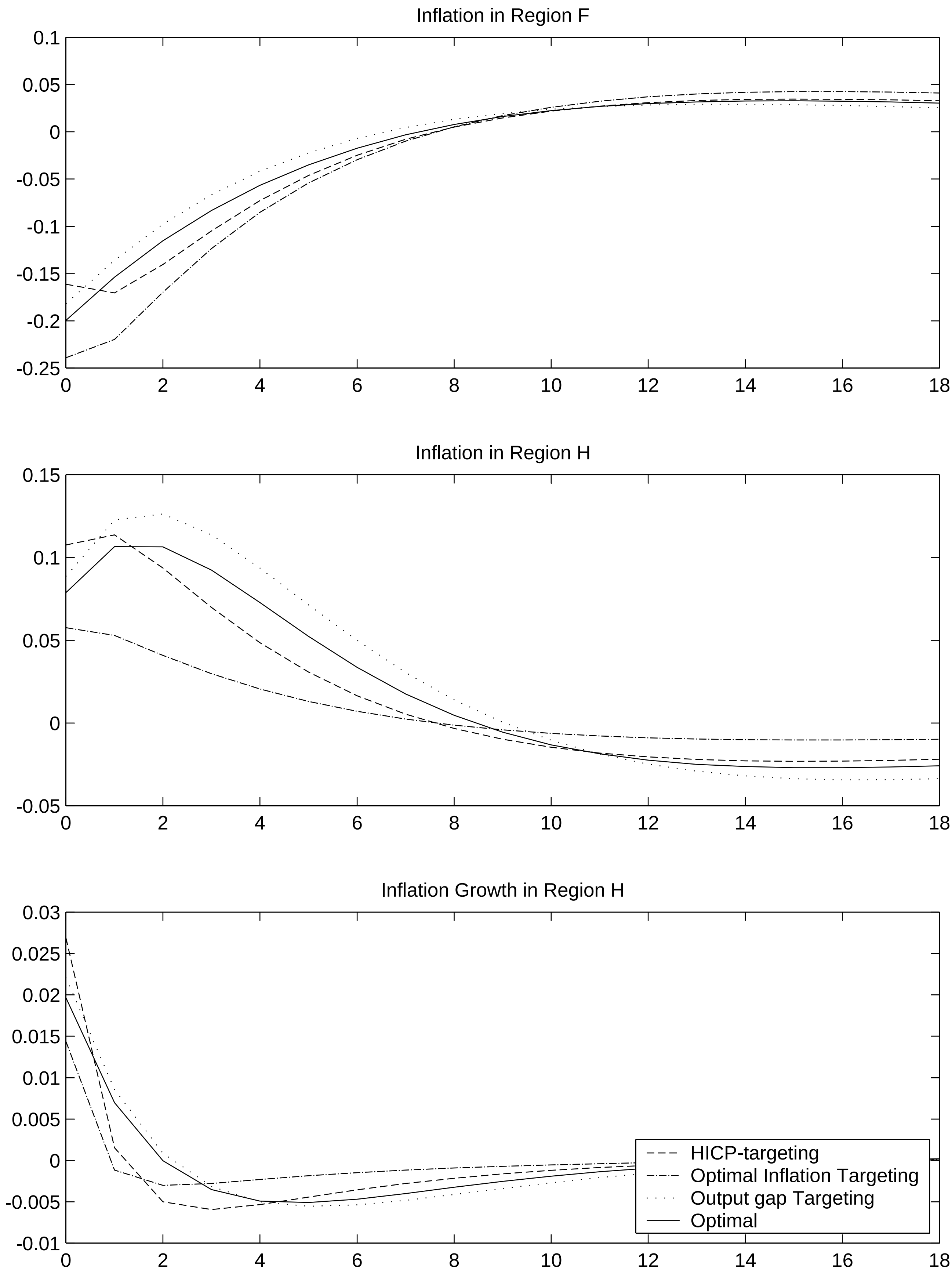

Figure 5: Impulse Response Functions, α_H=0.75, ω_H=0.48, α_F=0.785

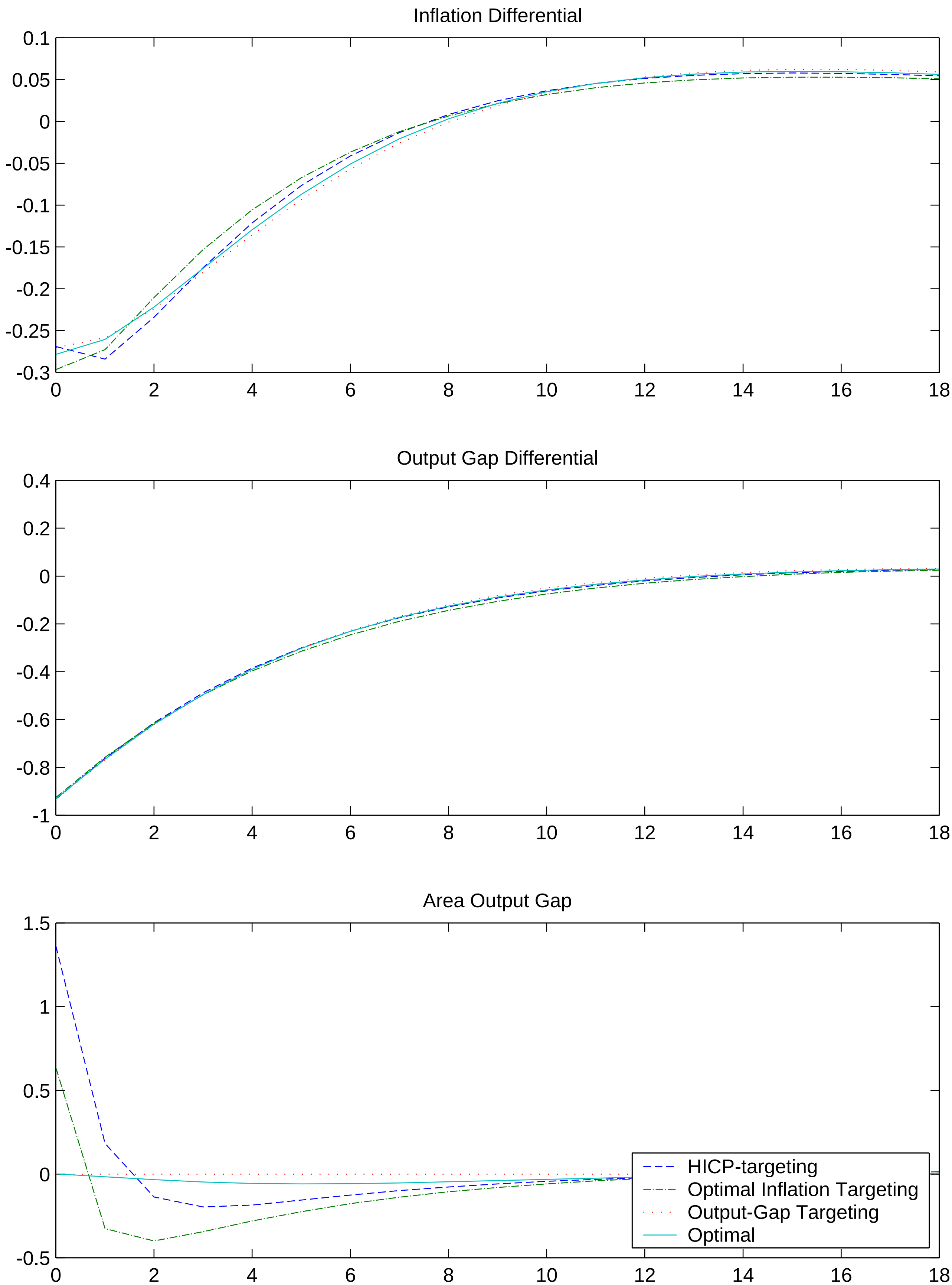

Figure 6: Welfare Comparisons, Average Duration= 6 quarters

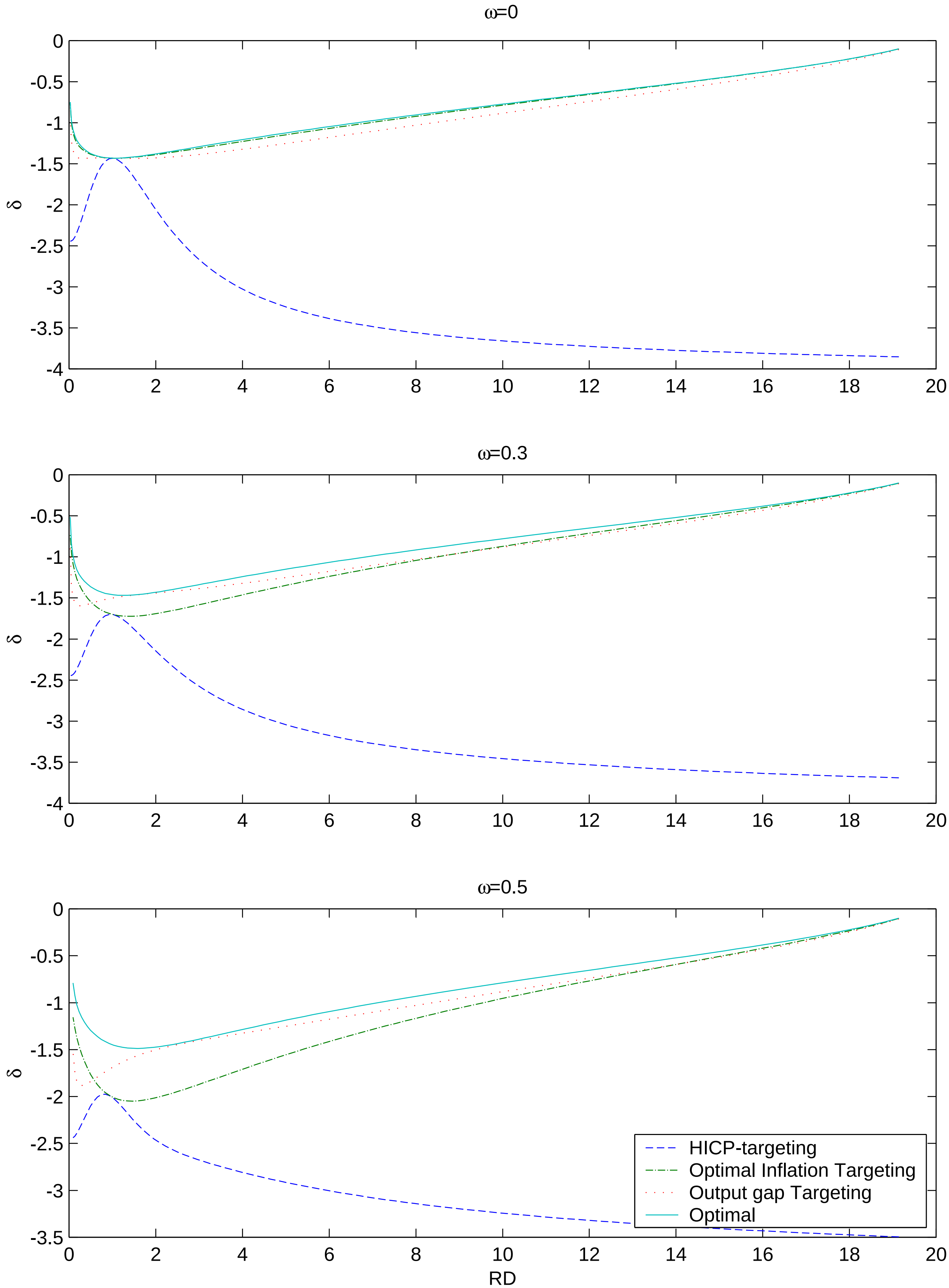

Figure 7: Welfare Comparisons, Average Duration = 3 quarters

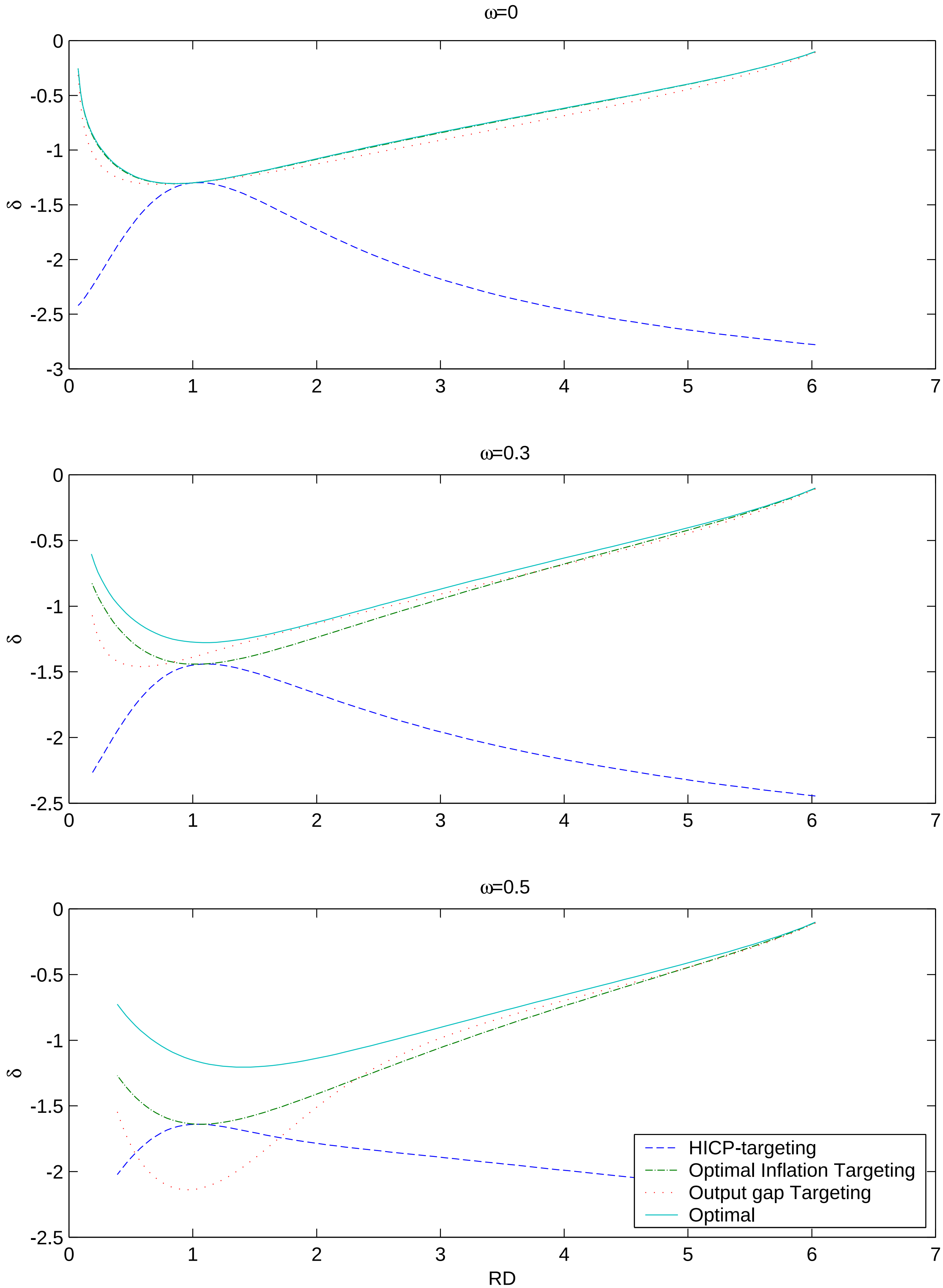

Figure 8: Impulse Response Functions, α_H=0.5, ω_H=0.48, α_F=0.785

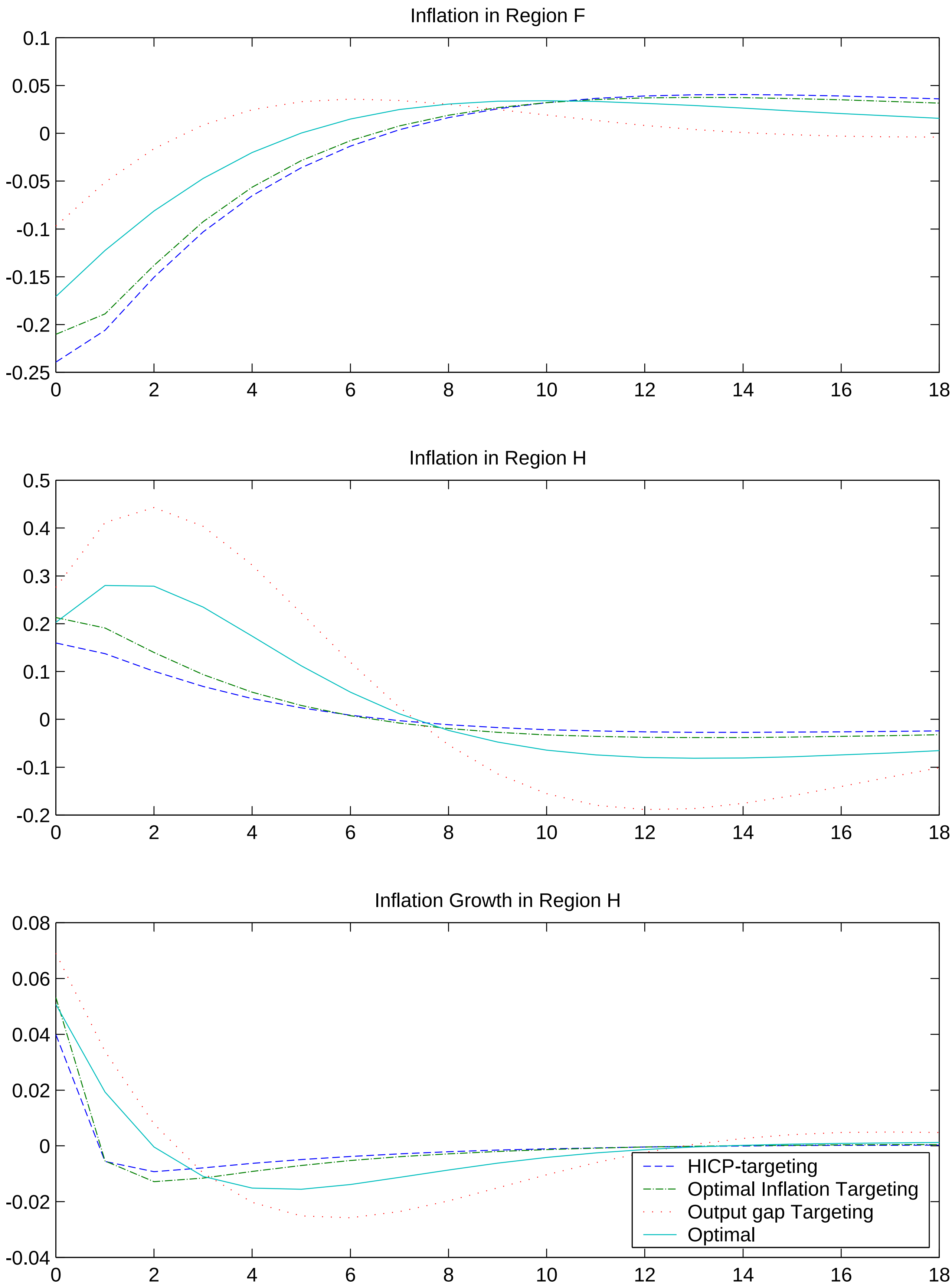

Figure 9: Impulse Response Function, α_H=0.5, ω_H=0.48, α_F=0.785