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INFLATION DIFFERENTIALS AND THE DIFFERENCES OF MONETARY POLICY EFFECTS AMONG EURO AREA COUNTRIES

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Abstract

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Inflation Differentials and the Differences of Monetary Policy Effects among Euro Area Countries*

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JEL classification: E31, E32, E52

Keywords: Euro Area Countries, Inflation Differentials, Hybrid Phillips Curve, Monetary Policy

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1. Introduction

A unified monetary policy has been adopted among the euro area countries since the third stage of Economic and Monetary Union (EMU) started on 1 January 1999. A single monetary policy is conducted in the Eurosystem, which composes of the European Central Bank (ECB) and the 15 national central banks of the euro area countries. A primary objective of the ECB's monetary policy is to maintain price stability. The ECB aims at inflation rates of below, but close to, 2% over the medium term. A smooth and effective transmission of the single monetary policy in the euro area countries is necessary for accomplishing the ECB's primary objective.

Since all countries face the same short-term nominal interest rate set by Eurosystem under the money market integration, persistent inflation differentials among euro area countries would cause the persistent short-term real interest rate differentials. This implies that Eurosystem's policy would be excessively tight for low inflation countries and loose for high inflation countries, henceforth, unified monetary policy conducted by Eurosystem would have different effects in different countries. Therefore, understanding the causes of the inflation differential is important.

However, it is known that persistent inflation differentials continue to exist in the euro area countries. According to a hybrid Phillips curve, which is derived from the assumption that there exist "backward-looking" firms which use a simple rule-of-thumb when setting their price, together with the "forward-looking" firms, inflation rate today depends on the past inflation rate (inflation persistence), expectation of inflation rate and output gap (cyclical components). As pointed out by Hofmann and Remsperger (2005), the firm's price setting behavior would differ depending on differences in the past monetary policy regime. In countries where high inflation and/or inertia in inflation were observed, consumers and firms would form expectation for future inflation rates depending on the past observation, and would use indexing practice when setting prices and/or wages. These practices would cause the inflation persistence. Hence, the differences in degree of inflation persistence among countries would be the source of the persistent inflation differentials. In addition, the asymmetry of cyclical components variations among countries due to the asymmetric shocks causes the inflation differentials among countries. Moreover, even if the cyclical components among euro area countries commoves with each other, the differences in the sensitivities of inflation rates to the change in cyclical components would cause the inflation differentials. In these circumstances, the unified monetary policy would have asymmetric effects on inflation.

The purpose of this paper is to investigate (i) at first whether there exists persistent inflation differentials among euro area countries, namely, whether inflation rates among euro area courtiers have converged, (ii) next if there exists persistent inflation differentials among euro area countries, we will investigate which factor causes the inflation differentials, inflation persistence components (backward-looking price setting behavior) or cyclical components, (iii) at last whether monetary policy has different effects.

The remainder of this paper is organized as follows. In Section 2, we investigate whether there exist persistent inflation differentials among euro area countries, namely, whether inflation rates among euro area courtiers have converged or not. We will analyze the β- and σ-convergence proposed by Adam *et al.* (2002) by using panel unit root methods. In Section 3, we introduce the Dynamic Stochastic General Equilibrium (DSGE) model with a hybrid IS curve and a hybrid Phillips curve, following Christiano, Eichenbaum and Evans (1999), Erceg, Henderson and Levin (2000) and Smets and Wouters (2002), to consider the sources of inflation differentials. In Section 4, we will estimate the hybrid Phillips curve using Generalized Methods of Moments (GMM). In Section 5, we conduct a Structural VAR analysis to examine whether the differences in the sources of inflation among countries cause the differences in monetary policy effects among countries. Section 6 is a conclusion.

2. Inflation Rates Convergence among Euro Area Countries

In this section, we investigate whether inflation rates have converged among euro area countries using β-convergence and σ-convergence approach proposed by Adam *et al.* (2002). Adam *et al.* (2002) propose β-convergence and σ-convergence measure, which they borrow from the economic growth literature to investigate whether interbank interest rate among euro area countries relative to corresponding German rate have reduced or not. In the growth theory, β-convergence applies if a poor economy tends to grow faster than a rich, so that the poor country tends to catch up with the rich one in terms of the level of per capita income. Therefore, β-convergence measure in Adam *et al.* (2002) is based on the idea that nominal interest rate in countries with relatively high have a tendency to decrease more rapidly than in countries with relatively low and it examines the speed of convergence. The second alternative concept of convergence in growth theory concerns cross-sectional dispersion. In this concept, convergence occurs if the dispersion, which is usually measured by the standard deviation or variance of the logarithm of per capita income across a group of countries, declines over time. This concept of convergence is called σ-convergence. Therefore, σ-convergence in Adam *et al.* (2002) examines the cross sectional dispersion in interest rates to measure the degree of financial integration at any point in time.

In what follows, we introduce a model to measure the β- and σ- convergence of inflation rates in euro area countries and then, estimate the model using panel unit root methods.

2-1. Methodology

β-convergence

At first, we assume that the inflation rate in country i, denoted $\pi_{i,t}$ ($i = 1, \cdots, N$), follows AR(p) process;

$$\pi_{i,t} = \mu_i + \alpha_{i1}\pi_{i,t-1} + \alpha_{i2}\pi_{i,t-2} + \cdots + \alpha_{ip_i-1}\pi_{i,t-p+1} + \alpha_{ip_i}\pi_{i,t-p} + \varepsilon_{i,t} \tag{1}$$

where μ_i reflects idiosyncratic factors in country i.

Equation (1) is rewritten as

$$\Delta\pi_{i,t} = \mu_i + \beta_i \pi_{i,t-1} + \sum_{j=1}^{p_i} \gamma_j \Delta\pi_{i,t-j} + \varepsilon_{i,t} \tag{2}$$

where $\beta_i = -\left(1 - \sum_{j=1}^{p_i} \alpha_{ij}\right)$ and $\gamma_j = \sum_{k=j}^{p_i} \alpha_{ik}$.

Since $\beta_i = \Delta(\Delta\pi_{i,t}) / \Delta\pi_{i,t-1}$, a negative β_i indicates that the change of inflation rate $\Delta\pi_{i,t}$ is inversely related to $\pi d_{i,t-1}$, in other word, inflation rate in countries with relatively high have a tendency to decrease more rapidly than in countries with relatively low. Then, the size of β_i is a direct measure of the speed of convergence in the overall market. Since a negative β is equivalent to the stationality of $\pi_{i,t}$. Therefore, equation (2) can be estimated by panel unit root test methods. Panel unit root tests have been advanced by Levin and Lin (1992, 1993), Levin, Lin and Chu (2002, LLC hereafter), Im, Pesaran and Shin (1997, IPS). These tests are extension of augmented Dickey and Fuller (1979, 1981, ADF) unit roots test on individual time series to panel data sets.

In LLC test, we estimate equation (2) and test for the null hypothesis $H_0 : \beta_i = \beta = 0$, against the alternative hypothesis $H_1 : \beta < 0$.

For our purpose to measure the speed of convergence in the overall market assumption of homogeneity in β_i s is relevant, however, this assumption is restrictive and subject to the possible heterogeneity bias.

Im, Pesaran and Shin (1997) allow β_i to differ across countries and devise a test for the null $H_0 : \beta_i = 0$ for all i, against the alternative $H_1 : \beta_i = 0$ for $i = 1, 2, \cdots, N_1$ but $\beta_i < 0$ for $i = N_1 + 1, N_1 + 2, \cdots, N$.

The details of LLC test and IPS test are explained in Appendix 1[1].

σ-convergence

Since β-convergence measures whether the interest rate converges to the same steady state value and measures the speed of convergence, it does not indicate to what extent markets are already integrated. On the other hand, σ-convergence measures the degree of financial integration at any point in time.

To understand σ-convergence, assume that $\pi_{i,t}$ follows $AR(1)$ process with fixed effects term for simplicity;

$$\pi_{i,t} = \mu_i + \alpha_1 \pi_{i,t-1} + \varepsilon_{i,t} \tag{3}$$

Equation (3) can also be rewritten as

$$\Delta\pi_{i,t} = \mu_i + \beta\pi_{i,t-1} + \varepsilon_{i,t} \tag{4}$$

[1] See for Banerjee (1999) and Smith and Fuertes (2004) for panel unit root test.

where $\beta = 1 - \alpha_1$. By taking the mean of both sides of equation (4) over N countries for time t, we obtain

$$\bar{\pi}_t = \bar{\mu} + \alpha_1 \bar{\pi}_{t-1} \tag{5}$$

where $\bar{\pi}_t \equiv N^{-1}\sum_{i=1}^{N} \pi_{i,t}$ and $\bar{\mu} \equiv N^{-1}\sum_{i=1}^{N} \mu_i$ [2]. From equation (3) and (5) and the sample analogue of the classical regression assumptions, we get

$$\sigma_{\pi,t}^2 = (\sigma_\mu^2 + 2\sigma_{\mu,\pi} + \sigma_\varepsilon^2) + \alpha_1^2 \sigma_{\pi,t-1}^2 \tag{6}$$

where $\sigma_{\pi,t}^2 \equiv N^{-1}\sum_{i=1}^{n}(\pi_{i,t} - \bar{\pi}_t)^2$, $\sigma_\mu^2 \equiv N^{-1}\sum_{i=1}^{n}(\mu_i - \bar{\mu})^2$ are variance of inflation rate across countries and variance of fixed effects terms across countries respectively. We assume that variance of error terms, $\sigma_{\varepsilon,t}^2$ and a covariance between μ and π_{t-1}, $\sigma_{\mu,\pi} \equiv N^{-1}\sum_{i=1}^{n}(\mu_i - \bar{\mu})(\pi_{i,t} - \bar{\pi}_t)$ are both constant over time[3]. Equation (6) implies that the sequence of inflation rate differential $\pi_{i,t}$ follows stationary process, namely, $-1 < \alpha_1 < 1$, the sequence of variance of interest rate differentials among countries $\sigma_{\pi,t}^2$, also follows stationary process, since $-1 < \alpha_1^2 < 1$.

Equation (6) can also be written as

$$\sigma_{\pi,t}^2 = \sigma_\pi^{2*} + \alpha_1^{2t}(\sigma_{\pi,0}^2 - \sigma_\pi^{2*}) \tag{7}$$

where $\sigma_\pi^{2*} \equiv (\sigma_\mu^2 + 2\alpha_1\sigma_{u,\pi} + \sigma_\varepsilon^2)/(1-\alpha_1^2)$ denotes the steady state value of $\sigma_{id,t}^2$ [4].

As discussed in Barro and Sala-i-Martin (1995), equation (7) implies that $\sigma_{\pi,t}^2$ rises or falls over time depending on whether $\sigma_{\pi,0}^2$ begins below or above the steady-state value. Note especially that even if β-convergence holds, namely, $-1 < \alpha_1 < 1$ or $\beta < 0$ in equation (3) or (4), the dispersion of inflation rates would tend to rise if $\sigma_{\pi,0}^2 < \sigma_\pi^{2*}$ holds at the initial period. Thus, β-convergence is a necessary condition but not a sufficient condition for σ-convergence.

In what follows, we estimate the augmented version of equation (4),

$$\sigma_{\pi,t}^2 = \mu + \alpha_1\sigma_{\pi,t-1}^2 + \alpha_2\sigma_{\pi,t-2}^2 + \cdots + \alpha_{p-1}\sigma_{\pi,t-p+1}^2 + \alpha_p\sigma_{\pi,t-p}^2 + \varepsilon_t \tag{8}$$

$$\Delta\sigma_{\pi,i,t}^2 = \mu + \beta\sigma_{\pi,i,t-1}^2 + \sum_{j=1}^{p}\gamma_j\Delta\sigma_{\pi,i,t-1}^2 + \varepsilon_{i,t} \tag{9}$$

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2 In derivation o equation (5), we use $N^{-1}\sum_{i=1}^{N}\varepsilon_{i,t} = 0$, because the mean of error terms is zero.

3 In derivation of equation (6), we use $N^{-1}\sum_{i=1}^{N}(\mu_i - \bar{\mu})\varepsilon_{i,t} = N^{-1}\sum_{i=1}^{N}(\pi_{i,t-1} - \bar{\pi}_{t-1})\varepsilon_{i,t} = 0$, because covariance between independent variables and error terms is zero. Note that

4 At the steady state, $\sigma_\pi^{2*} = (\sigma_\mu^2 + 2\alpha_1\sigma_{\mu,\pi} + \sigma_\varepsilon^2) + \alpha_1^2\sigma_\pi^{2*}$ would hold. By subtracting this equation from equation (6), we obtain the difference equation, $\sigma_{\pi,t}^2 - \sigma_\pi^{2*} = \alpha_1^2(\sigma_{\pi,t-1}^2 - \sigma_\pi^{2*})$, which leads to desirable equation (7).

where constant term μ includes σ_{μ}^{2}, $\sigma_{\mu,\pi}$ and σ_{ε}^{2}, and $\beta = -\left(1 - \sum_{j=1}^{p} \alpha_j\right)$ and $\gamma_j = \sum_{k=j}^{p} \alpha_k$. Equation (9) can be estimated by ADF unit root test methods to investigate whether the sequence of $\sigma_{\pi,t}^{2}$ would follow stationary process.

2-2. Data

At present, euro area countries are constituted by 15 countries; Austria, Belgium, Cyprus, Finland, France, Germany, Greece, Italy, Ireland, Luxemburg, Malta, Netherlands, Slovenia, Spain and Portugal. We exclude Slovenia which introduced euro 1 January 2007 and Cyprus and Malta which introduced euro 1 January 2008 from our sample countries. Data are with quarterly frequency and whole sample period is 1999Q1 to 2007Q4, which starts with the introduction of euro.

Data on inflation rate are calculated from Harmonized Consume Price Index (HCPI). All data are from *Eurostat*.

Figure 1 shows the averaged annual inflation rates of area wide euro area and 13 countries from 1999 to 2007. From this figure, we can find that inflation rates vary around 2%, with ranges from about 1.5% in Finland to about 3.5 % in Ireland.

From Figure 2, which shows the quarter to quarter inflation rate, we can see that inflation rate in each country varies within some ranges, but it has not fully converged.

<Insert Figure.1, 2>

2-3. Empirical Results

β-convergence

Table 1 reports the results of LLC and IPS tests. Lag length is selected based on SBIC. Statistics for LLC test stands for a t^*-statistics given by equation (A-1) and statistics for IPS test stands for $W_{\bar{t}_{NT}}$-statistics given by (A-3) in Appendix 1. From Table 1, we can see that the null hypothesis $H_0 : \beta_i = \beta = 0$ in LLC test and $H_0 : \beta_i = 0$ in IPS test can be rejected, which means that overall euro area inflation rates are in a process of convergence.

σ-convergence

Figure 3 presents the standard deviation of cross-country dispersion in inflation rate differentials. It seems that there exists little evidence of σ-convergence at first glance. In reality, the last row of Table 1, which displays the results of estimation of equation (9), highlights the fact that sequence of $\{\sigma_{\pi,t}^{2}\}_{t=1}^{T}$ does not follow stationary process. These results mean that cross-country dispersion in inflation rate has not declined, therefore σ-convergence does not occur. Lag length is set to 3 based according to SBIC.

<Insert Table 1 and Figure 3>

3. Model

From the results in Section 2, we can see that there exist persistent inflation differentials among euro area countries, namely, inflation rates among euro area courtiers have not converged. The problem, then, is to investigate the causes of the observed inflation differentials. In this section, we derive the hybrid Phillips curve in which inflation rate today depends on the past inflation rate, expectation of inflation rate and output gap. The model will be estimated in the next sections.

Our model is very similar to recent dynamic stochastic general equilibrium model (DSGE) with monopolistically competitive market structure and sticky price adjustments, including Christiano, Eichenbaum and Evans (1999), Erceg, Henderson and Levin (2000), Smets and Wouters (2002) and Steinsson, J. (2003).

We consider a closed economy which is composed of households, firms. Infinitely-lived households maximize a utility function which depends positively on consumption of goods relative to an external habit variable and negatively on labor supply. We assume the homogeneity of labor service of each household, for simplicity. Monopolistically competitive firms produce a differentiated good that is solely consumed by households. They set their prices in staggered contracts with timing like that of Calvo (1983). In addition, we assume the existence of "backward-looking" firms which uses a simple rule-of thumb when setting prices.

3.1 Households

There is a continuum of infinitely-lived households indexed by $i \in [0,1]$. Each of households has a utility function which depends positively on consumption of goods relative to an external habit variable and negatively on labor supply. Each household i maximizes its utility function given by

$$E_t \sum_{t=0}^{\infty} \beta^t \left[\frac{(C_{i,t} - H_t)^{1+\sigma_C}}{1+\sigma_C} e^{\varepsilon_{C,t}} - \frac{L_{i,t}^{1-\sigma_L}}{1-\sigma_L} e^{\varepsilon_{L,t}} \right] \tag{10}$$

where β is a discount factor, $C_{i,t}$ is a household i's consumption index defined by familiar Dixit-Stiglitz form

$$C_{i,t} = \left[\int_0^1 C_{i,t}(j)^{\frac{\theta-1}{\theta}} dj \right]^{\frac{\theta}{\theta-1}} \tag{11}$$

where $C_{i,t}(j)$ is household i's consumption of good $j \in [0,1]$. Equation (11) implies that elasticity of substitution between goods is constant and equals to θ. H_t is an external habit variables, $L_{i,t}$ is a household i's labor supply, σ_C and σ_L are coefficients of relative risk aversion of household with respect to consumption and labor respectively, and $\varepsilon_{C,t}$ and $\varepsilon_{L,t}$ represent preference shocks and labor supply respectively, which follow a first order autoregressive process with an i.i.d. normal error term,

$$\varepsilon_{C,t} = \rho_C \varepsilon_{C,t-1} + \nu_{C,t} \tag{12}$$

$$\varepsilon_{L,t} = \rho_L \varepsilon_{L,t-1} + \nu_{L,t} \tag{13}$$

The external habit is assumed to be proportional to aggregate past consumption and it is not affected by any single household.

$$H_t = hC_{t-1} \tag{14}$$

where aggregate consumption is defined as $C_t = \int_0^1 C_{i,t} di$.

Household i maximizes their utility function subject to an intertemporal budget constraint given by

$$C_{i,t} + \frac{B_{i,t}}{P_t} = \frac{W_t}{P_t} L_{i,t} + I_{t-1} \frac{B_{i,t-1}}{P_t} + \Psi_{i,t} \tag{15}$$

where $B_{i,t}$ is household i 's bond holding from t to $t+1$, P_t is a price index corresponding to equation (15), W_t is a nominal wage, $\Psi_{i,t}$ is a profit of firm i, and $I_t (\geq 1)$ is a nominal interest rate on bonds between t and $t+1$. The price index P_t is defined so as to equal to a minimum expenditure for which a unit of consumption index $C_{i,t}$ can be purchased and it can be derived as

$$P_t = \left[\int_0^1 P_t(j)^{1-\theta} dj \right]^{\frac{1}{1-\theta}} \tag{16}$$

In each period, household i faces two utility-maximizing problems, namely, (i) how much to consume the consumption index $C_{i,t}$ under the intertemporal budget constraint (15), and (ii) how much to consume each individual differentiated goods $C_{i,t}(j)$.

As for the problem (ii), the demand for each individual good is given by

$$C_{i,t}(j) = \left(\frac{P_t(j)}{P_t} \right)^{-\theta} C_{i,t} \tag{17}$$

and aggregating equation (17) over households $i \in [0,1]$, total demand for goods j by all consumers as

$$C_t(j) = \left(\frac{P_t(j)}{P_t} \right)^{-\theta} C_t \tag{18}$$

where $C_t(j) = \int_0^1 C_{i,t}(j) di$.

As for the problem (i), we form the Lagrangian,

$$L_t = E_t \sum_{t=0}^{\infty} \beta^t \left[\left\{ \frac{(C_{i,t} - hC_t)^{1-\sigma_C}}{1-\sigma_C} e^{\varepsilon_{C,t}} - \frac{L_{i,t}^{1+\sigma_L}{}_t}{1+\sigma_L} e^{\varepsilon_{L,t}} \right\} + \lambda_{i,t} \left\{ \frac{W_t}{P_t} L_{i,t} + I_{t-1} \frac{B_{i,t-1}}{P_t} + \Psi_{i,t} - \left(C_{i,t} + \frac{B_{i,t}}{P_t} \right) \right\} \right]$$

and differentiate it with respect to $C_{i,t}$ and $B_{i,t}$ to get first order conditions,

$$(C_t - hC_{t-1})^{-\sigma_C} e^{\varepsilon_{C,t}} = \lambda_{i,t} = \lambda_t \tag{19}$$

$$\frac{\lambda_t}{P_t} = E_t\left[\frac{\beta I_t \lambda_{t+1}}{P_{t+1}}\right] \tag{20}$$

where $\lambda_{i,t}$ is the Lagrangian multiplier. In deriving equation (19) and (20), we use the fact that the marginal utility of consumption is identical across households. Combining the above two first order conditions, we can obtain the following Euler equation:

$$\frac{(C_t - hC_{t-1})^{-\sigma_C} e^{\varepsilon_{C,t}}}{P_t} = E_t\left[\frac{\beta I_t (C_{t+1} - hC_t)^{-\sigma_C} e^{\varepsilon_{C,t+1}}}{P_{t+1}}\right] \tag{21}$$

Note that in this case the interest elasticity of output gap depends not only the intertemporal elasticity of substitution, but also on the habit formation parameter.

Next we turn to the labor supply decisions of each household. We differentiate the above Lagrangian with respect to $L_t(i)$ to get first order condition

$$e^{\varepsilon_{L,t}} L_{i,t}^{\sigma_L} = \lambda_t \frac{W_t}{P_t} \tag{22}$$

and substitute equation (22) into equation (19), the labor supply equation is derived as

$$L_{i,t}^{\sigma_L} = (C_t - hC_{t-1})^{-\sigma_c} \frac{W_t}{P_t} e^{-\varepsilon_{L.t}} \tag{23}$$

3.2 Firms

We assume a continuum of monopolistically competitive firms indexed by $j \in [0,1]$ produce a differentiated good. For simplicity, we ignore capital and define the production function of firm j as

$$Y_t(j) = e^{\varepsilon_{Y,t}} N_{j,t} \tag{24}$$

where constant return to scale is assumed . $N_{j,t}$ is a labor demand of firm j and $\varepsilon_{Y,t}$ represents productivity shock which follows a first order autoregressive process with an i.i.d. normal error term,

$$\varepsilon_{Y,t} = \rho_Y \varepsilon_{Y,t-1} + \nu_{Y,t} \tag{25}$$

Before analyzing the firm's pricing decision, consider its cost minimization problem, which is specified as,

$$\min_{\{N_{j,t}\}} \frac{W_t}{P_t} N_{j,t} + \phi_{j,t}(\varepsilon_{Y,t} N_{j,t} - Y_t(j)) \tag{26}$$

From the first order condition, we can see that marginal cost equals across firms and equals to Lagrangian multiplier,

$$\frac{W_t / P_t}{\varepsilon_{Y,t}} = \phi_{j,t} = \phi_t \tag{27}$$

Since aggregated labor supply $L_t = \int_0^1 L_{i,t} di$ must equal to aggregated labor demand $\int_0^1 N_{j,t} dj$ in equilibrium, equation (23) can be written as

$$N_t^{\sigma_L} = (C_t - hC_{t-1})^{-\sigma_C} \frac{W_t}{P_t} e^{\varepsilon_{L,t}} \tag{28}$$

We now turn to the pricing decisions. Following Gali and Gertler (1999), we assume that a fraction of $1-\alpha$ of the firms can set a new price in each period. Namely, each firm is able to set a new price with probability $1-\alpha$ in each period. The probability that a firm will be allowed to reset its price in any period does not depend on how long its existing contract has been in effect. With probability α, it cannot change price so that its price is remained to P_{t-1}. Moreover, there exist two types of the firms in the economy when it comes to price decisions. A fraction $1-\omega$ of the firms, which we refer to "forward-looking" firms behave optimally, and remaining firms of fraction ω, which we refer to "backward-looking" firms, use a simple rule-of-thumb when setting their price.

Therefore, price index (16) can be rewritten as

$$P_t = \left[\alpha P_{t-1}^{1-\theta} + (1-\alpha)\omega P_t(b)^{1-\theta} + (1-\alpha)(1-\omega) P_t(f)^{1-\theta} \right]^{\frac{1}{1-\theta}} \tag{29}$$

where $P_t(b)$ and $P_t(f)$ are the new price set by "forward-looking" firms and "back-ward looking" firms respectively.

We assume that backward-looking firms set their prices according to the following rule,

$$P_t(b) = P_{t-1}^n \Pi_{t-1} \tag{30}$$

where $\Pi_{t-1} = P_t / P_{t-1}$ and we define the index for newly set prices P_t^n by

$$P_t^n = P_t(b)^{\omega} P_t(f)^{1-\omega} \tag{31}$$

Since production function is homogeneous so that average cost equals to marginal cost, present discounted value of forward-looking firm's profit can be written as

$$E_t \sum_{l=0}^{\infty} (\beta\alpha)^l \left[\frac{P_t(f)}{P_{t+l}} - \phi_{t+l} \right] Y_{t+l}(f) \tag{32}$$

where $Y_t(f)$ is the output of representative "forward-looking" firms.

As both government and foreign sectors are absent in our model, market clearing condition must satisfy,

$$Y_t(j) = C_t(j) \tag{33}$$

$$Y_t = C_t \tag{34}$$

and the total demand for goods j by all consumers $C_t(j)$ is given by equation (22), we can rewrite equation (36) as

$$E_t \sum_{l=0}^{\infty} (\beta\alpha)^l \left[\left(\frac{P_t(f)}{P_{t+l}} \right)^{1-\theta_C} - \phi_{t+l} \left(\frac{P_t(f)}{P_{t+l}} \right)^{-\theta_C} \right] Y_{t+l} \tag{35}$$

Therefore, first order condition of profit maximization problem of "forward-looking" firm is given by

$$\frac{P_t(f)}{P_t} E_t \sum_{l=0}^{\infty} (\beta\alpha)^l \left(\frac{P_{t+l}}{P_t} \right)^{\theta_C - 1} Y_{t+l} = \frac{\theta}{\theta - 1} E_t \sum_{l=0}^{\infty} (\beta\alpha)^l \phi_{t+l} \left(\frac{P_{t+l}}{P_t} \right)^{\theta_C} Y_{t+l} \tag{36}$$

3.3 Log-linear approximation

We denote the percentage deviation of variable X_t around the steady state as $\hat{x}_t \equiv \frac{X_t - \bar{X}}{\bar{X}} \approx \log(X_t) - \log(\bar{X})$.

Log-linearizing equation (21) and using the linearized market clearing conditions (33) and (34) results in hybrid IS curve,

$$\hat{y}_t = \frac{h}{1+h} \hat{y}_{t-1} + \frac{1}{1+h} E_t[\hat{y}_{t+1}] - \frac{1}{\sigma_C (1+h)} E_t[\hat{i}_t - \hat{\pi}_{t+1}] + \frac{1}{\sigma_C (1+h)} E_t[\varepsilon_{C,t} - \varepsilon_{C,t+1}] \tag{37}$$

When $h = 0$, this equation reduces to the traditional forward-looking IS curve. With external habit formation, output gap defined as the percentage deviation of real GDP from its steady state value depends on a weighted average of past and expected future output gap.

Next, we log-linearize equation (29), (30), (31) and (36),

$$\hat{\pi}_t = \frac{1-\alpha}{\alpha} \{\omega \hat{p}_t(b) + (1-\omega) \hat{p}_t(f)\} \tag{38}$$

$$\hat{p}_t(b) = \hat{p}_{t-1}^n - \hat{\pi}_t + \hat{\pi}_{t-1} \tag{39}$$

$$\hat{p}_t^n = \omega \hat{p}_t(b) + (1-\omega) \hat{p}_t(f) \tag{40}$$

$$\hat{p}_t(f) = (1-\beta\alpha)\hat{\phi}_t + \beta\alpha E_t[\hat{p}_{t+1}(f)] + \beta\alpha E_t[\pi_{t+1}] \tag{41}$$

where $\hat{p}_t(b)$, $\hat{p}_t^n$ and $\hat{p}_t(f)$ denote percent deviation of $P_t(b)/P_t$, $P_t(f)/P_t$ and P_t^n/P_t, respectively, from its steady state value. Next, we combine equation (38) to (40) to eliminate $\hat{p}_t(b)$ and $\hat{p}_t^n$. This gives

$$\hat{p}_t(f) = \frac{\alpha + (1-\alpha)\omega}{(1-\alpha)(1-\omega)} \hat{\pi}_t - \frac{\omega}{(1-\alpha)(1-\omega)} \hat{\pi}_{t-1} \tag{42}$$

Inserting equation (42) to (41) leads to marginal cost-based hybrid Phillips curve,

$$\hat{\pi}_t = \frac{\omega}{\omega(1-\alpha+\alpha\beta)+\alpha} \hat{\pi}_{t-1} + \frac{\beta\alpha}{\omega(1-\alpha+\alpha\beta)+\alpha} E_t \hat{\pi}_{t+1} + \frac{(1-\omega)(1-\alpha)(1-\beta\alpha)}{\omega(1-\alpha+\alpha\beta)+\alpha} \hat{\phi}_t \tag{43}$$

Hybrid Phillips curve can be obtained as follows. We begin by log-linearizing equation (27), (24) and (28):

$$\hat{\phi}_t = (\hat{w}_t - \hat{p}_t) - \varepsilon_{Y,t} \tag{44}$$

$$\hat{y}_t = \varepsilon_{Y,t} + \hat{n}_t \tag{45}$$

$$\sigma_L \hat{n}_t = -\varepsilon_{L,t} - \sigma_c (\hat{y}_t - h\hat{y}_{t-1}) + (\hat{w}_t - \hat{p}_t) \tag{46}$$

Next, we combine equations (45) and (46) and eliminate $\hat{n}_t$ to obtain the real wage as

$$\hat{w}_t - \hat{p}_t = (\sigma_L + \sigma_c)\hat{y}_t + \sigma_C h\hat{y}_{t-1} + (\varepsilon_{L,t} - \sigma_L \varepsilon_{Y,t}) \tag{47}$$

From equations (44) and (47), we can see that marginal cost is given by

$$\hat{\phi}_t = (\sigma_L + \sigma_c)\hat{y}_t + \sigma_C h\hat{y}_{t-1} + \varepsilon_{L,t} - (1+\sigma_L)\varepsilon_{Y,t} \tag{48}$$

Finally, we combine equations (43) and (48) to obtain the following hybrid Phillips curve:

$$\begin{aligned}\hat{\pi}_t = &\frac{\omega}{\omega(1-\alpha+\alpha\beta)+\alpha}\hat{\pi}_{t-1} + \frac{\beta\alpha}{\omega(1-\alpha+\alpha\beta)+\alpha}E_t\hat{\pi}_{t+1} + \frac{(1-\omega)(1-\alpha)(1-\beta\alpha)(\sigma_L+\sigma_c)}{\omega(1-\alpha+\alpha\beta)+\alpha}\hat{y}_t \\ &+ \frac{(1-\omega)(1-\alpha)(1-\beta\alpha)\sigma_c h}{\omega(1-\alpha+\alpha\beta)+\alpha}\hat{y}_{t-1} + \frac{(1-\omega)(1-\alpha)(1-\beta\alpha)}{\omega(1-\alpha+\alpha\beta)+\alpha}\{\varepsilon_{L,t} - (1+\sigma_L)\varepsilon_{Y,t}\}\end{aligned} \tag{49}$$

From equation (49), we can see that inflation at time t depends on the backward-looking term π_{t-1}, forward-looking term $E_t\pi_{t+1}$ and cyclical components $\hat{y}_t$.

4. Estimation of Hybrid Phillips Curve

In this section, we estimate the hybrid Phillips curve as shown in equation (49) for five major euro area countries; France, Germany, Italy, Netherlands and Spain, which together account for over 80 percent of the euro area real GDP.

4.1 Empirical Methods

Benigno and López-Salido (2002) used the generalized method of moments (GMM) to estimate hybrid Phillips curve for five major euro area countries over the period 1970Q1 to 1997Q1. von Hagen and Hofmann (2004) focused on the implication of inflation differentials in euro area countries and estimate backward-looking IS curve for 10 euro countries over the period 1993Q1 to 2004Q4 including the domestic interest rate, the real exchange rate and euro area interest rate. Angeloni and Ehrmann (2004) used panel instrumental variables to estimate hybrid IS curve and hybrid Phillips curve separately for 12 countries from 1998Q1 to 2003Q2. Similarly, Hofman and Remsperger (2005) used panel instrumental variables to estimate hybrid IS curve and hybrid Phillips curve separately for 11 countries over the period 1999Q1 to 2004Q1.

Following Benigno and López-Salido (2002), we estimate the IS curve and the Phillips curve for area wide euro area separately using GMM. We use expression (37) and (53) as an orthogonality condition,

$$E_t[(\hat{y}_{i,t} - \delta_b\hat{y}_{i,t-1} - \delta_f E_t[\hat{y}_{i,t+1}] + \delta_r E_t[\hat{i}_{i,t} - \hat{\pi}_{i,t+1}])z_{i,t}^{IS}] = 0 \tag{50}$$

$$E_t[(\hat{\pi}_{i,t} - \gamma_{b,i}\,\hat{\pi}_{i,t-1} - \gamma_{f,i}E_t\hat{\pi}_{i,t+1} - \gamma_{y,i}\hat{y}_{i,t})z_{i,t}^{P}] = 0 \tag{51}$$

where $z_{i,t}^{IS}$ and $z_{i,t}^{P}$ denote vectors of instrumental variables in estimation for IS curve and Phillips curve, respectively. Our set of instruments $z_{i,t}^{IS}$ is constituted by the output gap with lags of two to five, nominal interest rates with lags of one to four and inflation rate with lags of zero to three, and $z_{i,t}^{P}$ is constituted by the combination of inflation rate with lags of two to five, output gap with lags of one to four and the logarithm of real wage, denoted by $rw_{i,t-j}$, with lags of one to two. We include the logarithm of real wage in our instruments set, taking into account the marginal cost-based hybrid Phillips curve, equation (43).

4.2 Data

Our sample countries are constituted by five major countries; France, Germany, Italy, Netherlands and Spain. Data are with quarterly frequency and our whole sample period is 1991Q1 to 2006Q4, which starts slightly after the start of the first stage of EMU in July 1990 and starts with the integration of Western and Eastern Germany. Because, as mentioned above, the firm's price setting behavior would differ depending on differences in the past monetary policy regime, we extend the sample period. Data on inflation rate are quarterly inflation rates calculated from GDP deflator, since data on HCIP is available only from 1998Q1. Output gap is measured as the percent deviation between logarithm of real GDP and potential GDP, and calculated by using a standard Hodrick-Prescott filter with smoothing parameter of 1,600. Data on nominal interest rate is interbank market rates with three monthly maturities. Data on GDP deflator are from *International Financial Statistics*, IMF, and data on GDP are from Eurostat.

Table 2 shows the correlation matrix of estimated output gaps. From this table, we can see that business cycle synchronization has not occurred, for example, the output gaps in France and Germany are positively correlated but they are negatively correlated with that in Italy.

<Insert Table 2>

4.3 Empirical Results

Table 3 shows the results of our GMM estimation of hybrid IS curves. The first three columns report the estimates of the parameters $\delta_{b,i}$, $\delta_{f,i}$ and $\delta_{r,i}$, and their standard errors, t-value and p-value. The last column displays the Hansen's J-test of overidentifying restrictions.

From Table 3, we can see that the all coefficients of hybrid IS curves are well estimated in correct signs except for Spain where the coefficient on real interest rates is estimated in the opposite sign. Moreover, the coefficient on real interest rate in Italy is not significant.

Table 4 shows the results of our GMM estimation of hybrid Phillips curves. The first three columns report the estimates of the parameters $\gamma_{b,i}$, $\gamma_{f,i}$ and $\gamma_{y,i}$, and their standard errors, t-value and p-value. The last column displays the Hansen's J-test of overidentifying restrictions.

From Table 3, we can see that the all coefficients of hybrid Phillips curves are well estimated in correct signs, but their significance are different in different countries. The coefficients of backward-looking terms in Germany, Netherlands and Spain are estimated to be low and are not significant, on the other hand, those in France and Italy are relatively high and significant. The magnitudes of the estimated coefficients on cyclical components are almost the same in all countries, but their significance are heterogeneous, namely, they are significant in Italy and Spain but not significant in France, Germany and Netherlands. These results mean that the both inflation persistence and cyclical components would contribute to the inflation differentials among euro area countries.

Therefore, we can classify the five countries into four groups as shown in Table 4.

Group 1 is composed of countries where backward-looking term is not significant (inflation persistent is not observed) but cyclical component is significant. In these countries, when monetary policy is tightened and nominal interest rate rises, the inflation rate would fall immediately and largely. This is because forward-looking firms decrease their prices in expectation that inflation rates would fall in the future, which leads to a fall of inflation rate today. In addition, the rise of inflation expectation would raise the real interest rate, which leads to a decline of output gap. Since the cyclical component is significant, that leads to a fall of inflation rate today. Italy and Spain are classified in this Group 1.

Group 2 is composed of countries where both inflation persistent and cyclical components are not significant. In these countries, inflation rate falls immediately but not larger than countries in Group 1. This is because as like countries in Group 1, inflation expectation would fall immediately, which leads to a fall of inflation rate today. However, since the effects of the decline of output gap on inflation are not significant, the degree of inflation fall is smaller than that of Group 1. Germany is classified into this group.

Group 3 is composed of countries where inflation persistent is significant, but cyclical component is not significant. In these countries, the inflation rate would not fall after the rise of nominal interest rate. This is because inflation expectation does not fall largely due to the backward-looking expectation, which also does not decrease the inflation rates today. In addition, the sticky inflation expectation would not raise the real interest rate therefore, would not decrease the output gap largely. Moreover, since cyclical component is not significant, the effects of output gap on inflation would be negligible. France and Netherlands are classified in Group 3.

Group 4 is composed of countries where both inflation persistent and cyclical components are significant. In these countries, the effects of nominal interest rate rise on inflation rate are not obvious. This is because as like Group 3, inflation expectation does not fall largely, which would not fall inflation rate today. In addition, the sticky inflation expectation would not decrease the real interest rate largely, therefore, would not decrease the output gap largely. However, the change of cyclical components affects inflation rate in these countries. Therefore, if the degree of sensitivity of inflation rate to the change of cyclical component is large (small), inflation would (not) fall. There are no countries classified in this group.

In the next section, we consider whether there exists the differences in monetary policy transmission in these countries, and whether these differences reflect above estimated results.

<Insert Table 3, 4>

5. Monetary Policy Transmission in the Euro Area Countries

In this section, we investigate the monetary policy transmission in the euro area. Especially, we focus on whether there exist differences between low inflation countries and high inflation countries in their impulse response of price level to monetary policy shocks. To do this, we employ structural VAR (SVAR) model approach. When we use the SVAR model to investigate monetary policy transmission, it is necessary to identify monetary shocks by imposing the identifying restrictions. For the purpose, we employ the block recursive approach proposed by Christiano, Eichenbaum and Evans (1999, 2005)[5].

It is a merit of the approach that if we can identify the monetary policy shocks correctly, we can estimate the impulse response functions of each variable to monetary shocks correctly even though we do not identify all the economic structure.

5.1 Model and Empirical Method

Let X_t denote the $k \times 1$ vector of variables included in the analysis and we assume that the structural VAR (SVAR) model of X_t is given by

$$A_0 X_t = A_1 X_{t-1} + A_2 X_{t-2} + \cdots + A_p X_{t-p} + \varepsilon_t, \quad \varepsilon_t \sim i.i.d.(0, D) \tag{52}$$

where p is a nonnegative integer which represents the lag order, A_i $(i = 0,1,2,\cdots,p)$ is a $k \times k$ coefficient matrix and ε_t represents structural shocks with diagonal variance-covariance matrix.

The reduced form of SVAR model corresponding to equation (52) is written as

$$X_t = B_1 X_{t-1} + B_2 X_{t-2} + \cdots + B_p X_{t-p} + u_t, \qquad u_t \sim i.i.d.(0, \Sigma_u) \tag{53}$$

where B_i $(i = 1,2,\cdots,p)$ is a $k \times k$ coefficient matrix.

Since

$$B_i = A_0^{-1} A_i, \quad (i = 1,2,\cdots,p) \tag{54}$$

$$u_t = A_0^{-1} \varepsilon_t \tag{55}$$

$$\Sigma_u = A_0^{-1} D (A_0^{-1})' \tag{56}$$

are obtained from the above two equations, the problem, then, is to take the observed value of u_t

5 For the other identification, see Sims (1992), Sims and Zha (1996) and Bernanke and Mihov (1998).

and restrict the system so as to recover ε_t as $\varepsilon_t = A_0 u_t$. Using OLS in equation (53), we can obtain the variance-covariance matrix Σ_u. Since Σ_u is symmetric, it contains only $k(k+1)/2$ distinct elements. Given the diagonal elements of A_0 are all standardized to unity, A_0 contains $k(k-1)$ unknown parameters. In addition, there are k unknown values of diagonal variance-covariance matrix D for a total of k^2 unknown values in the structural model. Therefore, to identify the structural model from an estimated reduced form of SVAR model, it is necessary to impose $k(k-1)/2$ identifying restrictions on the structural model.

We now discuss how we estimate the dynamic response of key macroeconomic variables to a monetary policy following Christiano, Eichenbaum and Evans (1999, 2005).

At the start, we assume that the ECB conducts a monetary policy so as to follow

$$i_t = f(\Omega_t) + \varepsilon_t \tag{57}$$

where i_t is a money market interest rate (MMR), f is a linear function which represents the feedback rule, Ω_t is an information set , and ε_t is the monetary policy shock which is orthogonal to the elements in Ω_t.

We partition X_t into three blocks as follows,

$$X_t = [X_{1t}, i_t, X_{2t}]'. \tag{58}$$

Here, we assume that (i) the vector X_{1t} consists of k_1 variables whose time t values are contained in Ω_t and that are assumed not to respond contemporaneously to a monetary shock., in other words, the monetary policy shock is orthogonal to the elements in X_{1t}, and that (ii) the ECB does not see the vector X_{2t}, which is composed of k_2 ($k_1 + 1 + k_2 = k$) variables of all the other variables in Ω_t, when I_t is set.

From these recursiveness assumptions, A_0 can be written as

$$A_0 = \begin{bmatrix} \underset{(k_1 \times k_1)}{A_{11}} & \underset{(k_1 \times k1)}{0} & \underset{(k_1 \times k_2)}{0} \\ \underset{(1 \times k_1)}{A_{21}} & \underset{(1 \times 1)}{A_{22}} & \underset{(1 \times k_2)}{0} \\ \underset{(k_2 \times k_1)}{A_{31}} & \underset{(k_2 \times 1)}{A_{32}} & \underset{(k_2 \times k_2)}{A_{33}} \end{bmatrix} \tag{59}$$

The zero block in the first row of A_0 reflects the assumption (i), and the zero block in the middle row of this matrix reflects the assumption (ii).

In this paper, we follow Christiano, Eichenbaum and Evans (2005), but depart from them slightly. We include logarithm of international commodity price index ($p_{c,t}$), logarithm of real GDP (y_t), logarithm of price index (p_t) in X_{1t} $(k_1 = 3)$ and logarithm of money supply (m_t) in X_{2t} $(k_2 = 1)$.

The reason for including the international commodity price index in X_{1t} is to solve or reduce the so-called "price puzzle" problem. Here, "price puzzle" stands for the phenomenon that the impulse response function of price level such that it would rise rather than fall in response to a positive interest rate shock is observed in VAR-based analysis. Sims (1992) proposed that the one solution to this "price puzzle" is to include the leading indicator such as commodity price index. This is because when the leading indicator would rise, the monetary authority would expect the future rise in price level and then rise interest rate endogenously. However, if the leading indicators would not included in these circumstances, interest rate shock contains not only exogenous interest rate change but also endogenous interest rate change which corresponds to the expectation of future rise in price level.

Unfortunately, the recursive assumption is not sufficient to identify all the elements of A_0 and to distinguish the first k_1 equations from each other, since equation (59) contains only $k_1 + (k_1 \times k_2) + k_2 = 5$ restrictions, contrary to the requirements that $k(k-1)/2 = 10$ restrictions are needed. However, Christiano, Eichenbaum and Evans (1999) show that (i) there is lower triangular with positive terms on diagonal, which are consistent with the recursiveness assumption, that (ii) each member of this family generates precisely the same dynamic response function of the element of X_t to a monetary policy shock, and that (iii) the dynamic response function of the element of X_t are invariant to the ordering of variables in X_{1t} and X_{2t}. Therefore, we can set A_0 to be the lower triangular and can apply the familiar Cholesky decomposition[6].

In what follows, we employ block recursive approach to identify monetary policy shocks and investigate the monetary policy effects.

5.2 Data

Our sample countries are constituted by five major countries analyzed in Section 2; France, Germany, Italy, Netherlands and Spain. Data are with quarterly frequency and whole sample period is from 1999Q1 to 2006Q4. Data on real GDP is nominal GDP deflated by HCIP. Data on price index is HCIP. Data on commodity price is IMF world commodity price index. Data on MMR is 3-month Euribor. Data on money supply is M3 in the 13 euro area countries because the growth of M3 is the Eurosystems' reference value of monetary aggregate. Data on commodity price index is from *International Financial Statistics,* IMF and the other data are from. Eurostat.

5.3 Empirical Results

Since our sample periods are small relative to our large VAR model (5 variables included), we set lag lengths $p = 1$ in order to secure the degree of freedom. Figure 1 shows the impulse response functions of variables to a unit structural shock in interest rate over 12 periods (3 years). Bootstrapped standard errors with 95% coverage for each impulse response function are also calculated.

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[6] Given a positive-definite symmetric matrix Σ_u, there is one and only one decomposition into $\Sigma_u = PP'$ such that P is lower triangular with positive element of diagonal.

When we focus on the results of impulse response functions of HCIP to interest rate shocks, the results are highly consistent with our expectations in Section 4. In Group1 countries; Italy and Spain, HCIP declines sharply and immediately following the tightening of money market interest rate. In Group 2 countries; Germany, HCIP responds gradually and in a hump-shaped fashion, bottoming after about one and a half years and starting to return to pres-shock levels. In Group 3 countries; France and Netherlands, HCIP rises rather than fall after the Contractionary monetary policy but starts to decline gradually after about one year.

These results show that the combination of the degree of inflation persistence and the degree of sensitivity of inflation rate to cyclical component is the source of persistent inflation differentials[7].

< Figure 4>

6. Conclusion

In this paper, at first, we investigate whether there exists persistent inflation differentials among euro area countries, namely, whether inflation rates among euro area courtiers have converged by analyzing the β and σ-convergence by using panel unit root techniques. From the empirical result, we can find that the evidence of β-convergence, but cannot find that of σ-convergence. This means that overall euro area inflation rates are in a process of convergence but cross-country dispersion in inflation rate across countries has not been eliminated.

Next, we investigate the causes of inflation differentials. Following Christiano, Eichenbaum and Evans (1999), Erceg, Henderson and Levin (2000), Smets and Wouters (2002) and Steinsson (2003), we introduce the DSGE model with hybrid IS curve and hybrid Phillips curve. According to hybrid Phllips curve, inflation rate today depends on the past inflation rate (inflation persistence), expectation of inflation rate and output gap (cyclical components). And then, we estimate the hybrid Phillips curve for France, Germany, Italy, Netherlands and Spain. The all coefficients of hybrid Phillips curves are well estimated in correct signs, but their significance are different in different countries. These results mean that the both inflation persistence and cyclical components would contribute to the inflation differentials among euro area countries. In Italy and Spain, inflation persistent is not significant but cyclical component is significant. In these countries, the inflation rate would be expected to fall immediately and largely after the rise of interest rate. In Germany where both inflation persistent and cyclical components are not significant, inflation rate would be expected to fall but smaller than Italy and Spain. In France and Netherlands, inflation persistent is significant, but cyclical component is not significant. In these countries, the inflation rate would be expected not

7 However, when we see the impulse response functions of real GDP to interest rate shocks, the GDP increases but rather decrease after the tight monetary policy in Italy and Spain. These results are consistent with the estimation of hybrid IS curves. In these countries, the coefficient on real interest rate is not significant or estimated in opposite signs.

to fall after the rise of nominal interest rate.

At last, we consider whether there exist the differences in monetary policy effects among these countries, using block-recursive SVAR model proposed by Christiano, Eichenbaum and Evans (1999). The results obtained are consistent with our expectations stated above. In Italy and Spain, HCIP declines sharply and immediately following the tightening of money market interest rate. In Germany, HCIP responds gradually and in a hump-shaped fashion, bottoming after about one and a half years and starting to return to pres-shock levels. In France and Netherlands, HCIP rises immediately after the rise of money but starts to decline gradually after about one year.

These results show that the combination of the degree of inflation persistence and the degree of sensitivity of inflation rate to cyclical component is the source of persistent inflation differentials.

Appendix 1. Panel Unit Root Test

LLC test

The LLC test is performed as follows.

In the first stage, we begin by estimating two auxiliary equations for a given set of lag orders; regressing $\Delta\pi_{it}$ and $\pi_{i,t-1}$ on the remaining variables (deterministic and the lagged difference) to obtain the residuals $\hat{e}_{i,t}$ and $\hat{v}_{i,t}$.

In the second stage, we regress $\hat{e}_{it}$ on $\hat{v}_{i,t-1}$

$$\hat{e}_{i,t} = \beta_i \hat{v}_{i,t-1} + \varepsilon_{i,t}$$

for individual country separately and adjust $\hat{e}_{it}$ and $\hat{v}_{it}$ as $\tilde{e}_{it} = \hat{e}_{it} / \hat{\sigma}_{\varepsilon_{it}}$ and $\tilde{v}_{i,t-1} = \hat{v}_{i,t-1} / \hat{\sigma}_{\varepsilon_{it}}$ respectively to account for heteroskedastiity, where $\hat{\sigma}_{\varepsilon i} = (T - p_i - 1)^{-1} \sum_{t=p_i+2}^{T} (\hat{e}_{i,t} - \hat{\beta}_i \hat{v}_{i,t-1})^2$ [8].

In the final third stage, we estimate the panel regression

$$\tilde{e}_{i,t} = \beta \tilde{v}_{i,t} - 1 + \tilde{\varepsilon}_{i,t}$$

and compute the t-statistics for $\hat{\beta} = 0$ as

$$t_\beta = \frac{\hat{\beta}}{RSE(\hat{\beta})}$$

where $RSE(\hat{\beta}) = \hat{\sigma}_\varepsilon \left[\sum_{i=1}^{N} \sum_{t=p_i+2}^{T} \tilde{v}_{i,t-1}^2 \right]^{-\frac{1}{2}}$, $\hat{\sigma}_{\varepsilon}^2 = (N\tilde{T})^{-1} \sum_{i=1}^{N} \sum_{t=p_i+2}^{T} (\tilde{e}_{i,t} - \hat{\beta} \tilde{v}_{i,t-1})^2$ and $\tilde{T} = T - N^{-1} \sum_{i=1}^{N} p_i - 1$.

If there are no deterministic in the first-stage regressions, the resulting t-statistics is asymptotically standard normally distributed as $T \to \infty$ and $N \to \infty$. However, if there is a constant or a time trend in the first regressions, then the resulting t-statistics tends to infinity as $T \to \infty$, even if the null is true. Levin and Lin (1993) suggest a correction of t-statistics called t^*-statistics to remove the bias and to obtain an asymptotic standard normal distribution for the test statistics. t^*-statistics is given by

$$t_\beta^* = \frac{t_\beta - (N\tilde{T}) \hat{S}_{N,T} \sigma_{\tilde{\varepsilon}}^{-2} RSE(\hat{\beta}) \tilde{\mu}_T}{\tilde{\sigma}_T} \qquad \text{(A-1)}$$

where $\mu_{\tilde{T}}$ and $\sigma_{\tilde{T}}$ are mean and standard deviation adjustment terms which are computed by Monte Carlo simulation and tabulated in their paper. t^*-statistics is asymptotically standard

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[8] In this stage, an estimate of the long-run variance of id_i,

$$\hat{\sigma}_{\pi_i}^2 = (T-1)^{-1} \sum_{t=2}^{T} \Delta\pi_{i,t}^2 + 2 \sum_{L=1}^{\bar{K}} w_{\overline{KL}} \left((T-1)^{-1} \sum_{t=L+2}^{T} \Delta\pi_{i,t} \Delta\pi_{i,t-L} \right)$$

and the mean of the ratio of $\sigma_{id,i}^2$ to the innovation standard deviation for each country,

$$\hat{S}_{NT} = N^{-1} \sum_{i=1}^{N} (\hat{\sigma}_{\pi_i} / \hat{\sigma}_{e_i})$$

are also calculated, where $\bar{K}$ is the lag truncation parameter and $w_{\overline{KL}}$ is lag window.

normally distributed as $T \to \infty$ and $N \to \infty$.

IPS test

IPS test is performed as follows. In the first stage, the separate ADF regressions of equation (4) are estimated and the average of t-statistics for β_i is calculated as

$$\bar{t}_{NT} = N^{-1}\sum_{i=1}^{N} t_{iT_i}(p_i) \qquad \text{(A-2)}$$

where $t_{iT_i}(p_i)$ denotes t-statistics on β_i for country i and represents the fact that it depends on the sample period T_i and the lag length p_i. Im, Pesaran and Shin (1997) show that

$$W_{\bar{t}_{NT}} = \frac{\sqrt{N}\left(\bar{t}_{NT} - N^{-1}\sum_{i=1}^{N} E(\bar{t}_{iT}(p_i))\right)}{\sqrt{N^{-1}\sum_{i=1}^{N} Var(\bar{t}_{iT}(p_i))}} \qquad \text{(A-3)}$$

is asymptotic standard normal distributed as $N \to \infty$ and $T \to \infty$,where $E(\bar{t}_{iT}(p_i))$ and $Var(\bar{t}_{iT}(p_i))$ are average and variance of $\bar{t}_{iT_i}(p_i)$ respectively, which Im, Pesaran and Shin (1997) computed by simulation as the average and variance over 50,000 Monte Carlo simulations for different values of T and p, and are reported in Table 3 (IPS table) in their paper.

Appendix 2.

Derivation of equation (16)

The price index P_t solves the problem,

$$\min_{\{C_{i,t}(j)\}} Z_{i,t} = \int_0^1 P_t(j)C_{i,t}(j)dj$$

subject to

$$\left[\int_0^1 C_{i,t}(j)^{\frac{\theta-1}{\theta}} dj\right]^{\frac{\theta}{\theta-1}} = 1 .$$

We form the following Lagrangian,

$$L = \int_0^1 P_t(i)C_{i,t}(j)dj - \lambda\left(1 - \left[\int_0^1 C_{i,t}(j)^{\frac{\theta-1}{\theta}} dj\right]^{\frac{\theta}{\theta-1}}\right)$$

and differentiate it with respect to $C_{i,t}(j)$ to get first order condition,

$$P_t(j) = \lambda C_{i,t}(j)^{-\frac{1}{\theta}} .$$

Therefore, we can see that the minimized expenditure over one unit of $C_{j,t}$ equals to Lagrangian multiplier λ.

$$Z^* = \int_0^1 P_t(j)C_{i,t}(j)dj = \lambda \int_0^1 C_{i,t}(j)^{\frac{\theta-1}{\theta}} dj = \lambda$$

Since $C_{i,t}(j) = \left[\frac{P_t(j)}{\lambda}\right]^{-\theta}$ and $\int_0^1 C_{i,t}(j)^{\frac{\theta-1}{\theta}} dj = \int_0^1 \left[\frac{P_t(j)}{\lambda}\right]^{1-\theta} dj = 1$, we can obtain the desired results

$$\lambda = Z_{i,t}^* = \left[\int_0^1 P_t(j)^{1-\theta} dj\right]^{\frac{1}{1-\theta}}.$$

■

Derivation of equation (17)

The demand for each individual good can be obtained by solving the following problem,

$$\max_{\{C_{i,t}(j)\}} C_{i,t} = \left[\int_0^1 C_{i,t}(j)^{\frac{\theta-1}{\theta}} dj\right]^{\frac{\theta}{\theta-1}}$$

subject to

$$\int_0^1 P_t(j)C_{i,t}(j)dj = Z_{i,t}$$

where $Z_{i,t}$ is any fixed total nominal expenditure on goods. We form the following Lagrangian,

$$L = \left[\int_0^1 C_{i,t}(j)^{\frac{\theta-1}{\theta}} dj\right]^{\frac{\theta}{\theta-1}} - \lambda\left(Z_t - \int_0^1 P_t(j)C_{i,t}(j)dj\right)$$

and differentiate it with respect to any two goods $C_{i,t}(j)$ and $C_{i,t}(j')$, to get

$$C_{i,t}(j) = \left[\frac{P_t(j)}{\lambda}\right]^{-\theta}$$

$$C_{i,t}(j') = \left[\frac{P_t(j')}{\lambda}\right]^{-\theta}$$

From above two equation,

$$C_{i,t}(j') = C_{i,t}(j)\left[\frac{P_t(j)}{P_t(j')}\right]^{\theta}$$

is hold. Plugging this expression into the preceding budget constraint and using equation (15),

$$\int_0^1 P_t(j')C_{i,t}(j)\left[\frac{P_t(j)}{p_t(j')}\right]^{\theta} dj' = C_{i,t}(j)P_t(j)^{\theta}\int_0^1 P_t(j')^{1-\theta} dj' = C_{i,t}(j)P_t(j)^{\theta} P_t^{1-\theta} = C_{i,t}(j)\left[\frac{P_t(j)}{P_t}\right]^{\theta} P_t = Z_{i,t}$$

and using

$$C_t P_t = Z_{i,t}$$

show that the representative agent's demand for good j is given by

$$C_{i,t}(j) = \left(\frac{P_t(j)}{P_t}\right)^{-\theta} \frac{Z_{i,t}}{P_t} = \left(\frac{P_t(j)}{P_t}\right)^{-\theta} C_t$$

■

Derivation of equation (36)

We differentiate equation (35) with respect to $P_t(f)$ to get the first order condition,

$$E_t \sum_{l=0}^{\infty} (\beta\alpha)^l \left[(1-\theta) \frac{1}{P_{t+l}} \left(\frac{P_t(f)}{P_{t+l}} \right)^{-\theta} + \theta \phi_{t+l} \frac{1}{P_{t+l}} \left(\frac{P_t(f)}{P_{t+l}} \right)^{-\theta-1} \right] Y_{t+l} = 0$$

Above equation can be arranged as

$$\frac{P_t(f)}{P_t} E_t \sum_{l=0}^{\infty} (\beta\alpha)^l P_{t+l}^{\theta-1} (P_t^{1-\theta} P_t^{\theta}) Y_{t+l} = \frac{\theta}{\theta-1} E_t \sum_{l=0}^{\infty} (\beta\alpha)^l \phi_{t+l} P_{t+l}^{\theta} Y_{t+l}$$

which leads to equation (36).

■

Derivation of equation (37)

From market clearing condition, equation (20) can be written as

$$1 = E_t \left[\frac{\beta I_t}{\Pi_{t+1}} \frac{e^{\varepsilon_{C,t+1}} (Y_{t+1} - hY_t)^{-\sigma_C}}{e^{\varepsilon_{C,t}} (Y_t - hY_{t-1})^{-\sigma_C}} \right]$$

Above equation can be log-linearized as follows,

$$1 = E_t \left[\frac{\beta \bar{I}}{\bar{\Pi}} [1 + \hat{i}_t - \hat{\pi}_{t+1} - \sigma_C \{(\hat{y}_{t+1} - h\hat{y}_t) - (\hat{y}_t - h\hat{y}_{t-1})\} + (\varepsilon_{C,t+1} - \varepsilon_{C,t})] \right]$$

Note that $\beta \bar{I} / \bar{\Pi} = 1$ in steady state, thus, after some arrangements, the hybrid new IS curve is obtained.

■

Derivation of equation (38)

Dividing both side of equation (29) by P and after some arrangement, we get

$$1 = \frac{1}{P_t} \left[\alpha P_{t-1}^{1-\theta} + (1-\alpha)\omega P_t(b)^{1-\theta} + (1-\alpha)(1-\omega) P_t(f)^{1-\theta} \right]^{\frac{1}{1-\theta}}$$

$$1 = \left(\frac{1}{P_t} \right)^{1-\theta} \left[\alpha P_{t-1}^{1-\theta} + (1-\alpha)\omega P_t(b)^{1-\theta} + (1-\alpha)(1-\omega) P_t(f)^{1-\theta} \right]$$

$$1 = \left[\alpha \left(\frac{P_{t-1}}{P_t} \right)^{1-\theta} + (1-\alpha)\omega \left(\frac{P_t(b)}{P_t} \right)^{1-\theta} + (1-\alpha)(1-\omega) \left(\frac{P_t(f)}{P_t} \right)^{1-\theta} \right]$$

$$1 = \left[\alpha \left(\frac{1}{\Pi_t} \right)^{1-\theta} + (1-\alpha)\omega \left(\frac{P_t(b)}{P_t} \right)^{1-\theta} + (1-\alpha)(1-\omega) \left(\frac{P_t(f)}{P_t} \right)^{1-\theta} \right]$$

Then, we log-linearize above equation to get,

$$1=\alpha\left(\frac{P}{\overline{P}}\right)^{1-\theta}\{1-(1-\theta)\hat{\pi}_t\}+(1-\alpha)\omega\left(\frac{\overline{P}(b)}{\overline{P}}\right)^{1-\theta}\{1+(1-\theta)\hat{p}_t(b)\}+(1-\alpha)(1-\omega)\left(\frac{\overline{P}_f}{\overline{P}}\right)^{1-\theta}\{1+(1-\theta)\hat{p}_t(f)\}$$

Since in equilibrium, $\overline{P}=\overline{P}(b)=\overline{P}(f)$, we can obtain

$$\hat{\pi}_t=\frac{1-\alpha}{\alpha}\{\omega\hat{p}_t(b)+(1-\omega)\hat{p}_t(f)\}$$

■

Derivation of equation (39)

Dividing both side of equation (30) by P and after some arrangements, we get

$$\frac{P_t(b)}{P_t}=\frac{P_{t-1}^n}{P_{t-1}}\frac{\Pi_{t-1}}{\Pi_t}$$

Then, log-linearinzing and using the fact that $\overline{P}=\overline{P}(b)=\overline{P}(f)$ in equilibrium leads to equation (39)

■

Derivation of equation (41)

Left hand side of equation (36) can be log-linearized as follows,

$$\begin{aligned}
&\frac{\overline{P}(f)}{\overline{P}}(1+\hat{p}_t(f))E_t\sum_{l=0}^{\infty}(\beta\alpha)^l\left(\frac{\overline{P}}{\overline{P}}\right)\{1+(\theta-1)(\hat{p}_{t+l}-\hat{p}_t)\}\overline{Y}(1+\hat{y}_{t+l})\\
&=(1+\hat{p}_t(f))E_t\sum_{l=0}^{\infty}(\beta\alpha)^l\overline{Y}\{1+(\theta-1)(\hat{p}_{t+l}-\hat{p}_t)+\hat{y}_{t+l}\}\\
&=(1+\hat{p}_t(f))\frac{\overline{Y}}{1-\beta\alpha}+E_t\sum_{l=0}^{\infty}(\beta\alpha)^l\overline{Y}\{(\theta-1)(\hat{p}_{t+l}-\hat{p}_t)+\hat{y}_{t+l}\}
\end{aligned}$$

On the other hand, right hand side of equation (36) can be log-linearized as follows

$$\begin{aligned}
&\frac{\theta}{\theta-1}E_t\sum_{l=0}^{\infty}(\beta\alpha)^l\overline{\phi}(1+\phi_{t+l})\left(\frac{\overline{P}}{\overline{P}}\right)^{\theta}\{1+\theta(\hat{p}_{t+l}-\hat{p}_t)\}\overline{Y}(1+\hat{y}_{t+l})\\
&=\frac{\theta}{\theta-1}\frac{\overline{\phi}\cdot\overline{Y}}{1-\beta\alpha}+\frac{\theta}{\theta-1}\overline{\phi}E_t\sum_{l=0}^{\infty}(\beta\alpha)^l\overline{Y}\{1+\hat{\phi}_{t+l}+\theta(\hat{p}_{t+l}-\hat{p}_t)+\hat{y}_{t+l}\}\\
&=\frac{\overline{Y}}{1-\beta\alpha}+E_t\sum_{l=0}^{\infty}(\beta\alpha)^l\overline{Y}\{1+\hat{\phi}_{t+l}+\theta(\hat{p}_{t+l}-\hat{p}_t)+\hat{Y}_{t+l}\}
\end{aligned}$$

Note that $\frac{\theta}{\theta-1}=\frac{1}{\overline{\phi}}$. Combining both sides of equation (36) leads to

$$
\begin{aligned}
\hat{p}_t(f) &= (1-\beta\alpha)E_t\sum_{l=0}^{\infty}(\beta\alpha)^l(\hat{\phi}_{t+l}+\hat{p}_{t+l}-\hat{p}_t) \\
&= (1-\beta\alpha)\{\hat{\phi}_t+\beta\alpha E_t\sum_{l=0}^{\infty}(\beta\alpha)^l(\hat{\phi}_{t+l+1}+\hat{p}_{t+l+1}-\hat{p}_t)\} \\
&= (1-\beta\alpha)[\hat{\phi}_t+\beta\alpha E_t\sum_{l=0}^{\infty}(\beta\alpha)^l\{\hat{\phi}_{t+l+1}+\hat{p}_{t+l+1}-\hat{p}_{t+1}+(\hat{p}_{t+1}-\hat{p}_t)\}] \\
&= (1-\beta\alpha)\hat{\phi}_t+\beta\alpha(1-\beta\alpha)E_t\sum_{l=0}^{\infty}(\beta\alpha)^l\{\hat{\phi}_{t+l+1}+\hat{p}_{t+l+1}-\hat{p}_{t+1}\}+(1-\beta\alpha)\beta\alpha E_t\sum_{l=0}^{\infty}\hat{\pi}_{t+1} \\
&= (1-\beta\alpha)\hat{\phi}_t+\beta\alpha E_t[\hat{p}_{t+1}(f)]+\beta\alpha E_t[\hat{\pi}_{t+1}]
\end{aligned}
$$

■

Derivation of equation (42)

Inserting equation (40) to (38), we get

$$\hat{p}_t^n = \frac{\alpha}{1-\alpha}\hat{\pi}_t$$

and plugging this expression to equation (39), we get

$$\hat{p}_t(b) = \frac{\alpha}{1-\alpha}\hat{\pi}_{t-1}-\hat{\pi}_t+\hat{\pi}_{t-1} = \frac{\hat{\pi}_{t-1}}{1-\alpha}-\hat{\pi}_t$$

We combine equation (38) and above equation to obtain equation (42).

■

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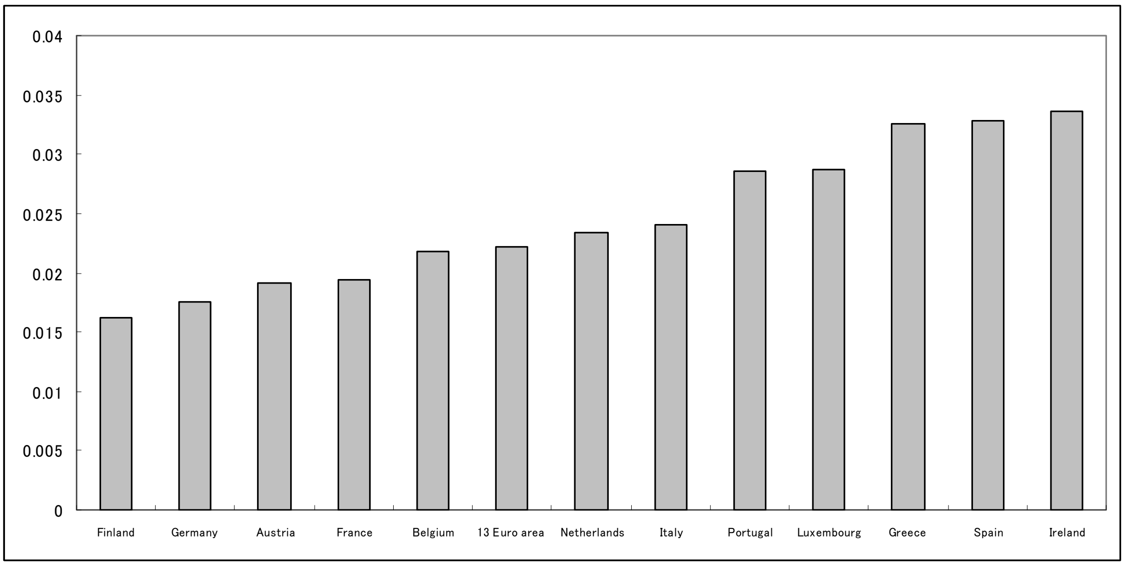
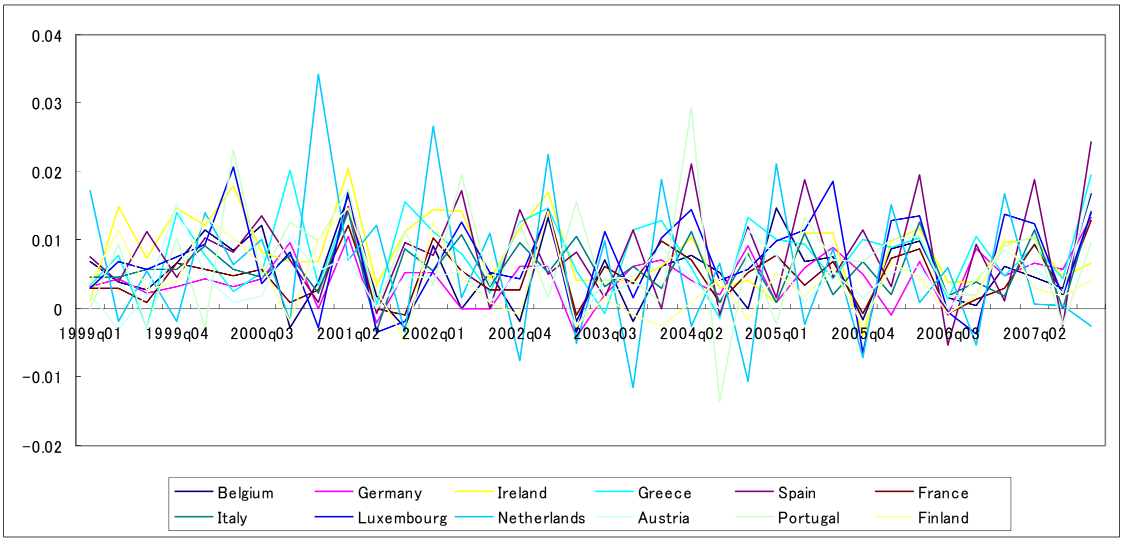
Tables and Figures

Figure 1. Averaged Inflation Rates (Annual ,1999Q1-2007Q4)



(Source) Eurostat

Figure 2. Inflation Rates (Quarter to Quarter, 1999Q1-2007Q4)



(Source) Eurostat

Figure 3. Standard Deviation of Inflation Rates

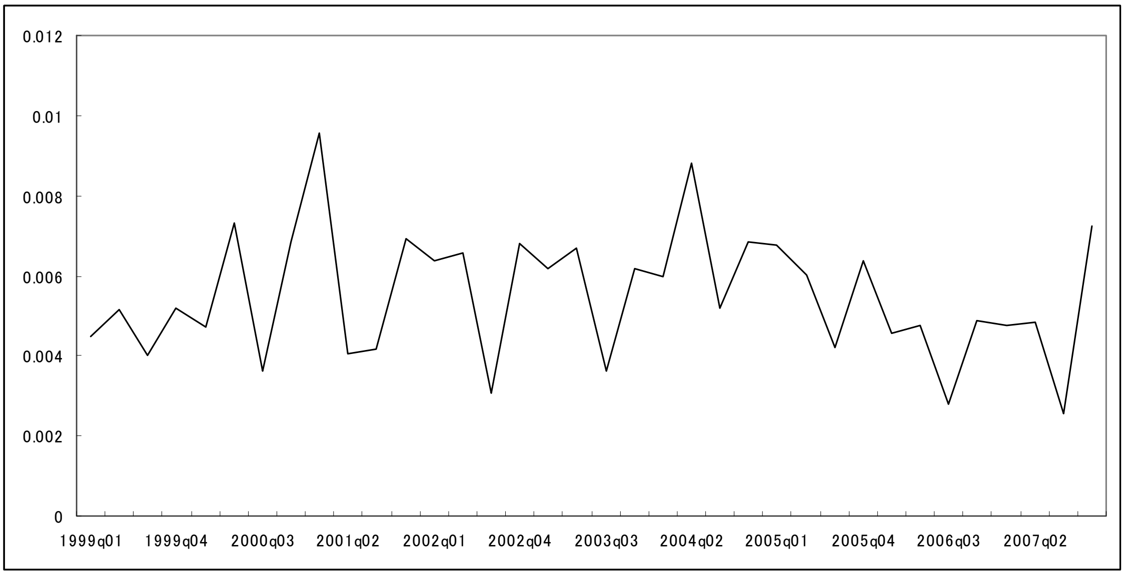
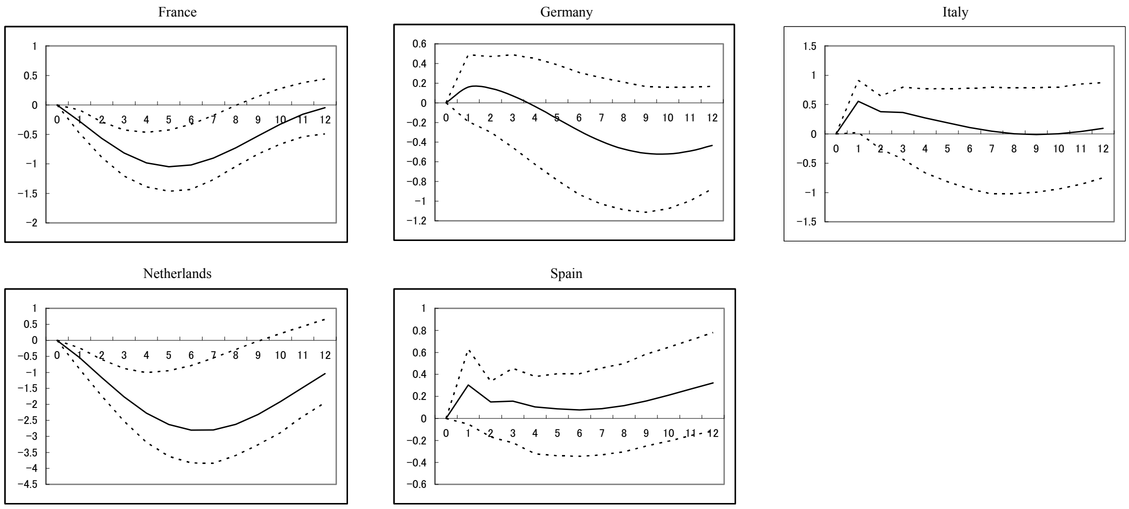
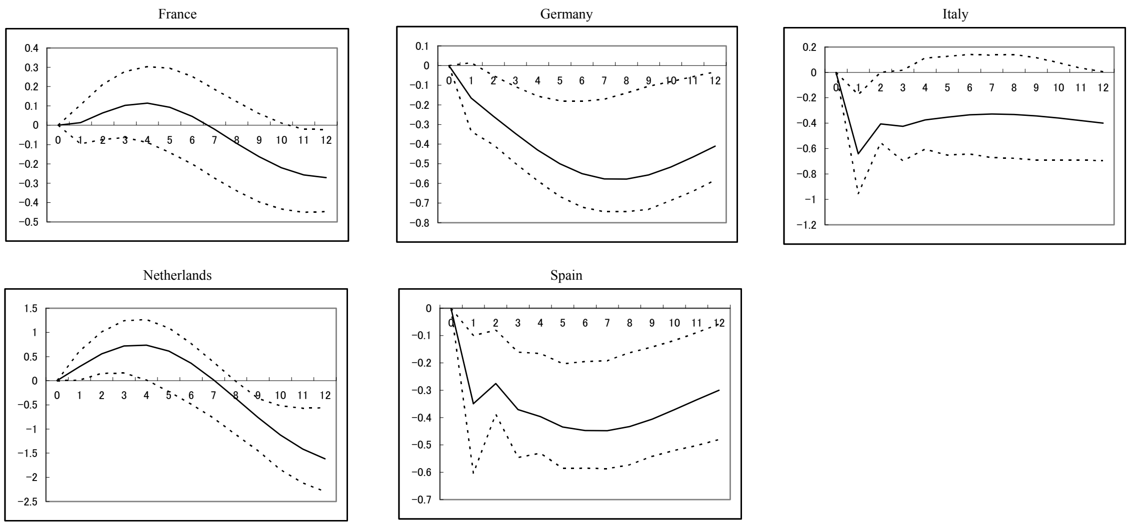


Figure 4. Impulse Response Functions of variables to Interest Rate Shocks

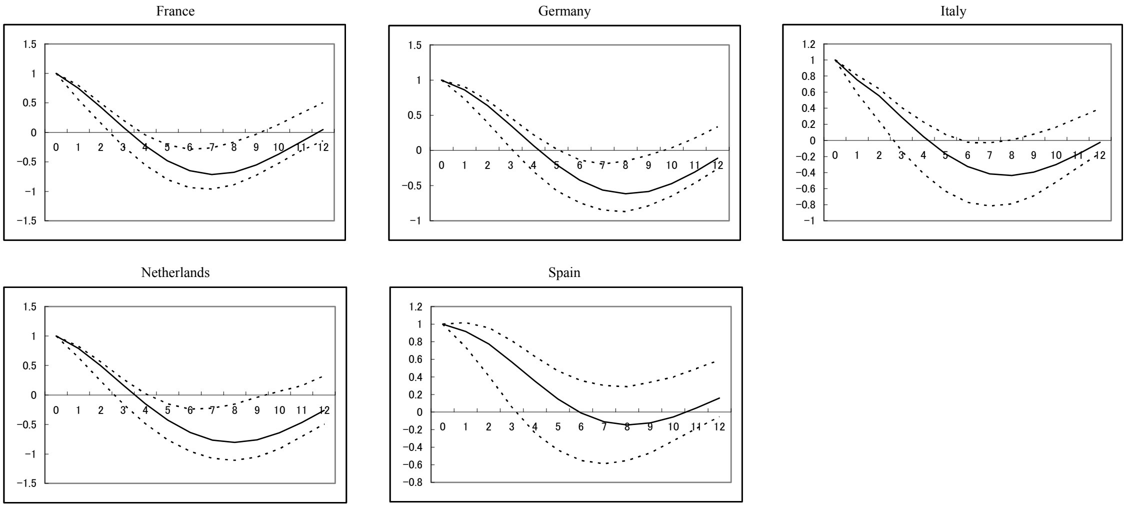
(a)GDP



(b)HCIP



(c)Money Market Interest Rates



(d)M3

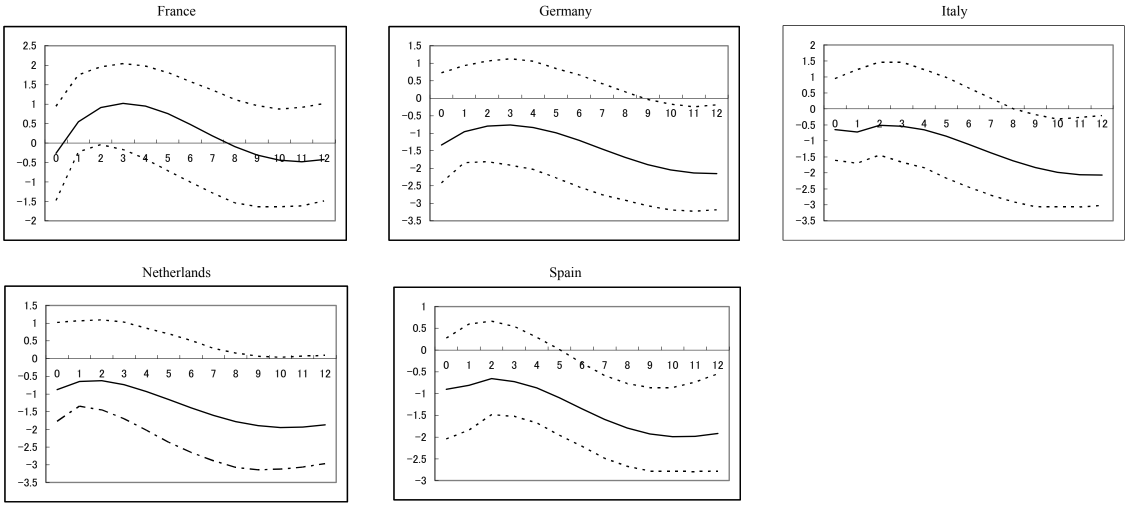


Table 1. Estimation Results of Inflation Convergence

Method	Statistic	Prob
β-convergence		
Levin, Lin & Chu	-23.8338	0
Im, Pesaran and Shin	-22.2732	0
σ-convergence		
Augmented Dickey-Fuller	-1.705095	

Table 2. Correlation Matrix of Output gaps

	France	Germany	Italy	Netherlands	Spain
France	1				
Germany	0.67845	1			
Italy	-0.247153	-0.484592	1		
Netherlands	-0.158892	0.074481	-0.130226	1	
Spain	0.150811	-0.139293	0.677425	-0.130812	1

Table 3. GMM Estimation of Hybrid IS Curve

		δ_b	δ_f	δ_r	J-statistics	Instrumentals
France	Coefficient	0.5313	0.3828	−0.0010	0.0345	$z_t^{IS} = \{\hat{y}_{t-2}, \hat{y}_{t-3}, \hat{y}_{t-4}, \hat{y}_{t-5}, i_{t-1}, i_{t-2}, i_{t-3}, i_{t-4}, \pi_t, \pi_{t-1}, \pi_{t-2}, \pi_{t-3}\}$
	S.E.	0.0008	0.0011	0.0001		
	t-value	676.3994	340.3707	−8.1912		
	p-value	0.0000	0.0000	0.0000		
Germany	Coefficient	0.4212	0.6266	−0.0265	0.0982	$z_t^{IS} = \{\hat{y}_{t-2}, \hat{y}_{t-3}, \hat{y}_{t-4}, \hat{y}_{t-5}, i_{t-1}, i_{t-2}, i_{t-3}, i_{t-4}, \pi_t, \pi_{t-1}, \pi_{t-2}, \pi_{t-3}\}$
	S.E.	0.0372	0.0339	0.0050		
	t-value	11.3136	18.5019	−5.3151		
	p-value	0.0000	0.0000	0.0000		
Italy	Coefficient	0.4851	0.5421	−0.0005	0.1320	$z_t^{IS} = \{\hat{y}_{t-2}, \hat{y}_{t-3}, \hat{y}_{t-4}, \hat{y}_{t-5}, i_{t-1}, i_{t-2}, i_{t-3}, i_{t-4}, \pi_t, \pi_{t-1}, \pi_{t-2}, \pi_{t-3}\}$
	S.E.	0.0788	0.1242	0.0129		
	t-value	6.1539	4.3660	−0.0405		
	p-value	0.0000	0.0001	0.9679		
Netherlands	Coefficient	0.3879	0.4036	−0.0343	0.0536	$z_t^{IS} = \{\hat{y}_{t-2}, \hat{y}_{t-3}, \hat{y}_{t-4}, \hat{y}_{t-5}, i_{t-1}, i_{t-2}, i_{t-3}, i_{t-4}, \pi_t, \pi_{t-1}, \pi_{t-2}, \pi_{t-3}\}$
	S.E.	0.0666	0.0849	0.0157		
	t-value	5.8200	4.7535	−2.1794		
	p-value	0.0000	0.0000	0.0336		
Spain	Coefficient	0.4762	0.5375	0.0038	0.0690	$z_t^{IS} = \{\hat{y}_{t-2}, \hat{y}_{t-3}, \hat{y}_{t-4}, \hat{y}_{t-5}, i_{t-1}, i_{t-2}, i_{t-3}, i_{t-4}, \pi_t, \pi_{t-1}, \pi_{t-2}, \pi_{t-3}\}$
	S.E.	0.0212	0.0238	0.0058		
	t-value	22.4578	22.5632	0.6541		
	p-value	0.6190	0.0000	0.0263		

Table 4. GMM Estimation of Hybrid Phllips Curve

		γ_b	γ_f	γ_y	J-statistics	Instrumentals
France	Coefficient	0.556	0.461	0.005	0.043	$z_t^P = \{\pi_{t-2}, \pi_{t-3}, \hat{y}_{t-1}, \hat{y}_{t-2}, \hat{y}_{t-3}, \hat{y}_{t-4}\}$
	S.E.	0.108	0.103	0.013		
	t-value	5.167	4.462	0.354		
	p-value	0.000	0.000	0.725		
Germany	Coefficient	0.134	0.897	0.018	0.092	$z_t^P = \{\pi_{t-2}, \pi_{t-3}, \pi_{t-4}, \hat{y}_{t-1}, \hat{y}_{t-2}, \hat{y}_{t-3}, \hat{y}_{t-4}, rw_{t-1}\}$
	S.E.	0.143	0.163	0.013		
	t-value	0.352	0.000	0.160		
	p-value	0.936	0.000	0.736		
Italy	Coefficient	0.362	0.579	0.027	0.042	$z_t^P = \{\pi_{t-2}, \pi_{t-3}, \hat{y}_{t-1}, \hat{y}_{t-2}, \hat{y}_{t-3}\}$
	S.E.	0.472	0.489	0.017		
	t-value	0.767	1.184	1.610		
	p-value	0.446	0.241	0.113		
Netherlands	Coefficient	0.262	0.825	0.069	0.030	$z_t^P = \{\pi_{t-2}, \pi_{t-3}, \pi_{t-4}, \pi_{t-5}, \hat{y}_{t-1}, \hat{y}_{t-2}, \hat{y}_{t-3}, rw_{t-1}, rw_{t-2}\}$
	S.E.	0.076	0.142	0.092		
	t-value	3.438	5.821	0.752		
	p-value	0.001	0.000	0.455		
Spain	Coefficient	0.062	0.948	0.018	0.036	$z_t^P = \{\pi_{t-2}, \pi_{t-3}, \hat{y}_{t-1}, \hat{y}_{t-2}, \hat{y}_{t-3}, \hat{y}_{t-4}\}$
	S.E.	0.125	0.128	0.008		
	t-value	0.500	7.383	2.281		
	p-value	0.619	0.000	0.026		

Table 4. Four Groups

Group 4 : none

Inflation persistence : ○

Cyclical Components : ○

$$i_t \uparrow \Rightarrow \bar{\pi}^e_{t+1} \Rightarrow \bar{\pi}_t$$

$$\Rightarrow \bar{r}_t \Rightarrow \bar{\hat{y}}_t \Rightarrow \pi_t \downarrow$$

$$\Rightarrow \bar{\pi}_t \,?$$

Group 1: Italy, Spain

Inflation persistence : ×

Cyclical Components : ○

$$i_t \uparrow \Rightarrow \pi^e_{t+1} \downarrow \Rightarrow \pi_t \downarrow$$

$$\Rightarrow r_t \uparrow \Rightarrow \hat{y}_t \downarrow \Rightarrow \pi_t \downarrow$$

$$\Rightarrow \pi_t \downarrow \downarrow$$

Group 3: France, Netherlands

Inflation persistence : ○

Cyclical Components : ×

$$i_t \uparrow \Rightarrow \bar{\pi}^e_{t+1} \Rightarrow \bar{\pi}_t$$

$$\Rightarrow r_t \Rightarrow \hat{y}_t \Rightarrow \bar{\pi}_t$$

$$\Rightarrow \bar{\pi}_t$$

Group 2: Germany

Inflation persistence : ×

Cyclical Components : ×

$$i_t \uparrow \Rightarrow \pi^e_{t+1} \downarrow \Rightarrow \pi_t \downarrow$$

$$\Rightarrow r_t \uparrow \Rightarrow \hat{y}_t \downarrow \Rightarrow \bar{\pi}_t$$

$$\Rightarrow \pi_t \downarrow$$