Stabilization Effects of the Euro Area Monetary Policy
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Abstract

The primary objective of the European Central Bank is price stability for the Euro Area. The current economic problems in the Euro Area countries suggest that it is possible for monetary policy stabilization effects in the aggregate and member economies to differ. In addition, the effects might vary across countries. To address this issue, we first estimate a Euro Area policy interest rate rule in a flavor of a Taylor rule. We then assess the importance of the country-specific differentials from the aggregate for the central bank interest rate setting. Further, we incorporate the empirical findings in a theoretical framework, where the country-specific stabilization effects of the aggregate monetary policy are formalized. We show that within typical parameter values the "Taylor principle" is satisfied for the aggregate, yet it is not satisfied for the currency union as a whole suggesting unstable local equilibrium.

Keywords: multi-country models, monetary policy rules, dynamic stability, Euro Area

*The views expressed in this paper are those of the authors' alone and do not reflect the opinions of the Federal Reserve Bank of St. Louis, the Federal Reserve System or the Bank of Canada.

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1 Introduction

The primary objective of the European Central Bank (ECB) is price stability. Based on its mandate the central bank can pursue the objectives of the European Union (EU) stated as "economic and social progress and a high level of employment and to achieve balanced and sustainable development." Nevertheless, if a conflicting situation is to arise, the ECB is committed to give priority to price stability.[1]

Price stability is measured in terms of "a year-on-year increase in the Harmonized Index of Consumer Prices (HICP) for the Euro Area below 2%." It is worth noting that the 2% inflation target is a medium-term target and as such it implies forward looking policymaking. In addition, the HICP for the Euro Area is calculated as a weighted average of the country-specific HICP-s proportional to their economic size. More specifically, the weights are calculated as shares of country-specific household consumption expenditures in the total for the Euro Area (EA) and are updated annually.[2]

The theoretical literature, on the contrary, suggests different weighting for the aggregate inflation than is used for aggregation in practice. Benigno (2004) considers a currency area model where the member economies exhibit various degrees of price rigidities. Given the environment, the optimal monetary policy weights the country-specific inflations proportional to the degree of nominal rigidity observed in each individual economy. In this specific setup, weighting according to the economic size is optimal only when the degrees of nominal rigidities are equal across countries. Galí and Monacelli (2008), on the other hand, show that when fiscal policy is introduced to the the mix of policy alternatives, it is optimal for monetary authority to stabilize aggregate inflation, while fiscal authority targets the asymmetries associated with heterogeneity in nominal rigidities across the countries.

The purpose of this paper is to evaluate what the ECB does in practice. We estimate a simple monetary policy rule for the EA from a family of Taylor rules in accord to Taylor (1993). Then we augment it with country-specific differentials from the aggregate in an effort to learn about the weights associated with country-specific deviations in the monetary policy rule. Further we elaborate on the aggregate and country-specific dynamic stability properties of the Euro Area

[1] Detailed discussion of the European Central Bank, its mandate and policy objectives is provided in The European Central Bank (2009). **Double check this reference.**

[2] There are a few things worth to note in this regard. First, other aggregate variables pertaining to the Euro Area are also weighted averages, were the weights in concern are calculated as a member's share in the Euro Area with respect to an activity. For example, in weighting the total Industrial Production Index, the weights used are based on value added. Most of these weights are similar to each other and are proportional to the country size. For example the weight on German price level in the HICP calculation is 29.0% for 2005, while the weight used for the IPI (2005 is the base year for IPI) is 30.6%. The same numbers for Belgium, for example, are 3.7% and 3.3% respectively. Contrary to the HICP, the weights on the IPI do not get updated, they are based on the base year. Second, as the composition of the Euro Area is changing, the weights on countries are changing as well, since by construction all weights need to sum to one. This is an additional source of time variation in the weights as opposed to the relative changes in size of the countries that are already in the union. The variations in the weight changes for most countries are not large. For example the HICP weight on France was 21.1% in 1999 and 20.8% in 2010. The same numbers for Belgium are 4.00% and 3.2%. The most drastic change in the HICP weight has been for Germany: the weight has dropped from 34.5% to 26.2% between 1999 to 2010.

policy interest rate rule.

The contributions of the paper are twofold. First, it gives new evidence about the stance of the monetary policy in the EA relying on the post-Euro data. As such, it contributes to the vast literature on the evaluation of monetary policy rules in practice as in Clarida et al. (1998) and Orphanides (2002) to name a few. Second, by estimating the importance of country-specific deviations in the monetary policy interest rate rule we can analyze the country-specific stabilization effects of aggregate monetary policy and assess the country-specific differentials in the Euro Area from the perspective of dynamic (in)stability as in Clarida et al. (2000) for the United States.

The remainder of the paper proceeds as follows. Section 2 describes the Taylor rule models considered. Section 3 estimation details and presents the empirical results. In order to analyze the stabilization effects of the policy rule, we introduce a theoretical framework in 4. Section 5 concludes.

2 Taylor Rule Specifications

We consider two types of Taylor rules. The first one is stated as a monetary reaction function that stabilizes the aggregate economy, where the economic fundamentals monetary policy reacts to are weighted averages of country-specific fundamentals as in the official statistics reported for the Euro Area by the Eurostat. Second, we consider a disaggregated monetary reaction function, where we postulate a monetary policy rule that explicitly targets the country-specific deviations in addition to the aggregates, thus uncovering the weighting implicitly used in policymaking.

2.1 Benchmark Taylor Rule

We follow Clarida et al. (1998) in postulating the aggregate monetary reaction function in the following form

$$r_t^* = \bar{r} + \beta(E[\pi_{t+h}|\Omega_t] - \pi^*) + \gamma(E[y_t|\Omega_t] - y_t^*), \tag{1}$$

where r_t^*, π^*, and y_t^* are the nominal interest rate, inflation, and output gap targets. $\bar{r}$ indicates the long-run equilibrium nominal interest rate, which we elaborate on further, while the central bank reacts to its expectations of h-period ahead inflation and contemporaneous output gap formed based on information available at time t, Ω_t.[3]

Taylor rules are important under the assumption that money has real effects, which is in essence possible if the economy can be characterized by nominal rigidities either in product or labor markets or in both. In this case, it is optimal for the monetary policy to make the rigidities non-binding by its interest rate instrument. Suppose, the nominal rigidities are in the product market. By setting the interest rate at a level consistent with zero inflation the central bank yields nominal rigidities

[3]This restriction ensures that the central bank conducts monetary policy based on Taylor Principle, which eliminates the sunspot equilibria in which self-fulfilling expectations drive the explosive dynamics of inflation and output. The relevance of the sunspot equilibria in historic analysis of the monetary policy for the U.S. is provided in Clarida et al. (2000).

non-binding: when there is no inflation it would not matter for the overall dynamics of the economy that prices are slow to adjust. Consequently, it is optimal for the policy authority to stabilize the economy at the flexible price equilibrium output level and not at any other level. We denote that point by y_t^*. The nominal interest rate that prevails at the bliss points of inflation, $\pi_t^* = 0$, and output, y_t^*, is referred to as long-run or natural interest rate and is denoted by $\bar{r}$.

It is observed that the central banks move the interest rates in a smooth fashion. Clarida et al. (1998) suggest the unwillingness of the policy authority to disrupt the capital markets or lose credibility from the policy jumps as possible reasons.[4] To account for this observation, we follow the literature in assuming that the actual nominal interest rate adjusts to the target in the following way

$$r_t = (1-\rho)r_t^* + \rho r_{t-1} + \nu_t, \tag{2}$$

where $\rho \in (0,1)$ and ν_t are i.i.d. policy shocks.

Equations (1) and (2) give us the interest rate rule that we consider in the empirical application. Let $x_t = y_t - y_t^*$ and $\alpha = \bar{r} - \beta\pi_t^*$. We will refer to x_t as output gap in the remainder of the paper. By substitution and reparameterization we obtain

$$\begin{aligned} r_t &= (1-\rho)(\bar{r} + \beta(E[\pi_{t+h}|\Omega_t] - \pi^*) + \gamma(E[y_t|\Omega_t] - y_t^*)) + \rho r_{t-1} + \nu_t, \\ &= (1-\rho)\alpha + \rho r_{t-1} + (1-\rho)\beta\pi_{t+h} + (1-\rho)\gamma x_t + \epsilon_t, \end{aligned} \tag{3}$$

where ϵ_t is a linear combination of inflation and output gap forecast errors and structural disturbance ν_t.

$$\epsilon_t = -(1-\rho)(\beta(\pi_{t+h} - E[\pi_{t+h}|\Omega_t]) + \gamma(x_t - E[x_t|\Omega_t])) + \nu_t.$$

2.2 Alternative Taylor Rule

Given the discussion of the literature, one could suppose that the ECB recognizes the possibility that an alternative weighting of the countries-specific fundamentals might result in an improving outcome. We can incorporate that idea into a Taylor Rule estimation by suggesting alternative indices for prices and output, such that the target union-wide inflation rate, as well as the output gap can be stated as

$$\begin{aligned} \hat{\pi}_{t+h} &= \pi_{t+h} + \sum_{i=1}^{n} \omega_i(\pi_{t+h}^i - \pi_{t+h}) \\ \hat{x}_t &= x_t + \sum_{i=1}^{n} \lambda_i(x_t^i - x_t) \end{aligned} \tag{4}$$

[4] An alternative explanation of the interest rate smoothing is purely econometric, in that it is a result of model misspecification. For a recent discussion and references see Coibion and Gorodnichenko (2011).

Equation (5) postulates what we refer to as an alternative monetary policy rule: it considers the policy rule of equation (3) with alternative measures of inflation and output gap as specified in (4). In particular, we estimate the following for n member countries in the currency union.

$$\begin{aligned} r_t &= (1-\rho)\alpha + \rho r_{t-1} + (1-\rho)(\beta\pi_{t+h} + \beta\sum_{i=1}^{n}\omega_i(\pi^i_{t+h} - \pi_{t+h})) \\ &+ (1-\rho)(\gamma x_t + \gamma\sum_{i=1}^{n}\lambda_i(x^i_t - x_t)) + \epsilon_t \end{aligned} \tag{5}$$

The maintained null hypothesis is that the country-specific deviations from the aggregate are irrelevant for the policy rule, i.e. $\omega_i = 0$ and $\lambda_i = 0$, for $i = 1, ..., n$. Under the null hypothesis, the alternative specification nests the benchmark specification.[5]

3 Estimation and Results

We estimate the Taylor rules specified in (3) and (5) by instrumental variables approach. Let X_t be a set of variables in the information set of the policy authority at time t (i.e. $X_t \in \Omega_t$), such that $E(\epsilon_t|X_t) = 0$ and $E(u_t|X_t) = 0$. We follow Clarida et al. (1998) and include 1-6, 9 and 12 lagged values of inflation (π_t), output gap (x_t), day-to-day money market interest rate (r_t), the log difference of world commodity prices (o_t) and euro/dollar real exchange rates (q_t) in the instrument set X_t.

In the disaggregate specification we consider the six largest economies of the Euro zone, i.e. Belgium, Germany, France, Spain, Italy, and the Netherlands. Similar to Boivin et al. (2008), we justify this choice by the observation that the six countries combined have about 90% of the EA output and population. We use the growth rate of the Harmonized Index of Consumer Prices (HICP) to measure aggregate and country-specific inflation rates.[6] Output gap is measured with HP-filtered (log-transformed) Industrial Production Index (IPI). We use the average day-to-day money market interest rate as a monetary policy instrument.

The data we use is at monthly frequencies and spans the period 1999:1-2010:12. All series, but the ones specifically mentioned, are taken from the Eurostat. When constructing the instrument set we use the growth rates of the end of month values for Commodity Research Bureau Spot Index and USD-Euro bilateral nominal exchange rates. We obtain the real exchange rate by multiplying the bilateral nominal exchange rates with a ratio of seasonally adjusted consumer prices in the Euro Area and the US. The US CPI is taken from the FRED database of the Saint Louis Fed.

INSERT FIGURES 1 AND 2 HERE

[5] The Euro Area composition has changed over the years, however, as we elaborate further on, we consider $n = 6$, which is less than the number of countries that have been in the Euro Area from commencement in 1999.

[6] The HICP data provided by the Eurostat are not seasonally adjusted. We seasonally adjust the series by X-12 trend filtering in EViews.

Figure 1 depicts the dynamics of the aggregate variables. The interest rates show two episodes of tightening and subsequently two periods of expansion. Not surprisingly, the tightening occurs in periods when the economy is overheating (output gap is positive). As the output gap becomes negative, interest rates fall. Prior to the beginning of the financial crises in 2008, inflation rate has been hovering slightly above the 2%, which is the ECB target level, with a big jump and drop prior to the crises. The last two years of the sample introduce large swings to the model. One alternative is to truncate that part of the sample and not use for the analysis. However, given the short sample available for the Euro Area, in addition to the fact that the economic dynamics over the sample period has been fairly stable, one could think that the volatility introduced at the end of the sample could improve the estimation results.

Figure 2 shows the average country-specific deviations of inflation and output gap from the Euro Area aggregate. The range of average inflation differential is about 1.2 percentage points. Belgium, Spain, Italy, and the Netherlands exhibit above aggregate inflation on average, while Germany and France are on average below. The range for the output gap variation is smaller: it is about 0.15 percentage points. In the case of the output gap, Spain and Italy are on average above the Euro Area aggregate, while the remaining countries in the sample are below.

INSERT TABLES 1 - 4 HERE

Tables 1 - 4 show volatility and correlation measures for the inflation and output gap differentials. Tables 1 and 3 suggest that the volatility of the output gap differentials is about 10 times higher than that of the inflation differentials, suggesting that inflation misalignments across the countries are more persistent. The Netherlands appears to be the exception with an output gap volatility that is about three times as much.

Correlations between inflation differentials suggested by Table 2 are not very strong. The strongest positive correlation is between France and Italy and it is 0.21, while most of the cross-country correlations are negative. As shown in table 4, for many countries the output gap differentials are also negatively correlated. Overall the correlations are higher compared to the case of inflation, the strongest positive correlation being between the Netherlands and France. In general, it is also true that a positive correlation on the inflation differential side does not suggest the same on the output differential side. For example, the correlation between Belgian and German inflation differentials is positive, but it is negative in the output gap dimension.

We conduct a 2-stage GMM estimation, where the optimal weighting matrix is obtained with a Bartlett window $L_{(j,n)} = 1 - j/(l+1)$, where $j = 1, ..., l$ and $l = 12$ is the maximum lag length used in constructing a HAC consistent weighting matrix. The minimization algorithm is initialized at values of reduced form coefficients obtained via OLS. The local stability condition is verified by alternatively choosing starting conditions at one standard deviations of the reduced form parameters. The coefficients are restricted such that $\rho \in [0, 0.99]$, $\beta > 0$, and $\omega_i \in [0, 1]$ and $\lambda_i \in [0, 1]$, for all $i = 1, ..., n$. In addition, it is imposed that the weights sum up to one in that $\sum_{i=1}^{n} \omega_i \leq 1$ and $\sum_{i=1}^{n} \lambda_i \geq 1$. We do not impose the constraint that $\gamma \leq 0$ in the estimation, but the results satisfy the constraint.

Estimation results of the aggregate Taylor rule in equation (3) are in Table 5. The interest rate smoothing parameter is relatively high at 0.92. The relative weight on inflation is much higher than that on the output, though the output gap also enters the policy reaction function with statistical significance. It appears that the ECB is conducting an inflation "hawkish" policy, by increasing the interest rate with 2.42 percentage points for every percentage point increase in the anticipated inflation. It reacts to the contemporaneous output gap changes with a 0.58 percentage point increase.

The estimation results from the alternative specification of Taylor rule in equation (5) are presented in Table 6. The J-statistics, which is a re-scaled version of the GMM objective function is slightly lower for the alternative model compared to the benchmark, though in both cases the model specification is not rejected. The alternative specification results in a policy interest rate rule that is somewhat less persistent (i.e. the AR coefficient is 0.89 compared to 0.92), and that reacts to the contemporaneous output gap fluctuations somewhat less (i.e. the coefficient is 0.52 compared to 0.58), though these differences are not statistically significant at least at 5% significance level. The statistical significant differences arise in the estimation of the constant term, as well as the β coefficient which governs the reaction of the policy interest rate to the aggregate inflation fluctuations. When incorporating the country-specific differentials into the reaction function, this coefficient declines from 2.42 to 1.23. In the alternative, some country-specific deviations become important. The deviations of the Dutch inflation rates from the Euro Area aggregate, as well as the deviations of the Spanish and French output gaps are significant at 5% significance level. The Wald-test results considered in Table 7 show that we fail to reject the null hypothesis that the weights on country-specific deviations are jointly zero, the weights on inflation and output-gap deviations separately are jointly zero, and that the weights imposed on inflation differentials and output gap differentials are equal to each other.

4 Theoretical Framework

In order to analyze the aggregate and country-specific stabilization effects of the estimated Taylor Rules, we postulate a theoretical framework. We assume that each country in the union is a small open economy governed by the laws of motion similar to that of Galí and Monacelli (2005). In each economy consumers choose between domestic and foreign consumption guided by a preference parameter for a home bias. Producers in the member economies are monopolistically competitive firms which set prices taking into account the fact that with some probability they might not be able to adjust their prices in the future. Consumers can invest in foreign bonds, thus perfect international risk sharing is in place. Producers are paid subsidies to eliminate the inefficiencies associated with monopolistic power, thus the only rigidity binding the economy is the nominal rigidity associated with sticky prices. There are two sources of uncertainty in the economy: technology shocks and foreign output shocks. The main equations are summarized in the Appendix A.

4.1 Aggregate Economy Dynamics

We first consider the Euro Area as an aggregate economy, where the IS-curve and CPI Phillips curve are stated as

$$\begin{aligned} x_t &= E_t\{x_{t+1}\} - \frac{1}{\sigma_\alpha(1-\alpha)}(r_t - E_t\pi^i_{t+1} - \rho) + \psi_{13}a_t - \psi_{14}y^*_{t-1} \\ \pi_t &= \beta E_t\{\pi_{t+1}\} + (1-\alpha)\lambda\left(\varphi + \sigma_\alpha\right)x_t + \alpha(r_{t-1} - \beta r_t - (1-\beta)\rho) + \psi_{24}y^*_{t-1}, \end{aligned} \tag{6}$$

where x_t is the output gap, π_t is the CPI inflation, a_t describes the technology, and y^*_t is the world output.[7] We close the aggregate model by an interest rate rule

$$r_t = \rho + \rho_r r_{t-1} + \phi_\pi \pi_t + \phi_x x_t. \tag{7}$$

We re-write the system in the following state-space form

$$\begin{pmatrix} E_t x_{t+1} \\ E_t \pi_{t+1} \\ r_t \end{pmatrix} = A \begin{pmatrix} x_t \\ \pi_t \\ r_{t-1} \end{pmatrix} + B \begin{pmatrix} \rho \\ a_t \\ y^*_{t-1} \end{pmatrix},$$

where

$$A = \begin{pmatrix} 1 & \frac{1}{\sigma_\alpha(1-\alpha)} & -\frac{1}{\sigma_\alpha(1-\alpha)} \\ 0 & \beta & -\alpha\beta \\ 0 & 0 & 1 \end{pmatrix}^{-1} \begin{pmatrix} 1 & 0 & 0 \\ -(1-\alpha)\lambda(\varphi+\sigma_\alpha) & 1 & -\alpha \\ \phi_x & \phi_\pi & \rho_r \end{pmatrix}$$

4.2 Currency Union Dynamics

Next, we consider a currency union model, where the IS-curve and CPI Phillips curve for the member economy i, $i = 1, ..., n$ are stated as

$$\begin{aligned} x^i_t &= E_t\{x^i_{t+1}\} - \frac{1}{\sigma_\alpha(1-\alpha)}(r_t - E_t\pi^i_{t+1} - \rho) + \psi_{13}a^i_t - \psi_{14}y^*_{t-1} \\ \pi^i_t &= \beta E_t\{\pi^i_{t+1}\} + (1-\alpha)\lambda\left(\varphi + \sigma_\alpha\right)x^i_t + \alpha(r_{t-1} - \beta r_t - (1-\beta)\rho) + \psi_{24}y^*_{t-1}, \end{aligned} \tag{8}$$

where x^i_t is the output gap, π^i_t is the CPI inflation, and a^i_t is the country-specific technology. Structural parameters can differ across the countries, though for notational simplicity that is not made explicit above. The foreign output and the stochastic process guiding its dynamics is assumed to be the same for all members in the union. Countries also have a common interest rate.

We define the union inflation and output gap as a weighted sum of the country-specific ones.

[7] Both the IS-curve as well as the Phillips curve expressions look more complicated than they would have been had they were written in terms of the domestic good price level inflation. We re-write it in terms of the CPI inflation to make it more comparable to our empirical exercise.

We close the model with a policy interest rate rule that incorporates interest rate smoothing and targets union-wide inflation and output gap.

$$x_t^u = \sum_{i=1}^{n} \omega_i x_t^i \tag{9}$$

$$\pi_t^u = \sum_{i=1}^{n} \lambda_i \pi_t^i \tag{10}$$

$$r_t = \rho + \rho_r r_{t-1} + \phi_\pi \pi_t^u + \phi_x x_t^u \tag{11}$$

For simplicity, we assume there are two countries in the union and that the structural parameters in each country are the same. We can write the system of equations in the following state-space form

$$\begin{pmatrix} E_t x_{t+1}^1 \\ E_t \pi_{t+1}^1 \\ E_t x_{t+1}^2 \\ E_t \pi_{t+1}^2 \\ r_t \end{pmatrix} = A \begin{pmatrix} x_t^1 \\ \pi_t^1 \\ x_t^2 \\ \pi_t^2 \\ r_{t-1} \end{pmatrix} + B \begin{pmatrix} \rho \\ a_t^1 \\ a_t^2 \\ y_{t-1}^* \end{pmatrix}$$

For the stability of the system, it is important to analyze closely the formation of matrix A, which we rewrite below.

$A =$

$$\begin{pmatrix} 1 & \frac{1}{\sigma_\alpha(1-\alpha)} & 0 & 0 & -\frac{1}{\sigma_\alpha(1-\alpha)} \\ 0 & \beta & 0 & 0 & -\alpha\beta \\ 0 & 0 & 1 & \frac{1}{\sigma_\alpha(1-\alpha)} & -\frac{1}{\sigma_\alpha(1-\alpha)} \\ 0 & 0 & 0 & \beta & -\alpha\beta \\ 0 & 0 & 0 & 0 & 1 \end{pmatrix}^{-1} \begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ -\lambda(1-\alpha)(\varphi+\sigma_\alpha) & 1 & 0 & 0 & -\alpha \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & -\lambda(1-\alpha)(\varphi+\sigma_\alpha) & 1 & -\alpha \\ \phi_x\lambda_1 & \phi_\pi\omega_1 & \phi_x\lambda_2 & \phi_\pi\omega_2 & \rho_r \end{pmatrix}$$

4.3 Stability

The rational expectations equilibrium is determinate or dynamically stable if and only if the corresponding matrices A have as many eigenvalues inside the unit circle as there are predetermined endogeneous state variables and as many eigenvalues outside the unit root circle as there are non-predetermined endogeneous state variables. For both the aggregate and currency union models there is one predetermined endogeneous state variable and that's the interest rate (r_t). The aggregate system has 2 non-predetermined endogeneous state variables, i.e. output gap (x_t) and CPI inflation (π_t), while the currency union system has 4, i.e. output gap and CPI inflation for each country.

For the stability of the aggregate economy it is possible to obtain an analytical solution. However, for the stability of the currency union, it is not possible to obtain an analytical solution. For now, we try to obtain a solution for the eigenvalues of both systems numerically. For that, we use certain values of structural parameters as considered in Galí and Monacelli (2005) and in Smets and Wouters (2003). The structural parameters, their values, and sources are provided in the Table 8. In addition, for now we use the parameter values of the estimated benchmark Taylor rule listed in Table 5.

For given parameter values, the eigenvalues of the aggregate model are $2.78, 0.62, 1.12$, which satisfy the stability criteria in that two of them are outside the unit circle and one is inside. In order to evaluate the stability criteria for the currency union model, at this stage we consider a parameterization of the model, where all the structural parameters are the same, but the country-specific weights in the policy rule are different. More specifically, we consider the 2005 weights used for Germany and Belgium in constructing the Euro Area aggregate measures of IPI and HICP. We consider $\lambda_1 = 0.31, \lambda_2 = 0.04, \omega_1 = 0.29, \omega_2 = 0.03$, where the weights indexed by one pertain to Germany and the weights indexed by two pertain to Belgium. The eigenvalues of the currency union model in this case are $1.72, 0.66, 0.85, 1.20, 1.10$, which do not satisfy the stability criteria. For stability it is necessary that four of the eigenvalues are outside the unit root circle. In our case only three of them are.

5 Conclusion

The preliminary results suggest that the Taylor rule in the Euro Area satisfies the stability condition for the aggregate economy. However, for given weights for the member economies, the stability condition of the currency union is not satisfied. The next step is to do the stability analysis in a more systematic way such that it is not evaluated for specific parameter values, but rather as functions of specific parameters. This will enable us to analyze the importance of our estimated disaggregated Taylor rule as well, since it will allow us assess the importance of the alternative price index that ECB appears to target.

Tables and Figures

Table 1: **Variance-Covariance Matrix: Inflation Differences**

	BE	DE	ES	FR	IT	NL
BE	0.44	0.03	-0.01	0.01	-0.08	-0.28
DE	0.03	0.14	-0.09	-0.03	-0.07	-0.10
ES	-0.01	-0.09	0.39	-0.00	-0.04	-0.19
FR	0.01	-0.03	-0.00	0.08	0.02	-0.16
IT	-0.08	-0.07	-0.04	0.02	0.11	0.07
NL	-0.28	-0.10	-0.19	-0.16	0.07	1.42

Table 2: **Correlations: Inflation Differences**

	BE	DE	ES	FR	IT	NL
BE	1.00	0.12	-0.02	0.05	-0.36	-0.35
DE	0.12	1.00	-0.39	-0.32	-0.56	-0.22
ES	-0.02	-0.39	1.00	-0.03	-0.21	-0.25
FR	0.05	-0.32	-0.03	1.00	0.21	-0.46
IT	-0.36	-0.56	-0.21	0.21	1.00	0.18
NL	-0.35	-0.22	-0.25	-0.46	0.18	1.00

Note: Tables (1) and (2) report the variance-covariances and correlations of the country-specific inflation differences calculated as differences between one-year ahead country-specific inflations and Euro Area aggregate inflation. The adjusted sample period is 2000:M2-2009:M12. 'BE', 'DE', 'ES', 'FR', 'IT', and 'NL' stand for Belgium, Germany, Spain, France, Italy, and the Netherlands respectively.

Table 3: **Variance-Covariance Matrix: Output Gap Differences**

	BE	DE	ES	FR	IT	NL
BE	4.54	-0.57	-0.71	0.48	-0.03	0.07
DE	-0.57	1.38	-1.43	-0.62	0.12	-1.28
ES	-0.71	1.43	3.88	0.31	-0.44	0.63
FR	0.48	-0.62	0.31	1.10	-0.38	1.03
IT	-0.03	0.12	-0.44	-0.38	1.01	-0.61
NL	0.07	-1.28	0.63	1.03	-0.61	3.84

Table 4: **Correlations: Output Gap Differences**

	BE	DE	ES	FR	IT	NL
BE	1.00	-0.23	-0.17	0.22	-0.01	0.02
DE	-0.23	1.00	-0.62	-0.50	0.10	-0.56
ES	-0.17	-0.62	1.00	0.15	-0.22	0.16
FR	0.22	-0.50	0.15	1.00	-0.36	0.50
IT	-0.01	0.10	-0.22	-0.36	1.00	-0.31
NL	0.02	-0.56	0.16	0.50	-0.31	1.00

Note: Tables (3) and (4) report the variance-covariances and correlations of the country-specific output gap differences calculated as differences between country-specific and Euro Area output gap. The adjusted sample period is 2000:M2-2009:M12. 'BE', 'DE', 'ES', 'FR', 'IT', and 'NL' stand for Belgium, Germany, Spain, France, Italy, and the Netherlands respectively.

Table 5: **Benchmark Taylor Rule - Estimation Results**

	α	ρ	β	γ
Coefficient	-2.18	0.92	2.42	0.58
(St. Dev)	(0.52)	(0.01)	(0.25)	(0.03)

Note: The results are based on a 2-stage GMM estimation, where the optimal weighting matrix is obtained with Bartlett window $L_{(j,n)} = 1 - j/(l+1)$, where $j = 1, ..., l$ and $l = 12$ is the maximum lag length used in constructing a HAC consistent weighting matrix. The overidentifying restrictions test yields a statistics $J = 9.42$, with a p-value of 1.00.

Table 6: **Alternative Taylor Rule - Estimation Results**

	α	ρ	β	γ
Coefficient	0.24	0.89	1.23	0.52
(St. Dev)	(0.58)	(0.02)	(0.22)	(0.10)

	ω_i	λ_i		ω_i	λ_i
Belgium	0.31	0.13	France	0.00	0.44*
	(0.24)	(0.10)		(0.70)	(0.20)
Germany	0.00	0.14	Italy	0.00	0.03
	(0.75)	(0.32)		(0.60)	(0.24)
Spain	0.00	0.26*	Netherlands	0.48*	0.00
	(0.32)	(0.13)		(0.20)	(0.18)

Note: The results are based on a 2-stage GMM estimation, where the optimal weighting matrix is obtained with Bartlett window $L_{(j,n)} = 1 - j/(l+1)$, where $j = 1, ..., l$ and $l = 12$ is the maximum lag length used in constructing a HAC consistent weighting matrix. The overidentifying restrictions test yields a statistics $J = 9.14$, with a p-value of 1.00. The values in the parentheses are standard deviations. * indicates coefficient significance at 5% level.

Table 7: **Alternative Taylor Rule - Hypothesis Testing**

Hypothesis	Wald-stats	p-value
$\omega_i = 0, \lambda_i = 0, \forall i$	121.07	0
$\omega_i = \lambda_j, \forall i,\ j = i$	13.11	0.04
$\omega_i = 0, \forall i$	30.80	0.00
$\lambda_i = 0, \forall i$	22.01	0.00

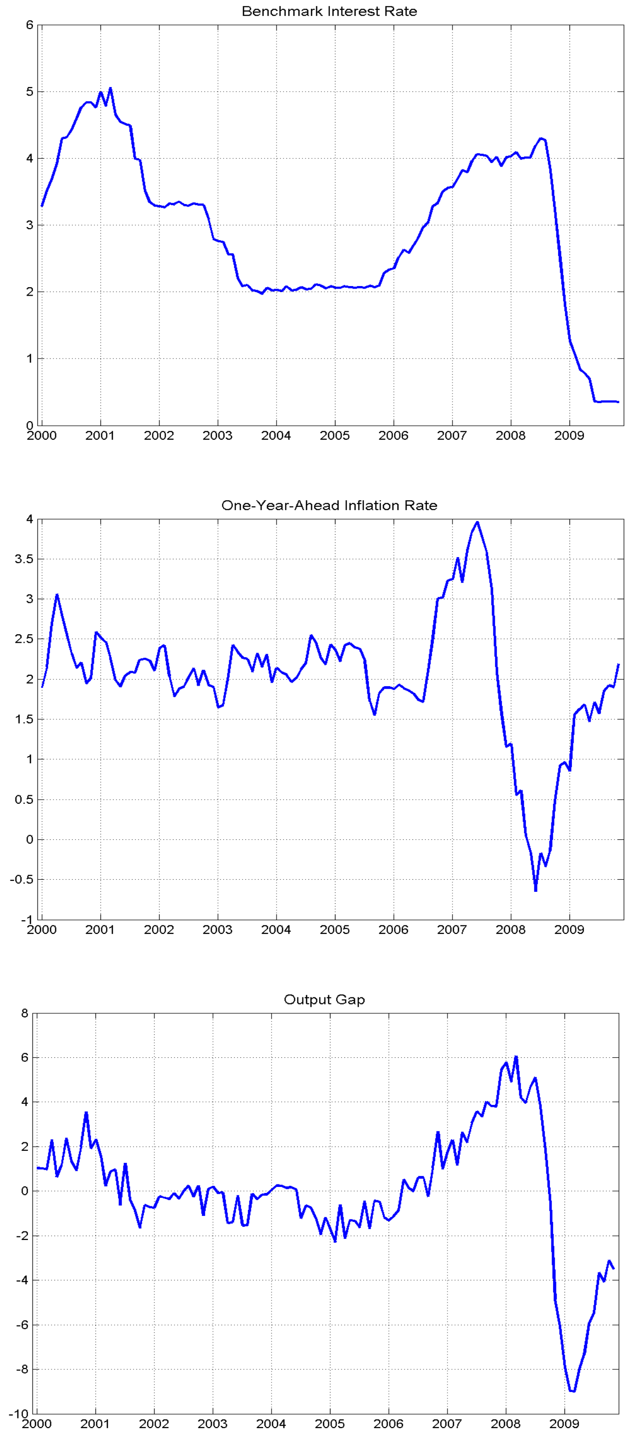
Note: The p-values are calculated based on a χ-squared distribution with 12 and 6 degrees of freedom for the first hypothesis and hypothesis 2-4 respectively.

Table 8: **Structural Parameters**

Parameter	Description	Value	Source
σ	intertemp elasticity of subst.	1.00	Galí and Monacelli (2005)
η	subst. between domestic & foreign goods	1.00	Galí and Monacelli (2005)
γ	subts. between foreign goods of diff origin	1.00	Galí and Monacelli (2005)
φ	employment subsidy	3.00	Galí and Monacelli (2005)
θ	Calvo price	0.92	Smets and Wouters (2003)
β	discount factor	0.99	Galí and Monacelli (2005)
α	share of imported goods	0.40	Galí and Monacelli (2005)
ρ_a	productivity shock	0.82	Smets and Wouters (2003)

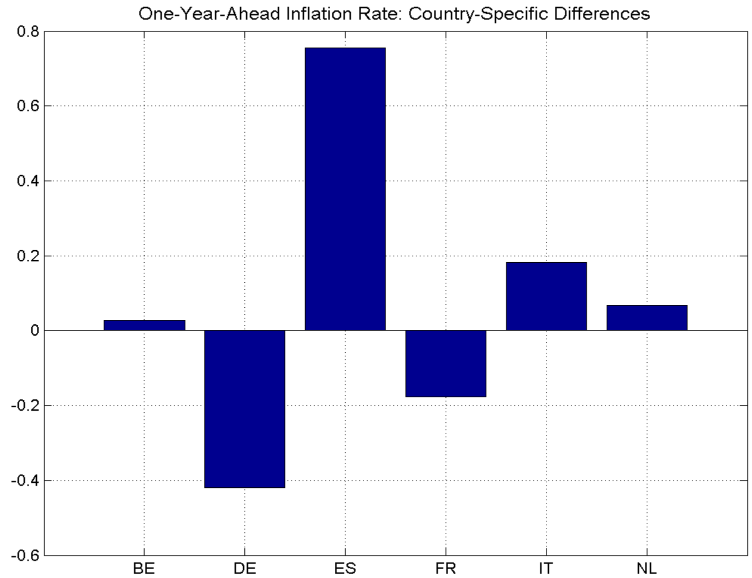
Note: $\varphi = 3$ implies a labor supply elasticity of 1/3. Some other structural parameters used in the analysis are functions of the ones listed above: $\omega = \sigma\gamma + (1-\alpha)(\sigma\eta - 1), \lambda = (1-\beta\theta)(1-\theta)/\theta, \sigma_\alpha = \sigma/(1+\alpha(\omega-1))$.

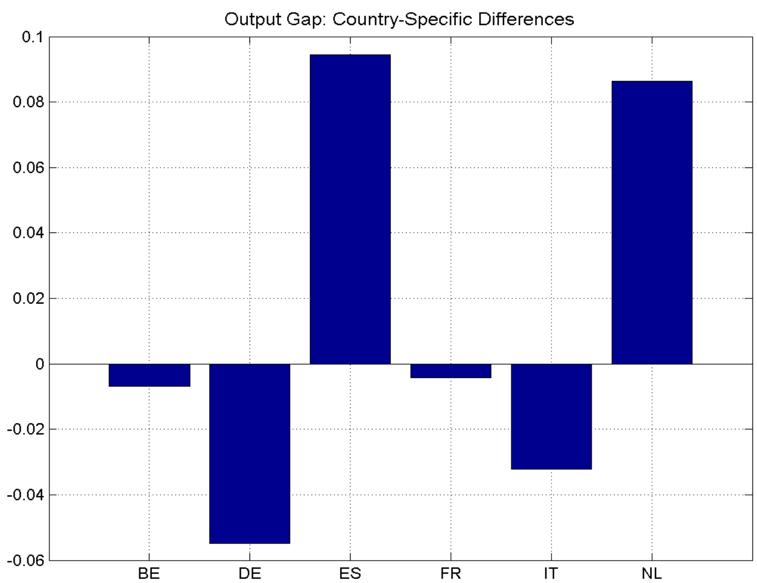
Figure 1: Euro Area Aggregate Variables



Note: The interest rate is the average day-to-day money market interest rate: Euro OverNight Index Average (EONIA); one-year ahead inflation is calculated as a year-over-year growth rate of the Harmonized Consumer Price Index (HCPI), while the output-gap is the HP-filtered Industrial Production Index (IPI). The adjusted sample period is 2000:M2-2009:M12.

Figure 2: Country-Specific Deviations





Note: The country-specific inflation differences are calculated as a difference between one-year ahead country-specific inflations and Euro Area aggregate inflation. The country-specific output gap differences are calculated as annualized differences between country-specific HP-filtered IPI-s and the Euro Area aggregate. The adjusted sample period is 2000:M2-2009:M12. 'BE', 'DE', 'ES', 'FR', 'IT', and 'NL' stand for Belgium, Germany, Spain, France, Italy and the Netherlands respectively.

A Small Open Economy Equilibrium Dynamics

Galí and Monacelli (2005) provide with a benchmark New Keynesian model that introduces the foreign sector into the domestic economy through the aggregate demand. The small open economy IS-curve is different from the closed economy one in that it incorporates the foreign consumption of domestic goods. Consequently, the foreign consumption also effects the marginal cost. The marginal effects of the domestic and foreign consumptions on the marginal cost are guiding through variety of structural parameters such as the substitutability of domestic and foreign goods, terms of trade, etc. The following equations summarize the equilibrium around a zero-inflation steady state in a log-linear form

$$
\begin{aligned}
y_t &= E_t\{y_{t+1}\} - \frac{1}{\sigma}(r_t - E_t\{\pi_{H,\, t+1}\} - \rho) - \frac{\alpha(\omega-1)}{\sigma}E_t\{\Delta s_{t+1}\}. && (12)\\
y_t &= y_t^* + \frac{1+\alpha(\omega-1)}{\sigma}s_t && (13)\\
\pi_{H,\, t} &= \beta E_t\{\pi_{H,\, t+1}\} + \lambda mc_t && (14)\\
mc_t &= -\upsilon + \sigma y_t^* + \varphi y_t + s_t - (1+\varphi)a_t + \mu. && (15)
\end{aligned}
$$

The system above and the variables therein simultaneously determine the state of the economy. y_t denotes output, $\pi_{H,\, t+1}$ denotes the inflation level of domestically produced goods, s_t stands for terms of trade, while mc_t is the real marginal cost. The remaining variables are purely endogeneous: q_t and e_t are the real and nominal exchange rates respectively, π_t is the CPI inflation, while c_t denotes the real consumption. The dynamics are determined via the following equations. However, the one we are particularly concerned with is equation (18), the CPI inflation equation.

$$
\begin{aligned}
q_t &= (1-\alpha)s_t && (16)\\
s_t &= e_t + p_t^* - p_{H,\, t} && (17)\\
\pi_t &= \pi_{H,\, t} + \alpha\Delta s_t && (18)\\
y_t &= c_t + \frac{\alpha\omega}{\sigma}s_t && (19)
\end{aligned}
$$

It is of interest to rewrite the state equations in terms of the CPI inflation instead of domestic price inflation. Thus, our aim is to rewrite equations (12-15) and (18) in terms of y_t and π_t. By plugging in (18) and (13) into (12), we get the following IS-curve relationship

$$
y_t = E_t\{y_{t+1}\} - \frac{1+\alpha(\omega-1)}{\sigma(1-\alpha)}(r_t - E_t\{\pi_{t+1}\} - \rho) + \frac{\alpha\omega}{1-\alpha}E_t\{\Delta y_{t+1}^*\} \qquad (20)
$$

By defining y_t^n as the output level at the flexible price equilibrium, we define the output gap as

$x_t = y_t - y_t^n$, where y_t^n can be found by setting the $mc_t = 0$.[8] The relationship between marginal cost and output gap is defined by

$$mc_t = \left(\varphi + \frac{\sigma}{1+\alpha(\omega-1)}\right) x_t \tag{21}$$

By substituting (18) and (13) in (14), together with (22) we get

$$\pi_t = \beta E_t\{\pi_{t+1}\} + (1-\alpha)\lambda mc_t + \alpha(r_{t-1} - \beta r_t - (1-\beta)\rho) - \alpha\sigma(\Delta y_t^* - \beta E_t\{\Delta y_{t+1}^*\}). \tag{22}$$

Plugging in (21), we get

$$\pi_t = \beta E_t\{\pi_{t+1}\} + (1-\alpha)\lambda\left(\varphi + \sigma_\alpha\right) x_t + \alpha(r_{t-1} - \beta r_t - (1-\beta)\rho) - \alpha\sigma(\Delta y_t^* - \beta E_t\{\Delta y_{t+1}^*\}), \tag{23}$$

where $\sigma_\alpha = \frac{\sigma}{1+\alpha(\omega-1)}$.

We rewrite (22) in terms of output gap in the following form

$$x_t = E_t\{x_{t+1}\} - \frac{1}{\sigma_\alpha(1-\alpha)}(r_t - E_t\pi_{t+1} - \rho) - \frac{1+\varphi}{\varphi+\sigma_\alpha}E_t\{\Delta a_{t+1}\} + \left(\frac{\alpha}{1-\alpha}\right)\frac{\omega\mu+\sigma}{\varphi+\sigma_\alpha}E_t\{\Delta y_{t+1}^*\}. \tag{24}$$

Similar to Galí and Monacelli (2005), we assume autoregressive stochastic processes for the technology, a_t, and world output, y_t^*, with autoregressive coefficients of ρ_a and ρ_{y^*} respectively. We rewrite the small open economy IS-curve and Phillips curve (in terms of CPI inflation). The equations are restated in the paper in the system of equations (8).

$$x_t = E_t\{x_{t+1}\} - \frac{1}{\sigma_\alpha(1-\alpha)}(r_t - E_t\pi_{t+1} - \rho) + \frac{1+\varphi}{\varphi+\sigma_\alpha}(1-\rho_a)a_t - \left(\frac{\alpha}{1-\alpha}\right)\frac{\omega\mu+\sigma}{\varphi+\sigma_\alpha}(1-\rho_{y^*})\rho_{y^*}y_{t-1}^*$$

$$\pi_t = \beta E_t\{\pi_{t+1}\} + (1-\alpha)\lambda\left(\varphi+\sigma_\alpha\right)x_t + \alpha(r_{t-1} - \beta r_t - (1-\beta)\rho) + \alpha\sigma(1-\rho_{y^*})(1-\beta\rho_{y^*})y_{t-1}^*$$

Let $\phi_{13} = \frac{(1+\varphi)}{(\varphi+\sigma_\alpha)}(1-\rho_a)$, $\phi_{14} = \frac{\alpha}{(1-\alpha)}\frac{(\omega\mu+\sigma)}{(\varphi+\sigma_\alpha)}(1-\rho_{y^*})\rho_{y^*}$ and $\phi_{24} = \alpha\sigma(1-\rho_{y^*})(1-\beta\rho_{y^*})$ A more compact form of the equations given this notation is restated in the main text of the paper in the system of equations (8).

[8] The natural level of output, as well as interest rates, are isomorphic to the restatement of the IS-curve and Phillips curve in terms of the CPI inflation.

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