UNIVERSITY OF COPENHAGEN
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Seminar paper

# One Rule to Rule Them All?

An Analysis of the Cross-Country Asymmetric Effects of the ECB's Monetary Policy

Anton Meier Ebsen Jørgensen, Jonas Skov Nielsen, & Sheng Ye Michael Chen

Supervisor: Michael Bergman

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**Abstract**

This paper examines whether a Taylor rule can describe the ECB's interest rate setting and whether a single rule can fit all euro area countries. We estimate backward-looking Taylor rule specifications for the ECB using quarterly data from 1999Q2 to 2024Q1. These include a simple Taylor rule and augmented specifications with financial stability indicators. All specifications are estimated using a two-step Generalized Method of Moments (GMM). Based on the estimated coefficients, we simulate synthetic interest rates for eight euro area countries to assess the cross-country asymmetries. Our findings indicate that the ECB does not consistently follow a Taylor rule, particularly in the post-crisis period, where the Effective Lower Bound leads to a flattening of the ECB's actual interest rate. Crucially, a single interest rate is unlikely to fit all euro area countries.

**Keywords:** Taylor Rule, Synthetic Interest Rates, ECB Monetary Policy, Asymmetries, GMM, Financial Stability.

**JEL classification:** E52, E58, E44, F45

**Contributions**
**Anton Meier Ebsen Jørgensen:** 2.1, 2.3, 2.4,2.5, 3, 5.1, 5.3.2, 5.3.5, 6.2, 6.3, Appendix B
**Jonas Skov Nielsen:** 2.2, 5.2, 5.3.1, 5.3.3, 5.3.4, 5.5.1, 5.5.2, 5.5.3, 7.2.3, 7.2.4, A.1, A.2
**Sheng Ye Michael Chen:** 2.6, 4.1, 5.4.1, 5.4.2, 5.4.3, 7.1.1, A.3, Appendix C,
**All:** Abstract, 1, 8

# Contents

# 1 Introduction

With the introduction of the euro, the European Central Bank (ECB) assumed control over national independent monetary policy authorities, which now apply a single rule across economies that differ in structure and economic and financial conditions. The primary issue is whether this ”one rule to rule them all” can be optimal for every member state or whether a single rule inevitably breeds policy misalignment within the euro area. This particular issue is now more relevant than ever, especially following the Global Financial Crisis and the European sovereign debt crisis, during which the ECB began to focus more on financial stability. Moreover, the ECB's interest rate was recently trapped in the Effective Lower Bound (ELB) and resorted to unconventional monetary policy.

Several papers have examined whether a Taylor-type rule can capture the ECB's interest rate-setting behavior, though their conclusions vary. For the pre-crisis period, Belke and Polleit (2007), Belke and Klose (2010), and Rühl (2015) find that the ECB placed more weight on the output gap, whereas Papadamou et al. (2018) find that the ECB prioritized inflation. For the crisis period, existing papers suggest a shift back to inflation targeting. Belke and Klose (2010) find that the ECB shifted back to its mandate of fighting inflation at the cost of output stabilization, which the findings of Papadamou et al. (2018) support.

This paper examines whether Taylor rules can accurately describe the ECB's interest rate setting and whether a single Taylor rule can fit all the individual euro area economies. First, we estimate a Taylor rule for the ECB using quarterly data from 1999Q2 to 2024Q1. We test whether a simple backward-looking Taylor rule, which links the short-term interest rate to inflation and the output gap, captures the interest rate setting of the ECB. Second, we augment this Taylor rule with financial stability indicators, including money supply growth (M3), the house price index, stock prices, exchange rates, and interest rate spreads. This approach is motivated by empirical findings that financial stability has become part of the reaction function for the ECB (e.g.,Belke and Klose (2010); Papadamou et al. (2018)). Finally, we examine whether the ECB's interest rate follows a consistent pattern and whether the same rule applies to different economic conditions by estimating the Taylor rule for three sub periods: the pre-crisis period (1999Q2–2007Q2), the crisis period (2008Q3–2015Q1), and the post-crisis period (2015Q2–2020Q1).

Previous papers emphasize the challenges of implementing a single monetary policy rule in the euro area. Papadamou et al. (2018) simulate synthetic interest rates in the crisis period and find that ECB's monetary policy was too tight for peripheral countries like Ireland and Greece and too loose for the core countries like the Netherlands and Germany. Similarly, Moons and Van Poeck (2008) define a Mean Interest Rate Gap ($\text{MIG}_i$), which is the average difference between the ECB's actual interest rate and the country-specific synthetic rates. They show that under a theoretically calibrated Taylor rule, the ECB's monetary policy was too tight for the core countries and too loose for the peripheral countries in the period 1999Q1-2003Q4.

We estimate all Taylor rule specifications using a two-step Generalized Method of Moments (GMM), thereby mitigating endogeneity problems. Using the estimated coefficients, we construct synthetic interest rates for eight euro area economies, chosen based on their core-periphery classification, as commonly done in the literature (e.g., (Nechio, 2011)). Synthetic interest rates represent the counterfactual interest rates that illustrate what national monetary policy rules would be if countries adhered to the ECB's estimated Taylor rules. We assess the asymmetries between the countries visually and via the $\text{MIG}_i$.

Our findings indicate that the ECB's interest rate does not consistently follow a Taylor rule across the whole sample and sub-periods. We find violations of the Taylor principle, as the inflation coefficient remains below unity, and the output gap has a counterintuitive sign. The simulations show that the model fit varies across sub-periods and Taylor rule specifications. The simple Taylor rule and the augmented Taylor rule specifications, which incorporate the money supply, stock price index, and exchange rate, perform best. However, almost no Taylor rule specification captures the ELB in the post-crisis period.

A common Taylor-type rule might lead to asymmetries within the euro area. Through the simulations and the $\text{MIG}_i$, we observe that the ECB's interest rate may have been too loose or too tight for specific euro area countries. The asymmetries are most considerable for the periphery countries, especially Ireland. This conclusion is robust across Taylor rule specifications, though the estimated Taylor rules for the ECB are not robust across alternative specifications. We conclude that it is unlikely that a single rule can apply to all euro area countries.

We organize the remainder of the paper as follows: section 2 provides the macroeconomic background. section 3 describes the data used to answer the research question. section 4 outlines the two-step GMM approach. section 5 presents the estimated Taylor rule specifications, simulations of synthetic interest rates, and mean interest rate gaps. section 6 discusses the robustness of our empirical results. section 7 compares the results across models, relates them to the literature, and criticizes the approach. Finally, section 8 concludes.

# 2 Macroeconomic background

In this section, we provide a brief account of the relevant theoretical and empirical background for our analysis of the asymmetric effects of the ECB's monetary policy. In this way, the ECB should follow a policy rule, such as the Taylor rule, to some extent. At last, we motivate and justify the inclusion of financial stability indicator variables in an augmented Taylor rule.

## 2.1 The ECB's monetary policy

The ECB conducts a single monetary policy for all 20 euro area member states, as these countries share the euro as their currency. In other words, the ECB sets the same interest rate for countries that differ in country-specific inflation rates and output gaps. In periods where these macroeconomic variables diverge across the euro area member states, this can result in challenges for the ECB.

One of these challenges is the asymmetries that can arise between countries. A single interest rate can be suboptimal for the individual member states if the country-specific inflation and output gaps differ significantly between countries.

Here, the country-specific central bank or monetary authority may have set a different interest rate than the ECB.

The literature categorizes countries into core and peripheral countries based on their economic differences (Nechio, 2011). Core countries, including Austria, Belgium, France, Germany, and the Netherlands, are characterized by lower inflation and stable GDP growth. In contrast, peripheral countries, including Ireland, Italy, and Spain, have higher inflation and more volatile GDP growth (Papadamou et al., 2018).

Investigating the asymmetries is important, as persistent asymmetries may lead to dissatisfaction among member countries and potentially result in exits from the Economic and Monetary Union (EMU).

## 2.2 Policy rules

In this section, we explain why the ECB is likely to follow a simple policy rule to some extent, based on the arguments presented by Lønning and Olsen (2000) in their paper.

There has been a debate in the monetary policy literature regarding the merits of rules versus discretion. One of the main arguments in favor of policy rules stems from the problem of time inconsistency (Barro and Gordon, 1983). According to this argument, if the ECB commits to a policy rule, it can enhance both transparency and credibility in the implementation of monetary policy.

Lønning and Olsen (2000) further argues in favor of using simple rules for interest rate setting. Simple rules perform surprisingly well when measured in terms of stabilizing inflation and output. They argue that while a rule may be optimal for a specific model, its performance can deteriorate when applied to alternative models. This argument suggests that simple rules are more robust across different model specifications than highly tailored optimal rules. As such, using a complex optimal rule from a model that does not accurately reflect the structures of the real economy would result in a suboptimal monetary policy.

Given the ECB's mandate to ensure price stability through low and stable inflation, simple policy rules might be more suitable. In a currency union like the Euro area, where inflation targeting is very important, the robustness and transparency of simple rules offer clear advantages.

## 2.3 The Taylor rule revisited

The most commonly used policy rule in macroeconomic theory and empirical papers is the Taylor rule, which Taylor (1993) proposed as a benchmark for central banks when conducting monetary policy.

$$i_t = r^* + \phi_\pi \left(\pi_t - \pi^*\right) + \phi_y \left(y_t - y^*\right) \tag{2.1}$$

The Taylor rule prescribes that the central bank, here, the ECB, sets its nominal interest rate based on the deviation of inflation from the target $(\pi_t - \pi^*)$ and on the output gap, $(y_t - y^*)$; thus, the ECB stabilizes inflation and supports the output. The coefficients for inflation $(c_\pi)$ and output gap $(C_y)$ are assumed to be positive in theoretical models such as the New Keynesian model.

In these models, a requirement is that the central bank responds more than one-to-one to inflation. This requirement is known as the Taylor principle. The central bank ensures stability in the model by raising the real interest rates when inflation rises, thereby reducing the inflationary pressures. Clarida et al. (2000) emphasize that it is necessary to satisfy the Taylor principle to avoid indeterminacy in the model's equilibrium. There is also empirical support for the Taylor principle in the case of the ECB. For example, Papadamou et al. (2018) find that the ECB responded to inflation with a coefficient greater than one, both before and during the crisis period.

Taylor (1993) proposes to set the nautral rate, $r^*$, constant to 2 percent. However, research indicates that the neutral rate differs over time and across countries (Holston et al., 2017).

## 2.4 Simulation of a theoretical Taylor rule for the euro area

A common approach in the literature is to simulate a simple Taylor rule, such as Equation 2.1, using theoretically calibrated coefficients (e.g., (Moons and Van Poeck, 2008), (Nechio, 2011)). Nechio (2011), for example, assumes $r^* = 1$, $\phi_\pi = 1.5$, and $\phi_y = 1$ for the euro area. Under these assumptions, the Taylor rule becomes:

$$i_t = 1 + 1.5(\pi_t - \pi^*) + y_t - y^* \tag{2.2}$$

We simulate the implied interest rate from this rule in Figure 2.1, alongside the Euribor, which is an interbank interest rate in the euro area (see).

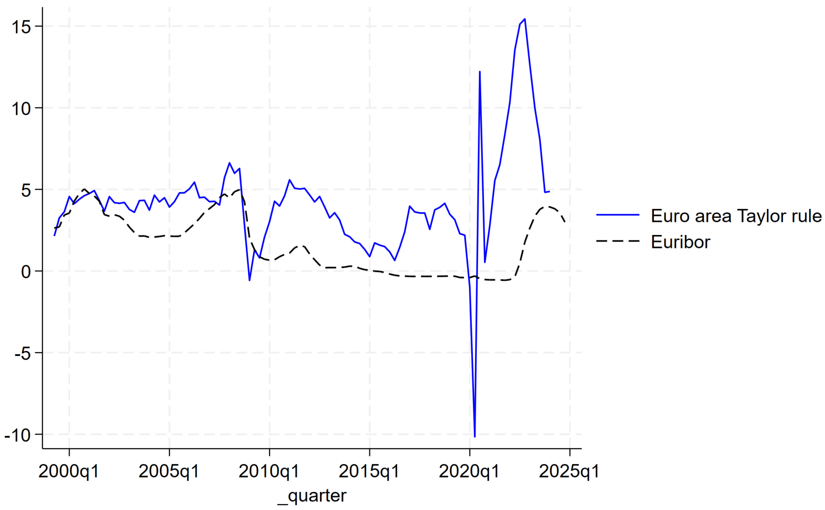



Figure 2.1: Theoretical Taylor rule simulation for the euro area

As shown in Figure 2.1, the theoretical Taylor rule tracks Euribor closely in the pre-crisis period. However, it diverges notably during the European sovereign debt crisis, the Effective Lower Bound (ELB) period, the COVID-19 pandemic, and the onset of the Russian invasion of Ukraine. During these periods, the simple rule is too aggressive, prescribing interest rates that are unrealistically high or low.

This simulation suggests that the ECB does not strictly follow a Taylor rule with theoretical coefficients. To obtain a more realistic view of country-specific interest rates and thereby better assess asymmetries, we estimate the Taylor rule for the ECB. Moreover, it also motivates augmenting the simple specification with financial stability indicators to improve the model fit of Euribor.

## 2.5 Motivation for an augmented Taylor rule

Taylor (1993) notes that central banks may deviate from the simple Taylor rule to account for special circumstances. An example is the Global Financial Crisis and the European sovereign debt crisis, where financial stability became a central concern for the ECB (Papadamou et al., 2018). This new priority reflects the fact that financial instability can significantly affect the real economy due to interconnected markets and contagion effects, where financial stress in one institution or market spreads to others (Crockett, 1997).

These developments have led to a broader recognition that monetary policy should consider financial stability alongside price and output stability. This new priority again motivates the use of augmented Taylor rules that include financial stability indicators. For instance, Papadamou et al. (2018) extend the standard rule by including:

$$X_t = \begin{bmatrix} \text{Money supply (M3)} \\ \text{House price index (HPI)} \\ \text{Stock price index} \\ \text{EUR/USD exchange rate} \\ \text{Interest rate spread} \end{bmatrix} \tag{2.3}$$

These variables may influence the ECB's interest rate setting but are absent in the simple Taylor rule in Equation 2.1. We outline the expected signs of the coefficients in subsection 2.6.

Our motivation for estimating augmented Taylor rules is twofold: (i) to assess whether financial indicators help better explain the ECB's interest rate setting, and (ii) to examine how their inclusion affects asymmetries across the euro area countries.

## 2.6 Justification for the financial stability indicators

We now argue for the relevance of the financial stability indicators in Equation 2.3. In the literature, it is common to include the money supply when assessing the ECB's monetary policy, as its primary objective is price stability. The ECB bases its monetary policy strategy on two pillars: (i) Monetary analysis has money as a key framework. The decisions reflect the view that changes in money primarily cause inflation in the medium to long term. The ECB monitors the broad monetary aggregate M3 as a key indicator within its monetary analysis, although it no longer maintains a formal reference value. (ii) Economic analysis focuses on the economic situation, which the ECB assesses using a broad range of economic and financial indicators to evaluate risks to price stability.

Papadamou et al. (2018) use the output gap to reflect the economy's behavior. Similarly, Gerlach and Svensson (2003) finds that the real money gap can be a predictor of future inflation. An increase in nominal M3 will ceteris paribus increase the real money gap, which will predict higher inflation rates in the future. They also find that growth in nominal M3 is a proxy for the real money gap. Therefore, we expect a positive coefficient on M3 in our estimation, reflecting the relationship between increased money supply growth and higher inflation rates, as well as vice versa.

Including asset prices, such as stock prices and house price indices, in the standard Taylor rule can be justified through the equity price channel described by Mishkin (1996). He argues that stock and housing prices can affect household wealth, thereby influencing consumption choices. An increase in asset prices raises perceived wealth, prompting households to increase their consumption. This rise in consumption increases aggregate demand, which can stimulate economic activity and contribute to higher inflation. Therefore, we expect the coefficients for the stock price index and house price index to be positive, as central banks may consider asset prices when setting interest rates to counter rising inflation.

The exchange rate is relevant for small open economies, and many euro area members fall into this category. For example, Norges Bank includes the exchange rate in its policy rule. As argued by Lønning and Olsen (2000), the exchange rate affects both inflation and output through two channels. First is the direct exchange rate channel, in which the depreciation of the euro increases import prices in domestic currency. Since import prices are a component of the Consumer Price Index (CPI), this leads to higher inflation. Second, the indirect exchange rate channel influences demand through changes in the relative price of domestic goods compared to foreign goods, thereby indirectly affecting inflation (Leitemo and Söderström, 2005). Therefore, when estimating the Taylor rule with the euro/dollar exchange rate, we expect a positive coefficient.

The final variable that might influence the ECB's decisions is the interest rate spread, which Papadamou et al. (2018) and Belke and Klose (2010) use to capture increased risk in capital markets. We expect central banks to lower their interest rates in response to a rise in the interest rate spread (Tucker, 2009). As a result, we expect the coefficient for the interest rate spread to be negative.

# 3 Description of Data

This section outlines the data we use in our analysis. We include a detailed sources and definitions of the data in Appendix A. We have followed Papadamou et al. (2018) as closely as possible when collecting the data. All data used in this paper cover the period from 1999Q2 to 2024Q1.

We analyze eight euro area countries (see Table A.1), which we select to reflect the core-periphery grouping used in the literature (e.g., Nechio (2011)) and data availability for all variables.

Real GDP data are from Eurostat and measured in chain-linked volumes with 2015 as the base year (index = 100). We use real GDP instead of nominal GDP because we already account for inflation as a separate variable in the Taylor rule. This approach avoids double-counting the inflation effects.

We collect inflation data from the OECD, which is measured quarterly and annualized as CPI growth. We use CPI for the euro area. Contrary to Papadamou et al. (2018), we also use the CPI for individual euro area countries due to limited data availability. While this introduces some inconsistency across the national consumption baskets, the results should be comparable.

To calculate the output gap, we apply the HP filter ($\lambda = 1600$) to real GDP growth. We then define the output gap as the difference between actual GDP growth and its trend.

For the interest rate, we use the 3-month Euribor as a proxy for ECB monetary policy. The Euribor reflects the short-term lending rates between banks and is influenced by both the ECB's monetary policy and the conditions in the financial markets, making it a relevant indicator to analyze during crisis periods.

We chose Euribor over the ECB's Main Refinancing Operations (MRO) rate, since Euribor is a market rate and therefore captures financial stability more directly. This makes it more suitable for our augmented Taylor rule with financial stability indicators. Sturm and Wollmershäuser (2008) find that Taylor rule estimations using Euribor or MRO yield similar results.

Our financial stability indicators include M3 money supply, house price index (HPI), EUR/USD exchange rate, stock price index, and interest rate spreads. We report data sources in Table A.2.

For these euro area aggregate variables: CPI, GDP, M3, and HPI, we use the EA20 aggregation (and changing composition for Euribor and interest rate spread), which includes all 20 current member states. We note that this creates a limitation early in the sample period since the euro area had fewer member states at the time. This assumption introduces a bias in the estimated ECB Taylor rule, but it still enables us to evaluate how well a common rule fit the euro area countries. The purpose of this paper is not to measure the exact policy misalignment but to assess asymmetries.

All data are seasonally adjusted to remove noise and reflect underlying macroeconomic trends, consistent with how central banks assess the economy.

# 4 Econometric model

## 4.1 Generalized Method of Moments

We estimate the Taylor rule using the Generalized Method of Moments (GMM), as specified by the following equation:

$$i_t = C_0 + C_\pi \pi_t + C_y(y_t - y^*) + C_x X_t + \varepsilon_t \tag{4.1}$$

Where $C_0$ is a constant. $i_t$ is the three-month Euribor in percentage at time $t$, $\pi_t$ is the inflation. We omit the inflation target from our equation and let it become absorbed into the estimated constant in the GMM estimation. $y_t - y^*$ is the output gap, and $X_t$ is a vector for the additional variables used to test for financial stability in the Euro Area, such as money supply (ms), House Price Index (hpi), stock price index (stocks), EUR/USD exchange rate (fx) and the interest rate spread (is). Lastly, we have the error term $\varepsilon_t$.

Following Holston et al. (2017) who argue that the natural interest rate varies over time, we do not impose a specific value on the natural interest rate. Instead, we absorb the natural interest rate into the estimated constant in the GMM estimation by omitting it from the estimation. As a result, we remove the bias that would occur if the natural rate were to change.

Papers have widely employed GMM to estimate the Taylor Rule, making it an appropriate method for this paper, as seen in Belke and Polleit (2007), Belke and Klose (2010), Rühl (2015), and Papadamou et al. (2018). In the context of Taylor Rule estimation, Ordinary Least Squares (OLS) are generally inconsistent and biased due to endogeneity between the nominal interest rate and the explanatory variables. Specifically, inflation, the output gap, and financial stability indicators may be endogenous, as the Euribor rate is determined simultaneously with these variables.

Furthermore, it is questionable whether the central bank observes the contemporaneous values of these variables when setting interest rates (Gerdesmeier and Roffia, 2003). GMM addresses this problem by assuming that the central bank makes decisions based on information from earlier periods. Therefore, we use lagged values of the explanatory variables as instruments (Belke and Polleit, 2007). We assume that these lagged variables correlate with the regressors but remain uncorrelated with the error term, $\varepsilon_t$. As a result, we estimate a backward-looking Taylor rule instead of a forward-looking Taylor rule.

In the GMM approach, we set up some moment conditions that must hold for the GMM estimator Hansen (1982):

$$\mathbb{E}\left[z_t \cdot \varepsilon_t\right] = 0 \tag{4.2}$$

Where our instruments are:

$$z_t = \begin{bmatrix} \pi_t \\ y_t \\ X_t \end{bmatrix} \tag{4.3}$$

In other words, Equation 4.2 shows that the instruments must be uncorrelated with the error term.

Papers recommend including up to twelve lags for monthly data and up to four for quarterly data (Rühl, 2015). This is consistent with the empirical approach by Gerdesmeier and Roffia (2003), Belke and Polleit (2007), Belke and Klose (2010), and Papadamou et al. (2018).

Our data uses quarterly data, so we use a maximum of 4 lags. We apply the same number of lags to inflation, the output gap, and the financial stability variable whenever we include them as instruments in the GMM estimation.

We also perform the Hansen J-test to examine the validity of the over-identifying restrictions and to assess whether our instruments are appropriate. A GMM model is over-identified when there are more instruments than estimated coefficients. Failure to reject the null hypothesis indicates that we cannot reject the validity of the instruments.

We use a two-step GMM estimator. In the first step, we estimate the model using a weighting matrix that assumes homoskedasticity. In the second step, we re-estimate the coefficients using an updated weighting matrix based on the residuals from the first stage. Consistent with the literature (e.g., Belke and Klose (2010), Rühl (2015) and Papadamou et al. (2018)), we apply a heteroskedasticity- and autocorrelation-consistent (HAC) covariance matrix with a Bartlett kernel, as proposed by Newey and West (1986), to obtain robust standard errors.

# 5 Empirical Results

This section presents the empirical results. We estimate ECB Taylor rule specifications, simulate synthetic interest rates, and calculate mean interest rate gaps to assess if one rule can rule them all.

## 5.1 Model specification

To determine the optimal lag length for the instruments, we estimate the model using two to four lags. With one lag, all estimated coefficients in the Taylor rule became insignificant. When we include two lags, the Hansen J-test rejects the null hypothesis of instrument invalidity, indicating a valid instrument set. With three and four lags, the Hansen J-test p-values become too large. Based on this, we select two lags for all variables as instruments in all the estimations of the ECB Taylor rule.

This specification also aligns with Papadamou et al. (2018), who use six lags in monthly data (equivalent to two quarters).

We test for stationarity using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. As shown in Table B.1, the output gap and money supply are stationary, while inflation is borderline stationary. The other financial stability indicators, as well as Euribor, show evidence of non-stationarity.

Despite this, we estimate the Taylor rule specifications in levels to remain consistent with the existing literature (e.g., Papadamou et al. (2018)). Furthermore, Johansen cointegration tests (see subsection B.4) indicate the presence of cointegration, suggesting that estimation in levels is appropriate even though some variables are non-stationarity.

## 5.2 Estimation results for the whole period

This subsection presents the results from our two-step GMM estimation of the Taylor rule specifications for the ECB over the whole period, 1999Q2 to 2024Q1. We do this based on Equation 4.1, and the estimated coefficients are reported in

Table 5.1. We use several programming and AI tools to estimate the empirical results (see subsection B.2 and subsection B.1).

Model (1.1) represents the simple Taylor rule specification, which includes only inflation and the output gap. Model (1.2) through (1.5) represents the Taylor rule specifications augmented with different financial stability indicators: (1.2) money supply, (1.3) HPI, (1.4) stock price index, (1.5) the exchange rate, and (1.6) interest rate spread.

The inflation coefficient is significant across all models; we observe this in Table 5.1. This finding lends some credence to the ECB's statement and communication, as highlighted in ECB (2022), that its primary goal is to create price stability and that its primary tool in this endeavor is inflation targeting. The estimated inflation coefficients range from 0.166 in the model (1.6) to 0.482 in the model (1.3). Hence, the Taylor principle does not hold as the inflation coefficient across all models is $0 \leq C_\pi \leq 1$. This result suggests that the ECB follows a destabilizing rule, where the real interest rate will not rise sufficiently to counteract high inflationary pressures. However, labeling the ECB's policy as destabilizing is not entirely accurate, as inflation in the euro area has remained under control since the introduction of the euro. A possible reason for these counterintuitive results is discussed later in this section. We discuss the limitations of using the CPI as a measure of inflation in section 7.

All models produce significant output gap coefficients; we observe this in Table 5.1. The size of these coefficients ranges between $-0.374$ in the model (1.2) to $-0.117$ in the model (1.4). The negative sign of these coefficients is counterintuitive, as we expect them to be positive. A negative coefficient implies that the ECB lowers interest rates as the output gap increases — i.e., when the economy is expanding — and raises interest rates when the output gap is falling, suggesting pro-cyclical rather than counter-cyclical monetary policy. This result contradicts our expectations, as we anticipate the ECB to employ counter-cyclical monetary policy to mitigate the impact of business cycles on the real economy. The fact that the absolute values of the output-gap coefficients and inflation coefficients are relatively close in size suggests that the ECB reacts to changes in output and inflation with similar intensity. This finding contrasts with their statement and communication that their primary objective is price stability through the use of inflation targeting ECB (2022).

Only money supply, among the financial stability indicators, has an estimated coefficient with the expected sign. We expect a positive sign, as an increase in money supply causes an increase in the real money gap, which then predicts higher inflation in the future. This expectation means that as the money supply increases, there will be an expectation of higher inflation in the future. Given the anticipation of inflationary pressure, we expect the ECB to increase its interest rate in response.

We expect coefficients for HPI and the stock price index to be positive. However, our estimations yield negative signs for these coefficients. This finding creates the counterintuitive implication that as asset prices increase, leading to increased household wealth, consumption, and demand, which in turn can lead to higher inflation, the ECB will respond by decreasing the interest rate.

We anticipate a negative sign on the coefficient for interest rate spread, as a widening spread typically signals tightening financial conditions and lower inflationary pressure. Instead, our estimations yield a positive estimated coefficient for interest rate.

A possible explanation for these counterintuitive results is that our Taylor rule specifications do not account for the Euribor hitting the effective lower bound (ELB) in the post-crisis period. This ELB constraint means that as our chosen variables fluctuate in the post-crisis period, the interest rate does not change significantly, as it is constrained by the ELB, thereby contributing to our counterintuitive results. Another thing our Taylor rule does not account for is the Quantitive Easing (QE) used by the ECB in the post-crisis period as an unconventional monetary policy tool.

The only financial stability indicator with an insignificant coefficient is the exchange rate in the model (1.5). A potential reason for this is the use of the Consumer Price Index (CPI) as our measure of inflation. Since CPI includes price changes from imported goods, which are affected by exchange rate fluctuations. As a result, the CPI may already indirectly account for the exchange rate channel.

The main reason for the small coefficient for the stock price indices is the larger magnitude of fluctuations in the stock price index compared to the other explanatory variables. To prevent these significant changes from disproportionately influencing the interest rate, the coefficient for the stock price index must be necessarily smaller.

We also attempted to estimate a Taylor rule that includes all financial stability indicators simultaneously. However, we chose not to include this specification in our paper, as it did not yield satisfactory results in the Hansen J-test.

| | (1.1) | (1.2) | (1.3) | (1.4) | (1.5) | (1.6) |
|---|---|---|---|---|---|---|
| $C_\pi$ | 0.329** | 0.313*** | 0.482*** | 0.389*** | 0.270*** | 0.166*** |
| | (0.139) | (0.0694) | (0.0457) | (0.103) | (0.0840) | (0.0563) |
| $C_y$ | -0.310*** | -0.374*** | -0.219*** | -0.276*** | -0.117** | -0.366*** |
| | (0.0997) | (0.135) | (0.0581) | (0.0804) | (0.0584) | (0.0986) |
| $C_{\text{M3}}$ | | 0.720*** | | | | |
| | | (0.109) | | | | |
| $C_{\text{HPI}}$ | | | -0.102*** | | | |
| | | | (0.0111) | | | |
| $C_{\text{stocks}}$ | | | | -0.0000222*** | | |
| | | | | (0.00000598) | | |
| $C_{\text{fx}}$ | | | | | -1.469 | |
| | | | | | (1.883) | |
| $C_{\text{is}}$ | | | | | | 0.346*** |
| | | | | | | (0.0374) |
| Obs | 98 | 98 | 98 | 98 | 98 | 98 |
| Hansen-J (p-val) | 0.60 | 0.65 | 0.68 | 0.71 | 0.66 | 0.64 |

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.010$

Table 5.1: GMM estimation of the Taylor rule for the ECB during the whole period (quarterly data, 1999Q2–2024Q1)

## 5.3 Simulations

In the following subsections, we simulate synthetic interest rates based on the Taylor rule estimated for the euro area in subsection 5.2. We do this to answer the primary purpose of this paper: If one rule can fit all countries.

### 5.3.1 How the synthetic interest rats are simulated

The analysis has two main objectives: (1) to assess how well the estimated Taylor rule specifications capture the ECB's interest rate setting, and (2) to explore how individual euro area countries would have set their interest rates if they had followed the exact Taylor rule specifications. These counterfactual simulations enable us to analyze potential asymmetries within the euro area visually.

To simulate the synthetic interest rates, we apply the following specifications from Equation 4.1:

$$i_t = C_0 + C_\pi \pi_t + C_y (y_t - y^*) + C_x X_t \tag{5.1}$$

Here, $C_0$ is a constant capturing both the inflation target ($\pi^*$) and the natural interest rate ($r^*$), in line with evidence that $r^*$ varies across countries and over time (Holston et al., 2017). Following the literature (e.g., Papadamou et al. (2018); Nechio (2011)), we use the estimated coefficients from Table 5.1 to simulate the implied interest rates using quarterly data on inflation, the output gap, and financial stability indicators for the euro area and each country.

While it would be ideal to construct confidence intervals around the synthetic interest rates, this paper aims to simulate a counterfactual scenario: what national interest rates might have been under the estimated ECB's Taylor rule. As such, the results are illustrative of this point. This approach is consistent with the purpose of Taylor rules in the literature as a policy benchmark rather than a causal relationship (Sturm and Wollmershäuser, 2008).

### 5.3.2 Simulation of Taylor rule-implied euro area interest rate

Following the approach of Nechio (2011), we first simulate the Taylor rule-implied interest rate for the ECB to assess the validity of our estimated Taylor rule. We do this because we want to check if the estimated Taylor rule is close to Euribor. Here, we use the estimated coefficients from subsection 5.2.

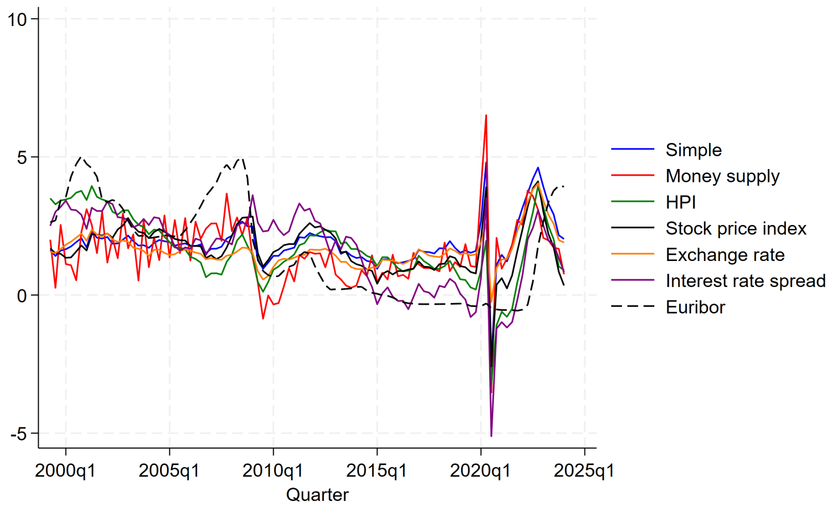



Figure 5.1: Simulation of Taylor rule-implied interest rate for the ECB

Over the sample, all of the Taylor rule specifications track Euribor and are closer than the theoretically calibrated one analyzed in Figure 2.1. However, even though they are closer, they still fail to capture the ELB constraint.

We have now estimated the ECB Taylor rule specifications and verified that they provide a good fit for Euribor. Therefore, it is reasonable to simulate the synthetic interest rates to analyze if a single rule can fit all euro area countries.

### 5.3.3 Simulation of synthetic interest rates

We present the simulations of synthetic interest rates for the euro area countries over the period 1999Q2-2024Q1 in Figure 5.2.

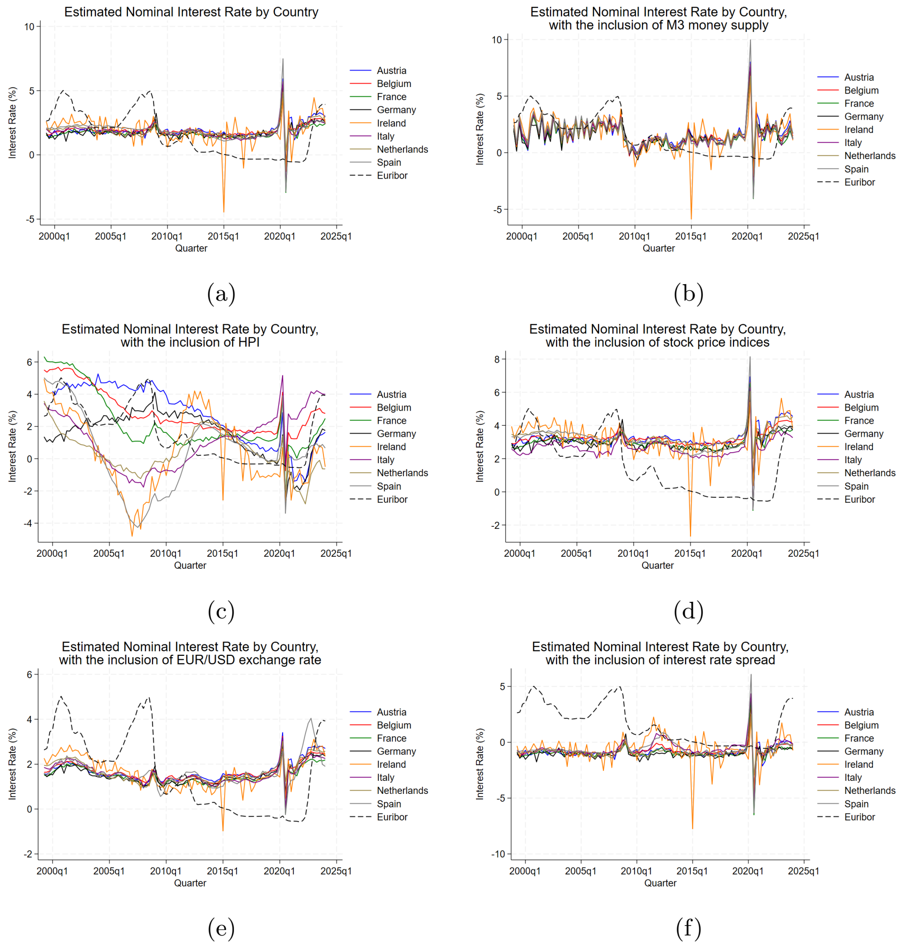



Figure 5.2: Estimated nominel interest rate for certain euro area countries - using different measures of financiel stability.

We base the simulated synthetic interest rates on the exact Taylor rule specifications estimated in subsection 5.2. We also include Euribor as a proxy for the ECB in Figure 5.2 to compare the synthetic interest rates with the ECB's interest rate.

Figures 5.2a, 5.2b, 5.2d and 5.2e show that the synthetic interest rates created by models (1.1)-(1.2) and models (1.4)-(1.5) follow Euribor the best among our models. This result suggests that the simple Taylor rule specification and the Taylor rule specifications with money supply, stock price indices, and exchange rates create synthetic interest rates that are closest to Euribor. However, significant deviations occur in the post-crisis period, where these models create synthetic interest rates that differ markedly from Euribor.

In contrast, Figure 5.2c, indicates that the Taylor rule specification with HPI creates wildly varying synthetic interest rates across countries before the Global Financial Crisis. Following the Global Financial Crisis and the European sovereign debt crisis, synthetic interest rates began to converge, following a more unified trend. This development could indicate that the housing market is susceptible to interest rate changes; as such, the interest rate hitting the Effective Lower Bound (ELB) could lead to less volatility in the housing market. It could also be a sign of the housing markets across countries becoming more regulated after the Global Financial Crisis, therefore creating less volatility. It could also perhaps suggest a convergence in housing market dynamics across euro area countries — although we have no empirical evidence to substantiate these interpretations.

From Figure 5.2f, we observe that the augmented Taylor rule specification with the interest rate spread consistently creates synthetic interest rates that are near the ELB. This observation holds for the entire period, 1999Q2-2024Q1, which is counterintuitive, as it would render the monetary policy authorities unable to effectively use interest rate setting as a means to conduct monetary policy. However, this also means that this Taylor rule specification creates synthetic interest rates that are very close to the Euribor in the period 2015-2020. This finding contrasts with the other Taylor rule specifications used in this paper.

In general, the synthetic interest rates for peripheral countries, especially Ireland, are the most volatile across all our Taylor rule specifications.

#### 5.3.4 ECB's monetary policy and the Effective Lower Bound

As shown in the earlier simulations, Euribor was close to zero during the post-crisis period and before the onset of the COVID-19 pandemic, indicating that the ECB had reached the effective lower bound (ELB). At this point, the ECB could no longer reduce the interest rates further to stimulate the economy, limiting the effectiveness of conventional monetary policy tools, given the assumption that interest rates cannot become too negative.

Compared to the relatively stable Euribor, the simulated synthetic interest rates exhibit greater fluctuations, suggesting that incorporating interest rate smoothing into the Taylor rule could enhance the model's accuracy. It is also highly likely that the ECB themselves make use of interest rate smoothing - gradually adjusting its policy rate rather than responding fully to contemporaneous changes in inflation or the output gap. Because of this, when estimating the most realistic Taylor rule specification for the ECB, including interest rate smoothing is a good idea; an example is including one lag for Euribor in the Taylor rule and also instrumenting this variable.

We will not include interest rate smoothing in the estimation of the ECB Taylor rule, as the purpose of this paper is to analyze the asymmetries that arise from following a common rule rather than estimating the most realistic ECB Taylor rule.

#### 5.3.5 Mean interest rate gaps

To assess how well synthetic interest rates align with Euribor over the simulation period, we calculate the mean interest rate gap ($\text{MIG}_i$), following Moons and Van Poeck (2008). This metric captures the average difference between Euribor (Moons and Van Poeck (2008) uses EONIA) and the simulated synthetic interest rates from Figure 5.2:

$$\mathrm{MIG}_i = \frac{\sum_{t=1}^{T} \left(i^*_{i,t} - \mathrm{Euribor}_t\right)}{T}, \quad i = 1, \ldots, 8. \tag{5.2}$$

A positive $\mathrm{MIG}_i$ means that Euribor was, on average, too low for euro area country $i$, i.e., the ECB's monetary policy was too loose. A negative value implies the opposite. We use point estimates from Table 5.1, as in the literature, to simulate these rates.

As in subsubsection 5.3.1, we do not construct confidence intervals and cannot interpret the significance of the $\mathrm{MIG}_i$. The indicator serves to illustrate long-term asymmetries, abstracting from short-term deviations, which we addressed in subsubsection 5.3.3.

We report $\mathrm{MIG}_i$ in Table 5.2.

| **Country** | **(1.1)** | **(1.2)** | **(1.3)** | **(1.4)** | **(1.5)** | **(1.6)** |
|---|---|---|---|---|---|---|
| Austria | 0.34 | 0.09 | 1.17 | 1.72 | 0.09 | -2.42 |
| Belgium | 0.33 | 0.08 | 1.29 | 1.68 | 0.07 | -2.38 |
| France | 0.11 | -0.13 | 0.65 | 1.39 | -0.10 | -2.53 |
| Germany | 0.17 | -0.08 | -0.02 | 1.37 | -0.06 | -2.61 |
| Ireland | 0.29 | 0.05 | -1.20 | 1.58 | 0.04 | -2.18 |
| Italy | 0.23 | -0.02 | -0.39 | 1.06 | -0.01 | -2.15 |
| Netherlands | 0.33 | 0.08 | -1.19 | 1.74 | 0.07 | -2.47 |
| Spain | 0.34 | 0.09 | -1.18 | 1.56 | 0.09 | -2.18 |

Table 5.2: Mean Interest Rate Gaps for the whole period (1999Q2–2024Q1)

Table 5.2 shows that in the simple Taylor rule specification, the specifications with money supply and exchange rate, the $\mathrm{MIG}_i$-values are small. In contrast, the Taylor rule specifications with HPI, stock price index, and interest rate spreads result in larger $\mathrm{MIG}_i$-values.

From Table 5.2, we observe signs of asymmetry. Larger economies like France and Germany have $\mathrm{MIG}_i$-values closer to zero in the simple Taylor rule specification, while smaller countries like Spain, Ireland, and Austria show larger deviations. The most significant differences between $\mathrm{MIG}_i$ appear when HPI is included: $\mathrm{MIG}_i$-values are positive for core countries (except Germany and the Netherlands) and negative for the periphery countries. In the Taylor rule specification with interest rate spread, the $\mathrm{MIG}_i$-values are all negative and large.

## 5.4 Estimation of the ECB Taylor rule in sub-periods

After estimating the Taylor rule specifications for the whole period, we proceed to investigate changes in the ECB's monetary policy response by dividing the sample into three sub-periods. The first sub-period is the pre-crisis period, from 1999Q2 to 2007Q2, which encompasses the period preceding the Global Financial Crisis and the European sovereign debt crisis. This split follows Papadamou et al. (2018). The second sub-period is the crisis period, spanning from 2008Q3 to 2015Q1, which encompasses the Global Financial Crisis and the European sovereign debt crisis. Finally, we define the post-crisis period as 2015Q2 to 2020Q1. This period is characterized by a shift in the ECB's policy strategy toward unconventional monetary policy tools due to the constraints of ELB.

### 5.4.1 Pre-crisis period

Table 5.3 shows that the coefficients for inflation are inconsistent across all models. In half of the models, the inflation coefficients are insignificant, while models (2.3), (2.5), and (2.6) yield significant coefficients greater than unity, indicating that the Taylor principle holds in these cases. However, the considerable variation in the significant estimates suggests that the ECB's response to inflation may not be robust.

The output gap is significant across all models, suggesting that the ECB also considered output stabilization during the pre-crisis period. However, the emphasis varies, as models (2.1), (2.2), and (2.5) suggest that the ECB placed more weight on the output gap, while the other specifications imply a greater response to inflation.

Examining the coefficients for financial stability indicators reveals that all are significant, except for the money supply. Model (2.3) shows that HPI is significant with a negative sign, which doesn't align with our theoretical expectations that a rise in house prices can signal an increase in inflationary risk. However, the coefficient is small. This finding suggests that while the ECB may have considered HPI when setting interest rates, it might not have been their primary focus.

The positive coefficient for the stock price index aligns with the theory that rising stock prices generate a wealth effect, which can boost consumption and, in turn, increase inflationary pressures that the ECB may need to consider when setting interest rates.

In model (2.5), the exchange rate coefficient is negative and statistically significant. This result contradicts our theoretical expectation that depreciation should lead to a higher interest rate, as the central bank aims to offset inflationary risks arising from more expensive imports and increased external demand.

Finally, the coefficient for the interest rate spread is significant and positive, indicating that the ECB responds to an increase in the spread by raising interest rates. This finding contrasts with our theory, which interprets a rising spread as a signal of increased risk in capital markets and would usually be met with a lower interest rate to support financial stability.

### 5.4.2 Crisis period

Looking at the estimation of the Taylor rule specifications for the ECB during the crisis period in Table 5.4, we find that the inflation coefficient is statistically significant in all models. The estimated values range from 0.37 to 0.50, which fall below the threshold of one and thus violate the Taylor principle. This finding suggests that the ECB did not adhere to the expected policy rule, which dictates that the nominal interest rate will increase by more than one-for-one when inflation rises.

| | (2.1) | (2.2) | (2.3) | (2.4) | (2.5) | (2.6) |
|---|---|---|---|---|---|---|
| $C_\pi$ | 0.823 | 0.770 | 4.966*** | 0.0773 | 2.080*** | 4.423*** |
| | (1.116) | (1.043) | (0.634) | (0.257) | (0.617) | (0.577) |
| $C_y$ | 1.383*** | 1.431*** | 2.890*** | -2.527*** | 2.232*** | 2.502*** |
| | (0.323) | (0.330) | (0.455) | (0.246) | (0.371) | (0.454) |
| $C_{\text{ms}}$ | | -0.0616 | | | | |
| | | (0.0890) | | | | |
| $C_{\text{hpi}}$ | | | -0.087*** | | | |
| | | | (0.0126) | | | |
| $C_{\text{stocks}}$ | | | | 0.0000843*** | | |
| | | | | (0.00000382) | | |
| $C_{\text{fx}}$ | | | | | -5.271*** | |
| | | | | | (0.411) | |
| $C_{\text{is}}$ | | | | | | 0.548*** |
| | | | | | | (0.0621) |
| Obs | 31 | 31 | 31 | 31 | 31 | 31 |
| Hansen J (p-val) | 0.51 | 0.72 | 0.79 | 0.87 | 0.72 | 0.63 |

Standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.010

Table 5.3: GMM estimation of the Taylor rule for the ECB *pre-crisis* period (quarterly data, 1999Q2–2007Q2)

Meanwhile, the output gap is significant and negative across all models. This counterintuitive result may reflect the fact that during periods of crisis, the ECB prioritized controlling inflation and maintaining price stability over addressing the output gap.

In model (3.2), we find that the money supply exhibits a significant and positive relationship with the interest rate. This result is consistent with our expectations. The ECB's monetary analysis framework uses M3 as a reference to monitor inflation risks, especially during periods of uncertainty such as the Global Financial Crisis and the European sovereign debt crisis. Under such conditions, the ECB may have responded more to changes in money supply.

Additionally, the coefficient for HPI is now statistically significant, indicating a positive effect on the interest rate, which is consistent with our theoretical expectation. The larger coefficient may suggest that the ECB placed greater emphasis on developments in house prices during the crisis period compared to the pre-crisis period.

We also find that the exchange rate becomes significant with a positive effect during the crisis period, aligning with theory and contrasting with the pre-crisis results. This result may reflect the impact of the Global Financial Crisis and the European sovereign debt crisis as external shocks affecting the exchange rate, leading to direct or indirect effects on import prices and aggregate demand. Those channels can influence inflation, which may explain why the ECB appears to account for the exchange when setting interest rates during the crisis period.

| | (3.1) | (3.2) | (3.3) | (3.4) | (3.5) | (3.6) |
|---|---|---|---|---|---|---|
| $C_\pi$ | 0.497*** | 0.389*** | 0.372*** | 0.481*** | 0.370*** | 0.494*** |
| | (0.128) | (0.0993) | (0.0891) | (0.107) | (0.0550) | (0.137) |
| $C_y$ | -0.484*** | -0.443*** | -0.473*** | -0.746*** | -0.828*** | -0.381*** |
| | (0.0912) | (0.147) | (0.0677) | (0.136) | (0.0757) | (0.0565) |
| $C_{\text{ms}}$ | | 0.685*** | | | | |
| | | (0.202) | | | | |
| $C_{\text{hpi}}$ | | | 0.135*** | | | |
| | | | (0.0173) | | | |
| $C_{\text{stocks}}$ | | | | 0.0000126 | | |
| | | | | (0.0000134) | | |
| $C_{\text{fx}}$ | | | | | 7.246*** | |
| | | | | | (1.801) | |
| $C_{\text{is}}$ | | | | | | 0.0490 |
| | | | | | | (0.0448) |
| Obs | 27 | 27 | 27 | 27 | 27 | 27 |
| Hansen J (p-val) | 0.47 | 0.66 | 0.62 | 0.70 | 0.64 | 0.66 |

Standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.010

Table 5.4: GMM estimation of the Taylor rule for the ECB during the financial-crisis period (quarterly data, 2008Q3–2015Q1)

### 5.4.3 Post-crisis period

| | (4.1) | (4.2) | (4.3) | (4.4) | (4.5) | (4.6) |
|---|---|---|---|---|---|---|
| $C_\pi$ | -0.128*** | -0.113*** | -0.0343 | -0.125*** | -0.0802*** | -0.138*** |
| | (0.0291) | (0.0213) | (0.0236) | (0.0232) | (0.0169) | (0.0163) |
| $C_y$ | 0.0866** | 0.0936*** | 0.0319 | 0.0197 | 0.102*** | 0.0184 |
| | (0.0414) | (0.0311) | (0.0271) | (0.0150) | (0.0331) | (0.0188) |
| $C_{\text{ms}}$ | | 0.0310 | | | | |
| | | (0.0319) | | | | |
| $C_{\text{hpi}}$ | | | -0.0130*** | | | |
| | | | (0.00363) | | | |
| $C_{\text{stocks}}$ | | | | 0.000000228 | | |
| | | | | (0.00000259) | | |
| $C_{\text{fx}}$ | | | | | -0.761** | |
| | | | | | (0.386) | |
| $C_{\text{is}}$ | | | | | | 0.0616*** |
| | | | | | | (0.00503) |
| Obs | 20 | 20 | 20 | 20 | 20 | 20 |
| Hansen-J | 0.48 | 0.63 | 0.69 | 0.63 | 0.64 | 0.85 |

Standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.010

Table 5.5: GMM estimation of the Taylor rule for the ECB, post-crisis period (quarterly data, 2015Q2–2020Q1)

From Table 5.5, we observe that in the post-crisis period, the coefficients for inflation are significant and negative, with the model (4.3) as the exception. This negative relationship could suggest a destabilizing monetary policy response, where the ECB appears to reduce interest rates in response to rising inflation. However, it is also possible that the negative relationship reflects the limitations of Taylor rule estimation in the post-crisis period, during which the ECB relied more heavily on unconventional monetary policy tools.

The output gap is significant in models (4.1), (4.2), and (4.3), with positive signs as predicted by the Taylor rule; however, the coefficients are relatively small. This result may reflect that our Taylor rule estimation does not account for the ECB's policy rate being constrained by the Effective Lower Bound (ELB), thereby limiting its ability to adjust interest rates in response to changes in both inflation and the output gap.

Looking at the financial stability indicators, we observe that all three significant coefficients are contrary to our theoretical expectations. The coefficient for HPI is significant with a negative sign. However, the coefficient is small, indicating that HPI had limited influence on interest rates during the post-crisis period.

The coefficient for the exchange rate is negative and significant in the post-crisis period, consistent with the unexpected result observed in the pre-crisis period.

Finally, the interest rate spread again exhibits a positive coefficient, which is contrary to our theoretical expectation that a rise in the spread signals increased risk in capital markets and would prompt the ECB to lower interest rates to mitigate that risk.

## 5.5 Simulations of sub-periods

We also examine synthetic interest rates in the sub-periods, as the Taylor rule estimations yield different coefficients than those estimated over the whole sample. The simulation method remains the same as described in subsubsection 5.3.3.

### 5.5.1 Pre-crisis period simulation

We visualize the simulations of synthetic interest rates for the pre-crisis period in Figure 5.3. The synthetic interest rates during this period are relatively volatile, making it difficult to visually assess how closely each Taylor rule specification tracks the Euribor. However, the simple Taylor rule and the Taylor rule augmented with money supply produce similar synthetic interest rates in this sub-period. Because of this, it is convenient to make use of the $\mathrm{MIG}_i$ mentioned in subsubsection 5.3.5. We report the $\mathrm{MIG}_i$ for the sub-periods in the appendix as subsection B.5.

According to the $\mathrm{MIG}_i$-values, the simple Taylor rule specification and the Taylor rule specification with money supply are closer to zero. The Taylor rule specifications, incorporating the HPI and the exchange rate, also perform reasonably well, although they yield more heterogeneous results across countries. The worst-performing Taylor rule specifications during this period are those that include the stock price index and the interest rate spread.

In the pre-crisis period, the simple Taylor rule specification and the Taylor rule specifications with money supply and exchange rate reveal asymmetries between core economies and peripheral countries. This result is illustrated in subsection B.5, where, in general, the core countries have negative $\text{MIG}_i$ values and the periphery countries have positive $\text{MIG}_i$ values for the three mentioned Taylor rule specifications.

By contrast, for the Taylor rule specifications with HPI, stock price index, and the interest rate spread, we do not observe a consistent pattern of divergence between core and periphery countries. These models yield more country-specific variation without a clear core-periphery divide.

Germany and France are the only two countries where the $\text{MIG}_i$s are positive across all models in the pre-crisis period. This result indicates that the monetary policy implemented by the ECB was too tight during the pre-crisis periods for these two countries.

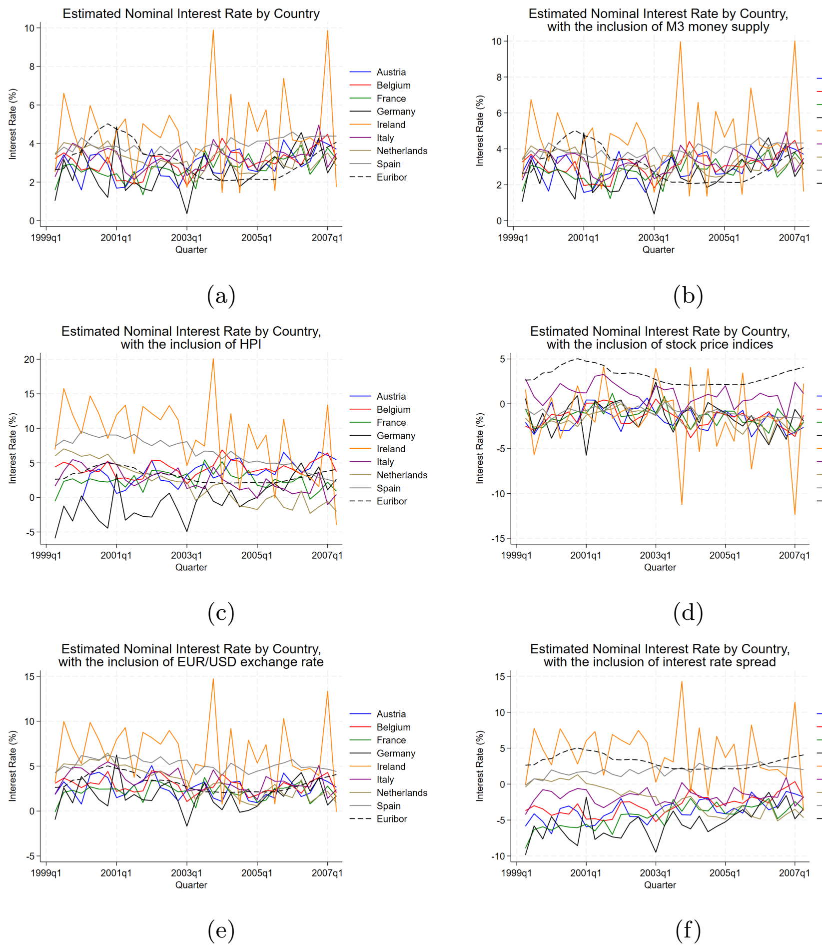



Figure 5.3: Estimated nominel interest rate for certain euro area countries in the pre-crisis, 1999Q2-2007Q2 - using different measures of financiel stability.

### 5.5.2 Crisis period simulation

We visualize the simulations of synthetic interest rates for the crisis period in Figure 5.4. Most Taylor rule specifications closely follow the Euribor. However, from 2011 Q2 onward, Euribor fell below the synthetic interest rates, indicating that the ECB's monetary policy was too loose.

The main exception is the Taylor rule specification with HPI. This Taylor rule specification produces more variation in the synthetic interest rates across countries throughout the crisis period. At the end of the crisis period, the synthetic interest rates converge across countries.

A particularly notable case is Ireland, where all models exhibit a sharp drop in the synthetic interest rate in 2015Q1. This sharp drop happened because Ireland experienced considerable growth in GDP in 2015, and our coefficients for the output gap were negative during the crisis period, as seen in our Taylor rule estimations for the sub-periods. As a result, a considerable increase in GDP growth will lead to an expansion of the output gap, resulting in a decrease in the synthetic interest rate for Ireland in our models.

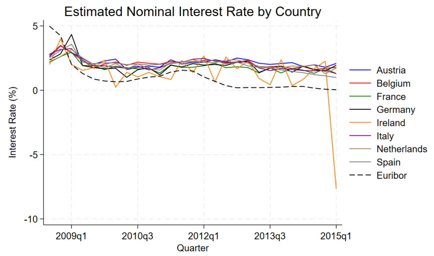
As shown in subsection B.5, the $\text{MIG}_i$-values in the crisis period are primarily positive. The only two exceptions are Ireland under the Taylor rule specifications with HPI and stock price index, where $\text{MIG}_i$ is negative.

### 5.5.3 Post-crisis period simulation

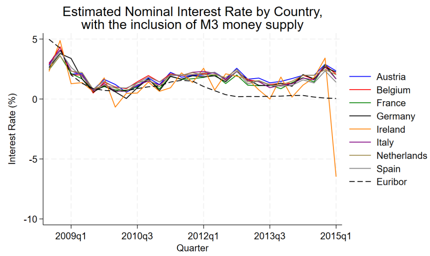
We visualize the simulations of synthetic interest rates for the post-crisis period in Figure 5.5. It appears that our simulated interest rates diverge from the Euribor. This discrepancy likely stems from the fact that our Taylor rules do not account for quantitative easing (QE) and the Euribor hitting the effective lower bound (ELB). In addition, our Taylor rule specifications do not include provisions to prevent synthetic interest rates from becoming too negative, i.e., from falling below the effective lower bound.

Our $\text{MIG}_i$, as reported in subsection B.5 are primarily positive. This result suggests that the monetary policy conducted by the ECB is too restrictive compared to what is prescribed by the synthetic interest rates. However, interpreting a policy stance at the ELB as "too tight" is problematic, as the ECB cannot lower the interest rates much further. This discrepancy arises because the effective lower bound does not constrain our synthetic interest rates.

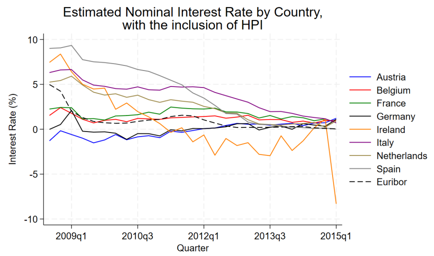
The Taylor rule specification with the stock price index is the only Taylor rule in this period that yields negative $\text{MIG}_i$ values. This result implies that, in this case, the ECB's monetary policy was looser than what the synthetic interest rates would have prescribed.



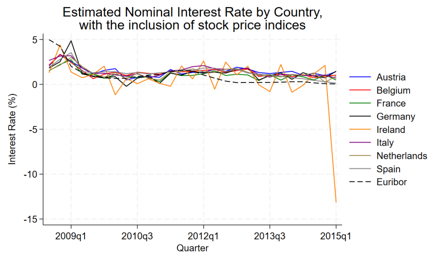

(a)



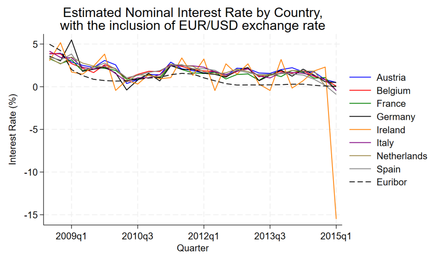

(b)



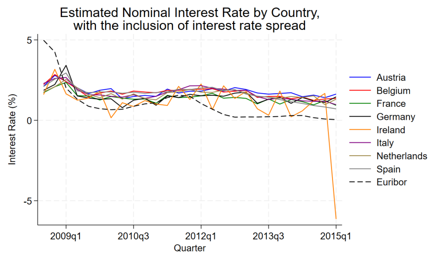

(c)




(d)

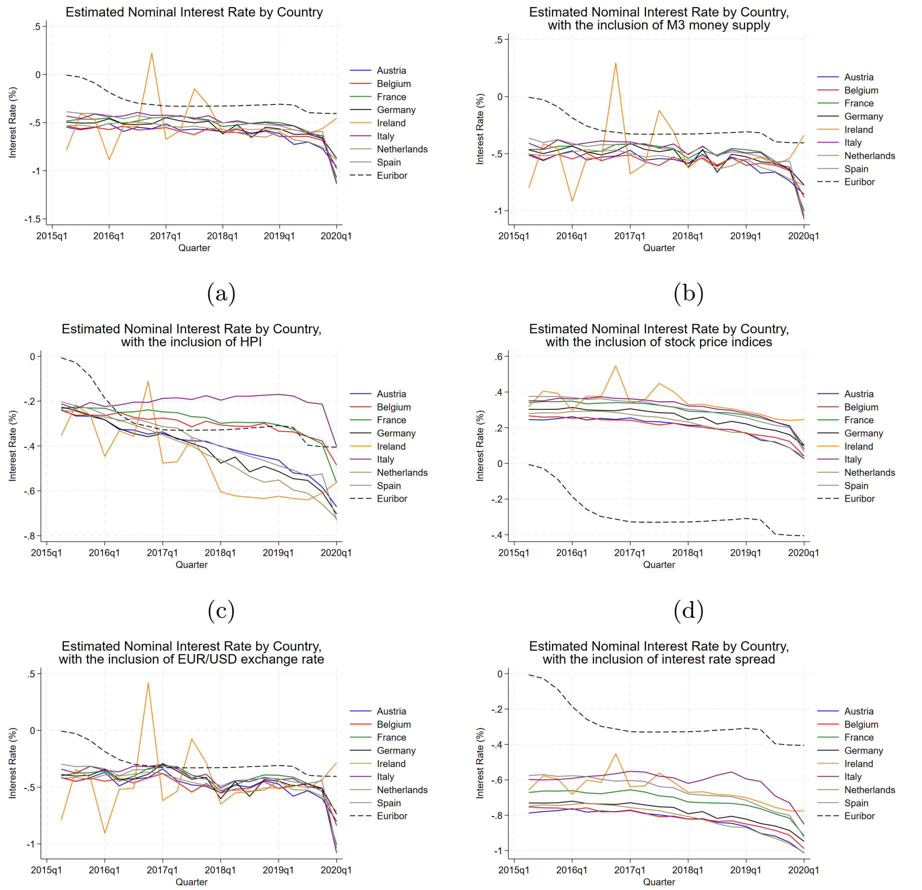



(e)




(f)

Figure 5.4: Estimated nominel interest rate for certain euro area countries in the crisis period, 2008Q3-2015Q1 - using different measures of financiel stability.




(a) (b)

(c) (d)

(e) (f)

Figure 5.5: Estimated nominal interest rate for certain euro area countries in the post crisis period, 2015Q2-2020Q1 - using different measures of financial stability

# 6 Robustness

We assess the robustness of our ECB Taylor rule estimations across the whole sample (1999Q2-2024Q1) in section 5 using three different specifications: (i) an alternative policy rate proxy, (ii) monthly data, and (iii) a forward-looking Taylor rule specification. For each of these estimations, we will not simulate the synthetic interest rates due to data unavailability, but we will verbally describe them.

## 6.1 Alternative policy rate specification

We re-estimate the Taylor rule specifications using the MRO rate instead of Euribor to assess whether our empirical results are robust to an alternative specification of the policy rate. As noted in section 3, Euribor is a market-based interest rate, while the MRO rate is the official policy rate directly set by the ECB. Euribor fluctuates around the MRO rate; thus, we expect to get similar estimation results.

As shown in Table C.1, results are highly robust since the signs, significance, and magnitudes of the estimated coefficients are nearly unchanged. This finding is consistent with what Sturm and Wollmershäuser (2008) find in their paper. Given these nearly identical estimates, we do not simulate synthetic country-specific interest rates using the MRO specification.

## 6.2 Estimation using monthly data

To check the robustness of the data frequency, we re-estimate the ECB's Taylor rule using monthly data (1999M3-2024M1). This robustness check is consistent with the standard practice in the literature (e.g., Sturm and Wollmershäuser (2008); Papadamou et al. (2018); Ullrich (2003)). Most papers use monthly data, as the governing council of the ECB meets monthly to review monetary policy (Sauer and Sturm, 2007).

For inflation, we use the HICP overall index, which takes into account changing composition and calculates percentage changes. As output gap data are unavailable at a monthly frequency, we use industrial production as a proxy, following standard practice (e.g., Ullrich (2003); Clarida et al. (1998)). We report the results in Table C.2.

The estimation results are partly robust to the data frequency, though there are some large differences. The coefficient for inflation is smaller in magnitude, and it becomes insignificant in model (6.3) and model (6.4). The coefficient for the output gap becomes positive, but it becomes insignificant in most specifications. Moreover, the coefficient for the interest rate spread becomes negative and remains significant. This finding is more consistent with our expectations.

The lower inflation coefficient would result in synthetic interest rates responding less aggressively to inflation, leading to fewer cross-country asymmetries. Moreover, the reversal of the estimated coefficient signs for the output gap could lead to a different conclusion regarding the direction of the mean interest rate gap for individual countries; however, it is difficult to say.

## 6.3 Estimation of forward-looking Taylor rule specifications

To analyze the robustness of the results we get from a backward-looking Taylor rule with ex-post inflation and the ex-post output gap, we estimate a forward-looking Taylor rule with expected inflation and the expected output gap.

From a theoretical perspective, the coefficients become more realistic since we assume that central banks conduct monetary policy based on expected inflation and the expected output gap in the New Keynesian model. Additionally, from an empirical perspective, most papers utilize expectations data for inflation and the output gap when estimating Taylor rule specifications for the ECB (e.g., Sturm and Wollmershäuser (2008); Ullrich (2003)).

We use ECB survey data on inflation and output gap as a proxy for expectations data. We estimate the following forward-looking Taylor rule specifications for the ECB:

$$\text{Euribor}_t = C_0 + \mathbb{E}_t[\pi_t] + C_y(\mathbb{E}_t[y_t] - \mathbb{E}_t[y^*]) + C_X X_t + \varepsilon_t \tag{6.1}$$

We report the estimation results for the forward-looking Taylor rule specifications in Table C.3. We observe that the ECB appears to respond more aggressively to expected inflation, consistent with Clarida et al. (1998), though the Taylor principle remains violated across the specifications. The output gap coefficient remains negative, potentially a result of using quarterly data, which smooths short-run fluctuations. However, the coefficients for the output gap have become closer to zero. The robustness check results for the financial stability indicators are consistent with the empirical results in subsection 5.2.

Given the larger inflation coefficient, the synthetic interest rates will become more sensitive to expected inflation, resulting in greater asymmetries between the core and peripheral economies. As a result, there would be relatively higher synthetic interest rates in the periphery countries. Because in these countries, inflation is often higher and more volatile.

In conclusion, the robustness checks indicate that the results for the primary purpose of this paper are robust: one rule is unlikely to fit all euro area countries. However, the estimation of Taylor rule specifications for the ECB is not robust, as some of the estimated coefficients depend on the model specification used.

# 7 Discussion

In this section, we will relate our empirical findings to the existing literature, highlighting similarities and differences, and discuss the limitations of our approach.

## 7.1 Comparison of whole period and sub- periods

In this section, we compare the estimations and simulations obtained in the different sample specifications. We do this to examine if the coefficients for the ECB's Taylor rule differ across time and to assess the asymmetries between the euro area countries.

### 7.1.1 Estimation

Comparing the estimation results for the whole period and the sub-periods, we observe notable patterns, especially between the whole period and the crisis period.

The coefficients for inflation in the whole period and the crisis period are significant across all models; however, there is a violation of the Taylor principle. This violation suggests that the ECB did not respond aggressively enough to inflation during these periods.

In contrast, the pre-crisis and post-crisis periods yield inconsistent inflation results, with coefficients that are either insignificant or significant and above one.

Other empirical studies also report mixed findings regarding the inflation coefficient across the pre-crisis and crisis periods. Belke and Polleit (2007) find that there is no violation of the Taylor principle in the period 1999Q1–2005Q2. Papadamou et al. (2018) report coefficients above one in both the pre-crisis and crisis periods. In contrast, Belke and Klose (2010) find that the Taylor principle is violated in the pre-crisis period but satisfied during the crisis period. Rühl (2015), on the other hand, finds that most inflation coefficients are insignificant for the period 1999M1–2007M12.

The coefficient for the output gap is significant, with a negative sign throughout the whole period and in the crisis period, which is a counterintuitive result. However, the negative coefficient is consistent with Belke and Klose (2010), who argue that the negative weight on the output gap during the Global Financial Crisis indicates that the ECB placed greater emphasis on fighting inflation and maintaining price stability. Papadamou et al. (2018) support a similar interpretation, noting that the ECB's responsiveness to the output gap declined during the crisis period compared to the pre-crisis period.

This finding for the output gap contrasts with both the pre-crisis and post-crisis periods. In the pre-crisis period, the output gap has a significant and positive coefficient, which aligns with both theoretical expectations and empirical findings in Belke and Polleit (2007), Belke and Klose (2010), Rühl (2015) and Papadamou et al. (2018), as we expect central banks to raise interest rates in response to an increase in the output gap. During the post-crisis period, we also observe a positive coefficient. However, the effect is modest, suggesting a limited interest rate response from the ECB to changes in the output gap.

Regarding the financial stability indicators, we find that the coefficient for money supply is significant in both the whole period and the crisis period. This pattern suggests that, during times of crisis, the ECB placed greater emphasis on money supply as part of its monetary pillar, possibly reflecting concerns that fluctuations in money growth signal changes in future inflation. Our findings for the money supply variable are consistent with Papadamou et al. (2018), who also report a positive coefficient. However, they find a relatively weak effect on the interest rate compared to our estimations. By contrast, Belke and Klose (2010) find that the impact of money supply turns negative during the crisis period. They argue that in times of crisis, stabilizing the economy takes precedence over concerns about future inflation.

The coefficient for HPI is significantly negative throughout the whole period, as well as in the post-crisis period. This finding contrasts with the pre-crisis and crisis periods, where it shows positive signs. Papadamou et al. (2018) also find a positive sign for the HPI coefficient, but only during the crisis period, similar to Belke and Klose (2010).

The interest rate spread is significantly positive in both the whole period and across all sub-periods. This result contradicts our theoretical expectation and the empirical finding of Belke and Klose (2010) and Papadamou et al. (2018).

Overall, the ECB's monetary policy response varies across sub-period estimations compared to the whole period, with notable changes in the response to inflation, the output gap, and financial stability indicators like money supply.

### 7.1.2 Simulations of synthetic interest rates

In the pre-crisis period, Taylor-rule performance varies substantially by specification. The HPI-augmented rule produces highly heterogeneous synthetic rates across countries, both in the sub-period and when simulating the entire pre-2008 span. The version including the interest-rate spread often yields sub-zero synthetic rates, indicating that these augmentations poorly represent ECB policy before the Global Financial Crisis. Moreover, synthetic rates in the pre-crisis sub-period are notably more volatile than those from the full-period simulation—a contrast to Papadamou et al. (2018), whose rates tended to hover around Euribor.

During the crisis, most specifications track Euribor closely, except the HPI-augmented rule, which continues to generate wide cross-country variation. This again differs from Papadamou et al. (2018), who found larger divergences in crisis-period synthetic rates. Over the full sample (pre-, crisis, and post-2008), the simple Taylor rule and variants including money supply or the exchange rate perform best during the crisis.

In the post-crisis era, no specification captures Euribor hitting the effective lower bound (ELB) in sub-period simulations—synthetic rates are mostly negative—while in full-sample simulations they remain positive but still fail to reflect the ELB. The rule augmented with the interest-rate spread comes closest in the full-period exercise, and only the stock-price-index augmentation yields positive sub-period rates.

Across all periods, peripheral countries—especially Ireland—exhibit the greatest volatility in synthetic rates, consistent with Papadamou et al. (2018). Greece is omitted here due to data limitations.

### 7.1.3 Mean Interest Rate Gaps

Our $\text{MIG}_i$-values are generally smaller in magnitude than those reported by Moons and Van Poeck (2008). They find that ECB policy was too loose for peripheral countries—especially Ireland —and too tight for core countries under a simple Taylor rule (1999Q1–2003Q4). We find similar but weaker patterns for the pre-crisis period. One explanation for this could be that Moons and Van Poeck (2008) use a calibrated rule with $\phi_y = 0.5$ while we estimate coefficients empirically. As shown in Figure 5.1, our estimated rule fits Euribor more closely than the theoretical rule in Figure 2.1, which is likely to improve country-level fits as well.

In the full-sample simulations, only the specification with HPI produces the classical core-periphery divide.

During the crisis period, $\text{MIG}_i$-values converge across countries, with ECB monetary policy appearing too loose in nearly all specifications. This convergence may reflect reduced asymmetries during a common shock.

In the post-crisis period, $MIG_i$-values are less informative due to poor model fit, as the synthetic rates in Figure 5.5 fail to track Euribor.

In conclusion, our findings support the conclusion of Moons and Van Poeck (2008): a single rule does not suit all euro area economies.

## 7.2 Limitations and potential problems

In this section, we discuss the limitations and potential problems of our approach.

### 7.2.1 Limitations of the method

A limitation is that we have an estimation bias when we estimate the Taylor rule for the euro area using aggregate data. This bias occurs because large economies naturally weigh more in the estimation of the Taylor rule. As a result, the estimated coefficients in the Taylor rule will not be as optimal for smaller countries as for larger countries by construction. However, it makes sense that larger countries will weigh more heavily in the ECB's interest rate setting since economic downturns in larger countries have more considerable consequences.

### 7.2.2 General data limitations

Our dataset has several limitations, which could explain the inconsistent results compared to the literature. We addressed some of these limitations in section 6.

Using quarterly data reduces the number of observations in each of our sub-periods compared to papers using monthly data (e.g., Papadamou et al. (2018)), which increases the risk of small-sample bias. Alternatively, we could have used more advanced econometric models to account for the different periods in the ECB's Taylor rule rather than splitting the sample into sub-periods. Examples here could be rolling regressions or models with regime-switching parameters.

### 7.2.3 CPI as a measurement of inflation

The CPI is a widely used measure of inflation, but it is not without problems. The CPI is a weighted index that can be susceptible to biases. Some of these biases include substitution bias, quality change bias, new-item bias, and new-outlets bias. According to Neves and Sarmento (1997), these biases cause the CPI to overestimate the cost of living. Whether or not these biases are significant in our data is uncertain. Bryan and Cecchetti (1993) finds that the weighting bias of the CPI is roughly 0.6% for the period 1967-1992 in the USA but that the size of the bias varies widely in sub-periods. However, they claim that the bias in the CPI was negligible from 19981 to 1992 in the USA.

Another problem with using the CPI to measure inflation is that non-monetary events, such as sector-specific shocks and measurement errors, can introduce transitory noise into the price data. According to Bryan and Cecchetti (1994), this noise affects the aggregated price indices more when looking at higher-frequency price index data. Therefore, a possible solution to this is using lower frequency price data, but this is generally not a viable solution for policy-makers as it *"[...] greatly reduces the timeliness, and therefore the relevance, of the incoming data."* Bryan and Cecchetti (1993). An alternative approach is to use core inflation, which excludes the most volatile components of the CPI, thereby reducing the influence of transitory shocks. This method involves removing prices with high noise variance from the aggregate index. However, the significance of this transitory noise is beyond the scope of this paper.

#### 7.2.4 Uncertainty in GDP and output gap

Univariate time-series methods are not necessarily reliable for calculating the output gap. According to St-Amant and Van Norden (1997) *"[...] the causal relationship between potential and the gap can limit the information we can hope to gain about the current gap [...]"*. The same paper also notes that economic theory offers little guidance on which decomposition method to favor. Inadequate guidance can be problematic, as the decomposition method can significantly impact the calculated output gap. However, we still use the HP filter, as it is widely used in the literature and due to its ease of use.

A possible error in the GDP data is that Ireland has experienced misleadingly high economic growth, which may be due to the presence of large multinational corporations (MNCs). Although they have experienced real GDP growth, it is merely the size of the GDP growth rate, and hence the output gap, that is misleading. Some of the ways these MNCs have affected the Irish economy include reporting large profits in Ireland and owning substantial assets. The acquisition of these assets does not directly affect GDP, but the depreciation of these assets does Honohan et al. (2021). According to Honohan et al. (2021), the exceptionally high GDP growth in 2015 can be attributed mainly to the increase in depreciation resulting from the MNC's decision to transfer its intellectual property rights to affiliates in Ireland.

Another uncertainty about GDP data is that the relative sizes of the shadow economies are different across countries. The GDP does not directly account for the shadow economy, but after 2014, Eurostat required EU member states to include approximations of the shadow economy in their GDP calculations. Hence, this measurement error is larger earlier in the sample (European Commission, Eurostat, 2018).

# 8 Conclusion

Our paper's primary focus was to investigate whether a Taylor rule can describe the ECB's interest rate and whether a single rule can fit all individual euro area countries.

Our empirical results show that, from 1999Q2 to 2024Q1, there is a violation of the Taylor principle. As a result, the ECB follows a destabilizing rule whereby the real interest rate does not rise when inflation is higher. When examining the full sample, the only financial stability indicator coefficient with the expected sign is the money supply. A possible explanation for these counterintuitive results is that our Taylor rule specifications fail to account for the Effective Lower Bound.

Simulations for the simple Taylor rule and the augmented Taylor rule specifications, incorporating money supply, stock price indices, and the exchange rate, create synthetic interest rates that are, on average, closest to the Euribor. However, most synthetic interest rates diverge from the Euribor in the post-crisis period. An exception to this is the Taylor rule specification with the interest rate spread, which performs best after the crisis period but before the start of the COVID-19 pandemic. This finding suggests that the ECB employs tools beyond the Taylor rule to determine interest rates when they reach the effective lower bound.

The findings for the sub-periods suggest that there is no conclusive evidence indicating that the ECB's policy rate follows a systematic reaction function across all periods. During the pre-crisis period, results are inconsistent, with some models exhibiting stronger responses to inflation while others place greater emphasis on the output gap. During the crisis period, inflation is significant across all models, but there is a violation of the Taylor principle. The negative coefficient on the output gap suggests that the ECB prioritized inflation control over output stabilization. In the post-crisis period, the inflation coefficient is significant and negative in almost all models; The output gap has a small coefficient. These results reflect the constraints posed by the effective lower bound and the shift toward unconventional monetary policy tools.

In the pre-crisis period, simulated interest rates are more volatile, with systematic differences between core and peripheral countries only appearing under the simple Taylor rule and specifications including money supply and exchange rates. Core countries like France and Germany faced overly tight policy, while peripheral countries such as Ireland and Spain experienced overly loose policy.

During the crisis, all Taylor rule specifications closely follow Euribor, diverging slightly at the end. $\text{MIG}_i$-values indicate ECB policy was generally too loose, though cross-country asymmetries declined, likely due to the common shock.

In the post-crisis period, synthetic rates deviate significantly from Euribor, as the Taylor rule does not account for the effective lower bound, making asymmetry assessments unreliable.

Across all specifications and sub-periods, Ireland has the most volatile synthetic interest rates.

Our findings suggest that the ECB does not consistently follow a Taylor rule. However, our findings during the crisis period suggest that the Taylor rules effectively describe the ECB's interest rate setting during crisis periods. However, we observe that our Taylor rules are inadequate descriptions of the ECB's monetary policy in the post-crisis period. Crucially, our results indicate asymmetries between core and periphery countries. A single rule is unlikely to fit all euro area countries.

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# Appendix A Data appendix

## A.1 List of euro area countries

We try to include as many of the same countries in our country sample as Papadamou et al. (2018). The list of euro area countries in our sample is Austria, Belgium, France, Germany, Ireland, Netherlands, and Spain. Our sample does not include Greece, as in Papadamou et al. (2018)'s paper, since we were unable to find early data for the stock price index for Greece.

Table A.1: Core/periphery grouping for euro area countries

| **Country** | **Group** |
|---|---|
| Austria | Core |
| Belgium | Core |
| France | Core |
| Germany | Core |
| Ireland | Periphery |
| Italy | Periphery |
| Netherlands | Core |
| Spain | Periphery |

## A.2 Variable definitions

This section defines all the variables used in the empirical results. We collect most data in line with Papadamou et al. (2018) but with a few differences. For inflation, output gap, and the interest rate proxy, we also include the definitions of the variables used in the robustness checks.

### A.2.1 Inflation

**Empirical results: CPI** We use the CPI as the price index measure for the euro area and its individual member countries. We use percent per annum as the unit of measure. Unlike Papadamou et al. (2018), we do not HP-filter the inflation because this would smooth the quarterly inflation too much, removing the short-run fluctuations that are important for simulating the synthetic interest rates.

**Robustness check 2: HICP Overall index** We use HICP in the overall index for the euro area. It accounts for changing composition. We collect it at a monthly frequency.

**Robustness check 3: HICP Inflation forecasts** We use HICP Inflation forecasts, which are mean point estimates in all survey rounds for the next calendar year. Eurostat defines inflation in this variable as the year-on-year percentage change.

### A.2.2 Output gap

**Empirical results: GDP:** We use GDP in chain-linked volumes (the base year 2015 = 100) in a million euros at market prices.

From this data, we calculate the quarterly growth rates in GDP, which is why our estimation sample begins in 1999Q2 rather than 1999Q1. We calculate potential GDP growth using the Hodrick-Prescott (HP) filter. We use $\lambda = 1600$, which is the standard for quarterly data. The HP filter calculates the potential output by minimizing this problem:

$$\tau_t = \min_{\{\tau_t\}_{t=1}^{T}} \left\{ \sum_{t=1}^{T} (y_t - \tau_t)^2 + \lambda \sum_{t=2}^{T-1} [(\tau_{t+1} - \tau_t) - (\tau_t - \tau_{t-1})]^2 \right\} \tag{A.1}$$

We can then use the potential output to calculate the output gap as the difference between actual and potential output:

$$\tilde{y} = y_t - \tau_t \tag{A.2}$$

**Robustness check 2: Industrial production:** We use industrial production total excluding construction for Euro area 20 as a proxy for Real GDP. We collect it monthly. To calculate the potential output, we use $\lambda = 14400$, which is the recommended $\lambda$ for monthly data.

**Robustness check 3: Real GDP growth forecasts** We use real GDP growth forecasts, which are mean point estimates in all survey rounds. Eurostat defines real GDP growth as the year-on-year percentage change in real GDP.

### A.2.3 Interest rate proxy

We use two interest rate proxies: Euribor in the empirical results in section 5 and the MRO rate in the robustness check in subsection 6.1.

**Empirical results: Euribor** Our nominal interest rate proxy for the ECB is the 3-month Euribor. We use historical close values, which are the average of the observations in the given quarter. The data for Euribor uses the changing composition as defined by the euro area. We collect it monthly and aggregate it into quarterly averages.

**Robustness check 1: Main Refinancing Operations (MRO)** For the Main Refinancing Operations (MRO) rate, we use the fixed rate in levels. The euro area definition is changing composition. We collect the MRO rate daily and aggregate it as a quarterly simple average.

### A.2.4 Money supply

For the money supply variable, we use M3 as the proxy. M3 is the broadest definition of the money supply, and it includes the following: cash, overnight deposits, short-term deposits, money market fund shares, and short-term debt securities.

We collect M3 monthly and aggregate it by taking quarterly averages.

### A.2.5 House Price Index

We use the real (inflation-adjusted) House Price Index (HPI) at quarterly frequency. It is indexed with a base year of 2015 (2015 = 100), being seasonally adjusted but not calendar-adjusted. HPI measures the changes in the purchase prices of properties for households.

### A.2.6 Stock price index

A stock price index is an aggregate index that represents the weighted average prices of a group of stocks, typically comprising large and important firms listed on a stock exchange.

We collect stock price indices on a monthly basis and aggregate them into quarterly simple averages.

### A.2.7 Exchange rate

We use the EUR/USD nominal exchange rate, and it is quoted as US dollars per euro. We use this particular exchange rate since the US is the EU's most important financial partner, and the dollar is the global reserve currency.

We collect the exchange rate monthly and aggregate it to quarterly averages.

### A.2.8 Interest rate spread

We calculate two different interest rate spreads: one for the euro area and one for the individual countries.

For the euro area, we calculate the interest rate spread, $\mathrm{IS}_t^{\mathrm{EA}}$, as:

$$\mathrm{IS}_t^{\mathrm{EA}} = i_t^{10\mathrm{Y}} - i_t^{3\mathrm{M}} \tag{A.3}$$

Where $i_t^{10\mathrm{Y}}$ is the monthly yield for the 10-year euro area government benchmark bond with changing composition and $i_t^{3\mathrm{M}}$ is the Euribor (**??**).

We calculate the interest rate spread, $\mathrm{IS}_t^c$, for the the given country $c$ as:

$$\mathrm{IS}_t^c = i_t^c - i_t^{\mathrm{DE}} \tag{A.4}$$

Where $i_t^c$ is a 10-year government bond for the given country $c$, and $i_t^{\mathrm{DE}}$ is the 10-year government bond for Germany. $\mathrm{IS}_t^c$ can be viewed as a country-specific credit risk relative to Germany.

We calculate the two interest rate spread variables using monthly data, which we aggregate as quarterly simple averages.

## A.3 Data sources

We report the data sources for the variables in Table A.2.

Table A.2: Sources for the data used in the paper

| Category | Data | Level | Source |
|---|---|---|---|
| **Simple Taylor rule variables** | | | |
| | Output | EA, National | Eurostat |
| | Inflation | EA, National | OECD |
| | Euribor 3-month | Euro area | ECB |
| **Financial stability indicators** | | | |
| | Money Supply (M3) | Euro area | OECD |
| | House Price Index (HPI) | National | OECD |
| | EUR/USD Exchange Rate | Euro area | ECB |
| *Stock price indices* | | | |
| | EURO STOXX 50 | Euro area | Curvo |
| | CAC 40 (`^FCHI`) | France | Yahoo Finance |
| | DAX (`^GDAXI`) | Germany | Yahoo Finance |
| | ISEQ All Share (`^ISEQ`) | Ireland | Yahoo Finance |
| | IBEX 35 (`^IBEX`) | Spain | Yahoo Finance |
| | FTSE MIB Index (`^FTSEMIB.MI`) | Italy | Yahoo Finance |
| | AEX-Index (`^AEX`) | Netherlands | Yahoo Finance |
| | ATX (`^ATX`) | Austria | Yahoo Finance |
| | BEL 20 (`^BFX`) | Belgium | Yahoo Finance |
| *Government bond yields (10Y)* | | | |
| | Euro area | Euro area | ECB |
| | Germany | National | Banque de France |
| | France | National | Banque de France |
| | Ireland | National | Banque de France |
| | Spain | National | Banque de France |
| | Italy | National | Banque de France |
| | Netherlands | National | Banque de France |
| | Austria | National | Banque de France |
| | Belgium | National | Banque de France |
| **Robustness checks** | | | |
| *Robustness check 1* | | | |
| | MRO | Euro area | ECB |
| *Robustness check 2* | | | |
| | HICP - Overall index | Euro area | ECB |
| | Industrial production | Euro area | ECB |
| *Robustness check 3* | | | |
| | HICP Inflation forecasts | Euro area | ECB |
| | Real GDP growth forecasts | Euro area | ECB |

All the data we have collected can be revised. The data used in this paper reflects the values we retrieved on March 2, 2025.

# Appendix B Empirical results appendix

In this section, we include relevant appendices related to the empirical results.

## B.1 Use of AI tools

We have utilized AI tools to support us in the technical aspects of this paper. We created a custom GPT on chatGPT, which assisted us with (i) cleaning data and (ii) programming. Furthermore, we used Grammarly to correct spelling and grammar mistakes and clarify some sentences. All the reasoning, theory, and other relevant information are either from the literature or our work.

## B.2 Programming notes

We retrieved the stock price index data from Yahoo Finance using the `yfinance`-library in Python. We calculate the output gap using the HP-filter plugin in Microsoft Excel.

All stationarity tests, GMM estimations, simulations of synthetic interest rates, and the calculations of $\text{MIG}_i$ were all coded in Stata 18. For the GMM estimations, we used the *'ivregress gmm'*-command with *'wmatrix(hac nwest)'* to apply a Newey-West weighting matrix. To verify the correctness of our GMM estimations, we cross-checked all estimations with the point-and-click tools in Eviews 13.

## B.3 Unit root analysis

We test for stationarity using the Augmented Dickey-Fuller (ADF) test and the Phillips-Perron (PP) test. We do this because if there are non-stationary variables and no cointegration, then there is a risk of spurious estimation results.

The null- and alternative hypotheses in the ADF and PP tests are:

$$\begin{cases} \mathcal{H}_0 & : \text{The variable has a unit root} \\ \mathcal{H}_a & : \text{The variable is stationary} \end{cases} \tag{B.1}$$

We report the p-values from the ADF and PP tests in Table B.1.

| **Variable** | **ADF p-value** | **PP p-value** | **Stationary?** |
|---|---|---|---|
| Output gap | 0.0000 | 0.0000 | Yes |
| Inflation | 0.0006 | 0.0918 | Borderline |
| Money supply | 0.0127 | 0.0000 | Yes |
| House Price Inflation | 0.1908 | 0.3133 | No |
| Stock price index | 0.9690 | 0.9681 | No |
| Exchange rate | 0.3747 | 0.3562 | No |
| Interest rate spread | 0.4134 | 0.5534 | No |
| Euribor | 0.1815 | 0.6184 | No |

Table B.1: Results from unit root tests

Summary of our results:

- **Stationary (I(0))**: Output gap and money supply are stationary in both tests. Inflation is stationary under ADF and borderline stationary under PP; we will, therefore, treat it as stationary.

- **Non-stationarity (I(1))**: Euribor, HPI, stock price index, exchange rate, and interest rate spread are non-stationary across all tests.

### B.4 Cointegration analysis

To assess the presence of long-run relationships among the variables used in our Taylor rule estimation, we conducted a Johansen cointegration test using Python code provided by Michael Bergman (2023). We do this because Euribor, HPI, stock price index, exchange rate, and interest rate spread are non-stationary; however, we estimate them in levels to be consistent with the literature (e.g., Papadamou et al. (2018)).

Our cointegration procedure follows these steps:

- We estimate a VAR model for the full sample with the variables used in section 5 and a constant and two lags, selected based on the Akaike Information Criterion (AIC) and Hannan-Quinn Criterion (HQ).
- We test for the presence of a deterministic linear trend in the cointegration vector. The p-value of 0.4606 leads us to fail to reject the null hypothesis of no trend, which indicates that a model with a constant, but not a trend, in the cointegration vector, is appropriate.
- Based on this, we estimate the cointegration relationship using the following error correction term:

$$\alpha\,(\beta' y_{t-1} + c_0) + c_1 \tag{B.2}$$

  which corresponds to model 3 (constant in the cointegration vector, linear trend in levels).

We report the results from the Johansen trace test in Table ??.

| $r$ | **Trace Statistic** | **Critical Value (5%)** | **Critical Value (10%)** | **p-value** | **Eigenvalue** |
|---|---|---|---|---|---|
| 0* | 258.391 | 159.530 | 153.632 | 0.001 | 0.6395 |
| 1* | 158.399 | 125.618 | 120.369 | 0.001 | 0.4214 |
| 2* | 104.783 | 95.754 | 91.108 | 0.010 | 0.3325 |
| 3 | 65.173 | 69.819 | 65.819 | 0.112 | 0.2355 |
| 4 | 38.853 | 47.856 | 44.493 | 0.288 | 0.1729 |
| 5 | 20.253 | 29.798 | 27.066 | 0.442 | 0.0842 |
| 6 | 11.635 | 15.495 | 13.430 | 0.175 | 0.0718 |
| 7 | 4.338 | 3.842 | 2.706 | 0.037 | 0.0433 |

Table B.2: Results from Johansen cointegration test

To determine the number of cointegrating relationships, we apply the Pantula principle. Starting from the null hypothesis $\mathcal{H}_0 : r = 0$, we proceed sequentially upward and test for higher ranks. We reject $\mathcal{H}_0 : r = 0$, $\mathcal{H}_0 : r = 1$, and $\mathcal{H}_0 : r = 2$, but fail to reject at $\mathcal{H}_0 : r = 3$. Therefore, we conclude that the system contains $r = 3$ cointegrating vectors. Hence, we do have evidence of cointegration between the variables.

## B.5 Mean Interest Rate Gaps ($\mathrm{MIG}_i$) for sub-periods

| **Period** | **Country** | **Simple** | **ms** | **hpi** | **stocks** | **fx** | **is** |
|---|---|---|---|---|---|---|---|
| Pre-crisis | Austria | -0.21 | -0.18 | 0.50 | -4.79 | -0.58 | -6.80 |
| | Belgium | -0.10 | -0.08 | 1.10 | -4.66 | -0.26 | -6.06 |
| | France | -0.37 | -0.33 | -0.66 | -4.57 | -0.96 | -7.63 |
| | Germany | -0.53 | -0.48 | -3.52 | -4.58 | -1.39 | -8.61 |
| | Ireland | 1.37 | 1.31 | 5.55 | -4.63 | 3.29 | 1.13 |
| | Italy | 0.12 | 0.13 | -0.67 | -2.03 | 0.29 | -4.86 |
| | Netherlands | 0.06 | 0.07 | -1.20 | -4.83 | 0.15 | -5.20 |
| | Spain | 0.81 | 0.77 | 3.40 | -4.06 | 2.03 | -1.24 |
| Crisis | Austria | 1.20 | 0.90 | -1.13 | 0.46 | 0.97 | 0.80 |
| | Belgium | 1.13 | 0.84 | 0.20 | 0.37 | 0.88 | 0.76 |
| | France | 0.79 | 0.57 | 0.68 | 0.05 | 0.62 | 0.40 |
| | Germany | 0.91 | 0.67 | -0.89 | 0.23 | 0.74 | 0.48 |
| | Ireland | 0.27 | 0.14 | -0.30 | -0.56 | 0.05 | 0.04 |
| | Italy | 1.02 | 0.75 | 2.82 | 0.48 | 0.81 | 0.69 |
| | Netherlands | 1.04 | 0.77 | 1.62 | 0.27 | 0.84 | 0.63 |
| | Spain | 1.01 | 0.74 | 3.09 | 0.36 | 0.81 | 0.68 |
| Post-crisis | Austria | -0.33 | -0.29 | -0.12 | 0.48 | -0.20 | -0.55 |
| | Belgium | -0.33 | -0.29 | -0.03 | 0.49 | -0.21 | -0.54 |
| | France | -0.25 | -0.22 | -0.01 | 0.58 | -0.16 | -0.44 |
| | Germany | -0.27 | -0.24 | -0.14 | 0.54 | -0.17 | -0.50 |
| | Ireland | -0.23 | -0.22 | -0.19 | 0.62 | -0.17 | -0.37 |
| | Italy | -0.23 | -0.21 | 0.07 | 0.59 | -0.15 | -0.33 |
| | Netherlands | -0.31 | -0.28 | -0.15 | 0.50 | -0.19 | -0.53 |
| | Spain | -0.23 | -0.21 | -0.10 | 0.58 | -0.14 | -0.38 |

Underlined countries are the periphery countries, while the others are core countries
Pre-crisis: 1999Q1-2007Q2, Crisis: 2008Q3-2015Q1, Post-crisis: 2015Q2-2020Q1.

# Appendix C Robustness appendix

## C.1 Robustness check with MRO as the interest rate

| | (5.1) | (5.2) | (5.3) | (5.4) | (5.5) | (5.6) |
|---|---|---|---|---|---|---|
| $C_\pi$ | 0.306** | 0.302*** | 0.493*** | 0.414*** | 0.260*** | 0.144** |
| | (0.130) | (0.078) | (0.049) | (0.060) | (0.083) | (0.061) |
| $C_y$ | −0.371*** | −0.452*** | −0.136*** | −0.182*** | −0.035 | −0.426*** |
| | (0.126) | (0.154) | (0.040) | (0.056) | (0.052) | (0.122) |
| $C_{\text{ms}}$ | | 0.878*** | | | | |
| | | (0.100) | | | | |
| $C_{\text{hpi}}$ | | | −0.103*** | | | |
| | | | (0.009) | | | |
| $C_{\text{stocks}}$ | | | | −0.00002*** | | |
| | | | | (0.000) | | |
| $C_{\text{fx}}$ | | | | | −1.716 | |
| | | | | | (1.441) | |
| $C_{\text{is}}$ | | | | | | 0.351*** |
| | | | | | | (0.042) |
| Observations | 98 | 98 | 98 | 98 | 98 | 98 |
| Hansen $J$ (p-val.) | 0.6 | 0.64 | 0.65 | 0.67 | 0.64 | 0.63 |

Standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.010

Table C.1: Robustness check 1: Estimation results for a Taylor rule with MRO

## C.2 Robustness check with monthly data

| | (6.1) | (6.2) | (6.3) | (6.4) |
|---|---|---|---|---|
| $C_\pi$ | 0.276*** | 0.374*** | 0.203 | 0.0906 |
| | (0.0964) | (0.126) | (0.125) | (0.108) |
| $C_y$ | 0.180 | 0.0110 | 0.229 | 0.377* |
| | (0.253) | (0.205) | (0.310) | (0.227) |
| $C_{\text{stocks}}$ | | −0.0000247*** | | |
| | | (0.00000851) | | |
| $C_{\text{fx}}$ | | | −1.508 | |
| | | | (1.992) | |
| $C_{\text{is}}$ | | | | −0.789*** |
| | | | | (0.122) |
| Observations | 298 | 298 | 298 | 298 |
| Hansen J (p-val) | 0.5 | 0.65 | 0.66 | 0.72 |

Standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.010

Table C.2: Robustness check 2: Estimation results using monthly data

## C.3 Robustness check with forward-looking Taylor rule

| | (7.1) | (7.2) | (7.3) | (7.4) | (7.5) | (7.6) |
|---|---|---|---|---|---|---|
| $C_{\mathbb{E}[\pi]}$ | 0.553*** | 0.605*** | 0.765*** | 0.712*** | 0.546*** | 0.347*** |
| | (0.137) | (0.0785) | (0.0587) | (0.0750) | (0.126) | (0.0657) |
| $C_{\mathbb{E}[y]}$ | −0.130** | −0.249*** | −0.0903** | −0.147*** | 0.0444 | −0.262*** |
| | (0.0640) | (0.0919) | (0.0412) | (0.0471) | (0.0600) | (0.0837) |
| $C_{\text{ms}}$ | | 0.794*** | | | | |
| | | (0.101) | | | | |
| $C_{\text{hpi}}$ | | | −0.106*** | | | |
| | | | (0.0106) | | | |
| $C_{\text{stocks}}$ | | | | −0.0000280*** | | |
| | | | | (0.00000465) | | |
| $C_{\text{fx}}$ | | | | | −1.123 | |
| | | | | | (1.852) | |
| $C_{\text{is}}$ | | | | | | 0.334*** |
| | | | | | | (0.0387) |
| Observations | 98 | 98 | 98 | 98 | 98 | 98 |
| Hansen J (p-val) | 0.52 | 0.65 | 0.68 | 0.69 | 0.65 | 0.64 |

Standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.010

Table C.3: Robustness check 3: Estimation results for a forward-looking Taylor rule