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# Do the projected fiscal deficits play a role in ECB monetary policymaking?[1]*

Linas Jurkšas[#], Francisco Gomes Pereira[$]

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**ABSTRACT**

We estimate a large number of alternative monetary policy reaction functions for the ECB in order to robustly find if fiscal stance matters for the monetary policy conduct. We use GMM and SVAR methods to estimate inflation-output reaction functions with and without a fiscal deficit indicator from 2001 until 2022 with the thick-modelling approach. The results revealed that ECB actions have exhibited desirable stabilising monetary policy properties and have generally been found to be consistent with the Taylor principle. Most importantly, the projected euro area fiscal deficit usually is not statistically significant in explaining ECB monetary policy stance. Nevertheless, when the fiscal deficit indicator is statistically significant, the sign of its coefficient is always positive, implying that increasing deficits lead to a more restrictive monetary policy stance. These findings speak against the "fiscal dominance" regime in the euro area where monetary policy is single and fiscal policies are decentralised. The results remain qualitatively similar independent of the precise specification of the GMM and SVAR models and if the sample period is shortened from 2012.

**Keywords:** ECB, monetary policy, reaction function, Taylor rule, fiscal deficits, fiscal stance.

**JEL codes:** E43; E52; E58; E61; E62; H62.

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# 1. INTRODUCTION

The ECB was set up in 1999 specifically as an independent institution upon a very clear mandate to maintain price stability in the euro area. At the time of ECB creation, the scenario of “fiscal dominance”, a situation when excessive deficits pressure the central bank not to have restrictive monetary policy, were still in the memories of policymakers. As a result, the Maastricht Treaty included strong safeguards against “fiscal dominance” by granting full operational and decision-making independence to the ECB. Central bankers often address the issue of independence by emphasizing the benefits that an independent monetary policy has been bringing to the economy and people (Mersch, 2020; Schnabel, 2020).

However, the relative independence of the ECB (as well as other central banks) has been increasingly questioned due to the spike in the fiscal debt levels since the onset of the Global financial crisis (GFC) of 2007-2008 and Covid-19 shock in 2020-2021. Although the euro area fiscal rulebook (such as the Stability and Growth Pact) was intended to limit the growth of public debt and in this way to shield ECB from the “fiscal dominance” risk, euro area governments have actually substantially increased their borrowings in order to reduce negative effects of the downturns. According to Rogoff (2020), no advanced country has figured out how to consistently conduct technocratic fiscal policy due to the politics that is hardwired into fiscal policy actions. The debt / GDP ratio has increased from 66% in 2007 to 95% in Q2 2022 in the euro area. Rising indebtedness means that governments have to roll over increasing amounts of debt.

These actions by governments coincided with low or even negative policy rates, vast sovereign bond purchases and other unconventional measures. For instance, the ECB lowered the deposit facility rate close to 0% level in mid-2009 and even lowered it to negative territory in 2014. The ECB started purchasing bonds of several euro area sovereigns in the context of the Securities Markets Programme in 2010 and announced Outright Monetary Transactions as a backstop to financial and fiscal fragmentation in 2012, although it was never used in practice (ECB, 2022). In addition, ECB started the Public Sector Purchase Programme with the ECB’s self-imposed purchase limits in 2015 and introduced the Pandemic Emergency Purchase Programme with the loosening of previously established limits in 2020. Similar actions were employed by other major central banks in the US, UK, Japan and other.

Many economists began questioning the boundaries between monetary and fiscal policies. According to Sims (2016), such fiscal and monetary actions were a move towards coordinated fiscal and monetary expansion. Blanchard and Pisani-Ferry (2020) stated that large central bank purchases of government debt increase the risk of “fiscal dominance”. Gros (2022) argued that central banks’ bond-buying programs constitute a quasi-fiscal policy that eventually might lead to central banks’ portfolio losses and that many historical examples show how high government debt is eventually “resolved” through financial repression, i.e., measures aiming to keep interest rates artificially low, and higher inflation. Buiter (2022) argues that the “fiscal dominance” interpretation might be particularly convincing in the case of ECB as it has to deal with several euro area sovereigns that are fiscally fragile.

Central banks publicly argue against fiscal repression and overall “fiscal dominance” regime. Schnabel (2022) and ECB (2022) stated, for example, that excessive fiscal accommodation would necessitate a stronger monetary policy response due to higher inflationary pressures. This means that the central bank would not accommodate higher deficits with the restrained interest rates as it is obliged to seek its primary mandate of price stability. Besides, monetary policy is single, while fiscal policy actions are decentralised in the euro area - this means that it would be way harder for a fiscal authority from a particular member state to bear a material influence on ECB actions.

In this context, it is important to check empirically if projected fiscal deficits are among the factors that have been influencing ECB monetary policy stance decisions. Friedman (1982) proposed that monetary policy should be based on rules as opposed to the discretion of the authorities. Traditionally, the most conventional policy rules are modelled in terms of inflation and the economic slack. In his seminal paper, Taylor (1993) found that monetary policy rules in which the FED changed short-term interest rates were linked to inflation and output gaps. Although Taylor-type rules neglect the significant uncertainty that monetary policymakers face when setting their policy, they still help to evaluate if monetary policy systematically pursues a course of action that is (in)consistent with the stated goals. However, there is an apparent lack of empirical papers that test if fiscal stance motives are inherent in monetary policymaking.

This study explores if ECB monetary policy reacts to the changing projected fiscal stance in the euro area. We address this issue with the "thick-modelling" approach by estimating up to 576 different policy rules for projected 4 different inflation, 6 output (gap) and 4 fiscal deficit indicators. We present the median values of the estimated parameters as well as the full distribution of coefficients for the analysed variables. The "thick-modelling" approach acknowledges the large information set at hand that policy makers might use in practice and helps to get more robust results. This is particularly important in the case of the euro area where the single monetary policy has to deal with often poorly coordinated fiscal stances of separate member-states.

Our main finding is that the projected fiscal stance is usually not statistically significant in altering monetary policy stance in the euro area. Irrespective of its significance, the estimate of fiscal deficit indicator is always positive, meaning that increasing fiscal deficits might have led to tighter monetary policy stance, suggesting against the "fiscal dominance" regime in the euro area. One possible explanation of this link is that projected fiscal deficits might act as some sort of leading indicator of potential inflationary pressures that might emerge in the future - similarly as stated by Schnabel (2022) and ECB (2022). We also find that the coefficients of other (standard) Taylor-type variables are positive and in line with other similar studies. Importantly, the coefficients of other variables do not change materially when a fiscal stance indicator is added to the model. This is also confirmed when the sample period is shortened from 2012 when non-standard measures were increasingly employed by the ECB and that also encompasses Covid-19 shock. The results of GMM methods were also confirmed by the impulse response functions (IRFs) obtained from a structural VAR model. Particularly, an innovation to the projected euro area fiscal deficit does not generate a significant and substantial response in the ECB monetary policy stance. An innovation to projections of output growth and inflation gap generates a positive and significant restrictive response in the ECB monetary policy stance, the magnitude being substantially larger for an innovation in the projected inflation gap variables. Forecast error variance decompositions also suggest that the ECB monetary policy stance response is primarily driven by inflation gap shocks. These findings are in accordance with the view that, during the estimated period, ECB monetary policy operated independently and was not affected by the fiscal policy stance.

Our paper provides several novel aspects. First, we propose empirical methods that might help answer the question if monetary policymakers have reacted to the changing fiscal stance. Although there is a separate and wide strand of literature of fully structural models that focus on monetary-fiscal interactions, particularly – on the implications of "fiscal dominance" regime (Sargent and Wallace, 1981; Cochrane, 2010; Sims, 2016), there are only a handful of papers that try to empirically investigate if there are fiscal stance implications in monetary policymaking. There are also a lot of studies on augmenting Taylor-type reaction functions with financial or other indicators, but the empirical investigation with fiscal variables is the rare exception, particularly for the advanced economies. We use two different methods – GMM and SVAR – to have more robust results. Second, we concentrate on the projected real-time variables to bring the theory closer to the practice of central bank actions. The indicators for fiscal stance, inflationary pressures and output are obtained from the publicly available institutional projections and surveys that have been available for the monetary policymakers at their decision time. As emphasized by Woodford (2007), an important feature of "optimal" monetary policy is that it should respond to the projected future path of the economy and not only to the current conditions. Third, to capture the ECB's general policy actions, we rely on a measure of aggregate monetary stance indicator – shadow rates – instead of the standard policy rates as they may not represent the full picture. Policy rates have been constrained by the zero lower bound since the GFC and, even more severely, since the European debt crisis of 2010-2012. Fourth, we also compare the results between the full data sample (i.e., since the creation of the euro area) with the shorter period since 2012 when ECB started increasingly undertaking various unconventional monetary policy measures and that includes the Covid-19 crisis period. In this way, we can test whether there are significant differences in the response coefficients in both periods. Fifth, we rely on a "thick modelling" framework that considers many quarterly-frequency variable selection variations for the ECB monetary policy reaction function. This enables us to acquire more reliable outcomes and to monitor the spread of potential parameter estimates.

The paper is organized as follows. The relevant literature of methodological aspects of monetary policy reaction functions is described in section 2. The data used and the methodology is described in section 3. The estimation results of GMM and SVAR methods are presented in section 4. Concluding remarks follow in section 5.

# 2. LITERATURE ON METHODOLOGICAL ASPECTS OF MONETARY POLICY REACTION FUNCTIONS

The seminal work of Taylor (1993) showed that a straightforward specification of monetary policy reaction function can relatively accurately mimic the actual FED interest rate changes in 1987-1992. This research has altered economic professionals' focus from monetary aggregates to interest rates as a suitable monetary policy instrument (Beck and Wieland, 2008). According to his initial rule, FED's nominal interest rate *(i)* is determined by the deviation of the inflation over four past quarters *(π)* from its target *(π*)* and to the deviations of the output growth *(y)* from its trend growth *(y*)*:

$$i_t = \pi_t + 0.5(\pi_t - \pi^*) + 0.5(y_t - y*) + 2\% \qquad (1)$$

As the initial coefficients set by Taylor (1993) for the inflation gap (as well as for the output gap) was 0.5 and additional 1 for the recent inflation, the overall reaction coefficient to inflation is assumed to be 1.5. This means that nominal interest rates should increase by more than the increase of inflation so that real interest rates would also increase.[2] As a result, such reaction of a central bank was regarded as showing stabilisation properties. For instance, Belke and Klose (2010) found that the "Taylor principle", i.e. the assumption of an inflation coefficient above unity, was violated by the FED reaction until the GFC, concluding that they do not find evidence supporting the "Taylor principle". Owusu (2020) found that coefficients of inflation for both ECB and Riksbank is above unity, suggesting the inflation-stabilizing motive in both central banks.

A wide range of other researchers tried to estimate the original or modified versions of Taylor (1993) rule. Usually, researchers try to estimate the actual coefficients for inflation, output and other variables, apply it for countries other than the US and employ alternative specifications by, for instance, changing the selected variables or adding the new ones. The conducted research usually differs in at least such important aspects: i) backward / forward looking-ness of the variables; ii) real-time versus *ad hoc* data; iii) type of output / slack variable; iv) rules with smoothing / non-smoothing element; v) type of implicit or explicit natural rate; vi) additional variables used; vii) expression of the dependent variable; viii) fully-structural, semi-structural or empirical type of studies.

The original Taylor rule is considered to be backward-looking, i.e., the central bank considers only the past values of inflation and output gap when setting the interest rate. Many other authors also prefer to use past values. Belke and Klose (2010) and Afonso et al. (2019) use values of past inflation and other variables.

[2] If the overall coefficient for inflation would be below 1, when the increase of inflation would lead to slower rise in nominal rates and thus real rates would actually decrease, meaning that monetary policy stance would become more accommodative in the face of increasing inflation.

Nyumuah (2018) finds that the model with backward-looking data appears to be more suitable in terms of consistency and robustness of their results. However, more recent research increasingly employs forward-looking variables because an important feature of "optimal" monetary policy is that it should respond to the projected future path of the economy (Woodford, 2007). Central banks usually commit to anchor their medium to longer-term inflation expectations. In this respect, Clarida et al. (2000) made an important innovation by relating nominal interest rates to the forward-looking indicators of inflation and output (employment) gap with smoothing parameter *(ρ)*:

$$i_t = \rho \cdot i_{t-1} + (1-\rho) \cdot [\alpha_0 + \beta_\pi \, (\pi_{t+h} - \pi^*) + \gamma_y \, (y_{t+k} - y *)] + \varepsilon_t \qquad (2)$$

This element of forward-lookingness postulated by Clarida et al. (2000) is often used in many subsequent studies. Blattner and Margaritov (2010) find that the ECB seems to react almost twice as strongly to the movements in inflation expectations for the next year as compared to the current year. They argue that if the central bank would only react to past inflation developments, it would face difficulties in stabilizing the economy given the significant lags in the transmission of monetary policy. Hartmann and Smets (2018) also tested several different forecast horizons and found that the one-year ahead projections for both GDP growth and inflation are the most informative for the ECB policy decisions. Paloviita et al. (2021) argues that it is very important to select correct horizon of the variables as, for instance, the projected values of the economic variables at the end of the forecast horizon might be biased towards the models' long-run equilibriums, i.e., values to which they are expected to converge in the absence of new shocks hitting the economy. Also, researchers usually choose the relatively short forecast horizons for reaction function variables due to poorer forecast accuracy over a longer period of time. Therefore, it is not advisable to use the variables of the end of the forecast horizon. When estimating the reaction functions for the ECB, Gerlach and Lewis (2014) as well as Neuenkirch and Tillmann (2014) consider one-year-ahead forecasts of inflation and output growth.

An inter-related issue that has often been neglected, particularly in earlier articles, is the timeliness of the data. Changes in the policy rates are often linked to the data that was not yet available to policymakers at the time of the decision. For instance, Orphanides (2001) uses quarterly data by implicitly assuming the policymakers' knowledge of that quarter's data, although such data was actually not available at that point in time. To make the research more in line with practice, more researchers started using the forecasted data. As a proxy for the information that is available for ECB at its monetary policy meeting time, the SPF (e.g., Gerlach and Lewis, 2014; Bletzinger and Wieland, 2017), Consensus forecast (e.g., Gorter et al. 2008) and, more lately, actual ECB forecasts[3] (Paloviita et al., 2021) have been used. For instance, Bletzinger and Wieland (2017) argue that nominal interest rates set by central banks are adjusted through two equally important elements: 4-quarters-ahead inflation gap and output gap forecasts from the most recent data point available, i.e., 3-quarters ahead for inflation and 2-quarters for output gap.

Another important innovation of Clarida et al. (2000) is the use of smoothing parameter *(ρ)* for nominal interest rate adjustment. This parameter is used in majority of subsequent research as in practice central banks adjust the interest rate gradually rather than immediately to the level that is expected to most rapidly close the expected output gap and keep expected inflation on target. Central banks tend to adjust interest rates in a sequence of smaller steps in the same direction (rather than one huge "jumbo" move) and rarely change the direction of interest rate movements. Clarida et al. (2000) motivate the inclusion of smoothing parameter to the fact that central banks usually try to avoid excessive volatility in interest rates, partly due

[3] The ECB staff projections of quarterly frequency became publicly available quite recently, so there is a lack of research on reaction functions with such frequency projections. It is also important to bear in mind that ECB staff projections are not approved by the ECB's Governing Council, but are only considered as one input among many in the decision-making process.

to the uncertainty of projected variables. Interestingly, Mishkin (2009) argued that it is important to investigate reaction functions during several different periods as, for instance, he found that monetary policy is less inertial during a financial crisis period.

There is a lot of discussion on what type of output / slack variable should be used in the central banks' reaction functions. Different measures of slack in real economic activity are likely to entail a very different policy response. Orphanides (2001) pointed out that a critical aspect of policy reaction rules is the emphasis on a concept of the economy's potential activity level, and it is unclear which of the concepts is the most appropriate for estimating the cyclical position of the economy. Originally, Taylor (1993) and Clarida et al. (2000) used the output gap indicator as it shows the economic situation relative to some economic trend or potential of a concrete period. Paloviita et al. (2021) state that the GDP projections by the ECB seem to capture the slowdown of long-run growth rates over time as they did not revert toward a single long-run value. In research, a lot of authors use the Hodrick-Prescott filter to generate the output gap from its trend (Nyumuah, 2018; Agnello et al., 2019), while others take the difference to the estimated potential level of the economy. Measuring an unobserved variable of output gap (in particular – potential output) is quite difficult and prone to error. Blattner and Margaritov (2010) argued that under some circumstances this might not just be a matter of magnitude: one measure might suggest a positive output gap, while another might imply a negative one. It is also questionable if it is a good practice in policymaking to base their decisions on such uncertain measures of the cyclical position of the economy. Orphanides (2001) shows that the key source of the policy failure associated with the Great Inflation in the United States was the pursuit of activist policies based on real-time estimates of potential output that were severely overstating the economy's capacity. The problem of reliable real-time output gap estimate is especially severe for the euro area due to a relatively short sample period and methodological issues on country aggregation. As a result, policymakers do not usually discuss the levels or changes of output gap measures when it communicates its policy decisions to the public.[4]

Another way to include activity variable into reaction functions is to consider indicator that does not directly rely on the output gap. A number of authors (Orphanides, 2001; Blattner et al., 2010; Papadamou et al., 2018) advocate using a simple output growth indicator as it suffers from fewer measurement problems. Such "growth" rules are hence a simple and effective approach for dealing with the ignorance about the degree of uncertainty surrounding the estimates of potential output in the real time. Avoiding the level of the output gap in the estimation of policy rules is a robust approach for hedging against non-trivial measurement problems.

There is also a difference in how the natural interest rate is expressed in monetary policy reaction functions. The natural interest rate (also called r*, neutral or equilibrium rate) is a rate at which monetary policy is neither stimulating nor restricting economic growth and can be traced back to Wicksell (1898). This rate is set to a constant value of 2% in the original Taylor (1993) rule under formula (1). Due to the fact that this rate is unobservable and there is considerable uncertainty of estimates of this rate, it is often held implicitly constant (as an intercept) in many similar types of research (e.g. Orphanides, 2001; Hartmann and Smets, 2018; Agnello et al., 2019). However, there is compelling evidence that during the last several decades the natural interest rates have trended downward in (at least) advanced economies. Yellen (2015) states that the US real natural rate has diminished through the time, so the reaction functions that include this time-varying assumption are more realistic. As a result, increasingly more researchers use time-varying natural rates. For instance, Belke and Klose (2010) include an explicit equilibrium real rate that is calculated in accordance with Laubach and Williams (2003) model. Paloviita et al. (2021) append some of the model specifications with the

[4] ECB President J. C. Trichet in November 2004 famously stated that it would even "be dangerous to derive monetary policy decisions from such an indicator *[as output gap]*. In my view, the example of the "output gap" demonstrates that theoretical economic models and monetary policy practice are, at times, quite far apart."

real interest rate as a proxy for the real natural rate (e.g. German government bond yields) - their results support specifications with reaction functions including a proxy for the natural interest rate.

Although two-variable reaction functions are easy to estimate and communicate publicly, policy-makers are unlikely to agree that the monetary policy actions are solely dependent only on the (projected) inflation and output. Econometric models try to simplify the reality, but a two-variable rule is an admittedly too simplistic approach to mimic the actual behaviour of policymakers. As central banks face great uncertainty about the state of the economy that are affecting their projections and risk balance, they typically monitor a large array of economic and financial indicators. While inflation and economic growth are the common targets of monetary authorities, they also have a great concern over the developments in the financial sector and other areas (Agnello et al., 2019). Therefore, there is certainly a set of other data beyond the inflation and output (gap) that might drive the interest rate setting behaviour of the central banks, in particular during exceptional times.

The additional variables that many researchers augment two-variable central bank reaction functions can be grouped into such broad buckets: i) exchange rates; ii) money supply and developments in credit market; iii) asset prices; iv) other variables. First, many researchers add exchange rates of the respective country on which central bank reaction function is estimated because the changes of domestic exchange rate affect the imported inflation and the balance of payments of particular country (Nyumuah, 2018; Owusu, 2020; Taguchi and Gunbileg, 2020; Papadamou et al., 2018; Anderl and Caporale, 2022). Second, money supply or credit dynamics might imply future inflationary pressures and are often regarded as leading indicators, particularly before the GFC of 2007-2008 (Belke and Klose, 2010; Castro, 2011; Afonso et al., 2019; Hartmann and Smets, 2018). Third, asset price developments might signal the changes in financial stability stance and thus might affect monetary and economic developments in the future (Castro, 2011; Papadamou et al., 2018; Zhu et al., 2021). Fourth, other authors add less traditional variables such as shadow banking proxies (Agnello et al., 2019), interest rate spreads (Belke and Klose, 2010), past inflation gap (Paloviita et al., 2021).

In an environment where central banks started employing various unconventional measures as policy rates reached or even broke the zero lower bound, the major issue associated with the estimation of central bank reaction function is that short-term policy rates do not represent the actual stance of monetary policy. Models based on the central bank policy rate are well suited to capture the impact of conventional monetary policy in “normal” times, while models should acknowledge the term spread in “exceptional” times (Holston et al., 2017). If the central bank wants to increase its monetary policy accommodation when interest rate is already constrained, it can employ various unconventional measures such as asset purchases, long-term refinancing operations and forward guidance. For instance, ECB has strengthened its communication and adopted a forward-guidance framework since 2013 in order to inform markets and the public on its future intentions with regard to key policy rates, in this way affecting the term premia of full rate spectrum. The ECB also launched a Public Sector Purchase Programme in March 2015 to address risks of prolonged periods of low inflation by impacting the long-term rates (ECB, 2021).

Under such circumstances, several authors have developed frameworks that allow to quantify the stance of monetary policy via the estimation of a synthetic indicator called “shadow rate” that captures unconventional as well as conventional policy measures. It indicates how much the central bank would have lowered the interest rates had the zero lower bound not been binding, i.e., it reflects monetary policy stance in a very low or even negative interest rate environment (Lombardi and Zhu, 2018; Krippner, 2015; Kortela, 2016; Wu and Xia, 2016). For instance, Lombardi and Zhu (2018) propose an estimated shadow policy rate for the US that helps to identify monetary policy shocks by also reflecting the FED’s unconventional policy measures.

Several recent empirical studies use shadow rates in similar type of reaction function analyses. Hartmann and Smets (2018) compare their results of the constructed reaction function to the changes in the shadow rates. Agnello et al. (2019) use shadow rates as well as term spread under their reaction functions and find that they usually react to the developments in the inflation rate and the output gap in the US. Paloviita et al. (2021) use shadow rates calculated for the euro area (Kortela, 2016; Wu and Xia, 2016) to compare them with the reaction function predictions. Lombardi and Zhu (2018) compare their shadow rate estimates with the levels of federal funds rate prescribed by Taylor rules.

There are many studies that deal with structural models on how fiscal policy actions might impact monetary policymaking. The main finding of Sargent and Wallace (1981) was that a central bank may not have the power to determine the long-run rate of inflation without fiscal support, i.e. an attempt of a central bank to tighten monetary policy for the purpose of reducing the long-run rate of inflation could conceivably backfire in the absence of fiscal support. Sims (2016) argued that insufficient support from fiscal and other economic policies has been discussed as one contributing factor for too low inflation. Cochrane (2010) emphasized that a fiscal inflation can come well before large deficits or monetization are realized, and is likely to come with stagnation rather than a boom. Ascari et al. (2022) found that in a fiscal regime, where monetary policy is accommodating fiscal policy, the anticipated government spending shock is expansionary and stimulates consumption.

Semi-structural models are also often used to assess the central bank reaction function. Vector autoregression models, since their introductions by Sims (1980), have been extensively used and adapted in the empirical macroeconomics literature. Much of their popularity is attributed to their simple formulation, flexibility and intuitive outputs (Watson, 1994; Stock and Watson, 2001). In particular, structural VAR models have been applied with much success in the context of monetary policy. However, an issue commonly encountered in these models is the “price puzzle”, which is characterized by an unexpected increase in inflation after a change in the central bank policy rate. This result clashes with theoretical assumptions and with the standard understanding of the channels of monetary policy. The presence of this puzzle is often attributed to the omitted variable bias (Sims, 1992). For instance, if the central bank increases the policy rate due to expected future supply side inflation (i.e. from increased commodity prices), the VAR results might be spurious because it is not capturing full-spectrum of the data that is actually factored in monetary policy decisions (Stock and Watson, 2001). The inclusion of commodity prices (as in Christiano et al., 1996) may help solve this issue, however the “price puzzle” remains prevalent in some VAR specifications even when including commodity prices (Hanson, 2004). The Bernanke and Blinder (1992) model consists of three variables, specifically the log of real GDP, the log of the real GDP deflation, and the federal funds rate. Christiano et al. (1996) subsequently extended this baseline model by including non-borrowed reserves and a commodity price index. By including their own novel shadow rate variable, Lombardi and Zhu (2018) sought to more accurately evaluate the FED monetary policy stance and enhance the understanding of the effects of unconventional monetary policies which is necessary to acquire more dependable results after the GFC in the US.

However, there is still a lack of empirical papers that augment traditional central bank reaction functions with fiscal stance indicators. This is possibly due to the complication in determining the most important fiscal stance indicator that might alter central bank reaction function and / or the time horizon of such variables. One of the rare examples of such research is the one of Mayandy (2019) who includes current fiscal deficit in the forward-looking reaction function for Sri Lanka central bank, but finds that this variable is statistically insignificant. Schnabel (2020) showed the results of similar empirical exercise for the euro area: the addition of government debt indicator as an explicit feedback variable to the estimated ECB policy rules did not change the coefficients of other estimated ECB reaction function variables, while the coefficient for government debt was shown not to be significantly different from zero. Afonso et al. (2019) studied the reaction function of different European countries by including output gap, inflation, and fiscal measure (the cyclically adjusted primary balance) for each country. They concluded that central banks do not react to fiscal policy because the cyclically adjusted primary balance was not statistically significant in their models.

## 3. DATA AND METHODOLOGY

We first describe and show the dynamics of the constructed projected inflation, economic activity, fiscal deficit and other variables since the creation of the euro area.

Then we present two main empirical methods that we use to answer the question if projected fiscal stance in euro area has an effect on ECB reaction function: i) GMM (Generalised method of moments); ii) Structural VAR.

### 3.1 Data

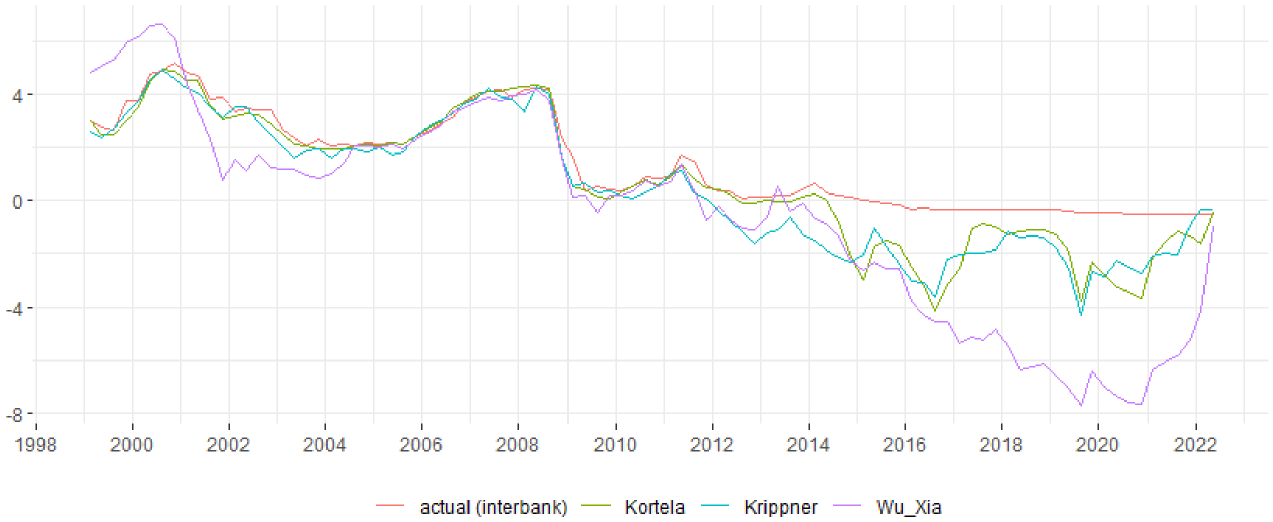
Our dataset includes the real-time[5] projections and the shadow rate for the euro area from 2001 until mid-2022, i.e., a relatively long time period that encompasses several different economic and monetary cycles. We use quarterly frequency data as this helps to directly link the monetary policy stance changes in the euro area with quarterly ECB macroeconomic projections. Below we describe our dependent and explanatory variables that we use to run various ECB reaction function specifications.

The dependent variable of this study is the shadow rate estimated for the euro area by several researchers. As the shadow rate is an imperfect and highly model-dependent gauge of the overall monetary policy stance, we use the time series of several different estimated shadow rates. The first one is calculated by Krippner (2015) with a two-factor arbitrage-free Nelson Siegel model (i.e., level and slope state factors) and a time-varying lower bound. The second one is estimated by Kortela (2016) with a multi-factor shadow rate term structure model and a time-varying lower bound too. The third one – Wu and Xia (2016) model – is a three-factor term structure model with a constant lower bound assumption.

The ECB policy rate (represented by the euro overnight interbank rate) fluctuated similarly as the estimated shadow rates, but diverged significantly when they crossed the zero lower bound (Figure 1). The shadow rates – particularly, Kortela (2016) and Krippner (2015) – have been very correlated with the overnight interbank euro rate that tracks ECB policy rate. However, the close link between policy and shadow rate broke down since around 2012 when the shadow rates went below 0% level while ECB policy rate has been stuck at this important bound. Although the main ECB policy rate – deposit facility rate – became negative in mid-2014, it did not come close to such negative levels as visible by the shadow rates because the latter represent the impact of ECB unconventional measures such as asset purchases, long-term refinancing operations and forward guidance. However, the dynamics of the shadow rate of Wu and Xia (2016) sometimes were not consistent with actual policy actions: it was often different from the euro interbank rate even before the zero lower bound was reached. This shadow rate also declined significantly in 2017-2018, although monetary policy accommodation (such as net asset purchases) has been gradually reduced. Therefore, it was decided to only use the shadow rates of Kortela (2016) and Krippner (2015) in subsequent reaction function models.

Figure 1. Actual ECB policy rate (represented by euro interbank overnight rate) and estimated shadow rates *(in percentage)* for the euro area

[5] The only exception is the natural rate indicator when it is used for particular regression. However, as this indicator is slow moving, the results do not change significantly if it is changed by the lag of the natural rate estimate.




The explanatory variables of the reactions function of the central bank are grouped into four different buckets: i) inflation gap projections; ii) economic projections; iii) fiscal projections; iv) other (control) variables.

We constructed four different indicators of <u>inflation</u> projections[6] that could approximate the ECB's medium-term orientation[7]:

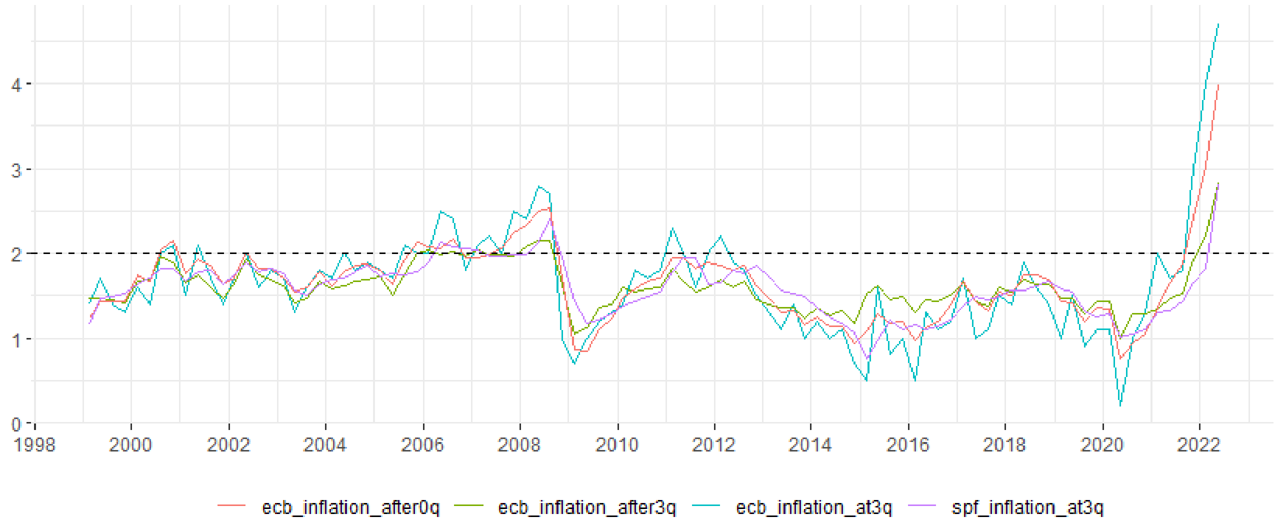
- ECB projected average *y-o-y* inflation for the full remaining projection horizon since the projections date
- ECB projected average *y-o-y* inflation after Q3 (from the projection date) until the end of the projection horizon
- ECB projected *y-o-y* inflation at Q3 after the projections date
- SPF (Survey of Professional Forecasters) projected *y-o-y* inflation at Q3 after the projections date

Although the construction and rationale for the four different projected inflation indicators is rather different, the actual dynamics of these indicators are rather similar (Figure 2). All four indicators were trending upwards until end-2008 and then slumped during the GFC. Since then, it has fluctuated in a relatively narrow range from around 1% to 2%. However, projected inflation increased substantially above the ECB inflation target in the aftermath of Covid-19 crisis and, in particular, since the jump in energy and commodity prices after Russia's invasion of Ukraine in February 2022. From all 4 indicators, the ECB projected inflation at Q3 after the projections' horizon seems to be the most volatile and usually changes the course earlier than other indicators.

Figure 2. The constructed indicators for the group of projected inflation in the euro area *(in percentage)*

[6] In GMM and SVAR models we use not projected inflation level, but the gap from the ECB target that we define as 1.9% (similarly as Paloviita, 2021) until July 2021 and 2% afterwards, i.e., after the outcome of ECB strategy review. However, the results remain almost identical if we use 1.8% or 1.7% for the ECB inflation target before July 2021.

[7] Although ECB does not provide the exact period of medium-term (as it can change under different circumstances and length of shocks), ECB since 2013 link its policy actions with the forward-looking perspective through its' forward guidance. For instance, since July 2021 until April 2022, ECB monetary policy decisions included such phrase: *"the Governing Council expects the key ECB interest rates to remain at their present [or lower] levels until it sees inflation reaching 2% <u>well ahead of the end of its projection horizon</u> and <u>durably for the rest of the projection horizon…</u>".* In this sense, the reference of this research to Q3 might act as a proxy to the ECB's decision part of "well ahead of the end of its projection horizon" and is in line with Bletzinger and Wieland (2017).




Projected economic activity group consists of 6 indicators that can be subdivided into two larger distinctive groups:

i) output growth:

- ECB projected *y-o-y* GDP growth at Q2[8] after the projections' date
- ECB projected average *y-o-y* GDP growth since the projections' date until the end of the projections' horizon
- SPF projected *y-o-y* GDP growth at Q2 after the projections' date

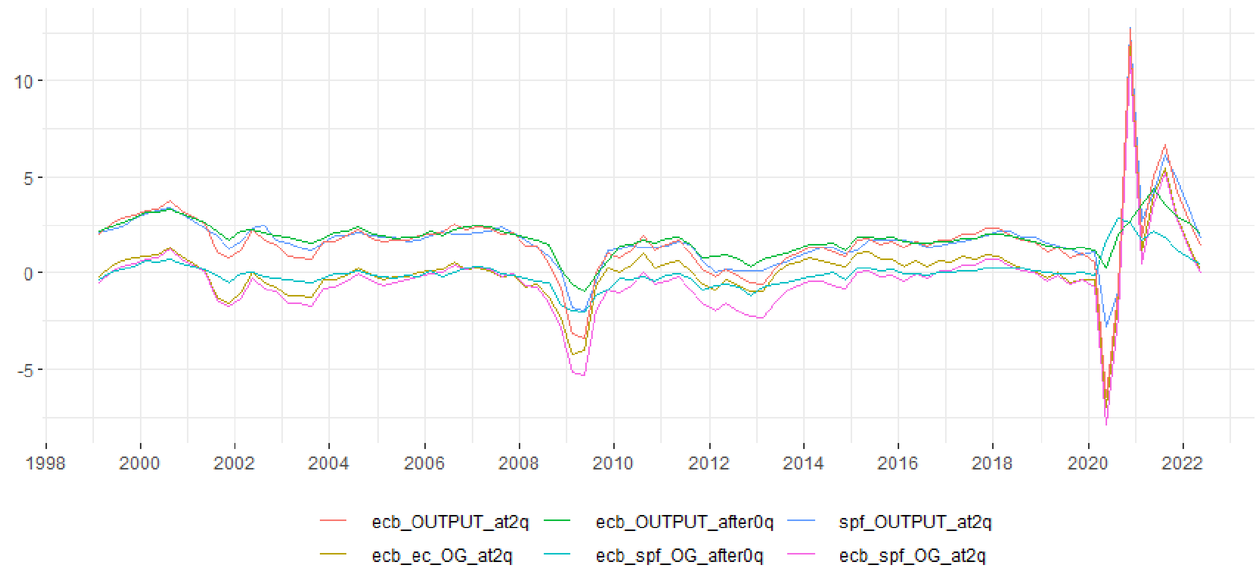
ii) output gap:

- ECB projected *y-o-y* GDP growth at Q2 after the projections' date minus SPF projected long-term GDP growth
- ECB projected average (since the projection's date until the end of the projections' horizon) *y-o-y* GDP growth minus SPF projected long-term GDP growth
- ECB projected *y-o-y* GDP growth at Q2 after the projections' date minus European Commission (AMECO) projected potential (long-term) GDP growth

These two groups fluctuate in quite distinct levels, though overall dynamics are rather similar (Figure 3). This finding is particularly clear during non-crisis times such as in 1999-2008 or 2010-2019. However, there are two evident slumps in economic activity indicators where the distinction between the lines of these two groups become less clear-cut: during the GFC and since the emergence of Covid-19 shock.

Figure 3. The constructed indicators for the group of projected output growth *(in percentage)* and projected output gap *(in percentage points)* in the euro area

[8] Reference point of Q2 is chosen for the group of projected output due to several reasons. There are many papers that support specifications with shorter projections horizon than in the case with inflation (Blattner and Margaritov, 2010; Bletzinger and Wieland, 2017). Bletzinger and Wieland (2017) specifically focus on the Q2 projections for output (and Q3 for inflation) as they wanted to use the 4-quarters-ahead forecast from the most recent data point available, e.g. the publication of GDP figures is lagging for more than one quarter in the euro area.

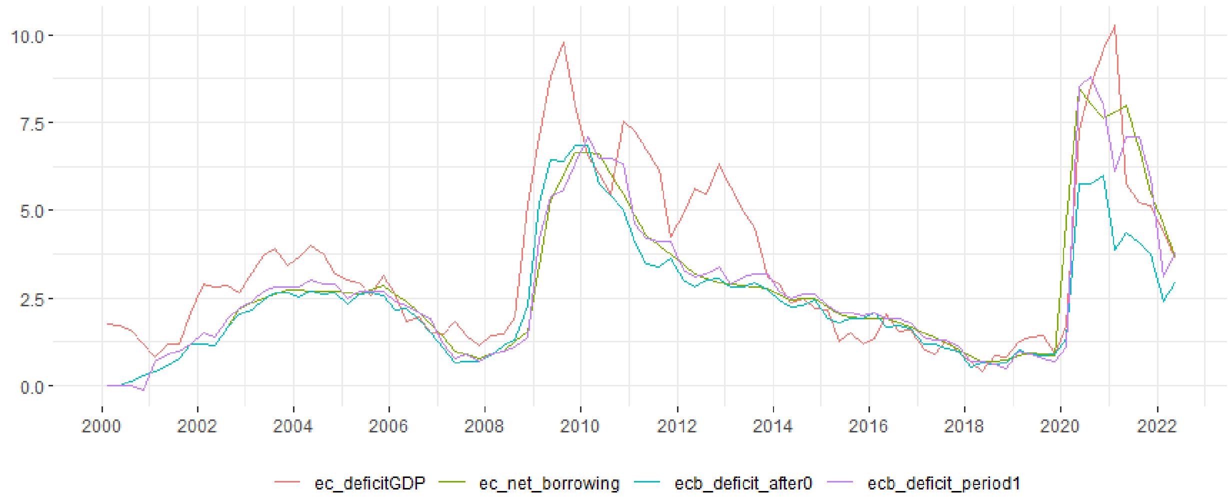



The projected fiscal deficit group consist of four different indicators:

- EC projected government deficit for the current year, % of GDP
- EC projected net borrowing by government for the next year, % of GDP
- ECB projected average general government budget balance for the full projection horizon (since the projections date until the end of the projections' horizon), % of GDP
- ECB projected general government budget balance for the next year, % of GDP

The dynamics of four different projected deficit indicators are also quite similar (Figure 4). The projected deficits were on average declining during periods of 2004-2008, 2010-2019 and since 2021, while there were two major jumps during the GFC and Covid-19 crisis. The EC indicator of projected government deficit for the current year has been more volatile during some periods. Overall, the four indicators carry a similar message about fiscal stance in the euro area, although the discrepancy between these indicators is more visible during Covid-19 crisis.

Figure 4. The constructed indicators for the group of projected fiscal deficit indicators in euro area




There are several other indicators used for particular model specifications. One of the main control variables is the natural rates estimates. We have collected three different estimates to proxy the unobservable indicator of natural rate in the euro area. Holston et al. (2017) model is built on the New Keynesian framework of a Phillips curve relationship and an intertemporal IS equation. Brand and Mazelis (2019) employ a semi-structural model with relatively similar features as in Holston et al. (2017). Ajevskis (2019) uses a macro-finance term structure model. Although the dynamics of these three natural rate estimates are often quite different, they all indicate that the natural rate has declined substantially in the euro area since 1999 (see Annex 1). In addition, we have also employed quite standard variables for GMM instruments in similar type of studies: *q-o-q* change in euro nominal effective exchange rate and Brent oil prices.

### 3.2 Methodology of GMM method

There are several reasons why the GMM method is often used in research on central bank reaction function (Clarida et al., 2000; Belke and Klose, 2010; Owusu, 2020; etc.). First, as argued by Hayo and Hofmann (2006), a major research problem with the reaction functions is that explanatory variables (both forward-looking and current) may be correlated with the error term, leading to biased estimates of the coefficient of interest. Therefore, these variables must be instrumented with additional variables. Second, the GMM method with correctly specified instruments accounts for potential simultaneity of the right-hand-side variables of the reaction function, i.e. monetary policy stance might be affecting the projections of inflation and output variables. Third, the error term may also be affected by autocorrelation and heteroscedasticity, so the use of heteroskedasticity and autocorrelation corrected GMM weighting matrix helps in this respect (Newey and West, 1987). Fourth, in some reaction functions we include unobservable natural rates – if these errors are correlated with other regressors, ordinary least squares could again give biased estimates.

Our GMM specification is similar to the one of Clarida et al. (2000) with several differences. First, we incorporate time-varying natural rates in half of our specifications as there are plenty of studies (such as Holston et al., 2017) arguing that natural rates have declined significantly during the last several decades. Second, in half of model specifications we use simple output growth variables rather than output gap indicators. Third, we employ fiscal stance indicators in half of model specifications too. The formula we use to estimate if projected fiscal stance indicator influences monetary policy stance (with output growth) is as follows:

$$i_t = \rho \cdot i_{t-1} + (1-\rho) \cdot \left[\alpha_0 + \beta_\pi(\pi_{t+h} - \pi^*) + \gamma_{\Delta y}(\Delta y_{t+k}) + \delta_{fd}(fd_{t+n}) + Dr_t^*\right] + \varepsilon_t \quad (3)$$

*where:*

- $i_t$ – shadow rate at time *t*
- $\rho$ – smoothing parameter (between 0 and 1)
- $\pi_{t+h}$ – *y-o-y* HICP inflation after period *h*
- $\pi^*$– inflation target (1.9% until July 2021, afterwards – 2%)
- $\Delta y_{t+k}$ – *y-o-y* GDP change after period *k*
- $fd_{t+n}$ – fiscal deficit after period *n*
- $r_t^*$– time-varying real natural rate
- *D* – dummy variable that equals 1 when real natural rate is added
- $\varepsilon_t$ – error term

The proper GMM estimator should satisfy the orthogonality condition between the error term $\mathcal{E}_t$ and a set of instruments $w_t$ which is within the information set at the time of central bank decision-making:

$$E[\mathcal{E}_t \mid w_t] = 0 \quad (4)$$

Likely candidates of $w_t$ include lagged terms of explanatory variables or other (current) variables that are uncorrelated with $\mathcal{E}_t$. Using GMM implies that information about error term distribution is not required.
The orthogonality condition can further be elaborated by this criterion function:

$$E[i_t - \rho \cdot i_{t-1} + (1-\rho) \cdot \left[\alpha_0 + \beta_\pi (\pi_{t+h} - \pi^*) + \gamma_{\Delta y} (\Delta y_{t+k}) + \delta_{fd}(fd_{t+n}) + Dr_t^*\right] \mid w_t] = 0 \quad (5)$$

The parameter vector of interest is [$\alpha_0$, $\beta_\pi$, $\gamma_{\Delta y}$, $\delta_{fd}$, ρ] that is estimated with the GMM procedure for various specifications with different variable combinations (e.g. $\delta_{fd}$ is estimated for half of the specifications).

The selection of instruments is an important part for GMM estimations. The suitable instruments should be exogenous (i.e. uncorrelated with the error term) and relevant (i.e. correlated with the endogenous regressors). Similarly as in other researches, we use lags of the regressors as instruments. We decided to use the same number of lags for the main Taylor-Rule type variables: 1-3 for inflation and 2-4 for the output (gap) as output numbers are revealed later than inflation values. We add lags of 1-2 periods for shadow rate and natural rate with lags of 2-3 periods for fiscal deficit whenever it is added to the GMM equation. Quarterly changes of euro nominal effective exchange rate as well as Brent prices are added as instruments too.

For the GMM estimator to be identified, there have to be at least as many instruments as there are parameters to estimate. Although GMM procedure has been shown to produce consistent estimates under some assumptions, GMM instrumental variables method can be ill-behaved if the instruments are weak even with large samples. As it is easy to find instruments that fulfil the orthogonality conditions between regressors and error term in time-series econometrics, it is necessary to test the validity of over-identifying restrictions when there are more instruments than estimated coefficients (Davidson and McKinnon, 1993). To test appropriateness of our selected set of instruments, we perform a J-test that assesses if the specifications of the monetary policy reaction function omit some important variables.

### 3.3 Methodology of SVAR model

We build a straightforward structural VAR model to test our hypothesis in the vein of Bernanke and Blinder (1992), Stock and Watson (2001), Clarida (2001), and Choi et al. (2010). These authors design a structural VAR in the context of a Taylor type rule and argue that this methodology provides a logical alternative for the analysis of a central bank reaction function to unexpected disturbances in macroeconomic variables. The principal argument for the usage of a structural VAR in this setting rests on the assumption that the typical variables in a classic monetary model are endogenous and, unlike a single equation model, a VAR can uncover dynamic variable interactions (Lütkepohl, 2005). These results might provide additional insight regarding the ECB behaviour. By employing this methodology in a “thick-modelling” approach, we estimate and report the median coefficients and trace the impulse response functions of the ECB monetary policy given an unexpected innovation to macroeconomic projections and thereby obtain a quantitative estimate of the ECB’s response. The main question we want to test is if an innovation to the projected fiscal deficit generates a statistically significant response in the ECB’s policy actions, proxied by the two measures of shadow rate described in the data section, Kortela (2016) and Krippner (2015). Our structural VAR model takes such form:

$$BY_t = \Gamma_0 + \sum_{j=1}^{n} \Gamma_j Y_{t-j} + \varepsilon_t \tag{6}$$

We estimate the reduced form representation of the structural model:

$$Y_t = B^{-1}\Gamma_0 + \sum_{j=1}^{n} B^{-1}\Gamma_j Y_{t-j} + B^{-1}\varepsilon_t \tag{7}$$

$$Y_t = A_0 + \sum_{j=1}^{n} A_j Y_{t-j} + u_t \tag{7.1}$$

*where* $A_0 = B^{-1}\Gamma_0$ and $A_j = B^{-1}\Gamma_j$ and $u_t = B^{-1}\varepsilon_t$

$A_0$ is a $K \times 1$ vector of intercepts. $A_j$ is a $K \times K$ matrix of coefficients. $u_t$ is a $K \times 1$ vector of disturbances. $Y_t$ is a vector with 4 endogenous variables, specifically.

$$Y_t = [fd_{t+n}, \Delta y_{t+k}, inf_{t+h}, i_t]'$$

*where, similar as before:*

- $fd_{t+n}$ – projected fiscal deficits after period *n*
- $\Delta y_{t+k}$ – projected *y-o-y* GDP change (or output gap) after period *k*
- $inf_{t+h}$ – projected inflation gap after period *h* ($\pi_{t+h}$ - $\pi^*$)
    - $\pi_{t+h}$ – *y-o-y* HICP projected inflation after period *h*

- $\pi^*$– inflation target (1.9% until 2021 July, afterwards – 2%)
- $i_t$ – shadow rate at time $t$

We assume the variables are covariance stationary. As a robustness exercise, we estimate an alternative model in which the shadow rate is expressed in first differences, but we obtained qualitatively similar results. Therefore, we have chosen to maintain the shadow rate in levels. We have decided to estimate the model with 1 lag. Nevertheless, we estimated the model with 2 and 3 lags and the results were again qualitatively similar. We are mostly interested in the model's policy reaction function equation, i.e. the shadow rate equation including the structural contemporaneous coefficients shown below:

$$i_t = c + \sum_{j=0}^{1} \beta_{j,1} fd_{t+n-j} + \sum_{j=0}^{1} \beta_{j,2} \Delta y_{t+k-j} + \sum_{j=0}^{1} \beta_{j,3} inf_{t+h-j} + \beta_{1,4} i_{t-1} + \varepsilon_t \quad (8)$$

The primary purpose of estimating the model is to assess the dynamic response of the ECB monetary policy stance (as captured by the shadow rate variable) in response to innovations in macroeconomic projections, through the examination of IRFs. The identification of the structural shocks is based on a recursive Cholesky identification. The basic layout is based on conventional structural VAR methodology, albeit taking on a forward looking approach.

Our main SVAR model is specified with the variable ordering as outlined above, i.e. first projections of the fiscal deficit, followed by projections of the output growth, followed by projections of the inflation gap, and lastly followed by the shadow rate. We assume that the shadow rate is impacted by contemporaneous projections of all three variables - this is natural as monetary policymakers base their decisions on the newest projections they have at that time, and we want to understand how monetary policy actions react to these three projected variables. Inflation projections will be impacted by contemporaneous values of projected output growth and the fiscal deficit. Output projections will be impacted by contemporaneous values of projected fiscal deficit. And the fiscal deficit will only react with lagged values of itself and the remaining variables. Whether fiscal deficit projections are determined based on contemporaneous future projections of output and inflation is something that is difficult to ascertain and many narratives can be constructed to support specific orderings. We selected the aforementioned ordering as it appeared to be the most logical choice and that is commonly used in relevant literature. Nevertheless, recognizing the disadvantage of not using a systematic mechanism for determining ordering – this being a well-known issue in structural VARS – we conducted a robustness exercise by estimating the model with different orderings, as suggested by Lütkepohl (2005). The qualitative results and general responses were similar, albeit to varying extents of statistical significance.

# 4. RESULTS

We present the results of two models – the GMM and SVAR – that help to reveal if projected fiscal deficits are affecting ECB monetary policy stance, and, if yes, in what way. We run these two models separately to obtain more robust findings from somewhat different angles. It is also important to check if the coefficients of standard Taylor-rule variables change materially when a fiscal variable is explicitly included in the particular model. In addition, we also run the simple OLS models for robustness check: although this model by itself does not solve the potential endogeneity problem, this might not be a major issue when forward-looking variables are used in the model (Blattner and Margaritov, 2010; Carvalho et al., 2021).

### 4.1 Results for GMM model

We start this investigation by running 576 GMM specifications of ECB reaction function when time-varying real natural rate is explicitly embedded in the model and 192 GMM specifications when real natural rate is not added. This separation is important as the results might differ substantially. Table 1 presents the median values of coefficients, standard errors as well as how many specifications for particular variable are statistically significant out of all specifications. The median determination coefficient across the different GMM models is very high – around 0.95. The median value of the coefficient of the lagged shadow rate is around 0.9 for models with time-varying natural rate and a bit higher when natural rate is not used. Importantly, the lagged shadow rate values are statistically significant (at 10% level) for all GMM specifications. This means that the ECB is significantly smoothing its policy actions in order not to shock the markets and account for high uncertainty of the projections and future economic performance.

The results for main Taylor-rule variables show that the projected inflation gap and, less frequently, economic activity has a statistically significant effect on monetary policy stance in the euro area. The median coefficient for the inflation gap is 3 – 4.5 in the specifications when time-varying natural rate is included in the specifications and even higher when natural rate is not included. It is important to note that the coefficient for inflation highly exceeds critical value of 1 and thus shows the stabilizing properties (as described by Clarida et al., 2000) of the monetary policy conduct. This coefficient is statistically significant for the vast majority of GMM specifications. Paloviita et al. (2021) find similarly high inflation coefficient (i.e., 4.45) for their preferable Taylor-rule specification for the ECB. As also stated by Blattner and Margaritov (2010), a stronger response to the projected inflation deviation from the target emphasises ECB's strong commitment to anchor inflation expectations. Meanwhile, the median coefficient for activity variable is positive and relatively similar between different indicators, but the number of significant specifications differs substantially. While output growth variable is statistically significant for 68-76% of GMM specifications, the output gap indicator is significant less frequently. For instance, the results of the GMM model without a natural rate estimate show that the output gap is insignificant (at 10% level) for almost all specifications. This suggests that simple output growth rules might be more relevant when central banks (in this case – ECB) undertake their monetary policy decisions. This is also confirmed by the verbal comments of ECB officials such as President Trichet (2004) statement that monetary policy decisions should not be made with such an unobserved (and thus impractical) indicator as output gap.

Table 1. Median results of different GMM specifications over full time sample (2001Q1-2022Q2)

| | | with time-varying natural rate | | | | no time-varying natural rate | | | |
|---|---|---|---|---|---|---|---|---|---|
| variable | | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| shadow rate (lag) | estimate | 0.878*** | 0.910*** | 0.880*** | 0.911*** | 0.922*** | 0.955*** | 0.929*** | 0.962*** |
| | st error | (0.036) | (0.041) | (0.034) | (0.037) | (0.021) | (0.025) | (0.022) | (0.024) |
| | significant | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| inflation gap | estimate | 2.939*** | 4.514*** | 3.545*** | 5.049** | 4.100*** | 7.833** | 5.1294** | 9.7187 |
| | st error | (0.867) | (1.869) | (1.133) | (1.955) | (1.567) | (3.641) | (2.218) | (5.759) |
| | significant | 100% | 92% | 100% | 86% | 97% | 76% | 98% | 49% |
| growth | estimate | 1.2659** | | 1.3065** | | 2.5923** | | 2.789** | |
| | st error | (0.59) | | (0.499) | | (1.178) | | (1.127) | |
| | significant | 79% | | 68% | | 86% | | 76% | |
| output gap | estimate | | 1.4964 | | 1.6921 | | 3.2999 | | 4.2485 |
| | st error | | (1.028) | | (0.884) | | (2.408) | | (3.002) |
| | significant | | 21% | | 27% | | 0% | | 2% |
| fiscal | estimate | | | 0.3616 | 0.3511 | | | 0.6395 | 0.7547 |
| | st error | | | (0.232) | (0.324) | | | (0.488) | (1.01) |
| | significant | | | 29% | 8% | | | 11% | 0% |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| inter-cept | estimate | -1.5337 | 1.24** | -2.162* | 0.4025 | -2.3065 | 2.7311** | -4.1767 | 0.9088 |
| | st_error | (1.075) | (0.634) | (1.245) | (0.892) | (2.065) | (1.324) | (2.939) | (2.261) |
| | significant | 39% | 58% | 54% | 27% | 31% | 69% | 33% | 14% |
| natural rate | | YES | YES | YES | YES | - | - | - | - |
| adj R2 | | 0.952 | 0.952 | 0.953 | 0.952 | 0.949 | 0.949 | 0.95 | 0.95 |
| J-statistic | | 8.38 | 8.4 | 8.63 | 8.3 | 8.35 | 8.47 | 8.33 | 8.3 |
| P(J-stat) | | 0.5 | 0.49 | 0.57 | 0.6 | 0.5 | 0.49 | 0.6 | 0.6 |

*Notes*: 1st line for each variable depicts the coefficient of the variables, 2nd line – standard errors (in brackets), 3rd line – number of statistically significant (at 10% level) variables across all specifications. Asterisk in the 1st line after coefficient indicate statistical significance of the median value at the 10% (*), 5% (**) and 1% (***) levels. Only the results of GMM specifications that pass the validity test of over-identifying restrictions are shown here.

The main results hold when ECB reaction function is augmented with a fiscal stance indicator and in most cases this variable is not significant. The statistical significance of the projected fiscal deficits varies highly for different model specifications: only 8-29% of specifications show the statistical significance when natural rate is explicitly added, while this number drops even further when natural rate is not added. In any case, the main finding from a variety of GMM model specifications is that the projected stance indicator in the euro area is rarely an important factor in explaining ECB reaction function. Similar finding was obtained by Afonso et al. (2019) and Mayandy (2019). Importantly, the median value of different specifications is positive, meaning that monetary policy is tightened (eased) when projected fiscal deficits increase (decrease). This speaks against the "fiscal dominance" regime in the euro area case, potentially because projected fiscal deficits might in some cases act as a leading indicator on how inflationary pressures might evolve due to changes in government spending and/or investments - this is often stated by central bankers themselves (e.g. Schnabel, 2022; ECB, 2022). This motivation about future inflationary pressures is similar as in the case with money supply or credit variables that were often included in similar type studies before the GFC.[9] Still, it seems that policymakers rarely base their decisions on the fiscal deficit variable as it is found to be statistically insignificant for the majority of GMM specifications. Although the addition of fiscal variable to reaction function somewhat increases the coefficients of other indicators for comparable model specifications (i.e. with/without natural rate or with particular output representation), the main findings remain the same: central bank in most cases directly react to the projected inflation gap and, less frequently, to activity forecasts.

Although the median values of "thick-modelling" approach give important insights of ECB reaction function, it hides the distribution across all model specifications. Therefore, the histogram below reveals high differences across different GMM specifications when a particular indicator is statistically significant and when time-varying natural rate is used.[10]

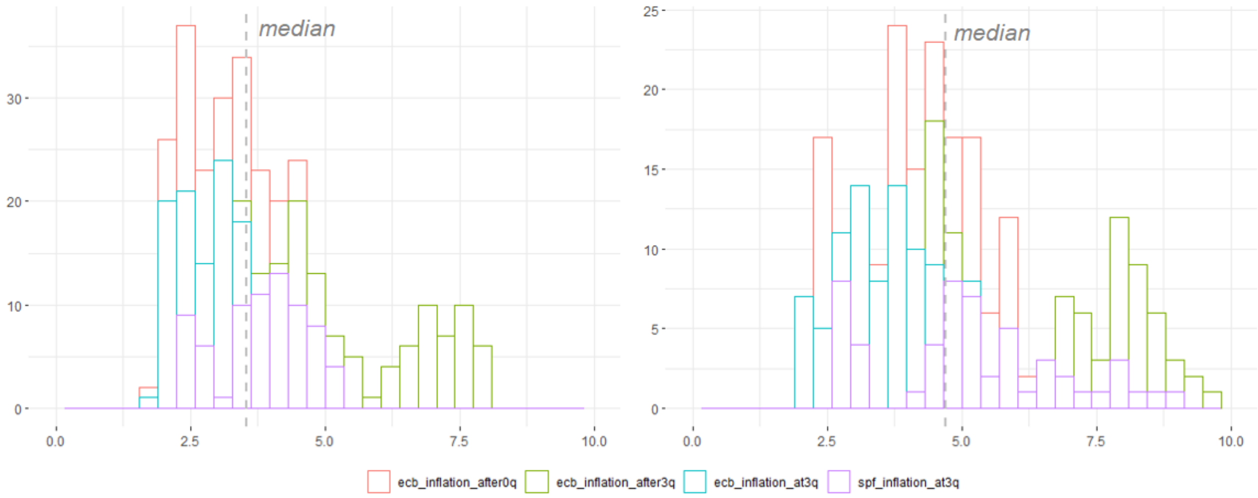
The inflation gap coefficients are much more dispersed for reaction functions with output gap variable (Figure 5, RHS) than with simple growth indicator (Figure 5, LHS). The coefficients for the inflation gap mostly concentrate between 2 and 5 for the majority of reaction function specifications with output growth indicator. Any deviation of projected inflation from its target seems to be strongly accommodated by the ECB – as monetary policy operates with a lag, real interest rates need to rise in response to an increase in the projected inflation gap. The coefficients are higher in the model specifications with ECB average inflation

[9] Masuch et al. (2004) argues that money supply can act as a useful information indicator in a world where indicators are imperfectly observed and can also act as an anchor for expectations to prevent divergent dynamics.

[10] The specifications with time-varying natural rate estimates seem to be a more rational case for the ECB reaction function due to the slump in natural rate in the euro area that is confirmed by many researchers.

projections after 3 quarters as they are somewhat less volatile, potentially because economic variables at the end of the forecast horizon might be biased towards the models' long-run equilibriums (Paloviita et al., 2021). Meanwhile, the coefficients are often larger and much more dispersed for the inflation coefficients in models with output gap estimates – this is potentially related to the high uncertainty of this directly unobservable variable.

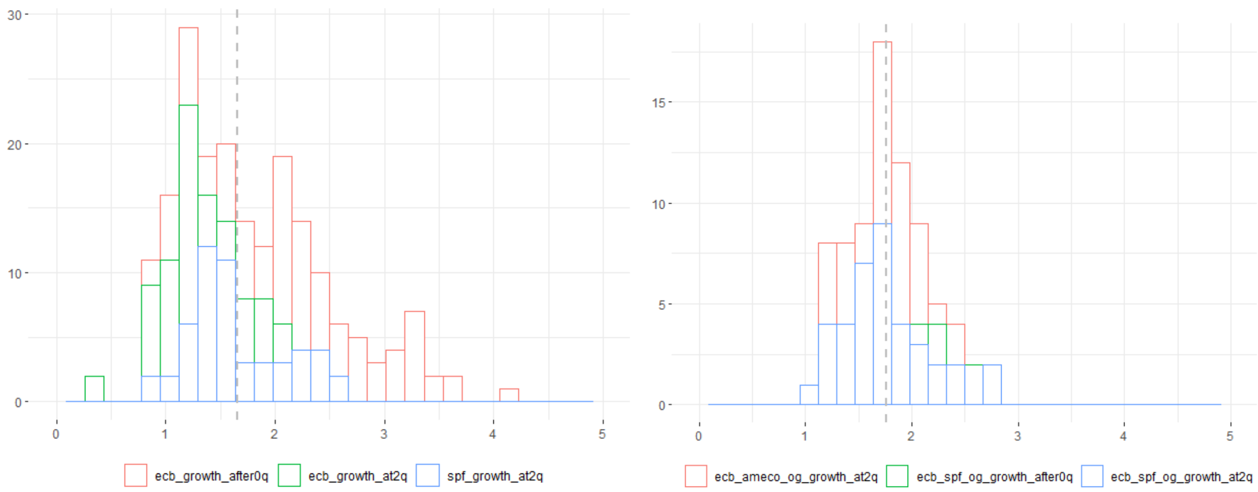
Figure 5. The histograms of statistically significant projected inflation gap coefficients: GMM specifications with projected growth (LHS) and with projected output gap (RHS) *(y: number of specifications)*




*Notes*: only the statistically significant estimates of ECB reaction function specifications when time-varying natural rate and fiscal variable are explicitly included in the model is shown here. X axis shows the estimates of inflation gap coefficient, while y axis – the number of specifications for particular inflation gap coefficient.

The statistically significant economic activity coefficients are highly dispersed, but all of them are in the positive territory (Figure 6). The majority of coefficients vary between around 0.9 and 2.5 for both output growth and output gap specifications. Importantly, it is visible that there are fewer statistically significant coefficients for specifications with output gap variable. In particular, the specifications with output gap indicator constructed with SPF long-term growth projections are almost all insignificant.

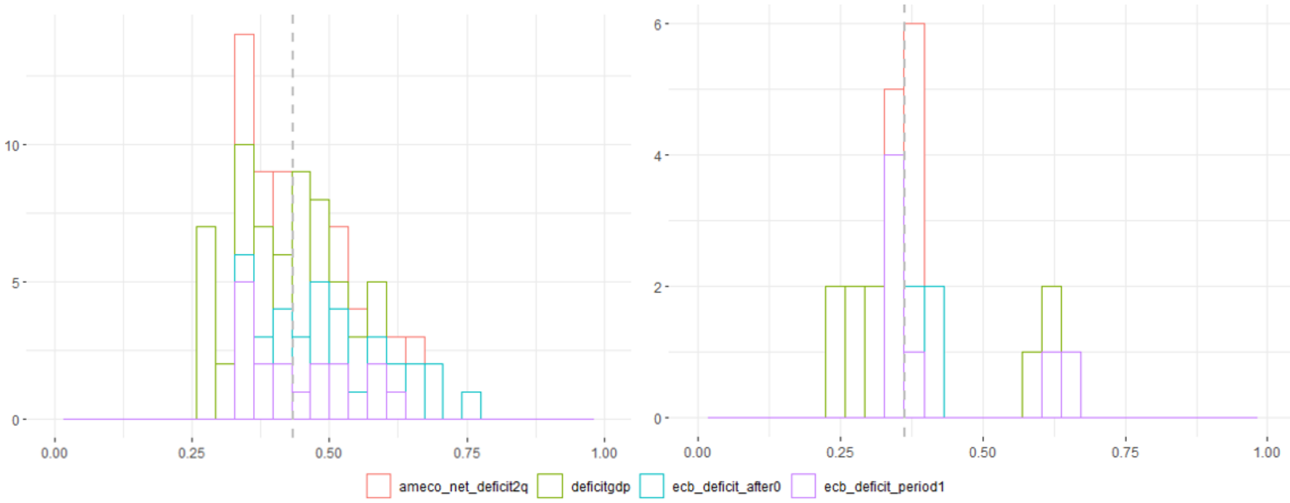
Figure 6. The histograms of statistically significant projected economic activity coefficients: GMM specifications with projected growth (LHS) and with projected output gap (RHS) *(y: number of specifications)*



*Notes*: only the statistically significant estimates of ECB reaction function specifications when time-varying natural rate and fiscal variable are explicitly included in the model is shown here. X axis shows the estimates of output (gap) coefficient, while y axis – the number of specifications for particular output (gap) coefficient.

The coefficients for all statistically significant projected fiscal deficit indicators are higher than 0 (Figure 7).[11] Although there is some dispersion between the coefficients, they all are much higher than 0. This implies that monetary policy reaction, if at all, to fiscal deficits is the direct one, meaning that higher projected deficits lead to higher policy rates or lower accommodation of other instruments, and *vice versa*. This finding holds for all different types of projected fiscal deficit indicators, i.e. projected by ECB or EC. Importantly, only a part of different GMM specifications show statistically significant results for the fiscal stance indicator.

Figure 7. The histograms of statistically significant projected fiscal deficit coefficients: GMM specifications with projected growth (LHS) and with projected output gap (RHS) *(y: number of specifications)*



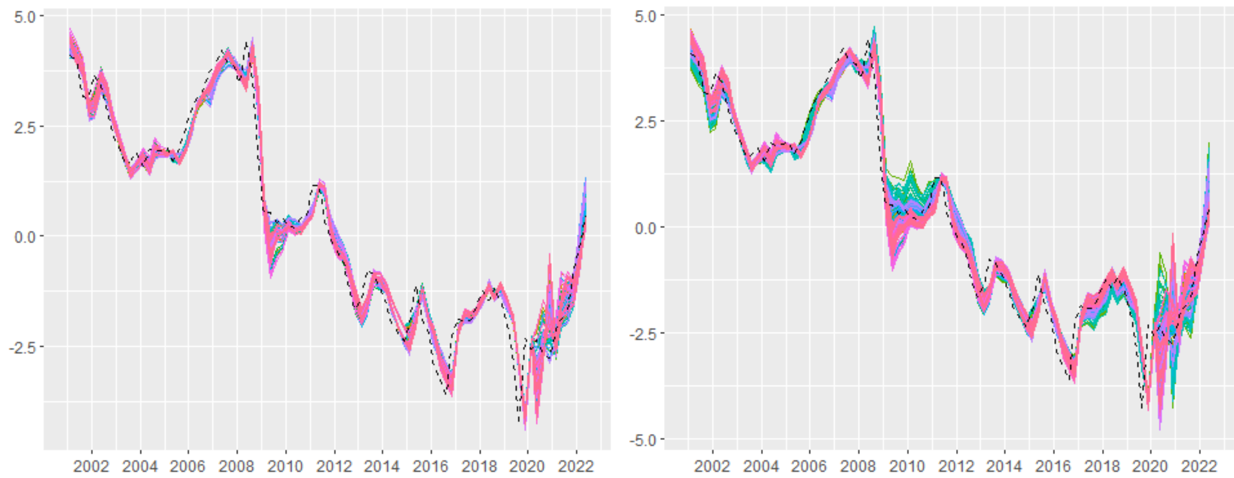

*Notes*: only the statistically significant estimates of ECB reaction function specifications when time-varying natural rate and fiscal variable are explicitly included in the model is shown here. X axis shows the estimates of fiscal deficit coefficient, while y axis – the number of specifications for particular fiscal deficit coefficient.

The dynamics of fitted values of various GMM model specifications do not change materially when a projected fiscal deficit indicator is added to the model. The fitted values of the 72 GMM specifications without fiscal deficit quite well track the actual movements of Krippner (2015) shadow rate (LHS of Figure 8).[12] There are some discrepancies as shadow rate sometimes seems to lead the prescribed rate dynamics, but they are not long-lasting and significant. Interestingly, the prescribed rate dynamics mostly suggest that monetary policy should be looser during the GFC when the policy rate came close to the zero lower bound. The fitted values of 288 GMM specifications with embedded fiscal stance indicator track the shadow rate similarly well (RHS of Figure 8). There seems to be no major change in the prescribed values when fiscal deficit enters the model. Although the range below and above the shadow rate is higher when a particular fiscal deficit indicator is added, it mainly comes due to the higher number of different GMM specifications when four types of deficit indicators are used. The range of different prescribed model values (both with and without deficit variable) widens during the crisis periods (such as in 2009 and 2020), potentially due to increased uncertainty in projections and higher divergence between indicators, e.g. projected inflation might not decline as much as the projected output.

[11] The statistically insignificant coefficients are also above 0, ranging between 0 and 0.7 (for output growth specifications) and between 0 and 1.5 (for output gap specifications).

[12] The main findings are the same for Kortela (2016) shadow rate and when the time-varying natural rate is not added to the model. These results are available upon request.

Figure 8. The Krippner (2015) shadow rate (dotted line) and fitted values of GMM models (colour lines) for the full sample period: without (LHS) and with projected fiscal deficit indicator (RHS) *(y: shadow rate estimate, in %)*




*Notes*: only the models with time-varying natural rate and Krippner (2015) shadow rate is shown here.

As the issue of the fiscal importance for monetary policymaking became more widely discussed after the GFC and the European sovereign debt crisis, we have also run different GMM specifications since 2012. This date also corresponds to the period when shadow rates for euro area from our sample declined to the negative territory due to the start of more accommodative monetary policy actions (such as the announcement of the OMT program and the "whatever it takes" speech by ECB President M. Draghi) when policy rates were already at the zero lower bound. Also, this period highlights the Covid-19 crisis period more than the full data sample - this shock undoubtedly had significant effects on the macroeconomic and financial variables.

The GMM results for this shorter sample period (Table 2) imply similar conclusions as for the full sample period. The coefficient for the lag of shadow rate is somewhat smaller, ranging from 0.7 to 0.8, implying a bit slower (albeit still fast) monetary policy activism. The median inflation gap coefficient remains the most consistently significant indicator among Taylor-type rule variables as it is statistically significant for 90-100% different model specifications. The inflation gap coefficient is somewhat smaller for this shorter sample period, but still higher than the stabilising value of 1: the median coefficient for projected inflation gap fluctuates in a narrow range of 2.5-2.8, while the vast majority of coefficients lie between 1 and 4.5 (see Annex 2). Regarding economic activity indicators, the difference between the number of statistically significant coefficients for output growth and output gap estimates is smaller than for the full sample period. This is potentially due to the fact that there was no major change in the long-term / potential growth values during this shorter period of time that is used for the output gap calculation, i.e., the output gap dynamics were quite similar as the changes in output growth. Importantly, the median estimates for activity variables are smaller than for the full data sample, meaning smaller focus of monetary policymakers for this indicator. This is also confirmed by the distribution of economic activity estimates, though all coefficients are still above 0 (see Annex 3). The determination coefficients for different model specifications remain very high - near 0.9.

Table 2. Median results of different GMM specifications over sample of 2012Q1-2022Q2

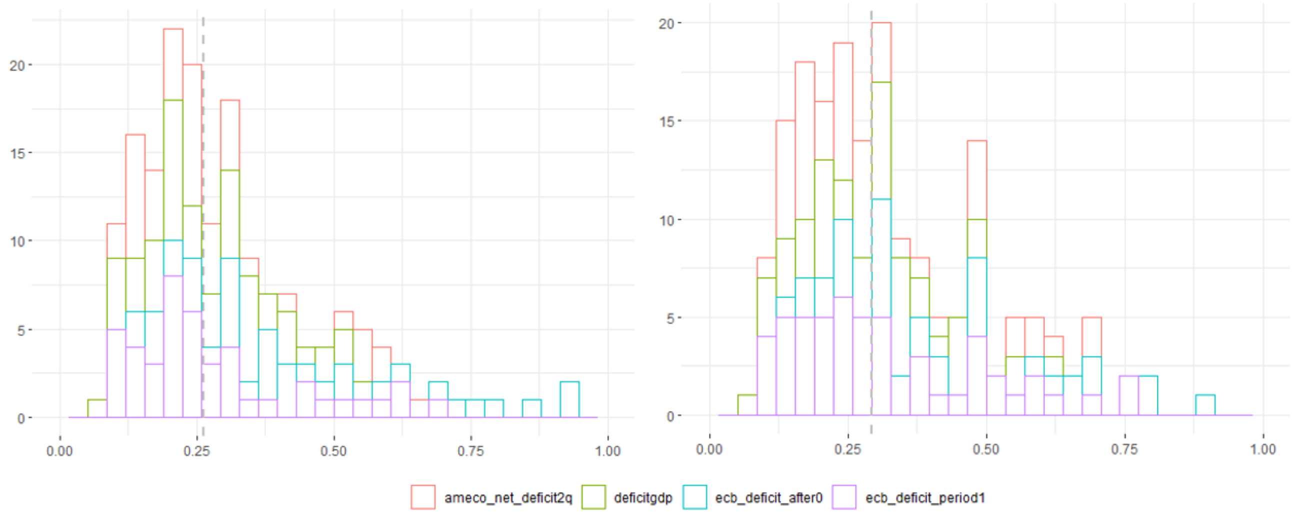
| | | with time-varying natural rate | | | | no time-varying natural rate | | | |
|---|---|---|---|---|---|---|---|---|---|
| variable | | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| shadow rate (lag) | estimate | 0.794*** | 0.791*** | 0.779*** | 0.760*** | 0.734*** | 0.730*** | 0.724*** | 0.697*** |
| | st error | (0.067) | (0.074) | (0.069) | (0.072) | (0.062) | (0.066) | (0.06) | (0.066) |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | significant | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| inflation gap | estimate | 2.710*** | 2.847*** | 2.811*** | 2.684*** | 2.471*** | 2.509*** | 2.685*** | 2.534*** |
| | st error | (0.725) | (0.882) | (0.671) | (0.655) | (0.565) | (0.602) | (0.543) | (0.531) |
| | significant | 94% | 90% | 97% | 98% | 100% | 97% | 100% | 100% |
| growth | estimate | 0.4912** | | 0.4409* | | 0.3405* | | 0.4275* | |
| | st error | (0.237) | | (0.171) | | (0.166) | | (0.168) | |
| | significant | 69% | | 51% | | 61% | | 53% | |
| output gap | estimate | | 0.4423* | | 0.1079 | | 0.2685 | | 0.0142 |
| | st error | | (0.207) | | (0.17) | | (0.144) | | (0.172) |
| | significant | | 61% | | 44% | | 49% | | 48% |
| fiscal | estimate | | | 0.2372* | 0.2499* | | | 0.1495 | 0.1757 |
| | st error | | | (0.131) | (0.135) | | | (0.114) | (0.114) |
| | significant | | | 59% | 63% | | | 36% | 49% |
| inter-cept | estimate | -1.261** | -0.2497 | -1.53*** | -0.985** | -1.14*** | -0.709** | -1.39*** | -1.11*** |
| | std_error | (0.494) | (0.441) | (0.589) | (0.489) | (0.402) | (0.317) | (0.45) | (0.387) |
| | significant | 62% | 47% | 65% | 58% | 76% | 58% | 90% | 70% |
| natural rate | | YES | YES | YES | YES | - | - | - | - |
| adj R2 | | 0.887 | 0.885 | 0.888 | 0.888 | 0.888 | 0.887 | 0.884 | 0.887 |
| J-statistic | | 8.29 | 8.18 | 8.47 | 8.36 | 8.24 | 8.23 | 8.4 | 8.42 |
| P(J-stat) | | 0.51 | 0.52 | 0.58 | 0.59 | 0.51 | 0.51 | 0.59 | 0.59 |

*Notes*: 1st line for each variable depicts the coefficient of the variables, 2nd line – standard errors (in brackets), 3rd line – number of statistically significant (at 10% level) variables across all specifications. Asterisk in the 1st line after coefficient indicate statistical significance of the median value at the 10% (*), 5% (**) and 1% (***) levels. Only the results of GMM specifications that pass the validity test of over-identifying restrictions are shown here.

The coefficients of fiscal stance indicators remain in the positive territory, but are statistically insignificant for around half of model specifications since 2012. Although the coefficients for projected fiscal deficits are smaller than for the full sample, the median values are still above 0. This again speaks that the increase (decrease) in projected deficits do not lead to a more accommodative (restrictive) monetary policy stance. It is statistically significant for 36-63% of specifications when the fiscal variable is included in the GMM models. The dispersion of statistically significant coefficients of fiscal deficit indicators reveals that they are also always positive (Figure 9). This again suggests that the ECB might take into account (if at all) euro area fiscal deficits as providing leading indications for potential inflationary pressures.

Figure 9. The histograms of statistically significant projected fiscal deficit coefficients since 2012: specifications with projected growth (LHS) and with projected output gap (RHS) *(y: number of specifications)*




*Notes*: only the statistically significant estimates of ECB reaction function specifications when time-varying natural rate and fiscal variable are explicitly included in the model is shown here. X axis shows the estimates of fiscal deficit coefficient, while y axis – the number of specifications for particular fiscal deficit coefficient.

For the robustness check, we also run the OLS regressions where no instruments are included. As stated by Blattner and Margaritov (2010), this type of analysis is suitable when the real-time data (that reflects the information available to policymakers at the decision time) is used, while Carvalho et al. (2021) adds that OLS avoids the issue of the validity of potential instruments that depend on various unobserved features of the economic environment. The results of the OLS analysis for the full data sample with and without time-varying natural rates is shown in Annex 4, implying that the main conclusions remain the same. Projected inflation gap is a statistically significant variable for almost all different specifications, although the median coefficient is somewhat smaller than in the GMM model (though still highly above 1). The economic activity coefficients are often statistically insignificant and much smaller than under the GMM model for the full sample period. Most importantly, the fiscal stance indicator is statistically insignificant in the vast majority of OLS specifications. The median coefficient of projected fiscal deficit is also somewhat smaller than in the case of the GMM model, but the distribution of statistically significant coefficients shows only positive values (see Annex 5). The finding that the coefficients of projected fiscal deficit are positive (but more often statistically insignificant) also holds if the sample period is shortened from 2012.[13]

### 4.2 Results for SVAR model

We start by reporting the median coefficients obtained for the shadow rate equation of the structural VAR model (with output growth as activity indicator) and their respective statistical significance as they can provide an initial insight into ECB behaviour (Table 3). The shadow rate by itself is very persistent with a coefficient of 0.96. Not surprisingly, the contemporary coefficients of the ECB reaction function are larger and more statistically significant than the lagged variables - monetary policymakers take into account the most up-to-date projections. Inflation gap projection is by far the most influential coefficient, with a magnitude of almost 2 and with a high statistical significance. The coefficient of the previous period's inflation projection is close to zero and statistically insignificant. The fiscal deficit and output growth report a positive and statistically significant coefficient of 0.43 and 0.45 respectively. Below, we present the median shadow rate equation from the VAR system with the median estimated coefficients (Table 3 indicates their statistical significance):

[13] The results are available upon request.

$$i_t = -0.28 + 0.96 i_{t-1} + 1.95 inf_{t+h} + 0.45 \Delta y_{t+k} + 0.43 fd_{t+n} - 0.01 inf_{t+h-1} + 0.08 \Delta y_{t+k-1} + 0.05 fd_{t+n-1} + \varepsilon_{j,t}$$

Table 3. Median results of different SVAR model with output growth specifications over full time sample (2001Q1-2022Q2)

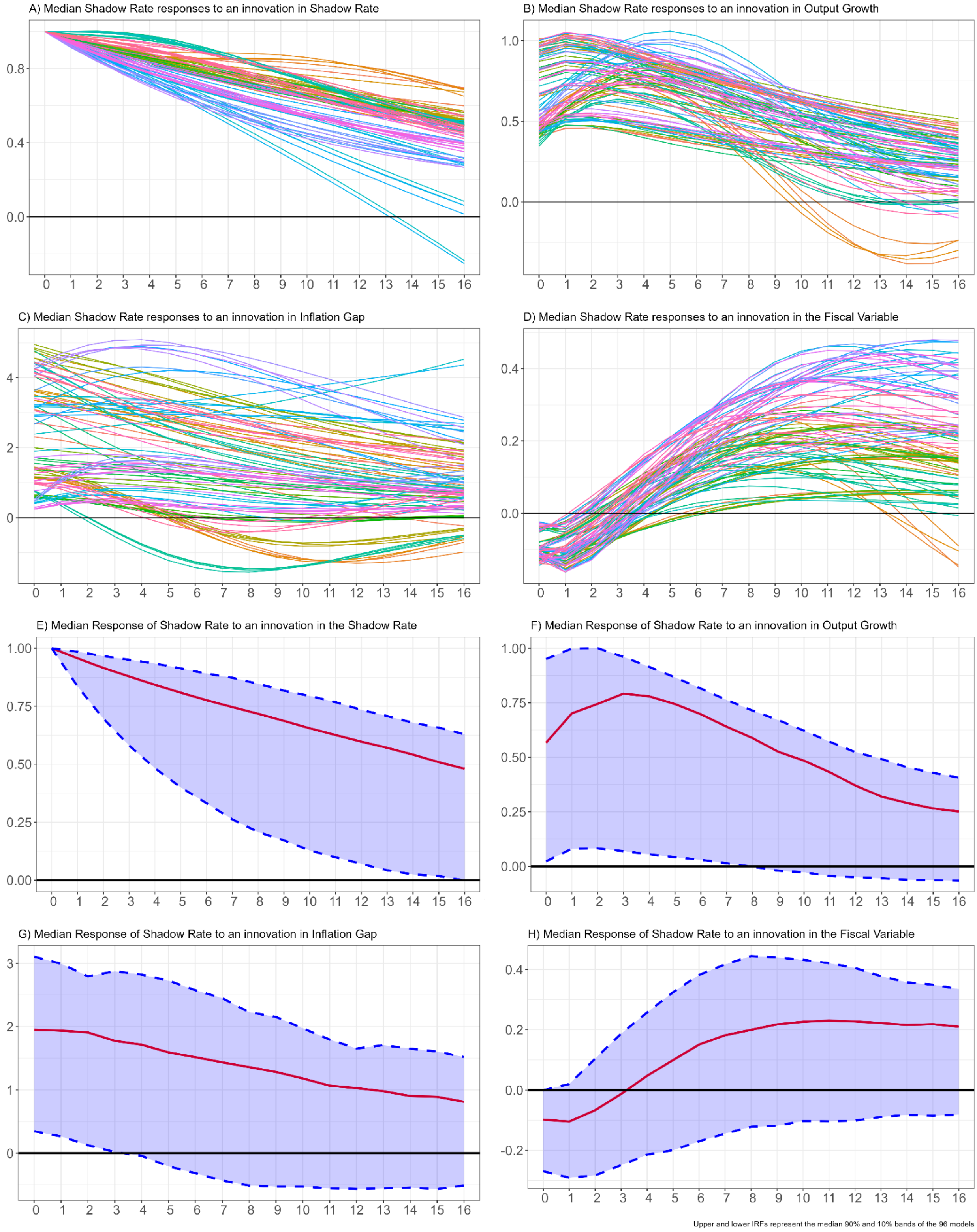
| Variables | Coefficient | Std. Error | t value | P(>\|t\|) |
|---|---|---|---|---|
| Intercept | -0.28328478 | 0.18905873 | -1.52924843 | 1.384554e-01 |
| Shadow Rate(-1) | 0.95641060*** | 0.03556086 | 26.89509333 | 7.969679e-42 |
| Inflation gap(0) | 1.95109984*** | 0.10846523 | 17.98825170 | 7.625124e-30 |
| Inflation gap(-1) | -0.01269468 | 0.17414518 | -0.07737535 | 9.385319e-01 |
| Output growth(0) | 0.45011000*** | 0.10901877 | 4.12873866 | 8.892702e-05 |
| Output growth(-1) | 0.07964357 | 0.05296900 | 1.92766403 | 1.568218e-01 |
| Fiscal deficit(0) | 0.42671527*** | 0.13218826 | 3.22808741 | 1.807736e-03 |
| Fiscal deficit(-1) | 0.04802548** | 0.02316476 | 2.07315718 | 4.138382e-02 |

*Notes:* Asterisks after coefficient indicate statistical significance of the median value at the 5% (**) and 1% (***) levels.

Estimating an endogenous model such as a SVAR offers the opportunity to explore the dynamic relationships between variables, thereby providing a more comprehensive understanding of the data. Therefore, we estimate impulse response functions to analyze the dynamic relationship to gain a better insight into the systematic monetary policy actions of the ECB.

Figure 10 reports the impulse response functions of the shadow rate – our aggregate monetary policy stance variable – given an unexpected disturbance in the projected inflation gap, output growth and fiscal deficit. The top four panels (A-D) report the distribution of the impulse response functions obtained following the “thick modelling” approach, exhibiting a total of 96 models when output growth is used as activity indicator. Panels E-H report the median value of the impulse response functions and the median 90% confidence intervals of the different model specifications. The results for standard Taylor-rule variables are consistent with those of the previously described GMM model and are in agreement with the findings reported in the literature. For instance, an unexpected innovation to the projected inflation gap generates a positive and statistically significant response on shadow rates up to 2 quarters after the initial shock (panel G). However, the distribution of the results exhibits significant variability (panel C) – similarly as with different GMM model specifications. This is due to the fact that the response of shadow rate is sensitive to the projected period and the particular combination of variables. At time horizon 0, all of the estimated shadow rate impulse response functions are above zero and range between 0.24% and 4.95% for a 1% unexpected disturbance in projected inflation. Regarding the economic activity variable (panel B and F), the response of shadow rate at horizon 0 following a 1% innovation in output growth ranges between 0.34% and 1% and the median is 0.57%. These impulse responses exhibit less variability than the inflation shock impulse responses.

Figure 10. Panels A-D report all the impulse responses given an unexpected innovation to the shadow rate according to the model described in Equation (7). Panels E-H represents the median value of the impulse responses and 90% confidence intervals based on bootstrapping replications at each given horizon.




*Notes*: The "thick modelling" approach has 2 shadow rates, 4 projected inflation indicators, 3 projected output growth measures, and 4 projections of fiscal deficit producing a total of 96 impulse responses. We report a horizon of 16 quarters (4 years).

The results of the primary impulse response function of interest in the context of this study (the shadow rate response to an unexpected 1% innovation to the projected fiscal deficit) is presented in panel D and H. Panel D demonstrates a consistent distribution of the impulse responses, particularly in the earlier horizons. At horizon 0 (contemporaneous period), the values range between -0.14% and -0.02% and median is -0.098%.

Even though the median impulse response is negative at time horizon 0, it is statistically insignificant as the median of the upper and lower 90% confidence interval bands do not cross the 0 threshold. The impulse response increased gradually up until 11 quarters following the initial shock, with the impulse response distribution now ranging between 0.03% and 0.46% and the median at 0.23%. It is possible that the impulse response at the earlier horizons may not accurately reflect the actual response of monetary policy due to the nature of the projected fiscal deficit indicator. It is likely that fiscal deficits might be projected to increase when the central bank has a more expansive stance as monetary policy can influence fiscal dynamics (Afonso and Sousa, 2012). As the projected fiscal spending is realized over time (e.g. during projection horizon), the shadow rate eventually increases, indicating a contractionary stance taken by the central bank, i.e. similarly as showed by the delayed response of shadow rates in Panel D and H. Furthermore, it is likely that increased fiscal spending and/or increased output will lead to inflation later (Afonso et al., 2019; ECB, 2022), which could also explain the delayed and restrictive response of the shadow rate.

The "thick modelling" approach catches a wide net of possible results. Variations in the selection of model variables may vary in terms of their credibility (i.e., longer projections of deficit impacting earlier projections of inflation gap). Because of these possibilities, we expect some results to make less intuitive sense than others. This seems particularly true for the response of the shadow rate to an innovation in projected inflation as there is significant dispersion. Nevertheless, given the numerous variables that central bankers must consider and the uncertainty regarding the appropriate variable selection, we expect that the median of the results can provide a reasonable approximation of the true parameters. The literature has conflicting views on the use of output gap as opposed to output growth, so we separately present the results for the output gap in Annex 6. The results obtained are qualitatively equal, the only difference being the magnitude of the response of the shadow rate given a shock to the output gap is somewhat smaller than output growth, as would be expected.

Table 4 reports the median of the forecasted error variance decompositions (FEVD) of all model variations. The FEVDs reports the contribution of each individual shock to explain variable response variation (Lütkepohl, 2005). We report the FEVDs up to 10 steps ahead. In the first step, about 72% error variance of the shadow rate is accounted for by inflation gap innovations, and about 19% of own innovations. In subsequent steps, the contributions to shadow rate variation remain relatively stable, with projected inflation gap innovations continuing to be the most significant factor at around 70% by step 10. Additionally, innovations in the fiscal deficit is the factor that contributes the least to variation in the shadow rate response, being close to zero. The results of this analysis indicate that the majority of the influence of innovations on the response of the shadow rate is attributable to the inflation gap, with a smaller (close to zero) contribution from the fiscal deficit innovations. This finding reinforces and is consistent with the previous results.

Table 4. Median of the forecast error variance decomposition (FEVD) for the shadow rate with output growth variable

| Period | Fiscal Deficit | Output Growth | Inflation Gap | Shadow Rate |
|---|---|---|---|---|
| 0 | 0.0013 | 0.0667 | 0.7227 | 0.1906 |
| 1 | 0.0013 | 0.0816 | 0.7221 | 0.1832 |
| 2 | 0.0012 | 0.0868 | 0.7238 | 0.1781 |
| 3 | 0.0011 | 0.0884 | 0.7260 | 0.1747 |
| 4 | 0.0013 | 0.0890 | 0.7276 | 0.1727 |
| 5 | 0.0014 | 0.0888 | 0.7262 | 0.1735 |
| 6 | 0.0017 | 0.0884 | 0.7201 | 0.1780 |
| 7 | 0.0023 | 0.0877 | 0.7142 | 0.1768 |
| 8 | 0.0029 | 0.0877 | 0.7087 | 0.1741 |
| 9 | 0.0037 | 0.0877 | 0.7036 | 0.1718 |

| | | | | |
|---|---|---|---|---|
| 10 | 0.0044 | 0.0854 | 0.6990 | 0.1711 |

To assess the robustness and provide an alternative model to compare the results, we estimate a similar model with 3 endogenous variables, omitting the fiscal deficit variable: $Y_t = [\Delta y_{t+k}, inf_{t+h}, i_t]'$. We report the impulse responses obtained from this model in Annex 7. The dynamics do not change when compared with the 4-variable model previously described. The main driver of the response in the shadow rate continues to be a shock in the inflation gap. The shadow rate response to inflation exhibited a magnitude of approximately 2.5% following a 1% innovation to the inflation gap - only slightly larger than the 4 variable model. As the results are very similar, it means that the addition of the projected fiscal deficit variable does not change the main links of the standard 3-variable model. We decided not to report the shorter time horizon model (as for GMM from 2012) due to the lack of stability of the time series data needed for SVAR model, which was shown to produce some explosive impulse responses, and therefore are not reported here.

# 5. CONCLUSIONS

Our study explores if ECB monetary policy reacts to the projected fiscal deficits in the euro area. Although there are a lot of studies that augment Taylor-type reaction functions with financial or other indicators, the empirical investigation with fiscal variables is the rare exception, particularly – for the advanced economies that have employed unconventional monetary policy measures.

We address this issue with the "thick-modelling" empirical approach by estimating up to 576 reaction functions for the projected 4 different inflation gap, 6 output growth (gap) and 4 fiscal deficit measures. In order to have more robust results, we compare the results between the full sample period and shorter one (since 2012) and use two different methods (GMM and SVAR). Our response variable in these models is not the policy rate (as was usual in earlier similar studies), but rather the shadow rate indicator because policy rates do not represent actual monetary policy accommodation when rates have approached the zero lower bound and central banks started employing unconventional measures since the GFC. We present the median values of the estimated parameters as well as the full distribution of estimates for the analysed variables.

Overall, our results from both models speak against the "fiscal dominance" or "financial repression" regime in the euro area as the (projected) fiscal stance indicator does not seem to have a meaningful impact on the ECB reaction function. On the contrary, we find that the sign for fiscal deficit is usually positive, implying anti-cyclical nature of monetary policy with respect to the fiscal stance.

More concretely on GMM results, the coefficients of projected fiscal deficits are always above 0, but usually insignificant. This implies that the increase (decrease) in the projected deficits do not lead to a looser (restrictive) monetary policy stance. The euro area fiscal deficits might act similarly as leading indicators for potential future inflationary pressures. This finding remains qualitatively similar for all different types of projected fiscal deficit indicators, i.e., projected by ECB or EC, and for different inflation and output variables. The coefficients for the projected inflation gap are mostly statistically significant and always highly above 1 that indicates the stabilizing properties of ECB monetary policy. The coefficient of output (gap) indicator is also always positive, but often statistically insignificant. The coefficients of standard Taylor-rule variables do not change materially when euro area fiscal stance indicator is added to the GMM model. We also run GMM specification with a shorter sample since 2012 when ECB started increasingly using unconventional monetary policy measures and shadow rates went into negative territory, particularly during the Covid-19 shock. The results imply similar conclusions: fiscal variable is always positive, but more often statistically significant than implied by the full sample model.

Regarding the SVAR results, the main messages remain the same. The analysis is done by first reporting the reaction function equation coefficients, then reporting the impulse response functions, and lastly – the FEVD. The coefficients from the estimated aggregate policy stance equation show that the largest coefficient is inflation gap, while the fiscal deficit coefficient is smaller, but still positive. From the estimated impulse response functions, an innovation to the projected fiscal deficit does not influence the shadow rate in a significant and substantial manner. The median impulse response increases for 11 quarters, which suggests a counter-cyclical monetary policy stance relative to the fiscal deficit; however, the results do not cross the threshold of significance. The remaining impulse response functions are consistent with both expectations and the existing literature. Specifically, the response of the shadow rate was found to be positive and significant following an innovation in the output growth and inflation gap, the magnitude being substantially larger for the inflation gap. A 1% innovation in the inflation gap generated a median shadow rate response of around 2%. Reinforcing these findings, the FEVD results report that the majority of the shadow rate forecast error variance is contributed predominantly by an inflation gap innovation, accounting for approximately 72%, while the contribution from fiscal deficit is negligible.

In summary, fiscal deficits do not seem to drive ECB monetary policy actions in a way that the "fiscal dominance" regime would imply. This might be related to the fact that monetary policy is single, while fiscal policy actions are decentralised in the euro area, so that it would be hard for a fiscal authority from a particular member state to bear a material influence on ECB. The conclusions from the SVAR model are qualitatively the same as the GMM model. Also, various robustness checks with different model specifications, economic activity variables, sample periods and types of models imply the same message of "monetary dominance" regime in the euro area.

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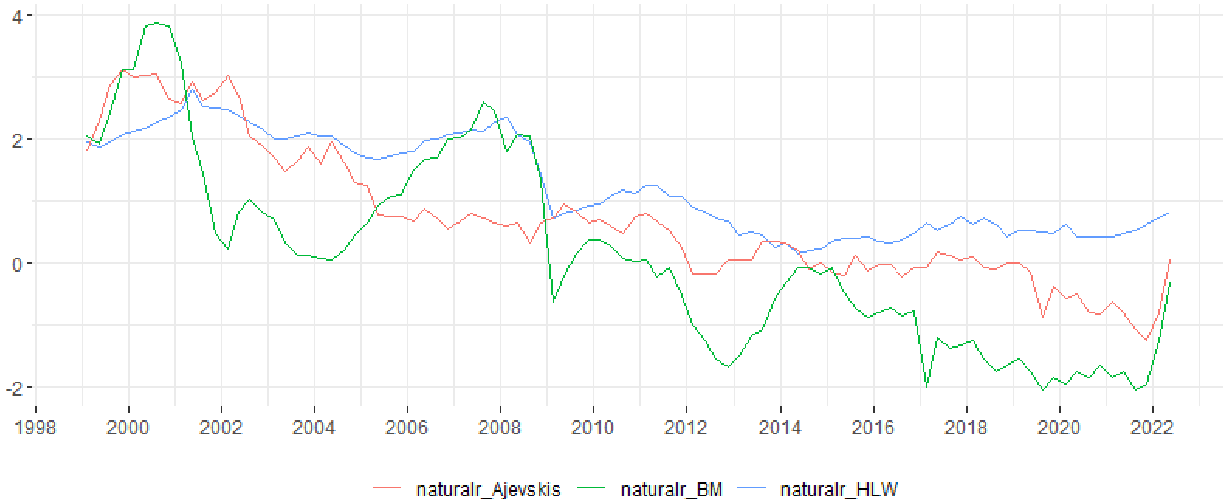
## ANNEXES

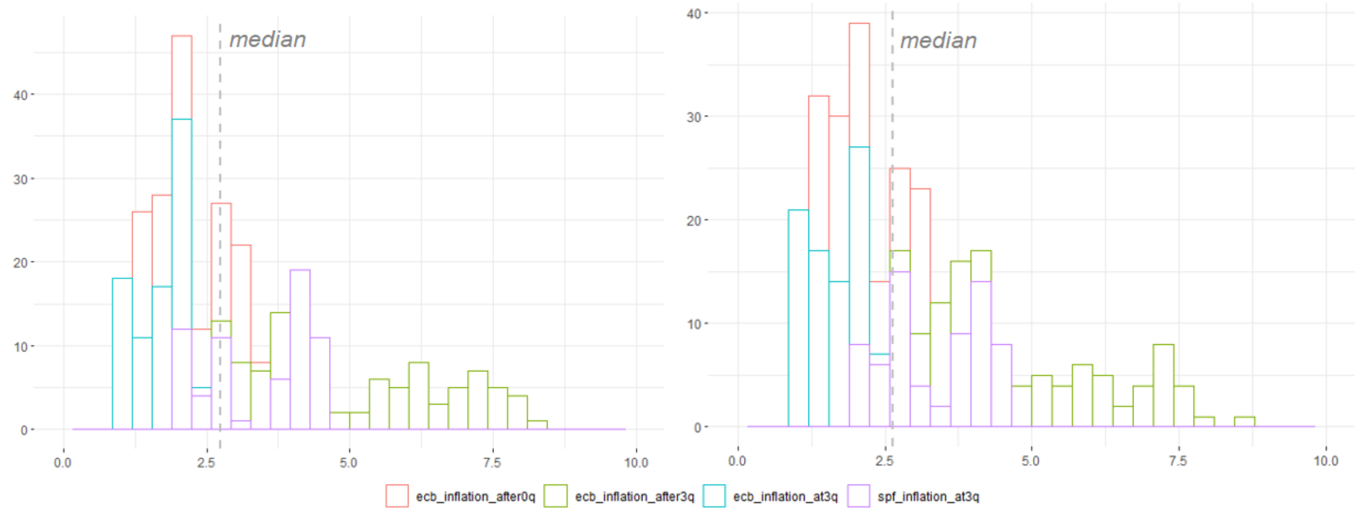
### Annex 1.

The real natural rate estimates for euro area *(in percentage)*




### Annex 2.

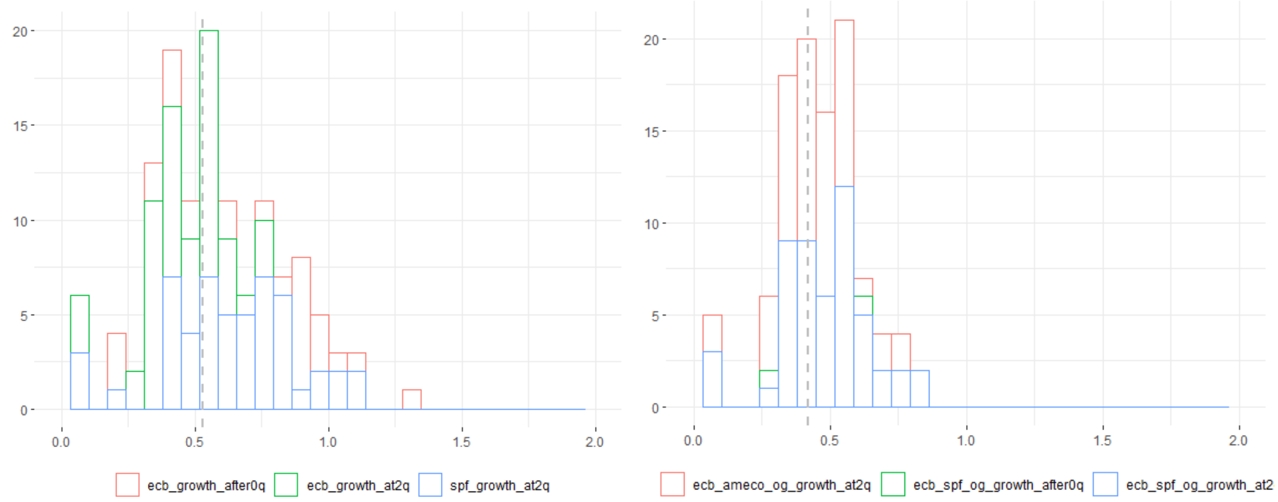
The histograms of statistically significant projected <u>inflation gap</u> coefficients since 2012: GMM specifications with projected growth (LHS) and with projected output gap (RHS) *(y: number of specifications)*




*Notes*: only the statistically significant estimates of ECB reaction function specifications when time-varying natural rate and fiscal variable are explicitly included in the model is shown here. X axis shows the estimates of inflation gap coefficient, while y axis – the number of specifications for particular inflation gap coefficient.

## Annex 3.

The histograms of statistically significant projected <u>output</u> coefficients since 2012: GMM specifications with projected growth (LHS) and with projected output gap (RHS) *(y: number of specifications)*




*Notes*: only the statistically significant estimates of ECB reaction function specifications when time-varying natural rate and fiscal variable are explicitly included in the model is shown here. X axis shows the estimates of output (gap) coefficient, while y axis – the number of specifications for particular output (gap) coefficient.

## Annex 4.

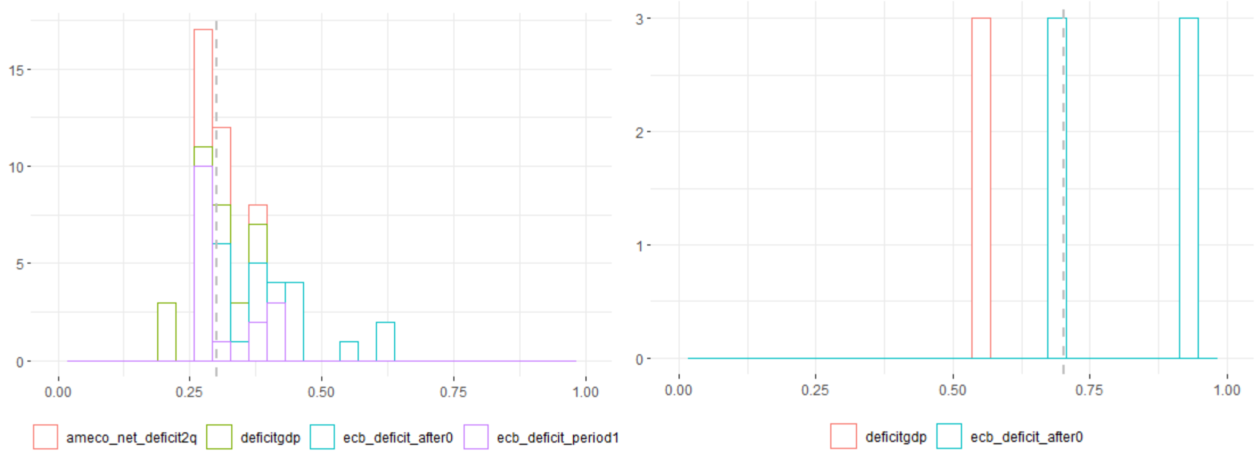
Median results of different OLS specifications over full time sample (2001Q1-2022Q2) for shadow rates

| | | with time-varying natural rate | | | | no time-varying natural rate | | | |
|---|---|---|---|---|---|---|---|---|---|
| variable | | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| shadow rate (lag) | estimate | 0.8453*** | 0.855*** | 0.848*** | 0.8563*** | 0.9102*** | 0.921*** | 0.912*** | 0.9232*** |
| | st error | (0.039) | (0.041) | (0.039) | (0.041) | (0.026) | (0.028) | (0.027) | (0.028) |
| | significant | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| inflation gap | estimate | 3.1989*** | 3.653*** | 3.427*** | 3.9085*** | 4.9123*** | 5.522*** | 5.248*** | 5.8459*** |
| | st error | (0.851) | (0.993) | (0.963) | (1.095) | (1.592) | (1.997) | (1.843) | (2.291) |
| | significant | 100% | 100% | 100% | 100% | 96% | 100% | 99% | 100% |
| growth | estimate | 0.3528 | | 0.3698 | | 0.6729 | | 0.6836 | |
| | st error | (0.256) | | (0.274) | | (0.479) | | (0.512) | |
| | significant | 32% | | 31% | | 42% | | 36% | |
| output gap | estimate | | 0.3903 | | 0.404 | | 0.7309 | | 0.8053 |
| | st error | | (0.285) | | (0.298) | | (0.564) | | (0.602) |
| | significant | | 10% | | 7% | | 4% | | 1% |
| fiscal | estimate | | | 0.2231 | 0.1923 | | | 0.3541 | 0.3313 |
| | st error | | | (0.188) | (0.199) | | | (0.355) | (0.398) |
| | significant | | | 12% | 6% | | | 3% | 0% |
| intercept | estimate | -0.1878 | 0.7551 | -0.7005 | 0.2622 | 0.0358 | 1.2542 | -0.7455 | 0.9222 |
| | std_error | (0.652) | (0.436) | (0.965) | (0.677) | (1.129) | (0.842) | (1.83) | (1.334) |
| | significant | 22% | 46% | 13% | 12% | 8% | 50% | 2% | 12% |
| natural rate | | YES | YES | YES | YES | - | - | - | - |
| adj R2 | | 0.956 | 0.956 | 0.957 | 0.956 | 0.954 | 0.954 | 0.954 | 0.954 |

*Notes*: 1st line for each variable depicts the coefficient of the variables, 2nd line – standard errors (in brackets), 3rd line – number of statistically significant (at 10% level) variables across all specifications. Asterisk in the 1st line after coefficient indicate statistical significance of the median value at the 10% (*), 5% (**) and 1% (***) levels.

## Annex 5.

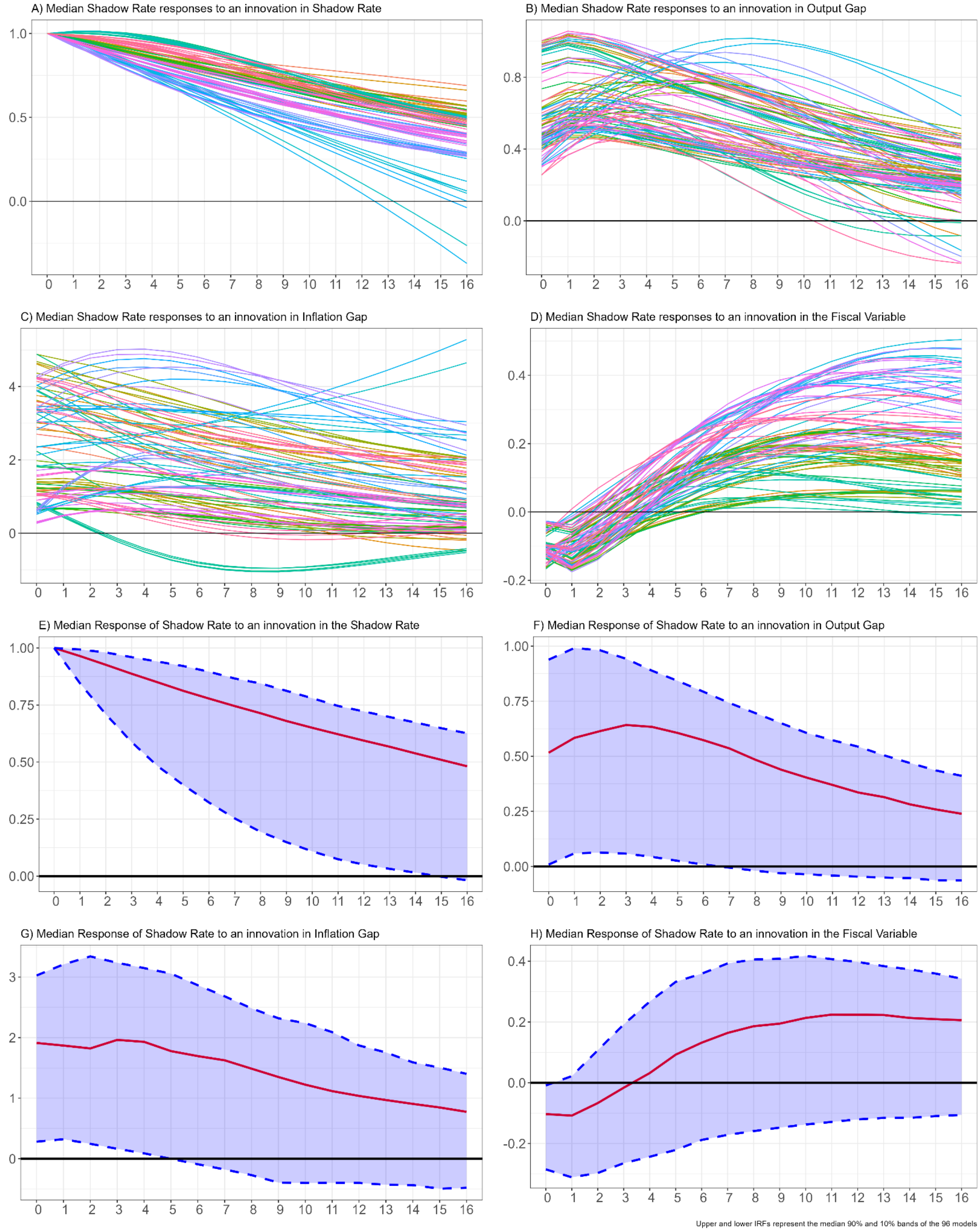
The histograms of statistically significant projected <u>fiscal deficit</u> coefficients for models: <u>OLS</u> specifications with projected growth (LHS) and with projected output gap (RHS) *(y: number of specifications)*




*Notes*: only the statistically significant estimates of ECB reaction function OLS specifications when time-varying natural rate and fiscal variable are explicitly included in the model is shown here. X axis shows the estimates of fiscal deficit coefficient, while y axis – the number of specifications for particular fiscal deficit coefficient.

## Annex 6

This figure reports similar results as in Figure 10, but using <u>output gap</u> instead of output growth. Panels A-D report all the impulse responses given an unexpected innovation to the shadow rate according to the model described in Equation (7). Panels E-H represent the median value of the impulse responses and 90% confidence intervals at each given horizon.




*Notes*: The "thick modelling" approach has 2 shadow rates, 4 projections of inflation, 3 projections of output gap, and 4 projections of fiscal deficit producing a total of 96 impulse responses. We report 16 quarter horizons (4 years).

# Annex 7

This figure reports the distribution and median impulse responses of a 3 variable model $Y_t = [\Delta y_{t+k}, inf_{t+h}, i_t]$. The plots represent the response of the shadow rate given an unexpected shock to macro projections, particularly output growth and inflation gap. Panels A-C reports the distribution of all IRFs obtained, while panels D-F represent the median values and 90% confidence intervals at each given horizon.