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The central bank or the government – who really dictates the terms of the policy-mix cooperation in economies with an independent monetary policy?

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ABSTRACT

The objective of this paper is to consider the cooperative game between the central bank and the government in the case of a non-euro country in the European Union or another country in the world that conducts an independent monetary policy and where statutory deficit restrictions were imposed on its budget. The study takes into account two independent players – the government and the central bank – that make autonomous decisions and are responsible for fiscal and monetary policy, respectively. Our mathematical policy mix model is based on the assumption that there exists some level of coordination between these policies. The article aims to analyse how the level of cooperation influences the behaviour of decision-makers in a specific policy mix model. As a result, the government taking into account the central bank's goals has no impact on the equilibrium of the budget deficit and interest rates. The conclusion about the central bank's privileged position emerged as a mathematical consequence of the proposed model. This is confirmed by another case where the government does not consider the central bank's target in its decisions; then, it does not prevent the monetary authorities from influencing the Nash equilibrium level of either decision variable.

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1. Introduction

The monetary and fiscal policy interactions were described by, among others, Sargent and Wallace (1985), who developed the concept of the so-called 'unpleasant monetarist arithmetic' in the context of which the credibility and transparency of policies pursued by governments and central banks are important. Research in this area has been conducted by Blinder (2000), Blackburn and Christensen (1989), Walsh (2001), and

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Gjedrem (2001), among many others. Monetary and fiscal authorities tend to make decisions independently, and the Nash equilibrium in such a game is equated with choosing a particular combination of monetary and fiscal policies. Players want the best possible result for themselves and must take into consideration the actions of others. Once a Nash equilibrium is achieved, players cannot improve their payout independently by changing their strategy. Thus, it is the best strategy, assuming that the other player has chosen a strategy and will not change it (Binmore, 2008; Scharpf, 2018).

The different objectives (and/or preferences) of the central bank and the government pose a challenge in the area of stabilising a country's economy. The optimal solution would be for the authorities to coordinate their actions and decisions, as coordination improves the situation of both decision-makers (Kuttner, 2002; Pindyck, 1976; Ribe, 1980). The greater the discrepancy between the preferences of the central bank and the government, the less favourable the policy mix is. Thus, it is worth emphasising the problems that face the policy mix. The combination of monetary and fiscal policies is inextricably linked with various problems and obstacles. One of the important issues that should be considered when implementing a policy mix is time lags (Goodhart, 2001). They constitute a source of complications in the functioning of the monetary and fiscal policy transmission channels, and they also hinder the selection of tools by decision-makers. Hagen and Harden (1994) report that the phase of government work is about six to thirteen months, and the phase of parliamentary work lasts two to three months. Altogether, this results in a delay of over a year in making decisions within the framework of fiscal policy. In the area of monetary policy, time-lags result from the reaction of the economy.

In this study, it is assumed that there could be some coordination between the monetary and fiscal policies, meaning that one player takes the aspirations of the other player into consideration in its objective function. Thus, in its objective function, the government will take into account the fiscal policy objectives and also give some weight to the preferences of the central bank, and vice versa – the central bank, in addition to the monetary policy objective in its objective function, accounts for (with particular weight) government preferences.

We analyse this interaction using the game theory[1] approach, which has already been employed in previous research devoted to the co-dependencies between monetary and fiscal policy (e.g., Saulo et al., 2013). The aim of the article is to investigate how the level of cooperation influences the decision making process in a specific policy mix model. The basis of our considerations is the theoretical model specified by particular variables, i.e., the budget deficit (which is a tool of government policy) and the interest rate[2] (which is a tool of the central bank). The article presents the model, the reaction functions of both players, and the Nash equilibrium (which depends on exogenous variables, such as the level of the inflation target, core inflation, and the Maastricht deficit limit – as a variable that is institutionally determined at the EU level, which is 3% of GDP) in the cooperative game between the central bank and the government.

The contribution of this article to the existing literature is as follows: first, we consider a non-euro area country in the EU, or a country where monetary policy is

conducted independently from interference by the fiscal authority and where statutory limits are imposed on its budget deficit – which is not a frequent subject of research in the context of policy mix. Secondly, we consider the game theory model, which depends on specific exogenous variables in the cooperative game between the bank and the government and which properly describes interactions between two economic entities, in this case, the central bank and the government. Thirdly, we consider and analyse a few special cases of the different attitudes of both players to cooperation. We do not make additional assumptions that put the central bank in a privileged position, as is the case in the Stackelberg model,[3] where the central bank is often considered a leader (Fialho & Portugal, 2005; Saulo et al., 2013; Tanner & Ramos, 2003). Despite the lack of these assumptions, we obtain an original result, indicating that it is only up to the central bank whether any elements of cooperation in the interaction of these two players can occur at all and affect the equilibrium levels of the decision variables.

The paper has the following structure. The next section discusses the literature on the interactions between fiscal and monetary policies in the context of game theory. In the third section, our model of a cooperative game between the two authorities (the central bank and the government) is developed. The section also presents the model's assumptions and different variants of the Nash equilibrium. The fourth section contains special cases of our model. The discussion of our findings is presented in the fifth section. The last section concludes.

2. The literature review

2.1. The importance of policy mix coordination for the economy

The policy mix is understood as a combination of monetary and fiscal policies. These policies affect economic activity of the country and, at the same time, they also influence each other. Brimmer and Sinai (1986) described the policy mix even as a contemporaneous joint state of monetary and fiscal policy that conditions the patterns of the business cycle and underlies the groundwork for future economic performance. This part of the literature review concentrates on how monetary and fiscal policy interactions affect the economy. Sargent and Wallace (1981) showed that the lack of coherence between the policies under consideration leads to heightened inflation, while coordinating these policies would provide a policy mix variant that was favourable for the economy. Similarly, Tabellini (1997), who combined game theory and the achievements of the public choice school in the context of public debt stabilisation and the inflation target of the central bank, found that the coordination of monetary and fiscal policy makes it possible to reduce the burden of public debt and provides a favourable policy mix variant.

The need for cooperation between monetary and fiscal authorities was also emphasised by Andersen and Schneider (1986), who used the solution of Nash and Stackelberg in their research. They considered three models (Keynesian, Keynesian-New Classical, and Classical) for each of these models to find a Nash and Stackelberg equilibrium. While in the state of equilibrium, the level of production and inflation

were different in each of the models, in all three models, cooperative solutions were definitely more effective in the sense of Pareto than non-cooperative solutions.

Meanwhile, Alesina and Tabellini (1987), who combined policy mix coordination and dynamic inconsistency, concluded that coordinated monetary and fiscal policies reduce the problem of dynamic inconsistency, and without coordination, even a rule-based policy does not improve the situation. In turn, van Aarle et al. (1995) argued that when considering debt stabilisation in the absence of government responsibility for its stabilisation, there is unpleasant monetarist arithmetic,[4] which is solved by the Pareto-effective policy mix coordination.[5] This coordination causes faster adjustments of inflation and debt, guaranteeing a lower deficit and inflation in equilibrium. Bhattacharya and Haslag (1999) found that fiscal policy limits the effectiveness of disinflation. The possibility of choosing instruments increases the central bank's room for manoeuver while coordinating both policies improves the situation of both decision-makers.

Nordhaus's model was the starting point for research on monetary and fiscal interactions related to stabilising the economy. He aimed to investigate which variant of the policy mix is the most favourable and why there exists the need to coordinate monetary and fiscal policy. In his model, he assumed that the central bank sets the interest rate and that the government influences the relationship between the structural budget surplus and Gross National Product (GNP). Additionally, both policy-makers – the government and the central bank – differ with regard to the preferred level of inflation, unemployment, and the potential output growth rate. Due to their different preferences, the outcome of the game depends on whether the players will cooperate or decide to work against each other. In the cooperation scenario, there is the so-called contract curve, which plots combinations of the interest rate and the budget balance that result from the government and the central bank's joint decisions. This curve indicates the points of coordination of monetary and fiscal policies and is a specific example of a compromise reached by the two players. It should be added that at no point on the contract (compromise) curve can one player improve its situation without deteriorating the other player's situation (Nordhaus et al., 1994).

Hallett and Petit (1990) developed important conclusions that indicate that central bank independence brings better results than subordination to government. This is because government instruments exert less influence on the economy than central bank tools; hence the central bank is better able to achieve its inflation target. According to Hallett and Petit (1990), the maintenance of price stability brings the additional benefits of increased economic growth while being a prerequisite for achieving it. Moreover, it was highlighted that the lack of coordination deteriorates the effectiveness of the economic policy, leading to a conflict between the goals of both decision-makers. However, if there was cooperation between both players, there would be no conflict between their goals.

The central bank's independence is also of key importance because, in the case of cooperative solutions, in which monetary authority shows high bargaining power and is an active partner of the government, it brings both players a better result. Eijffinger and DeHaan (1996) also stress the importance of the central bank's independence, mainly due to the greater effectiveness of the fight against inflation, lower

inflation volatility, and a positive impact on production levels. Further, Franta et al. (2011) showed that fiscal policy outcomes improve shortly after the adoption of an inflation-targeting regime, one of the main pillars of which is relatively high central bank independence.

Saulo et al. (2013) believe that coordinated monetary and fiscal policies play an important role in improving the welfare of society. Many studies show that in non-cooperative models of the monetary and fiscal game, solutions are not optimal and lead to the choice of a non-optimal policy mix. The reasons for such suboptimal solutions are, first of all, the different goals and preferences of both economic authorities, as well as differences in predicting the effects of the applied policies (Darnaut & Kutos, 2005; Frankel, 1988).

At this point, it is worth mentioning the study by Haga (2015). By examining the degree of central bank independence and monetary and fiscal policy coordination, he emphasised an important issue regarding the interaction between the central bank and government. He found an inverse relationship between the independence of the central bank and the size of political budget cycles.

2.2. The domination of the central bank or government and the equilibrium of the policy mix

Debelle and Fischer (1994) obtained interesting results considering the Stackelberg game. They noted that when the government was the leader, the rate of inflation was higher than in the Nash equilibrium. On the other hand, when the central bank was the leader, the inflation rate was lower than in the Nash equilibrium. The reason for this was the differences that result from the different preferences of the central bank and the government regarding inflation and production. Debelle and Fischer (1994) concluded that central bank 'leadership' was a better solution, and therefore postulated that the central bank should commit to a specific inflation target.

Dixit and Lambertini (2001) also demonstrated that the significance of the outcome of the policy mix game is influenced by the credibility of decision-makers. Their study concerned a non-cooperative game in which the parties most often make decisions simultaneously, which leads to the Nash equilibrium, which in this case is a suboptimal solution. They believe that a better solution, in this case, is like the Stackelberg equilibrium, where one of the decision-makers is the leader and the other the follower. However, their main conclusion is that due to different preferences, an uncoordinated monetary policy does not ensure stable prices, and the lack of fiscal discipline limits the effectiveness of the central bank rule.

Many studies (e.g., Fialho & Portugal, 2005; Saulo et al., 2013; Tanner & Ramos, 2003) show that in the case of an optimal fiscal policy as part of the Nash equilibrium solution, the central bank should move first, i.e., as a Stackelberg leader, leading to the smallest social loss. Some studies also highlight the Stackelberg equilibrium, which typically captures monetary leadership (Debelle, 1996; Hallett & Petit, 1990; Petit, 1989). Moreover, existing literature also provides an alternative interpretation of Stackelberg's leadership of the monetary player, which refers to the Economic and Monetary Union (EMU). It is due to the fact that the European Central Bank (ECB)

has to deal with several national governments, which strengthens the strategic position of the common central bank vis-à-vis governments (van Aarle, 1996).

Similarly, Darnaut and Kutos (2005) emphasised that in an exogenous inflation shock, the central bank most often takes the initiative and initiates a monetary tightening. However, it is worth quoting Blinder (1982), who noted that in the Stackelberg game, the follower influences the strategy leader's decision when the leader takes into account the follower's reaction function. Blinder showed that the outcome of this game with a restrictive monetary policy and an expansionary fiscal policy is not optimal, even if both decision-makers would prefer an expansionary monetary policy and a restrictive fiscal policy. Bennett and Loayza (2000) drew similar conclusions. In their leader-follower model, the central bank and the government differ in their preferences regarding inflation and output. A supply shock in the Stackelberg game, leads to higher deficits and higher real interest rates than those achieved when both policy instruments are controlled by one of these decision-makers or under cooperative solutions.

Afonso et al. (2019) provide further evidence that the monetary authority stabilises prices and that fiscal policy controls public debt. They also noted that if the government has too high public debt or a budget deficit, then the central bank takes a dominant position to solve the problematic situation caused by the fiscal authorities. This dependence occurs more in countries that remain outside the euro area, for example, where the monetary policy is the same, and the fiscal policy is completely different. They demonstrated that the way the relationship in each country is adopted between its two economic authorities is of great importance for sustained economic performance.

Research on dynamic leadership investigates the inability of monetary and fiscal policy to change its previous position. Libich et al. (2015) showed that the outcome of policy-makers' interactions, both short-term and long-term, depends on the relative degree of policy leadership, as well as on the uncertainty of the business cycle and the specific preferences of both players. This is because these variables influence the magnitude of potential conflict between players' policies in different phases of the business cycle. They concluded that, particularly when recovering from an economic crisis, a clear monetary policy commitment to the numerical target of average inflation may be necessary to avoid fiscal pressures and spillover effects. Setting a statutory inflation target supports the central bank's credibility throughout the business cycle. They believe that a long-term commitment to price stability may help improve both monetary policy performance and government discipline, contributing to better budgetary results. Such monetary leadership reduces the benefits of governments in avoiding the required fiscal reforms.

Summing up, based on the literature review, several points should be noted. First of all, the literature (including Sargent and Wallace (1985), Tabellini (1997), Andersen and Schneider (1986), Alesina and Tabellini (1987), Nordhaus et al. (1994), Badarau and Levieuge (2011) among others) emphasises the importance of coordinating monetary and fiscal policies, especially in the context of central bank independence (Eijffinger & DeHaan, 1996; Franta et al., 2011; Hallett & Petit, 1990) Moreover, Debelle and Fischer (1994) argued that central bank leadership is a better solution than government leadership given the Nash and Stackelberg game.

According to Dixit and Lambertini (2001), in the case of a non-cooperative game, the Stackelberg equilibrium is a better solution, where one of the decision-makers is the leader and the other the follower. According to Tanner and Ramos (2003), Fialho and Portugal (2005), and Saulo et al. (2013), under the Nash equilibrium solution, it is the monetary authority that should act as Stackelberg's leader.

The study presented in this paper did not assume which of the players – the government or the central bank – would be the game leader. The Nash equilibrium model was solved for a cooperative game by considering the different levels of cooperation between the economic authorities.

3. The simple model of the cooperative game

3.1. The assumptions of the policy mix model for cooperative games

In the proposed game in the given economy two entities are involved – the government (which is responsible for the fiscal policy) and the central bank (which shapes monetary policy). Both players make their decisions autonomously and independently. However, in the proposed model, there is an assumption that there is, to some extent, coordination of monetary and fiscal policy. This coordination is manifested by considering the goals of the opposite side in the goal functions. For example, the government in its decisions will take into account not only the fiscal policy objectives, but also, with a certain weight $\omega_F \in [0,1]$, it will pay attention to the implementation of monetary policy tasks. Similarly, when the central bank makes decisions, it will pursue the inflation target, and, in the same time it considers the government's goals with the weight $\omega_M \in [0,1]$. When $\omega_F = \omega_M = 0$, we are dealing with a non-cooperative model (discussed in detail and analysed in Stawska et al., 2019).

When $\omega_F = \omega_M = 1$, there is full coordination of the fiscal and monetary policy. For both the government and the central bank, the fiscal and monetary goals are equally important. In reality, however, it can be expected that the weights ω_F and ω_M have a value in the range $(0,1)$ – the actions of the government (central bank) are determined primarily by fiscal (monetary) tasks, and the monetary (fiscal) goals affect the undertaken decisions to a lesser extent.

Fiscal aspirations involve achieving the highest growth rate as possible while maintaining budgetary discipline in line with the Maastricht deficit limit. For this purpose, the government sets the optimal level of the budget deficit (or surplus). The monetary policy mainly focuses on keeping inflation as close to the target as possible, minimising the difference between actual inflation and the given target rate. For this purpose, the central bank sets the appropriate level of interest rates.

Both authorities shape their policies based, to some extent, on their counterpart's decisions, which means that their behaviours can be analysed with a use of the game-theory framework. The main challenge in modelling this cooperative game is to optimise the objective functions with respect to constraints. The optimisation procedure is explained below, step-by-step.

The government determines the level of the budget deficit d in order maximise its goal function[6]:

$$F_F(d) = g_y^2 - \alpha_0 \ (d - d_M)^2 - \omega_F(\pi - \pi^t)^2 \xrightarrow{d} \max \tag{1}$$

subject to the given budget constraint[7]:

$$g_y = \alpha_1 \cdot \ d + \alpha_2 \cdot \ r + \alpha_3 \cdot \pi \tag{2}$$

where g_y is the rate of growth of GDP per capita, r is the interest rate, d_M is the Maastricht deficit limit, π is the level of inflation, π^t is the inflation target, and $\alpha_0, \ \alpha_1, \ \alpha_3 > 0$ and $\alpha_2 < 0$ are constant parameters.[8] Parameter $\omega_F \in [0, 1]$ is the weight that determines the importance of monetary policy tasks in the government's efforts. The greater the value it takes, the greater is the monetary policy's impact on the government's fiscal decisions.

Similarly, the central bank determines the level of the interest rate r to minimise the square of the difference between current inflation and the inflation target[9]:

$$F_M(\pi) = (\pi - \pi^t)^2 - \omega_M \left[g_y^2 - \alpha_0 (d - d_M)^2 \right] \xrightarrow{r} \min \tag{3}$$

subject to:

$$\pi = \pi_0 + \beta_1 \cdot \ r + \beta_2 \cdot \ g_y + \beta_3 \cdot \ d \tag{4}$$

where $\pi_0 > 0$ is the base inflation, and $\beta_2, \ \beta_3 > 0$ and $\beta_1 < 0$ are constant parameters. Parameter $\omega_M \in [0,1]$ is the weight that determines the importance of fiscal policy tasks in the central bank's efforts. The greater the value it takes, the greater the fiscal policy's influence on the central bank's monetary decisions.

Therefore, in the government's goal function (1), there is also a component related to monetary policy pursuits. Similarly, in the central bank's goal function (3), apart from the inflation target, there is a component related to the fiscal policy tasks. Therefore, for $\omega_M \neq 0$ and/or $\omega_F \neq 0$, we consider it a cooperative game. Thus, when determining the size of the budget deficit, the government has to consider potential decisions that the central bank can take and the potential goals of the central bank, and vice versa. As a result, the goal function of the government (1) also depends on interest rate r, in the same way the goal function of the central bank (3) depends on the size of the current budget deficit d. Solving set of Equations (2) and (4) produces explicit macroeconomic restrictions:

$$g_y = \gamma_1 \cdot \ d + \gamma_2 \cdot r + \gamma_3 \cdot \pi_0 \tag{5}$$

$$\pi = \gamma_4 \cdot \pi_0 + \gamma_5 \cdot \ r + \gamma_6 \cdot \ d \tag{6}$$

where $\gamma_1, \ \gamma_3, \ \gamma_4, \gamma_6 > 0$, and $\gamma_2, \ \gamma_5 < 0$ are non-linear combinations of parameters[10] $\alpha_1, \ \alpha_2, \ \alpha_3, \ \beta_1, \ \beta_2, \ \beta_3$:

$$\gamma_1 = \frac{\alpha_1 + \alpha_3 \beta_3}{1 - \alpha_3 \beta_2}$$

$$\gamma_2 = \frac{\alpha_2 + \alpha_3\beta_1}{1 - \alpha_3\beta_2}$$

$$\gamma_3 = \frac{\alpha_3}{1 - \alpha_3\beta_2}$$

$$\gamma_4 = \frac{1}{1 - \alpha_3\beta_2}$$

$$\gamma_5 = \frac{\beta_1 + \beta_2\alpha_2}{1 - \alpha_3\beta_2}$$

$$\gamma_6 = \frac{\beta_3 + \beta_2\ \alpha_1}{1 - \alpha_3\beta_2}$$

After substituting Equations (5) and (6) for, respectively, (1) and (3), the final problem of the proposed cooperative game is as follows:

$$\begin{cases} F_F(d) = (\gamma_1 \cdot\ d + \gamma_2 \cdot r + \gamma_3 \cdot \pi_0)^2 - \alpha_0\ (d - d_M)^2 \\ \qquad -\omega_F\left(\gamma_4 \cdot \pi_0 + \gamma_5 \cdot\ r + \gamma_6 \cdot\ d - \pi^t\right)^2 \xrightarrow{d} \max \\ F_M(r) = \left(\gamma_4 \cdot \pi_0 + \gamma_5 \cdot\ r + \gamma_6 \cdot\ d - \pi^t\right)^2 \\ \qquad -\omega_M\left[(\gamma_1 \cdot\ d + \gamma_2 \cdot r + \gamma_3 \cdot \pi_0)^2 - \alpha_0(d - d_M)^2\right] \xrightarrow{r} \min \end{cases} \tag{7}$$

In the next section, we derive the government and the central bank reaction functions.

3.2. The reaction functions

The government and the central bank consider mutual aspirations in their decisions while remaining autonomous and independent entities. Therefore, in the first step of searching for a model solution, the reaction functions will be determined. They provide information about the government's best response to the central bank's decision and vice versa.

Determining the maximum of the one-variable function F_F from Equation (7) for budget deficit d, we obtain the reaction function of the government (denoted as $\tilde{d}$):

$$\tilde{d} = \tilde{a}_1 \cdot\ r + \tilde{a}_2 \cdot \pi_0 + \tilde{a}_3 \cdot\ d_M + \tilde{a}_4 \cdot \pi^t \tag{8}$$

where

$$\tilde{a}_1 = \frac{\omega_F\gamma_5\gamma_6 - \gamma_1\gamma_2}{\gamma_1^2 - \omega_F\gamma_6^2 - \alpha_0}$$

$$\tilde{a}_2 = \frac{\omega_F \gamma_4 \gamma_6 - \gamma_1 \gamma_3}{\gamma_1^2 - \omega_F \gamma_6^2 - \alpha_0}$$

$$\tilde{a}_3 = \frac{-\alpha_0}{\gamma_1^2 - \omega_F \gamma_6^2 - \alpha_0}$$

$$\tilde{a}_4 = \frac{-\omega_F \gamma_6}{\gamma_1^2 - \omega_F \gamma_6^2 - \alpha_0}.$$

To satisfy the sufficient condition:

$$\frac{\partial^2 F_F(d)}{\partial d^2} = 2\gamma_1^2 - 2\omega_F \gamma_6^2 - 2\alpha_0 < 0$$

which implies:

$$\gamma_1^2 - \omega_F \gamma_6^2 - \alpha_0 < 0.$$

We assume that the parameters on the left-hand side of this inequality are such that this condition is fulfilled.

Similarly, by determining the minimum of the one-variable function F_M from Equation (7) for interest rate r, we obtain the reaction function of the central bank (denoted as $\tilde{r}$):

$$\tilde{r} = \tilde{b}_1 \cdot \pi^t + \tilde{b}_2 \cdot \pi_0 + \tilde{b}_3 \cdot \ d \tag{9}$$

where

$$\tilde{b}_1 = \frac{\gamma_5}{\gamma_5^2 - \omega_M \gamma_2^2}$$

$$\tilde{b}_2 = \frac{\omega_M \gamma_2 \gamma_3 - \gamma_4 \gamma_5}{\gamma_5^2 - \omega_M \gamma_2^2}$$

$$\tilde{b}_3 = \frac{\omega_M \gamma_1 \gamma_2 - \gamma_5 \gamma_6}{\gamma_5^2 - \omega_M \gamma_2^2}.$$

To satisfy the sufficient condition:

$$\frac{\partial^2 F_M(r)}{\partial r^2} = 2\gamma_5^2 - 2\omega_M \gamma_2^2 > 0$$

which, in turn, implies:

$$\gamma_5^2 - \omega_M \gamma_2^2 > 0.$$

Therefore, we assume that the parameters on the left-hand side of this inequality are such that this condition is fulfilled.

Function (8) indicates what should be the optimal fiscal policy response of the central bank to the adopted monetary strategy. Similarly, (9) shows the level of interest rates set by the central bank at the government's budget deficit level.

Note that the reaction functions of individual players depend only on their own willingness to cooperate, not on the decisions made by the other side of the game. Thus, the government reaction function, which determines the government's response to the level of interest rates set by the central bank, depends on parameter ω_F, and not on parameter ω_M. Similarly, the central bank's reaction function is also insensitive to parameter ω_F.

Additionally, it should be noted that the obtained reaction functions in the analysed model differ from the reaction functions in the non-cooperative model. This is because when $\omega_F = \omega_M = 0$, then parameter $\tilde{a}_4 = 0$. Thus, in this case, the level of the inflation target set by the central bank does not affect the government's decision on the level of the budget deficit that maximises its target. To be specific, let us note that to $\tilde{a}_4 = 0$ it is enough if $\omega_F = 0$, which means that the government is not willing to take the central bank's aspirations into account. The central bank's decisions regarding cooperation with the government have no impact on this parameter.

Note also that there is no symmetrical relationship – the level of the budget deficit established by the Maastricht Treaty does not appear in the equation of the central bank's reaction curve, regardless of the level of parameters ω_F and ω_M. This means that the central bank decides on the level of interest rates irrespective of whether it or the government is willing to cooperate. To some extent, this proves that the central bank's decision-making is independent of the government, which, in view of previous considerations, the analogous situation cannot be said to be true of the government.

3.3. Nash equilibrium

The Nash Equilibrium of the proposed model (denoted as (d^*, r^*)) corresponds to the situation where actions of both sides – the government and the central bank – representing the best response of the other player. Therefore, levels d and r are the solutions to Equations (8) and (9). The Nash Equilibrium can therefore be written as:

$$d^* = a_1^* \cdot \pi^t + a_2^* \cdot \pi_0 + a_3^* \cdot \ d_M \tag{10}$$

$$r^* = b_1^* \cdot \pi^t \ + b_2^* \cdot \pi_0 + b_3^* \cdot \ d_M \tag{11}$$

where $a_1^*, a_2^*, \ a_3^*, \ b_1^*, b_2^*, \ b_3^* \in \mathbb{R}$ are also non-linear combinations of parameters $\alpha_0, \ \alpha_1, \ \alpha_2, \ \alpha_3, \ \beta_1, \ \beta_2, \ \beta_3, \ \omega_F, \omega_M$:

$$a_1^* = \frac{\tilde{a}_1\tilde{b}_1 + \tilde{a}_4}{1 - \tilde{a}_1\tilde{b}_3} = \frac{\gamma_2(\omega_F\omega_M\gamma_2\gamma_6 - \gamma_1\gamma_5)}{(\omega_F\omega_M\gamma_2\gamma_6 - \gamma_1\gamma_5)(\gamma_2\gamma_6 - \gamma_1\gamma_5) - \alpha_0\left(\gamma_5^2 - \omega_M\gamma_2^2\right)}$$

$$a_2^* = \frac{\tilde{a}_2 + \tilde{a}_1\tilde{b}_2}{1 - \tilde{a}_1\tilde{b}_3} = \frac{(\omega_F\omega_M\gamma_2\gamma_6 - \gamma_1\gamma_5)(\gamma_3\gamma_5 - \gamma_2\gamma_4)}{(\omega_F\omega_M\gamma_2\gamma_6 - \gamma_1\gamma_5)(\gamma_2\gamma_6 - \gamma_1\gamma_5) - \alpha_0\left(\gamma_5^2 - \omega_M\gamma_2^2\right)}$$

$$a_3^* = \frac{\tilde{a}_3}{1 - \tilde{a}_1\tilde{b}_3} = \frac{-\alpha_0\left(\gamma_5^2 - \omega_M\gamma_2^2\right)}{(\omega_F\omega_M\gamma_2\gamma_6 - \gamma_1\gamma_5)(\gamma_2\gamma_6 - \gamma_1\gamma_5) - \alpha_0\left(\gamma_5^2 - \omega_M\gamma_2^2\right)}$$

$$b_1^* = \frac{\tilde{b}_1 + \tilde{a}_4\tilde{b}_3}{1 - \tilde{a}_1\tilde{b}_3} = \frac{\gamma_1^2\gamma_5 - \omega_F\omega_M\gamma_1\gamma_2\gamma_6 - \alpha_0\gamma_5}{(\omega_F\omega_M\gamma_2\gamma_6 - \gamma_1\gamma_5)(\gamma_2\gamma_6 - \gamma_1\gamma_5) - \alpha_0\left(\gamma_5^2 - \omega_M\gamma_2^2\right)}$$

$$b_2^* = \frac{\tilde{a}_2\tilde{b}_3 + \tilde{b}_2}{1 - \tilde{a}_1\tilde{b}_3} = \frac{(\omega_F\omega_M\gamma_2\gamma_6 - \gamma_1\gamma_5)(\gamma_1\gamma_4 - \gamma_3\gamma_6) + \alpha_0(\gamma_4\gamma_5 - \omega_M\gamma_2\gamma_3)}{(\omega_F\omega_M\gamma_2\gamma_6 - \gamma_1\gamma_5)(\gamma_2\gamma_6 - \gamma_1\gamma_5) - \alpha_0\left(\gamma_5^2 - \omega_M\gamma_2^2\right)}$$

$$b_3^* = \frac{\tilde{a}_3\tilde{b}_3}{1 - \tilde{a}_1\tilde{b}_3} = \frac{\alpha_0(\gamma_5\gamma_6 - \omega_M\gamma_1\gamma_2)}{(\omega_F\omega_M\gamma_2\gamma_6 - \gamma_1\gamma_5)(\gamma_2\gamma_6 - \gamma_1\gamma_5) - \alpha_0\left(\gamma_5^2 - \omega_M\gamma_2^2\right)}.$$

The Nash Equilibrium levels of $(d^*,\ r^*)$ in Equations (10) and (11) depend on π^t, π_0, and d_M (the exogenous variables). In other words, the decisions of the government and the central bank are such that in the Nash Equilibrium the levels of the budget deficit and interest rate can be expressed as functions only of the exogenous variables – the level of inflation target, base inflation, and the Maastricht deficit limit.

The Nash Equilibrium levels of decision variables (the budget deficit and interest rate levels) are computed as a linear combination of exogenous variables and constant parameters $a_1^*, a_2^*,\ a_3^*,\ b_1^*, b_2^*,\ b_3^*$, which, in turn, are non-linear combinations of deep parameters[11] of the model. A change in any of these parameters implies changes in the parameters of the Nash Equilibrium equations, and it affects the levels of the decision variables. The problem is that any change in alphas or betas affects not one, but both of the reaction functions. The Nash Equilibrium level of the decision variables is obtained as a point of intersection of those reaction functions, so it is impossible to predict the direction of the change in d^* or r^* without being given the values of all deep parameters.

4. Special cases

In this section, we consider a few special cases for the given values of parameters ω_F and ω_M.

4.1. Special case – $\omega_F = \omega_M = 0$

In this case, neither entity – central bank or government – considers the other player's goals in their decisions. Therefore, the model is non-cooperative; it is analysed in detail, with a full solution and sensitivity analysis in Stawska et al. (2019).

4.2. Special case – $\omega_F \neq 0,\ \omega_M = 0$

Let us consider a special case where there is no willingness to cooperate from the central bank's side, which means that $\omega_M = 0$. Then, from (10) and (11):

$$d^* = \frac{-\gamma_1\gamma_2}{-\gamma_1(\gamma_2\gamma_6 - \gamma_1\gamma_5) - \alpha_0\gamma_5} \cdot \pi^t + \frac{-\gamma_1(\gamma_3\gamma_5 - \gamma_2\gamma_4)}{-\gamma_1(\gamma_2\gamma_6 - \gamma_1\gamma_5) - \alpha_0\gamma_5} \cdot \pi_0 + \frac{-\alpha_0\gamma_5}{-\gamma_1(\gamma_2\gamma_6 - \gamma_1\gamma_5) - \alpha_0\gamma_5} \cdot d_M$$

$$r^* = \frac{\gamma_1^2 - \alpha_0}{-\gamma_1(\gamma_2\gamma_6 - \gamma_1\gamma_5) - \alpha_0\gamma_5} \cdot \pi^t + \frac{-\gamma_1(\gamma_1\gamma_4 - \gamma_3\gamma_6) + \alpha_0\gamma_4}{-\gamma_1(\gamma_2\gamma_6 - \gamma_1\gamma_5) - \alpha_0\gamma_5} \cdot \pi_0 + \frac{\alpha_0\gamma_6}{-\gamma_1(\gamma_2\gamma_6 - \gamma_1\gamma_5) - \alpha_0\gamma_5} \cdot d_M$$

Therefore, when $\omega_M = 0$, the Nash Equilibrium state is independent of the values of any of the ω parameters. Thus, when the central bank is unwilling to consider the government's goal (i.e., total reluctance to cooperate), whether the government considers the goals of the central bank or not has no influence on the equilibrium level of the deficit and interest rates. The values of d^* and r^* depend then only on the values of the 'deep parameters' $\alpha_0,\ \alpha_1,\ \ldots,\ \beta_3$, and on the values of the exogenous variables of the model – $\pi_0,\ \pi^t,\ d_M$. This conclusion means that the central bank is in a privileged position because only it decides whether any elements of cooperation between these two entities can take place at all and affect the equilibrium levels of the decision variables.

The resulting conclusion about the central bank's privileged position emerged as a mathematical consequence of the proposed model. In this model, we assumed equality between the central bank and the government. Both entities could freely search for the best solution by optimising a given objective function. No additional assumptions were made that would give a privileged position to the central bank on an ad hoc basis.

4.3. Special case – $\omega_F = 0,\ \omega_M \neq 0$

Symmetrically, when $\omega_F = 0$, the parameters in the Nash equilibrium equations are dependent on the level of ω_M and take the following forms:

$$d^* = \frac{-\gamma_1\gamma_2\gamma_5}{-\gamma_1\gamma_5(\gamma_2\gamma_6 - \gamma_1\gamma_5) - \alpha_0\left(\gamma_5^2 - \omega_M\gamma_2^2\right)} \cdot \pi^t + \frac{-\gamma_1\gamma_5(\gamma_3\gamma_5 - \gamma_2\gamma_4)}{-\gamma_1\gamma_5(\gamma_2\gamma_6 - \gamma_1\gamma_5) - \alpha_0\left(\gamma_5^2 - \omega_M\gamma_2^2\right)} \cdot \pi_0 + \frac{-\alpha_0\left(\gamma_5^2 - \omega_M\gamma_2^2\right)}{-\gamma_1\gamma_5(\gamma_2\gamma_6 - \gamma_1\gamma_5) - \alpha_0\left(\gamma_5^2 - \omega_M\gamma_2^2\right)} \cdot d_M$$

$$r^* = \frac{\gamma_1^2\gamma_5 - \alpha_0\gamma_5}{-\gamma_1\gamma_5(\gamma_2\gamma_6 - \gamma_1\gamma_5) - \alpha_0\left(\gamma_5^2 - \omega_M\gamma_2^2\right)} \cdot \pi^t + \frac{-\gamma_1\gamma_5(\gamma_1\gamma_4 - \gamma_3\gamma_6) + \alpha_0(\gamma_4\gamma_5 - \omega_M\gamma_2\gamma_3)}{-\gamma_1\gamma_5(\gamma_2\gamma_6 - \gamma_1\gamma_5) - \alpha_0\left(\gamma_5^2 - \omega_M\gamma_2^2\right)} \cdot \pi_0 + \frac{\alpha_0(\gamma_5\gamma_6 - \omega_M\gamma_1\gamma_2)}{-\gamma_1\gamma_5(\gamma_2\gamma_6 - \gamma_1\gamma_5) - \alpha_0\left(\gamma_5^2 - \omega_M\gamma_2^2\right)} \cdot d_M$$

The government's possible decision not to cooperate with the central bank and not consider the central bank's goal in its decisions does not prevent the central bank from influencing (to a limited extent, but still) the Nash equilibrium level of both variables. Therefore, there is no symmetry in the position of either player in this partly non-cooperative game. The central bank seems to be in a better position as it may influence the Nash Equilibrium level of the decision variables without the government's cooperation ($\omega_F = 0$). The same is not true for $\omega_M = 0$. The government cannot change one-sidedly the Nash Equilibrium level of any variable.

4.4. Special case – $\omega_F = \omega_M = 1$

We now consider full cooperation between both sides. Both the central bank and government completely take into account the other player's goals, meaning that both sides consider the same goal function but optimise with respect to different variables. The entire process, however, seems to be multi-variable-multi-goal optimisation. The Nash Equilibrium takes the following form:

$$d^* = \frac{\gamma_2(\gamma_2\gamma_6 - \gamma_1\gamma_5)}{(\gamma_2\gamma_6 - \gamma_1\gamma_5)^2 - \alpha_0\left(\gamma_5^2 - \gamma_2^2\right)} \cdot \pi^t + \frac{(\gamma_2\gamma_6 - \gamma_1\gamma_5)(\gamma_3\gamma_5 - \gamma_2\gamma_4)}{(\gamma_2\gamma_6 - \gamma_1\gamma_5)^2 - \alpha_0\left(\gamma_5^2 - \gamma_2^2\right)} \cdot \pi_0 + \frac{-\alpha_0\left(\gamma_5^2 - \gamma_2^2\right)}{(\gamma_2\gamma_6 - \gamma_1\gamma_5)^2 - \alpha_0\left(\gamma_5^2 - \gamma_2^2\right)} \cdot d_M$$

$$r^* = \frac{-\gamma_1(\gamma_2\gamma_6 - \gamma_1\gamma_5) - \alpha_0\gamma_5}{(\gamma_2\gamma_6 - \gamma_1\gamma_5)^2 - \alpha_0\left(\gamma_5^2 - \gamma_2^2\right)} \cdot \pi^t + \frac{(\gamma_2\gamma_6 - \gamma_1\gamma_5)(\gamma_1\gamma_4 - \gamma_3\gamma_6) + \alpha_0(\gamma_4\gamma_5 - \gamma_2\gamma_3)}{(\gamma_2\gamma_6 - \gamma_1\gamma_5)^2 - \alpha_0\left(\gamma_5^2 - \gamma_2^2\right)} \cdot \pi_0 + \frac{\alpha_0(\gamma_5\gamma_6 - \gamma_1\gamma_2)}{(\gamma_2\gamma_6 - \gamma_1\gamma_5)^2 - \alpha_0\left(\gamma_5^2 - \gamma_2^2\right)} \cdot d_M$$

In this case – i.e., full cooperation – we have a special situation similar to when one entity deals with both monetary and fiscal policy. It does not matter whether the first decisions are made by the central bank or the government since they both perform the same objective function and act as one.

5. Discussion

Using the game theory approach, we investigated the phenomenon of the policy mix. We presented a specific policy mix model with elements of cooperation to verify if

and how different levels of cooperation influence the behaviour of the decision makers responsible for monetary and fiscal policy. Assuming different variants of interaction (e.g., when the central bank is **not willing to cooperate**, which means that $\omega_M = 0$) we come to the **unexpected** conclusion that whether the fiscal authority takes into account the goals of the monetary authority or not, it does not affect the Nash equilibrium. Thus, we note the privileged position of the central bank emerging as the mathematical consequence of the proposed model and not from additional assumptions.

In the literature, there are theoretical studies and articles that contain a mathematical model in which a similar conclusion is reached, that most often, the central bank should be the leader of the monetary and fiscal game. In all of these models, however, there is an a priori assumption that gives a privileged position to the central bank. For example, in the relationship between the monetary and fiscal players, the central bank is considered a leader in the Stackelberg model (see Fialho & Portugal, 2005; Saulo et al., 2013; Tanner & Ramos, 2003). Neck and Blueschke (2020) found that in the case of a negative demand shock, it is the central bank that bears the major burden of mitigating the effects of the shock by being required to go against its well-defined aims. In another study, Mosavi Jahromi et al. (2018) used the Stackelberg model and game theory approach and showed that if the central bank plays a dominant leadership role, the social loss can be kept to a minimum.

At the same time, our result contrasts with the conclusions obtained by Lambertini and Rovelli (2003). Their study on monetary and fiscal policy coordination in the process of macroeconomic stabilisation demonstrated that it is the government that emerges as the Stackelberg leader and conducts fiscal policy to the minimalisation of the social welfare function. In another study, however, Lambertini (2006) found that leadership equilibria are not the second-best solution (after cooperation), as optimal macroeconomic stabilisation requires either commitment of both policies, identical targets, or complete separation of tasks. Empirically, fiscal dominance and monetary policy subordination were ascertained by Jevđović and Milenković (2018) for five emerging European economies, i.e., Bulgaria, Hungary, Macedonia, Romania, and Serbia.

In the next case considered in our study, when the parameter $\omega_F = 0$ and $\omega_M \neq 0$, the government's decision not to cooperate with the central bank does not prevent the central bank from influencing the Nash equilibrium level, which confirms a more favourable situation of the central bank even when the government is reluctant to cooperate. Kappel and Janků (2014) investigated the mutual reactions of policy mix in the Visegrad Group. They point to the stabilising reaction of monetary policy to changes in inflation and output gap, with their results indicating the dominant role of central bank policy in the Czech Republic and Hungary.

We note that in the studies presented in the literature, the best solution is cooperation between the decisions of the monetary and fiscal authorities. In the study conducted in this article, we examined various variants of policy mix cooperation and noticed that regardless of the degree of such cooperation, the central bank is in a privileged position, and it is the central bank that decides whether to cooperate with the government or not. Whether or not the central bank decides to take government

decisions into account does not affect the Nash equilibrium. Our result is surprising in the context of previous studies where in the process of seeking an equilibrium, it is usually assumed that one player is the leader and the other a follower.

The main findings in our paper are in line with the expectations that can be logically derived from the fact that the central bank is autonomous and the government is constrained by budget deficits and debts, which are often considerable. Hence, statements appear in the literature that monetary policy has become 'the only game in the city' (Rajan, 2012).

We also shouldrefer to the importance of the policy mix during and after the global financial crisis (GFC) in 2008. On the one hand, the GFC contributed to central banks keeping interest rates at record lows, depriving banks of one of the basic tools to stabilise the economy. On the other hand, asset purchase programs have become a common instrument to support business. Developed countries have deviated from the traditional policy mix.[12] Monetary policy became the main means of stabilising the economy (central banks used unconventional instruments, including quantitative easing, due to the ineffectiveness of traditional monetary policy), and fiscal policy assumed a secondary role (government actions were more often based on active fiscal policy due to the negative effects of monetary policy savings) (Eggertsson et al., 2019; IMF., 2021; Mian et al., 2020; Summers, 2014).

The importance of cooperation between monetary and fiscal policies should be related to the post-pandemic policy mix, which will certainly have a different shape than before the pandemic. The COVID-19 crisis has emphasised the link between monetary and fiscal institutions. It can be argued that the economic authorities acted in conditions of an unprecedented economic downturn to prevent a worsening of the COVID-19 crisis (Bank for International Settlements, 2020). These unprecedented conditions probably meant that the economic authorities operate in a 'new normality'. It will now be up to policymakers to smoothly transition to a new, more resilient path (Borio, 2021).

6. Conclusions

In this paper, the authors proposed a solution to the original model of a cooperative game between the monetary and fiscal players. In the policy mix model, Nash equilibrium levels were determined, which are based on the assumption that the reaction of one player (bank or government) is the best response to the decisions of the other player (bank or government). In our model, in the Nash equilibrium, the level of the budget deficit (a government tool) and the interest rate (central bank tool) depend on exogenous variables, such as the inflation target level, core inflation, and the Maastricht deficit limit. Our research indicates that the central bank determines the level of interest rates regardless of whether it or the government is willing to cooperate. This shows that the central bank is independent of the government in making its decisions, although the government cannot be said to be independent of the central bank. Assuming a special case of the central bank's reluctance to cooperate, we note that the Nash equilibrium does not depend on whether the government takes central bank decisions into account or not. These results demonstrate an interesting

regularity, which indicates that it is the central bank that decides whether to cooperate with the government and then influence the equilibrium levels of the decision variables. The situation is not symmetrical in the sense that when the government is not willing to cooperate, but the central bank is, it can one-sidedly affect the equilibrium levels of the considered variables.

The novelty of this research lies in the fact that the literature lacks models with the game-theory approach in the cooperative game. This is especially true for countries such as European Union Member States that are outside of the euro area, which are subject to institutional restrictions, or countries with an independent monetary policy and a budget deficit with statutory limits. The originality of our study can be related to the research by Nordhaus et al. (1994), for example, where, in the case of cooperation, the contract curve was determined, on which the policy mix coordination points were indicated. At no point within this cooperation can the decision-maker ameliorate his situation without worsening the situation of the other player. However, in our model, if the government decides to cooperate unilaterally without reciprocity from the central bank, it will not change the Nash equilibrium or worsen the opponent's situation. Debelle and Fischer (1994), Tanner and Ramos (2003), Fialho and Portugal (2005) and Saulo et al. (2013) concluded that the leadership of the central bank is a better solution for the economy. However, our results go a step further. They indicate that it is the central bank that determines possible cooperation and that the decisions of the central bank influence the level of the Nash equilibrium regardless of the government's decisions about cooperation. The novelty of this result lies in the fact that we do not make additional assumptions that put the central bank in a privileged position, as is the case in the Stackelberg model, where the central bank is often regarded as the leader and the government as the follower. Similarly, if the government decides not to cooperate with the central bank and does not take into consideration the central bank's goal in its decisions, it will not prevent the central bank from influencing the Nash equilibrium level of both variables.

This research has some limitations. One limitation is that we place certain institutional limits on budget deficits, which may not be the case in some economies. In terms of budgetary restrictions, there may be additional constraints, such as non-compliance by governments with institutional restrictions on budget deficits or legal actions on the side of governments that hamper the smooth transmission of monetary policy, such as credit vacation introduced in crisis situations or some financial bonuses granted to those who have a loan in a bank. It is worth highlighting once again the limitations related to time lags that complicate the functioning of the policy mix transmission channels and the selection of tools by policy mix decision makers. Other limitations are related to our assumptions about the specific form of the bank's and government's objective functions and the specific expression of cooperation in the functions.

The conclusions of this study can constitute as a practical guide in decision-making by national monetary and fiscal authorities in EU countries. The recommendations for economic authorities include that central banks' decisions should be taken responsibly because their decisions have a crucial impact on the economy. This is essential in the context of the results of our research, as the central bank may decide

to cooperate with the government or not. Thus, the decisions of the central bank affect the variables in the Nash equilibrium. In such a case, the risk of dynamic inconsistency in monetary policy increases.

In terms of future analysis, we want to verify our mathematical policy mix model in empirical research. Attempting to find the Nash equilibrium in the cooperative game between monetary and fiscal policy in the euro area countries would also prove fruitful. Future research could use modified bank and government target functions, and it may also be interesting to investigate how policymakers would have behaved with a different expression of cooperation in the study. Finally, in the policy mix model, it would be useful to consider assumptions regarding a less conservative approach to fiscal policy in the framework of modern monetary theory (Kelton, 2021).

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Notes

1. Game theory was originally developed by Von Neumann and Morgenstern (1944) to solve economic problems. They claim that economics is very similar to a game in which players predict each other's movements, and therefore it required a new kind of mathematics, which they called game theory. By emphasising the strategic aspects of decision-making, that is, aspects controlled by players rather than purely by chance, game theory complements and even goes beyond classical probability theory. Nash (1950, 1953) implemented the economic application of game theory, explaining the Nash equilibrium through the theory of solving strategic non-cooperative games for mutual benefit. He then developed the concept of a solution for two-person cooperative games. As Friedman (1986) stated, in the cooperative game that we consider in this article, players are able to undertake certain binding agreements or declarations, but they cannot choose every strategy.
2. In our study, we understand the interest rate as the reference rate (base rate or key interest rate) of central banks, and we are aware that there are many interest rates that could be used, such as short-term interbank interest rates (which are closely related to the key interest rate of the central bank). Due to the zero lower bound phenomenon that re-emerged with the global financial crisis, there are also shadow rates that measure the economy when nominal interest rates approach zero. However, shadow rates cannot be directly observed in the market due to the option effect, so economists use models to estimate the value of these rates (Black, 1995).
3. In the Stackelberg model, the player to move first is called the leader, and the player to move second is called the follower. In this model, the leader is in a privileged position because he has the ability to determine the amount of production that will allow him to gain a greater market share than the follower. The rational response of the follower remains somewhat forced by the leader's decision (Başar & Srikant, 2002; Li et al., 2002).

4. Under conditions of expansionary fiscal policy, expressed in chronic fiscal deficits, the central bank will not be able to achieve its price stability target, as sooner or later it will be forced to finance the deficit with additional money issuance. Thus, a restrictive monetary policy in the current period will eventually lead to a higher inflation rate in the future (Sargent & Wallace, 1981).
5. Pareto-efficient coordination means optimal points in the set of combinations of, for example, the interest rate and the budget balance resulting from joint decisions of the monetary and fiscal institutions. This means that at no point in this set can a player improve his situation without making the other player worse.
6. Similar to Bennett and Loayza (2000) and Kuttner (2002).
7. As in Davig and Leeper (2011).
8. $\alpha_3 > 0$; simplifying, we assume that an inflation rate lower than the inflation target positively influences the GDP growth. As indicated, for example, by Barro (2013), high inflation negatively affects the economy. On the other hand, low inflation can positively influence economic growth. This phenomenon was also investigated by, e.g., Mallik and Chowdhury (2001), who emphasized a positive relationship between inflation and economic growth. A non-linear relationship was found by, e.g., Ghosh and Phillips (1998). In their study based on 145 countries, they found a positive relationship between inflation and economic growth when inflation is low, and negative for high inflation. As inflation in the euro area is under the control of the European Central Bank (the inflation target is set at 2%), we assumed there is a linear and positive relationship between economic growth and inflation.
9. See Blinder (1982) or Bennett and Loayza (2000).
10. We assume that $1 - \alpha_3\beta_2 > 0$ to assure proper signs of the parameters in equations (5) and (6).
11. Deep parameters are thought to be invariant against policy change, and because of the stability of these parameters, economists use them to evaluate economic policy.
12. In order to overcome the limitations of traditional monetary policy imposed by effective lower bound on short-term interest rates, central banks, mainly in advanced economies, implemented new tools such as quantitative easing or forward guidance (Gambacorta et al., 2014). According to, inter alia, Bernanke (2020), these new tools have proved to be effective in easing financial conditions when interest rates are limited to the zero lower bound and therefore these tools should become part of the standard monetary policy toolbox.

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