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EQUILIBRIUM STRATEGIES IN A FISCAL-MONETARY GAME. A SIMULATION ANALYSIS

The results from a simulation analysis of the policy-mix have been presented, carried out in a fiscal-monetary game, in which fiscal and monetary authorities make decisions from the point of view of realizing their own respective economic objectives. In order to represent the interrelations between, on the one hand, the instruments of fiscal policy and of monetary policy, and, on the other hand – the economic effects resulting from their application, a modified logistic function was used. The method adopted enables consideration of the specificity of the effects of these instruments on the business cycle, consisting in the limited effectiveness of applying any extremely restrictive or expansive policy, and the respective impact on the economy. The simulation study was meant to show the influence exerted both by the parameters of the function and the priorities of the fiscal and monetary authorities on the Nash equilibrium state, corresponding to the choice of a particular combination of budgetary and monetary policies.

Keywords: *fiscal-monetary game, policy-mix, fiscal policy, monetary policy, the Nash equilibrium*

1. Introduction

This paper concerns the problem of choosing a policy-mix in the context of game theory and the conditions of mutual decision making between the fiscal authorities (the government) and the monetary authorities (the central bank). A policy-mix constitutes, in this perspective, a combination of fiscal and monetary policies, each of them being characterized by specific degrees of restrictiveness and expansiveness.

In the discussions taking place around the problem of such policy mixes, arguments have been stated both for and against the independence of the central bank. The arguments for the independence of the central bank include higher effectiveness in

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countering inflation, lower variability of inflation, as well as a positive impact on the levels and variety of production (see, e.g., [7, 11, 12, 21, 22]. On the other hand, though, independence of the central bank may give rise to particular difficulties in coordinating monetary and fiscal policy. The source of these difficulties lies, above all, in the differing objectives of the monetary and fiscal authorities, and in the differing assessments of the potential effects of macroeconomic policies. Studies on the interdependence between monetary and fiscal policies were initiated by Sargent and Wallace [17] who formulated the concept of “unpleasant monetarist arithmetic”. In the discussion on the coordination of a macroeconomic policy, the significance of the reliability and clarity of the policy conducted is also emphasised [3, 4, 8, 20, 21].

Table 1. The fiscal-monetary game – the payoff matrix

Government – fiscal policy		Central bank – the monetary policy				
		← restrictive		expansive →		
		Monetary strategy M_1 (interest rate r_1)	Monetary strategy M_2 (interest rate r_2)	...	Monetary strategy M_n (interest rate r_n)	
restrictive ↑	Fiscal strategy F_1 (budgetary deficit b_1)	y_{11}	y_{12}	...	y_{1n}	
		p_{11}	p_{12}	...	p_{1n}	
	Fiscal strategy F_2 (budgetary deficit b_2)	y_{21}	y_{22}	...	y_{2n}	
		p_{21}	p_{22}	...	p_{2n}	
expansive ↓		
	Fiscal strategy F_m (budgetary deficit b_m)	y_{m1}	y_{m2}	...	y_{mn}	
		p_{m1}	p_{m2}	...	p_{mn}	

Source: Woroniecka-Leciejewicz [22], p. 191.

The subject of analysis is the fiscal-monetary game whose essence is shown in Table 1 presenting the payoffs. The strategies of the fiscal authorities are those of its budgetary policy – from extremely restrictive in the first row to extremely expansive in the last one. The measure of the degree of restrictiveness/expansiveness of the fiscal policy is understood here as the level of the budgetary deficit in relation to GDP. Analogously, the strategies of the monetary authorities range from extremely restrictive in the first column to extremely expansive in the last column, the degree of restrictiveness/expansiveness being simply equivalent to the value of the real interest rate. Payoffs are denoted in the following manner: y_{ij} – payoff of the fiscal authorities (GDP growth rate) in the case where the government applies the fiscal strategy F_i and the central bank applies the monetary strategy m_j ; p_{ij} – cost to the monetary authorities (inflation) for the same pair of policies. The symbol b_i denotes the budgetary deficit in relation to GDP, corresponding to the i -th fiscal strategy, while r_j denotes the real in-

terest rate, ascribed to the j -th monetary strategy. It is assumed that the fiscal and monetary authorities take decisions independently, and the Nash equilibrium state in such a game corresponds to the choice of a specific combination of budgetary and monetary policies.

An analogous fiscal-monetary game but with only two qualitatively different strategies: expansive and restrictive, was considered, in particular, in the studies of Blinder [5] and Bennett and Loayza [2]. They suggest that independently acting monetary and fiscal authorities would tend (according to the Nash equilibrium) to a restrictive monetary and an expansive budgetary policy, which means a Pareto non-optimal solution, similarly as in the prisoner's dilemma. In the opinion of Blinder [5] and Bennett and Loayza [2], only coordination of both policies can bring a better choice. Consideration of the results obtained by Blinder [5] and Bennett and Loayza [2] may be found in the papers by Woroniecka-Leciejewicz [25, 28] which present an analysis of the states of equilibrium and Pareto-optimality of the solutions in monetary-fiscal games between the fiscal and monetary authorities, both having either two or three qualitatively different strategies: expansive, neutral and restrictive. Two sets of assumptions about the influence exerted by the instruments of monetary policy and of fiscal policy on economic growth and inflation are considered. The results obtained indicate that, along with the case of the prisoner's dilemma, on which there is some discussion [5, 2], other situations may also occur, where the independent decisions of the central bank and the government do not necessarily lead to the choice of a Pareto non-optimal solution.

An interesting approach is presented by Nordhaus [14] who examines the issues of monetary-fiscal interactions and develops a game-theoretic model of the coordination of domestic fiscal and monetary policy. This approach provides a rich set of possible outcomes depending on the degree of coordination or independence, as well as the objectives, of the two players, and on the dynamics. An analysis and comparison of non-cooperative and cooperative equilibria of the game indicate that the Nash equilibrium is not Pareto optimal and the coordination of both policies enables achieving a better solution for each player. The repeated version of this game, with the use of particular behavioral rules, is analyzed. The fiscal authority optimizes with respect to the monetary rule – this leads to a rule equilibrium. Of the two players, the monetary policymaker has a more coherent approach, while fiscal policy tends to be dictated by elections, partisanship, etc.

The analysis presented here is a continuation of the investigations by the same author [23–31], concerning the issues of selecting a policy-mix with the use of a game between the government and the central bank. In earlier papers [24–29], the formulas defining the nonlinear interdependences of the values corresponding to economic growth and inflation with the policy-mix instruments were derived on the basis of a Taylor series expansion, and this was the foundation for the analysis of the equilibrium and the Pareto optimality of the solutions. In view of the wish to complement the theoretical considerations, contained in the papers mentioned, with a simulation analy-

sis, analyzing various variants, in particular – in the context of the effectiveness of fiscal and monetary policies according to their influence on the state of economy, in the last publication [23] a modified logistic function was applied in the fiscal-monetary game, and the results from the initial calculations were presented.

Application of this modified logistic function makes it possible to account for specific features of the influence exerted by the instruments of fiscal and monetary policies on the state of the economy (including the influence on GDP and inflation). The results indicate that an instrument is effective only within a particular range of values of that instrument, its effectiveness falling distinctly outside of this interval. This means, in particular, that the possibilities of lowering inflation by applying an increasingly restrictive monetary policy are limited, as are the possibilities of stimulating economic growth with an increasingly expansive fiscal policy.

This study, based on the use of the logistic function, was continued in the direction of considering – on the one hand – the influence exerted by the parameters characterizing the effectiveness of the policy-mix instruments, and – on the other hand – the impact of the macroeconomic objectives, assumed by the fiscal and monetary authorities, on the outcome of the game. This article describes the study conducted.

2. Assumptions concerning the influence of the policy-mix instruments on the state of economy

The game is analyzed under a set of assumptions concerning the influence exerted by the instruments of the fiscal and monetary policies on the state of the economy, as characterized by the GDP dynamics and inflation. Thus, it is assumed that:

- An increase in the interest rate, *ceteris paribus*, brings about a decrease in the rate of economic growth $\left(\frac{\partial y}{\partial r} < 0\right)$ and limits inflation $\left(\frac{\partial p}{\partial r} < 0\right)$.
- An increase in the budgetary deficit, *ceteris paribus*, contributes to an increase in inflation $\left(\frac{\partial p}{\partial b} > 0\right)$.

Since the impact of the budgetary deficit on real production growth in the economy is unclear, two variants are considered:

- A. An increase in the state budget deficit, *ceteris paribus*, causes an increase in the GDP growth rate $\left(\frac{\partial y}{\partial b} > 0\right)$.

B. An increase in the state budget deficit, *ceteris paribus*, limits the growth of GDP $\left(\frac{\partial y}{\partial b} < 0\right)$.

This study concentrates on the analysis of the fiscal-monetary game under variant A, which appears to reflect in a more realistic manner the influence of the fiscal policy on the possibilities of economic growth over a short time horizon.

It is additionally assumed that

$$\Delta b_i = b_i - b_{i-1} > 0, \quad \Delta r_j = r_j - r_{j-1} < 0$$

This assumption reflects the construction of the payoff table in that the fiscal and monetary strategies are ordered from restrictive to expansive, with increasing expansiveness of the fiscal policy being accompanied by an increasing budgetary deficit, and increasing expansiveness of the monetary policy by a decreasing interest rate.

For the purpose of reflecting the interdependence between economic growth and inflation on the one hand, and the instruments of macroeconomic policy on the other, a modified logistic function was used which accounts for the specific character of the impact of fiscal and monetary policy instruments, lying, in particular, in the fact that the effectiveness of these instruments is high within a certain interval of values, and drops outside of this interval. Application of the logistic function is important within this context, and an interpretation of the parameter values was presented in a recent paper by the author [20].

The logistic function has the form

$$y = f(x) = \frac{\alpha}{1 + \beta e^{-\chi x}}$$

When $\beta > 0$, the function is monotonic varying from the initial $f(x_0) = 0$ to the ultimate value of $f(x_k) = \alpha$ (for $\chi > 0$), or vice versa – from the value $f(x_0) = \alpha$ to the ultimate value of zero (for $\chi < 0$). Depending upon the values of the parameters α and χ , this logistic function is increasing when both parameters are of the same sign and is decreasing when the two parameters have opposite signs. By adding the constant δ , i.e.

$$y = f(x) = \frac{\alpha}{1 + \beta e^{-\chi x}} + \delta$$

this function can vary from an arbitrary initial value to an arbitrary ultimate value by adopting the appropriate values of α and δ . Simulations were performed for $\chi > 0$.

The influence of the fiscal instrument, the budgetary deficit relative to the GDP (b), on the rate of economic growth (y), is described by the increasing logistic function

$$y = f(b) = \frac{\alpha_1}{1 + \beta_1 e^{-\chi_1 b}} + \delta_1$$

with $\beta_1 > 0$, $\chi_1 > 0$, $\alpha_1 > 0$. This means that an increase in the budgetary deficit, *ceteris paribus*, stimulates economic growth $\left(\frac{\partial y}{\partial b} > 0\right)$ but the effectiveness of the budgetary policy on economic growth is limited to a particular range of values of the instrument. It is assumed that both the possibility of stimulating growth by applying an increasingly expansive fiscal policy (increasing the deficit) and the possibility of exerting a negative influence on the production dynamics by an increasingly restrictive policy of deficit reduction are limited. Under the most extreme restrictive fiscal policy, the rate of growth of GDP is the lowest and equals δ_1 ($y_{\min} = \delta_1$), and any further increase in the restrictiveness of the policy does not entail any change in the production dynamics. Analogously, under the most extreme expansive policy, the highest rate of GDP growth equals $\delta_1 + \alpha_1$ ($y_{\max} = \delta_1 + \alpha_1$), and any further increase in expansiveness is no longer effective at all.

The influence of the interest rate (r) on economic growth (y) is described by the decreasing logistic function

$$y = f(r) = \frac{\alpha_2}{1 + \beta_2 e^{-\chi_2 r}} + \delta_2$$

with $\beta_2 > 0$, $\chi_2 > 0$, $\alpha_2 < 0$. As the interest rate increases, the growth rate decreases $\left(\frac{\partial y}{\partial r} < 0\right)$ from its maximum value ($y_{\max} = \delta_2$) for the most extreme expansive monetary policy, corresponding to the lowest value of the interest rate, down to the lowest growth rate ($y_{\min} = \delta_2 + \alpha_2$), when the interest rate attains its upper extreme. The effect of the monetary policy on the GDP dynamics decreases as the policy becomes more extreme – expansive or restrictive. Thus, for instance, the possibility of stimulating economic growth by applying an increasingly expansive monetary policy is limited.

Analogously, the impact of the fiscal instrument on inflation (p) is described by the increasing logistic function

$$p = f(b) = \frac{\alpha_3}{1 + \beta_3 e^{-\chi_3 b}} + \delta_3$$

with $\beta_3 > 0$, $\chi_3 > 0$, $\alpha_3 > 0$. It is, therefore, assumed that increasing the budgetary deficit, corresponding to an expansive fiscal policy, *ceteris paribus*, increases the level of inflation $\left(\frac{\partial p}{\partial b} > 0\right)$, while decreasing the deficit reduces inflation, but the effectiveness

of the budgetary policy decreases as the policy becomes more extreme, either expansive or restrictive. For the most extreme restrictive fiscal policy, inflation is extremely low ($p_{\min} = \delta_3$) and any further increase in the restrictiveness of this policy does not decrease inflation. Similarly, the limited effectiveness of the fiscal policy on inflation can be observed for the most extreme expansive policy, when inflation is the highest ($p_{\max} = \delta_3 + \alpha_3$) and any further increase in expansiveness does not cause any further increase in the inflation rate.

The influence of the interest rate (r) on inflation (p) is described by the decreasing logistic function

$$p = f(r) = \frac{\alpha_4}{1 + \beta_4 e^{-\chi_4 r}} + \delta_4$$

with $\beta_4 > 0$, $\chi_4 > 0$, $\alpha_4 < 0$. Along with an increase in the interest rate, *ceteris paribus*, the inflation level is constrained $\left(\frac{\partial p}{\partial r} < 0\right)$, decreasing from its maximum ($p_{\max} = \delta_4$), under the most radically expansive monetary policy, to its minimum ($p_{\min} = \delta_4 + \alpha_4$), under the most radically restrictive policy. Again, the possibility of pressing down inflation by applying an increasingly restrictive monetary policy (raising the interest rate to extremely high values) is limited.

3. The Nash equilibrium and the priorities of the fiscal and monetary policies. Results of simulations

As indicated above, the calculation of the payoffs in the fiscal-monetary game was based on modified logistic functions. The payoff of the fiscal authorities (GDP growth rate, y) and the cost to the monetary authorities (inflation, p) depend upon the policy-mix instruments: the budgetary deficit in relation to the GDP (b_i) and the real interest rate (r_j):

$$y_{ij} = f(b_i, r_j) = \frac{\alpha_1}{1 + \beta_1 e^{-\chi_1 b_i}} + \frac{\alpha_2}{1 + \beta_2 e^{-\chi_2 r_j}} + \delta_1 \quad (1)$$

$$p_{ij} = f(b_i, r_j) = \frac{\alpha_3}{1 + \beta_3 e^{-\chi_3 b_i}} + \frac{\alpha_4}{1 + \beta_4 e^{-\chi_4 r_j}} + \delta_2 \quad (2)$$

The results of calculations for selected values of parameters (variant 1) are shown in Table 2. For each combination of the fiscal and monetary policies, the rate of GDP

growth (lower left corner of each cell) and the level of inflation (upper right corner) are given. The lowest inflation level, accompanied though by the lowest economic growth, occurs for the combination of the most extreme restrictive monetary and fiscal policies (the upper left-hand corner of the payoff table). Along with an increase in the expansiveness of the monetary policy, *ceteris paribus*, and decrease in the interest rate (passage to the right), both inflation and growth in GDP increase. The highest inflation and GDP growth occur under the most extreme expansive monetary and budgetary policies (lower right hand corner of the table).

The fiscal and the monetary authorities are driven by their own objectives when choosing their strategies. Two cases are considered in the study: the first one, in which it is assumed that the fiscal authorities aim to maximize the rate of GDP growth, and the monetary authorities aim to minimize inflation, and the second one, in which it is assumed that the monetary and fiscal authorities define concrete goals, meaning a desired inflation level and some planned GDP dynamics.

In the first of these cases, for each monetary strategy j , the fiscal authorities select the optimal fiscal response $i^*(j)$, which maximizes the rate of GDP growth: $\max_i y_{ij}$.

Analogously, the monetary authorities choose for each fiscal strategy i the optimal monetary strategy $j^*(i)$, which corresponds to the minimum inflation level. In such a situation, the fiscal authorities possess a dominant strategy, that is – a strategy, which is the optimal response from the point of view of the government irrespective of the decisions taken by the central bank with respect to the interest rate. The dominant strategy of the fiscal authorities is the most expansive budgetary policy. Analogously, the most radically restrictive monetary policy constitutes a dominant strategy for the monetary authorities, that is – one which is optimal no matter which fiscal strategy is chosen by the government. The equilibrium of the game is thus determined by the dominant strategies, motivating the combination of the most extreme restrictive monetary policy and the most extreme expansive fiscal policy (as shown in Fig. 1).

In the second case considered, it is assumed that the fiscal and monetary authorities aim to jointly minimize the divergence of GDP growth and inflation from the desired values, y^* and p^* , respectively. We assume, as before, that for each monetary strategy j , the fiscal authorities choose the optimal fiscal response $i^*(j)$, so as to minimise the square divergence of the GDP growth rate from the desired value: i.e. $\min_i (y_{ij} - y^*)^2$. Analogously, for a given fiscal strategy i the monetary authorities select the optimal monetary response $j^*(i)$, which minimises the square divergence between actual inflation and the desired inflation rate, i.e. $\min_j (p_{ij} - p^*)^2$. Thus, the optimal budgetary responses characterise the reaction of the fiscal authorities to the potential moves of the central bank, and, vice versa, the optimal monetary responses describe the reactions of the monetary authorities to various fiscal strategies.

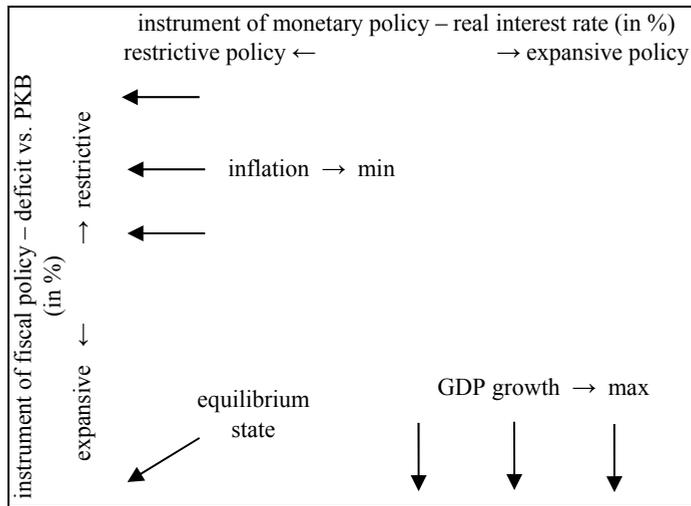


Fig. 1. Dominating fiscal and monetary strategies
– the case of maximisation of the real GDP growth and minimisation of inflation rate

For the case when the fiscal and monetary authorities aim to minimise the squared divergences of real economic growth and the inflation level from the desired values, calculations were performed under various assumptions. The location of the equilibrium point is no longer obvious and depends, in particular, upon the effectiveness of the fiscal and monetary policies adopted, as reflected by the values of the parameters of the modified logistic function, and upon the priorities of the government and the central bank. In the further course of the paper, the results of the analyses appropriate to these two factors are presented.

Table 2 shows the optimal fiscal responses, chosen by the government for each possible monetary strategy, based on minimizing the squared divergence of GDP growth from the desired value (the planned rate of growth is 3.5%). Likewise, the optimal monetary responses are shown, constituting the optimal reaction to potential fiscal strategies (based on minimizing the squared divergence between actual inflation and planned inflation, assumed to be 2.5%). It should be noted that the degree of restrictiveness of the monetary policy depends upon the choice of the fiscal policy by the government. The more expansive the fiscal policy, the more restrictive the monetary policy applied in response by the central bank, so as to avoid excessive inflation. For higher values of the budgetary deficit, the desired value of inflation is attained using appropriately higher interest rates. Analogously, when the government conducts a more restrictive budgetary policy, the central bank, aiming to attain the planned inflation rate, may settle on a less restrictive (more expansive) monetary policy, with appropriately lower interest rates. Likewise, the degree of restrictiveness or expansiveness of the fiscal policy depends upon the monetary policy applied by the central

bank. The more restrictive the monetary policy – the more expansive, in response, the budgetary policy, since attainment of the desired rate of economic growth under higher interest rates requires a more expansive fiscal policy, characterised by a higher budget deficit. Conversely, in response to a more expansive monetary policy, the government conducts an appropriately more restrictive fiscal policy.

Table 2. The payoff matrix. Optimal fiscal and monetary responses. The Nash equilibrium

	3.0	2.4	2.0	1.8	1.0	0.0
-1.0	-1.13	-0.74	-0.34	-0.09	<u>1.30</u>	3.84
0.0	0.02	0.41	0.81	1.06	<u>2.46</u>	5.00
1.0	1.18	1.57	1.97	2.22	<u>3.61</u>	6.16
1.4	1.53	1.93	2.32	3.52	3.97	6.51
1.6	1.68	2.07	<u>2.47</u>	2.72	4.12	6.66
1.8	1.81	2.21	<u>2.60</u>	2.85	4.25	6.79
2.0	1.93	<u>2.32</u>	2.72	2.96	4.36	6.90
2.4	2.11	<u>2.50</u>	2.90	3.14	4.54	7.08
3.0	2.28	<u>2.68</u>	3.07	3.32	4.72	7.26
6.0	<u>2.51</u>	2.90	3.30	3.55	4.95	7.49

Parameters (variant 1): $\alpha_1 = 6$, $\beta_1 = 1$, $\chi_1 = 1$, $\alpha_2 = -5$, $\beta_2 = 1$, $\chi_2 = 1$, $\delta_1 = 3$, $\alpha_3 = 5$, $\beta_3 = 1$, $\chi_3 = 1$, $\alpha_4 = -11$, $\beta_4 = 1$, $\chi_4 = 1$, $\delta_2 = 8$. Desired GDP growth – 3.5%, planned inflation – 2.5%. Optimal strategies: bold – fiscal, underlined – monetary, the Nash equilibrium – between the highlighted solutions. Rows correspond to the fiscal policy, columns to the monetary policy.

Figure 2 presents, in analogy to Table 2, the optimal fiscal and monetary responses, and the Nash equilibrium state for the same economic goals: GDP growth of 3.5% and inflation of 2.5%, where very small, close to zero, changes in the fiscal policy instrument (Δb_i) and the monetary policy instrument (Δr_j) are allowed. For illustration, a broader scope of change in the values of instruments is shown here compared to following figures. Owing to this, the specificity of the action of these instruments on the state of economy, including GDP growth and inflation, is better seen. Inside a certain interval of values of the fiscal and monetary policy instruments, which can be called effective values, the effect of the instruments on the economy is tangible, while outside of this interval, that is – for extreme values of the instruments, corresponding

to radically restrictive or expansive policies – the effectiveness distinctly drops off. It can be observed that within the effective range of values of the policy-mix instruments the choice of the optimum fiscal policy depends upon the decision of the monetary authorities – the more restrictive the monetary policy – the more expansive, in response, the fiscal policy, and vice versa. Yet, beyond this range of values, when we tend, for instance, towards a radically restrictive monetary policy, the optimal fiscal response does not change any more under the impact of further radicalization of the monetary policy by the central bank. Similarly, if we move towards an extremely expansive monetary policy, the optimal fiscal response no longer reacts to the further relaxation of the monetary policy. Summing up, in the regions of extremely restrictive or extremely expansive interest rate strategies, the optimal fiscal response turns into a dominant strategy.

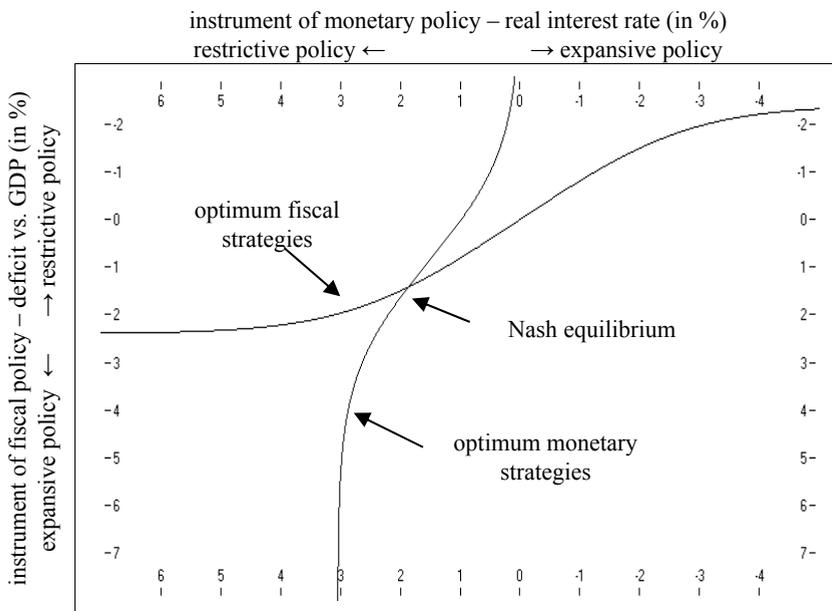


Fig. 2. Optimum fiscal and monetary strategies; desired GDP growth – 3.5%, inflationary goal – 2.5%. Results of simulations for variant 1, broader scope of changes in instrument values

Analogously, for a certain (effective) interval of values of the fiscal policy instruments, the choice of the optimal monetary response depends upon the budgetary policy selected by the fiscal authorities – the more expansive the fiscal policy, the more restrictive the monetary policy applied, in response, by the central bank (and vice versa). Outside of this interval, further radicalization of the budgetary policy turns the optimum monetary response into a dominant strategy.

For the assumed parameter values and the priorities of the fiscal and monetary authorities, the Nash equilibrium state corresponds to a combination of relatively neutral

fiscal and monetary policies, which are characterised by a budget deficit of approximately 1.42% of GDP and a real interest rate of roughly 1.87%.

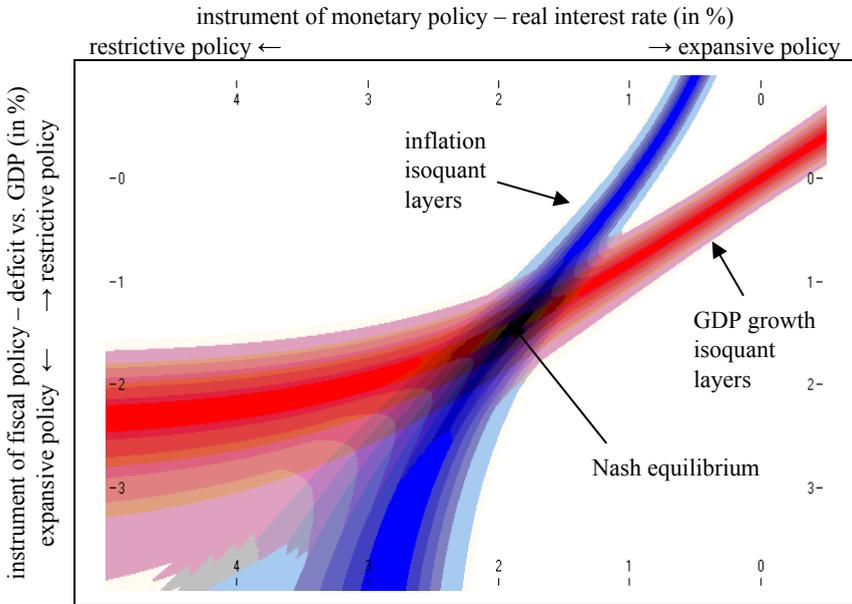


Fig. 3. Isoquants – a layered diagram with admissible deviations from the assumed goals for GDP growth (3.5%) and for inflation (2.5%). Results of simulations for variant 1

Figure 3 shows the isoquants of GDP growth and the isoquants of inflation, demonstrating what alternative policy-mixes (combinations of fiscal and monetary policies) enable the attainment of the assumed GDP growth and inflation (with a variable range of admissible changes with respect to the desired values). It can be noticed that solutions corresponding to a narrow range of admissible deviations from the desired values for, simultaneously, economic growth and inflation, are also contained in a small neighbourhood of the Nash equilibrium. If we admit a broader range of deviations from the assumed macroeconomic objectives, the region of “sufficiently good” solutions (that is – ones “sufficiently” close to the desired values of both planned GDP growth and inflation) broadens, as well. One can see a distinct asymmetry in the shape of the region of admissible solutions – this area extends in a more pronounced manner towards combinations of more expansive fiscal policies and more restrictive monetary policies, in comparison to the Nash equilibrium state.

The following simulations show the influence of changes in the priorities of the fiscal and monetary policies on the location of the Nash equilibrium, and hence also on the choice of the corresponding policy-mix. The respective results are shown in Figs. 4 and 5. A change in priorities in the framework of fiscal policy, reflected through a change

in the desired rate of GDP growth, brings about a shift in the optimal budgetary response, either in the direction of a more expansive fiscal policy, when more ambitious goals concerning economic growth are adopted, or in the direction of a more restrictive budgetary policy in the opposite case. Likewise, a change in the priorities of the monetary authorities, which is reflected in a shift of the desired level of inflation, entails a shift in the optimal monetary response – in the direction of a more expansive monetary policy in the case of a less demanding position from the central bank, i.e. accepting higher inflation, or in the direction of a more restrictive monetary policy, when the desired inflation level is lowered. Under the impact of changes in the priorities of the fiscal and monetary authorities, the location of the Nash equilibrium moves accordingly (Fig. 4).

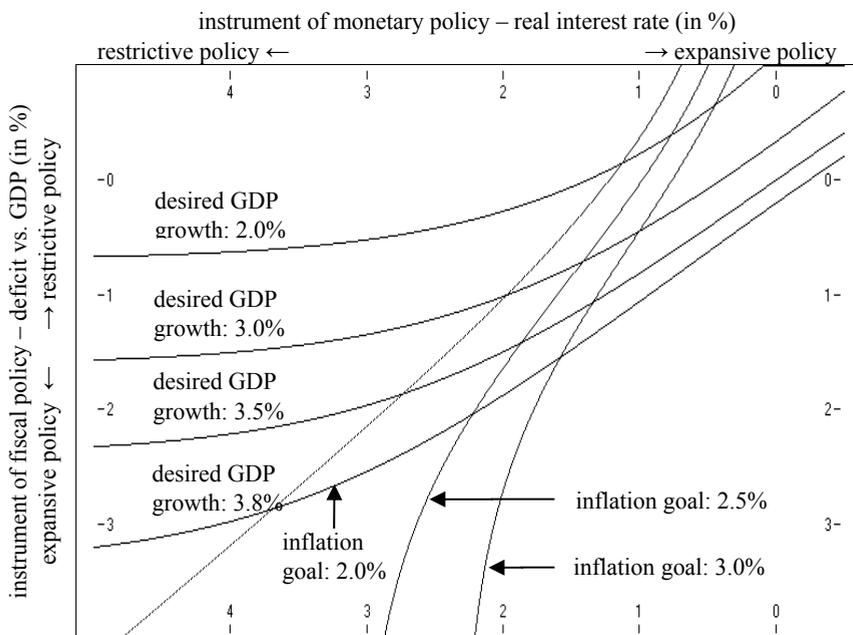


Fig. 4. Optimum fiscal and monetary strategies vs. priorities of the government and the central bank along with the corresponding Nash equilibrium states. Results of simulations for variant 1

Figure 5 illustrates a different case, namely when the excessively high expectations of the fiscal and/or monetary authorities make it impossible to attain the equilibrium state within the effective interval of values of the instruments of macroeconomic policy and thereby hamper rational choice in the domain of policy-mixes. The excessive expectations of the fiscal and monetary authorities result in choosing a combination of an extremely restrictive monetary policy and an extremely expansive budgetary policy. Calculations for variant 1 show that a very low planned inflation rate set by the monetary authorities (e.g. inflation at the level of 1.5% or 2%), coupled with very high

GDP growth planned by the fiscal authorities (e.g. 4.5% or 5%) results in just this kind of situation. The possibility of the occurrence of such cases implies a need for some degree of coordination of the monetary and fiscal policies.

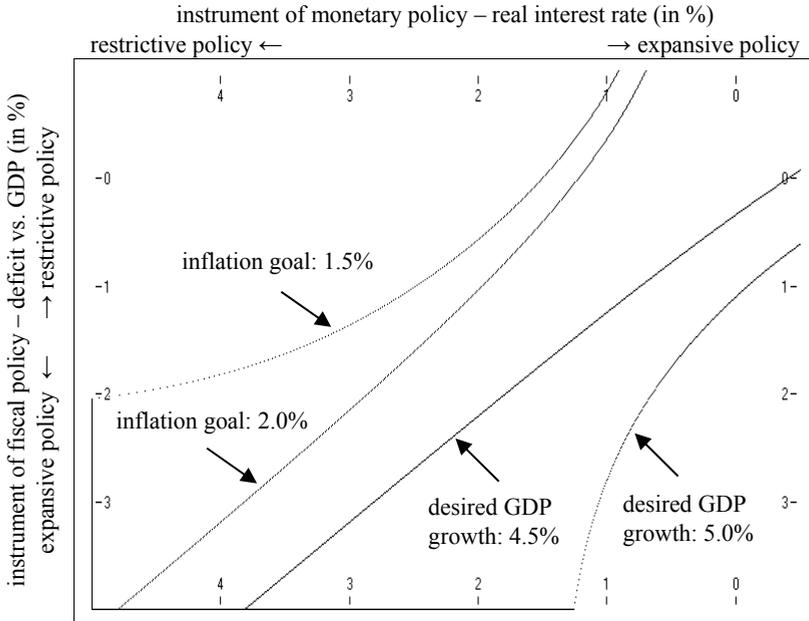


Fig. 5. Optimum fiscal and monetary strategies for the excessively ambitious (unrealistic) macroeconomic goals. Results of simulations for variant 1

4. The influence of the parameters of the logistic function on the optimal responses and equilibria

This simulation study concerned the analysis of the influence exerted by the parameters of the modified logistic function, associated with the effectiveness and the scope of action of the policy-mix instruments.

In the context of the assumption stipulating the limited capacity of the fiscal and monetary policies to exert influence on the economy, the parameter α_i characterises the maximum range of changes in the macroeconomic variables reflecting the state of the economy (the economic growth rate and inflation) which take place under the impact from the instruments (the gradual passage in the modified logistic function from the initial value for the most radically restrictive/expansive policy to the ultimate value accompanying the most radically expansive/restrictive policy (see Section 2 and [20]). An increase in the absolute value of the parameter α_i widens the interval of possible changes in production and inflation, with the parameter α_1 reflecting the influence of the

budgetary deficit on the GDP growth rate, α_2 reflecting the influence of the interest rate on the GDP growth rate, α_3 reflecting the influence of the budgetary deficit on inflation, and α_4 reflecting the influence exerted by the interest rate on inflation. Analogously, a decrease in the absolute value of the parameter α_i brings about a narrowing of the interval of possible values of GDP growth and inflation resulting from the economic policy.

Table 3. Payoff matrix for larger absolute values of the α parameters.
Optimal fiscal and monetary responses. The Nash equilibrium

	3.0	2.4	2.0	1.8	1.0	0.0
-1.0	-2.50	-2.04	-1.57	-1.27	0.38	<u>3.38</u>
0.0	-0.88	-0.42	0.05	0.34	<u>2.00</u>	5.00
1.0	0.73	1.20	1.67	<u>1.96</u>	3.61	6.62
1.4	1.23	1.70	2.16	<u>2.46</u>	4.11	7.12
1.6	1.44	1.91	<u>2.37</u>	2.67	4.32	7.32
1.8	1.62	2.09	<u>2.56</u>	2.85	4.50	7.51
2.0	1.78	2.25	<u>2.72</u>	3.01	4.66	7.67
2.4	2.03	<u>2.50</u>	2.97	3.26	4.91	7.92
3.0	2.28	<u>2.75</u>	3.22	3.51	5.16	8.17
6.0	<u>2.60</u>	3.06	3.53	3.83	5.48	8.17

Parameters: $\alpha_1 = 8$, $\alpha_2 = -6.5$, $\alpha_3 = 7$, $\alpha_4 = -13$, remaining parameters as in variant 1. Desired GDP growth – 3.5%, planned inflation – 2.5%. Optimal responses: bold – fiscal, underlined – monetary, the Nash equilibrium – highlighted cell.

Tables 3 and 4 show the results of simulations performed for various values of the parameter α_i . It can be observed that an increase in the absolute values of the parameters α_1 and α_2 , reflecting the influence of the policy-mix instruments on the GDP growth rate, brings about an increase in the range of GDP dynamics for the analysed interval of instrument values. For the values of the parameters α_1 and α_2 adopted in variant 1 (see Table 2), the rate of growth of GDP ranges from -0.15% for a budgetary surplus of 1% of GDP and real interest rate equal to 3%), increases gradually with the increasing expansiveness of the fiscal and monetary policies up to 6.49% for the combination of two extremely expansive policies (a budgetary deficit equal to 6% of GDP and real

interest rate equal to zero). Thus the range of possible GDP growth is 6.63%. For the very same range of changes in the values of instruments but higher values of the parameters α_1 and α_2 , similarly, the rate of growth of GDP increases from -1.04% to 7.73% , that is – the range is 8.77 percentage points (Table 3). Analogously, lowering the absolute values of α_1 and α_2 narrows the range of possible GDP growth (Table 4). For lower absolute values of the parameters α_1 and α_2 , the increase in expansiveness of the fiscal and monetary policies (within the limits shown in the table) brings about a smaller change in comparison with variant 1 – the GDP growth rate increases from 0.40% for the combination of the two most restrictive policies to 5.49% for the combination of the two most expansive policies – that is by 5.09 percentage points (see Table 4).

Table 4. Payoff matrix for smaller absolute values of the α parameters.
Optimal fiscal and monetary responses. The Nash equilibrium

	3.0	2.4	2.0	1.8	1.0	0.0
-1.0	-0.11	0.23	0.57	0.79	<u>2.00</u>	4.19
0.0	0.40	0.54	0.69	0.78	1.29	2.21
1.0	0.70	1.04	1.38	1.60	<u>2.80</u>	5.00
1.4	1.44	1.58	1.73	1.82	2.33	3.25
1.6	1.51	1.85	2.19	<u>2.41</u>	3.61	5.81
1.8	2.48	2.62	2.77	2.86	3.37	4.29
2.0	1.76	2.10	<u>2.44</u>	2.66	3.86	6.06
2.4	2.80	2.94	3.09	3.18	3.69	4.61
3.0	1.86	2.20	<u>2.54</u>	2.76	3.97	6.16
3.6	2.93	3.08	3.22	3.31	3.82	4.74
4.2	1.95	2.29	<u>2.64</u>	2.85	4.06	6.25
4.8	3.05	3.19	3.34	3.43	3.94	4.86
5.4	2.03	<u>2.37</u>	2.72	2.93	4.14	6.33
6.0	3.15	3.30	3.44	3.53	4.04	4.96
6.6	2.16	<u>2.50</u>	2.84	3.06	4.26	6.46
7.2	3.32	3.46	3.60	3.69	4.20	5.13
7.8	2.28	<u>2.62</u>	2.97	3.18	4.39	6.58
8.4	3.48	3.62	3.76	3.85	4.36	5.29
9.0	<u>2.44</u>	2.78	3.12	3.34	4.55	6.74
9.6	3.68	3.82	3.97	4.06	4.56	5.49

Parameters: $\alpha_1 = 4.5$, $\alpha_2 = -4$, $\alpha_3 = 3.5$, $\alpha_4 = -9.5$, remaining parameters as in variant 1. Desired GDP growth – 3.5% , planned inflation – 2.5% . Optimal responses: bold – fiscal, underlined – monetary, the Nash equilibrium – highlighted cell.

A similar effect can be observed for the influence exerted by the instruments of the policy-mix on inflation. Increasing the absolute values of the parameters α_3 and α_4 broadens the range of possible inflation rates for the adopted range of values of the instruments. In variant 1 (Table 2), the lowest level of inflation, -1.13% , (i.e. defla-

tion), corresponding to the combination of the two most restrictive policies, increases under the influence of growing policy expansiveness, both fiscal and monetary, to a maximum of 7.49% (range of 8.62 percentage points). For the same interval of instrument values, but for larger absolute values of the parameters, when the policies become increasingly expansive, inflation increases from -2.50% (deflation) to 8.48% , that is – by 10.98 percentage points. Along with a decrease in the absolute values of the parameters α_3 and α_4 , the range of the inflation rate narrows (Table 4).

A change in the values of the parameters α_1 and α_2 also brings about a change in the optimal budgetary responses, the reaction of the fiscal authorities to the decisions of the central bank, and, in analogy, a change in the values of the parameters α_3 and α_4 causes a shift in the optimum monetary response. Consequently, the location of the Nash equilibrium state correspondingly changes.

The parameter χ reflects the speed of transition of the output variable in reaction to an increase in the value of the explanatory (input) variable. The larger the absolute value of χ , the faster the transition is. Calculations were performed for parameter values $\chi > 0$. In reference to the function describing the state of the economy, characterizing the dependence of GDP growth and inflation upon the instruments of macroeconomic policy, it should be noted that a faster transition might be interpreted as a narrower interval of the values of the policy-mix instruments within which these instruments effectively influence the economy. In the analysis reported here the parameters χ_1 – χ_4 reflect, respectively:

- χ_1 – influence of the budgetary deficit on the GDP growth rate,
- χ_2 – influence of the interest rate on the GDP growth rate,
- χ_3 – influence of the budgetary deficit on inflation,
- χ_4 – influence of the interest rate on inflation.

The results of simulations for various values of the parameter χ_i are presented in Figs. 6–12. The diagram of Fig. 6 indicates that a change in the value of the parameters χ_1 and χ_2 , corresponding to the influence of the policy-mix instruments on the GDP growth rate, brings about a change in the optimal fiscal responses to strongly restrictive monetary strategies. The higher the values of the parameters χ_1 and χ_2 , the narrower the interval of the effective influence exerted by the macroeconomic instruments on economic growth are. The values of these parameters also influence the degree of restrictiveness/expansiveness of the fiscal policy which becomes dominant for extremely restrictive monetary policies. Analogously, Figure 6 shows how the optimal monetary responses change under the influence of changes in the values of the parameters χ_3 and χ_4 , reflecting the influence of the policy-mix instruments on inflation. Here, as well, the larger the values of the parameters, the narrower the interval of effective action of the instruments on the level of inflation are. The values of the parameters χ_3 and χ_4 also influence the degree of restrictiveness/expansiveness of the monetary policy which becomes dominant for extremely expansive/restrictive fiscal policies.

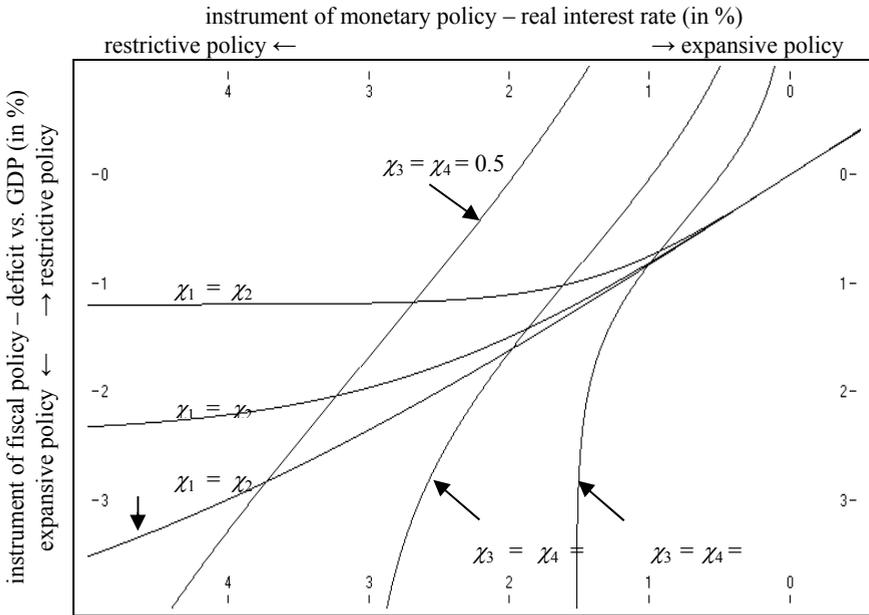


Fig. 6. Optimum fiscal and monetary strategies (desired GDP growth – 3.5%, inflationary goal – 2.5%). Equilibrium states for different χ_1 - χ_4 ; remaining parameters as in variant 1

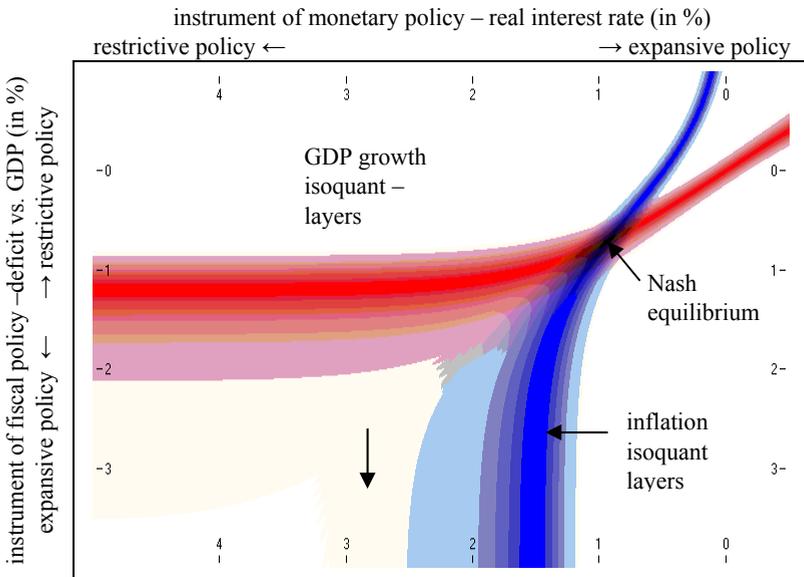


Fig. 7. Isoquants – layered diagram with admissible deviations from the assumed goal values: GDP growth – 3.5%, inflation – 2.5%. Results of simulations for: $(\chi_1$ - $\chi_4) = 2.0$; remaining parameters as in variant 1

Consequently, the location of the Nash equilibrium also depends upon the values of the parameters χ_i . For low values (e.g. for the parameter values $(\chi_1-\chi_4) = 0.5$), the Nash equilibrium state corresponds to a combination of an expansive fiscal policy and a restrictive monetary policy (budget deficit of roughly 2.84% of GDP, and real interest rate of around 3.7%) compared to variant 1. For high values (e.g. for the parameter values $(\chi_1-\chi_4) = 2.0$) the Nash equilibrium state corresponds to a combination of a rather restrictive fiscal policy and a rather expansive monetary policy (budget deficit of approximately 0.71% of GDP and real interest rate of around 0.72%).

The following figures present the results of simulations for larger (Figs. 7–9) and smaller (Figs. 10–12) values of the parameters χ_i . These figures present both the appropriate isoquants and diagrams illustrating the influence of the priorities of the fiscal and monetary authorities on the Nash equilibrium state and hence also on the choice of the corresponding policy-mix.

The influence of changes in the priorities of the fiscal and monetary authorities on the Nash equilibrium state and, consequently, on the choice of the policy-mix, is shown in Figs. 8, 9, and then 11 and 12.

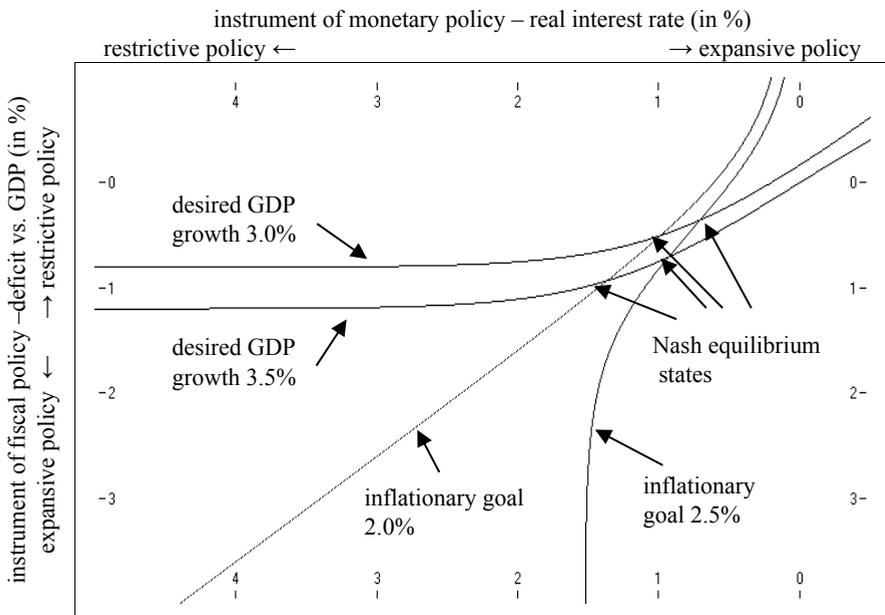


Fig. 8. Optimum fiscal and monetary strategies vs. priorities of the government and the central bank, and the corresponding Nash equilibria.

Results of simulation for variant 4aa: $(\chi_1-\chi_4) = 2.0$; remaining parameters as in variant 1

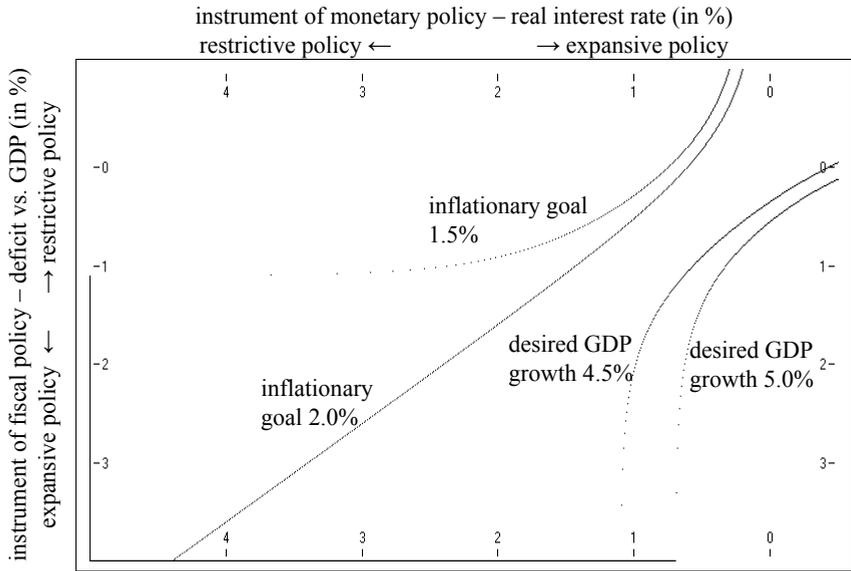


Fig. 9. Optimum fiscal and monetary strategies for the excessively ambitious (unrealistic) macroeconomic goals. Results of simulation for variant 4aa: $(\chi_1 - \chi_4) = 2.0$; remaining parameters as in variant 1

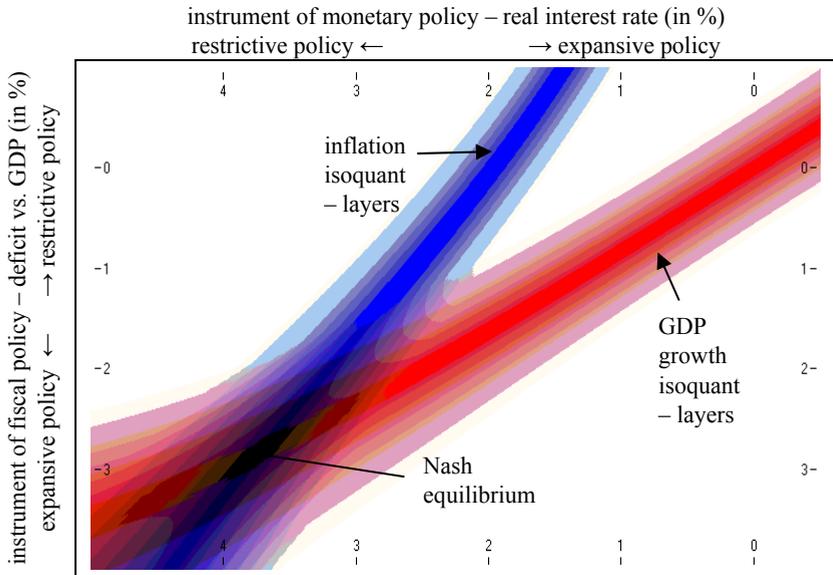


Fig. 10. Isoquants – layered diagram with admissible deviations from the assumed goal values: GDP growth = 3.5%, inflation = 2.5%. Results of simulation for variant 4bb: $(\chi_1 - \chi_4) = 0.5$; remaining parameters as in variant 1

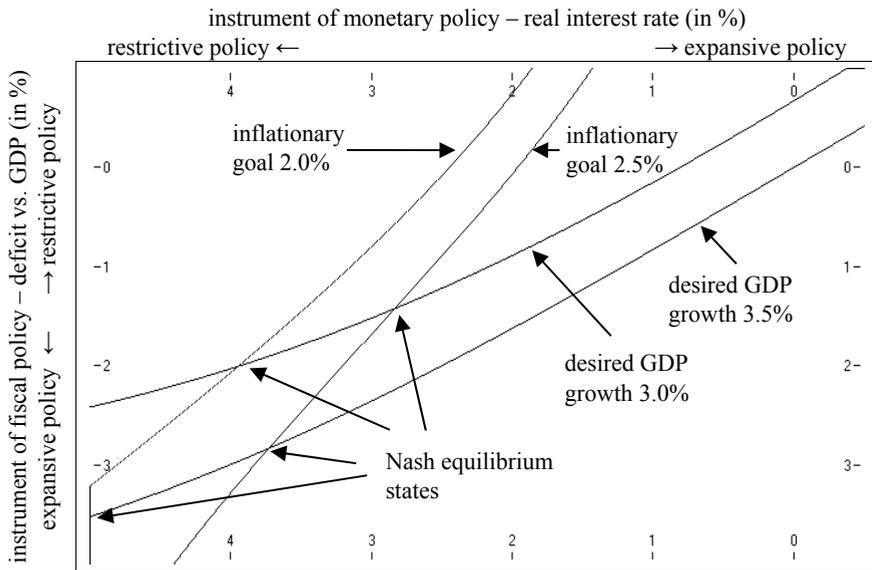


Fig. 11. Optimum fiscal and monetary strategies vs. priorities of the government and the central bank, and the corresponding Nash equilibria. Results of simulation for variant 4bb: $(\chi_1 - \chi_4) = 0.5$; remaining parameters as in variant 1

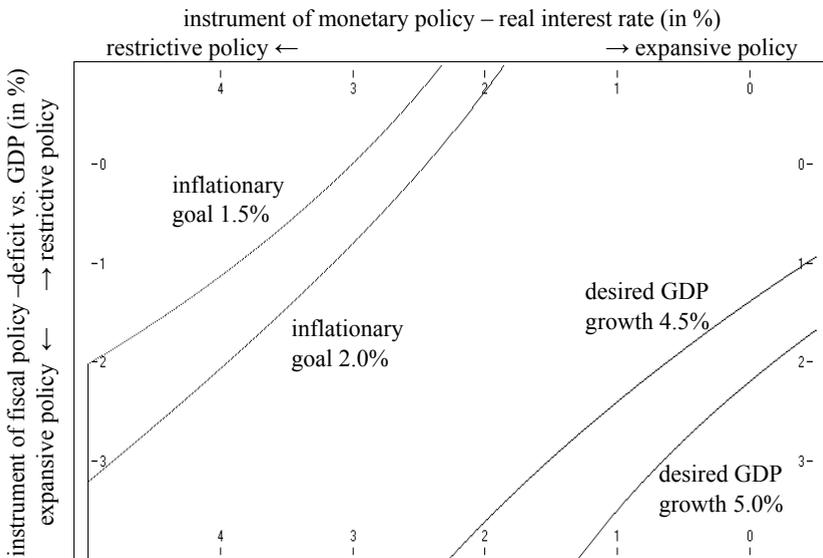


Fig. 12. Optimum fiscal and monetary strategies for the excessively ambitious macroeconomic goals. Results of simulation for variant 4bb: $(\chi_1 - \chi_4) = 0.5$; remaining parameters as in variant 1

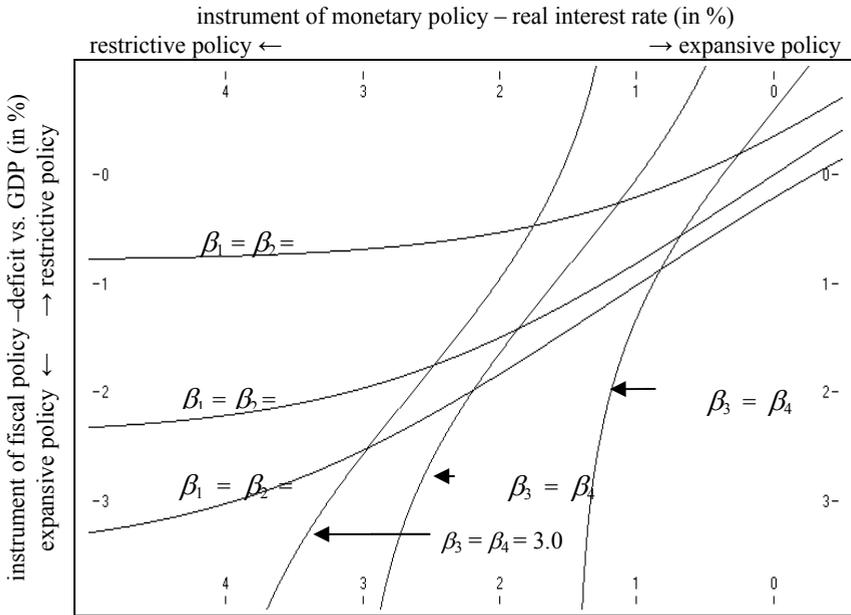


Fig. 13. Optimum fiscal and monetary strategies (the desired GDP growth – 3.5%, the inflationary goal – 2.5%. Equilibrium states for various values of parameters β_1 – β_4 ; remaining parameters as in variant 1

The direction of the impact of the economic objectives on the degree of restrictiveness/expansiveness in the optimum budgetary and monetary responses is analogous to the initial case with the values of the parameters χ_i , taken to be equal to 1.0. More ambitious goals related to the GDP growth result in the fiscal policy becoming more expansive, while acceptance of a lower growth rate leads to a more restrictive budgetary policy (Figs. 8 and 11). Likewise, a change in the planned inflation rate influences the character of the monetary policy – increasing the planned inflation rate leads to a more expansive monetary policy, while lowering the planned inflation rate increases the restrictiveness of the policy. Changes in the priorities of the fiscal and monetary authorities also shift the location of the Nash equilibrium. In addition, one can observe that the higher the values of the parameters χ_i , the narrower the area within which the equilibrium states are contained for macroeconomic goals that can change within a given interval are. In other words, for large values of the parameters χ_i , the same change in the priorities of the government and the central bank results in smaller changes in the equilibrium values of the fiscal and monetary policy instruments.

As in earlier simulations (variant 1), the calculations performed for other values of the parameters χ_i indicate the possibility of situations in which the overly ambitious goals of the fiscal and monetary authorities make it impossible to attain an equilibrium

inside the effective interval of the policy-mix instruments (Figs. 9 and 12). Both decision makers use dominant (or near dominant) strategies, i.e. the equilibrium is a combination of an extremely restrictive monetary policy with an extremely expansive fiscal policy.

Subsequent simulations concerned the influence of the parameter β on the optimal strategies and the Nash equilibrium state. It can be observed that as the value of this parameter increases, the inflexion point of the modified logistic function is shifted towards higher values of the instrument, this being equivalent to increasing the values of the instrument for which its effectiveness (strength of influence on the economy) is the greatest. The parameters β_1 – β_4 reflect, respectively: β_1 – the influence of the budgetary deficit on the GDP growth rate; β_2 – the influence of the interest rate on the GDP growth rate; β_3 – the influence of the budgetary deficit on inflation; and β_4 – the influence of the interest rate on inflation.

The results of simulations for various values of the parameters β_i are shown in Fig. 13. It can be observed that a change in the values of the parameters β_1 and β_2 , reflecting the influence of the policy-mix instruments on the rate of growth of GDP, brings about a change in the optimal fiscal responses. In particular, there is a shift of the interval of values of the fiscal strategy, which are truly effective with regard to economic growth, towards larger fiscal expansion. The diagram also shows that the larger the values of β_1 and β_2 , the more expansive the equilibrium budgetary policy is, partially as a response to the equilibrium monetary policy becoming more restrictive. The values of these parameters exert an influence, as well, on the degree of restrictiveness/expansiveness of the fiscal policy in the region, which becomes dominant or near-dominant for extremely restrictive monetary policies. The figure also shows how the optimum monetary responses change under the influence of changes in the values of the parameters β_3 and β_4 , reflecting the influence of the macroeconomic policy instruments on the level of inflation. Larger values of these parameters bring about a shift in the interval of effective action of the instruments upon inflation towards larger values of the monetary policy instrument, that is – towards higher interest rates. The values of the parameters β_3 and β_4 also influence the degree of restrictiveness/expansiveness of the monetary policy in the region, which becomes dominant or near dominant for extremely expansive/restrictive fiscal policies. The location of the Nash equilibrium point changes in accordance with the changes in the optimum fiscal and monetary responses.

5. Summary of the study

The present paper provides results of simulations for the fiscal-monetary game, in which the players' payoffs were determined using a modified logistic function, which

implies the assumption of a limited range of effectiveness of the instruments of fiscal and monetary policy in their action upon the economic situation, including GDP growth and inflation. This is equivalent to the assumption of a limited capacity of both stimulating growth through an increasingly expansive fiscal policy and lowering inflation by sharpening an already restrictive monetary policy. The assumption made in the study was that the monetary authorities aim at a desired level of inflation, while the fiscal authorities – at the attainment of a desired (planned) economic growth.

The results of the simulations indicate that the optimum fiscal and monetary responses depend upon both the parameters of the logistic function, reflecting the effectiveness and the scope of tangible action of the policy-mix instruments and upon the priorities adopted by the government and the central bank in the shaping of macroeconomic policies.

The action of these instruments on the economy is effective within a certain interval of values of the fiscal and monetary policy instruments. While the effectiveness of the instruments decreases very distinctly at extremely low/high values of the instruments, corresponding to radically restrictive or expansive policies. Within the interval of effective instrument values, the choice of the optimal fiscal response depends upon the decision of the central bank – the more restrictive the monetary policy, the more expansive, in response, the fiscal policy, and vice versa. Outside of this interval of effective action, as we move towards radically restrictive monetary policies – the optimal fiscal response stops changing as the monetary policy by the central bank becomes more restrictive. Similarly, as we move towards extremely expansive monetary policies – the optimal fiscal response stops reacting to further relaxation of the monetary policy. Thus, one can observe a tendency for a fiscal strategy to become dominant as the monetary policy becomes extremely restrictive/expansive. The optimal monetary response depends analogously upon the policy that is conducted by the fiscal authorities. The central bank reacts to an increase in the expansiveness of the budgetary policy by sharpening monetary policy, in order to avoid inflation exceeding the planned rate. For extreme budgetary policies it is, again, characteristic, that there exists a dominant or near-dominant monetary policy.

The results indicate that under the influence of changes in the priorities of the central bank and the government, the optimal fiscal and monetary responses change and, consequently, the Nash equilibrium shifts, this equilibrium being interpreted as the choice of the policy-mix. When the growth rate planned by the fiscal authorities increases, the optimal budgetary response becomes more expansive. Likewise, a change in the priorities of the monetary authorities, e.g. permitting a higher level of inflation, causes a shift in the optimum monetary strategies, here in the direction of a more expansive policy. The simulations conducted also indicate the possibility of a lack of coordination – where the goals of the fiscal and monetary authorities are unrealistically defined and hamper the attainment of the equilibrium state and thus also do not enable rational choice concerning the policy-mix.

On the basis of the results obtained, the isoquants of GDP growth and inflation were presented, showing what alternative policy-mixes (combinations of the fiscal and monetary policies) enable the attainment of the assumed GDP dynamics and inflation rate. This enables derivation of the equilibrium and near-equilibrium solutions (where growth and inflation are within an admissible range of deviations from the desired values).

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