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Assessment of the historical policy mixes for Poland using the game approach*

by

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Abstract: The study here presented pertains to the analysis of mutual interactions of the monetary and fiscal policies in the case of Poland. The historical policies carried out during different periods of time and their economic effects are compared with the possible strategies, obtained from the analysis of the proposed monetary-fiscal game. In the study, the methods of non-cooperative game theory are combined with macroeconomic modeling. The respective game is formulated for monetary and fiscal authorities as players. Strategies of these players refer to the respective instruments of their policies: the real interest rate and the budget deficit in relation to GDP. Payoffs include inflation and GDP growth, respectively. The payoffs are calculated using a recursive macroeconomic model estimated for the Polish economy. The model describes influences of the instruments of the monetary and fiscal policies on the state of the economy. The best response strategies, the Nash equilibria and Pareto optimality are analyzed. Changes of the policies towards the more restrictive or more expansive ones and their effects in comparison to the historically applied are discussed. This is performed for two different time periods – the time of recovery after 2004 and the time of the global financial crisis after 2008.

Keywords: game theory, economic modeling, policy mix, decision analysis, Nash equilibrium, Pareto optimality

1. Introduction

The paper deals with the analysis of alternative monetary-fiscal policies for Poland. The analysis is carried out with the use of a noncooperative game, describing mutual interactions of policies, implemented by the monetary authority (the central bank) and the fiscal authority (the government). This paper continues the research direction presented in the previous papers: Kruś and

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Woroniecka-Leciejewicz (2015, 2016a,b, 2017); Woroniecka-Leciejewicz (2016, 2015a, b, 2010, 2008, 2007). The previous papers include different variants of the macroeconomic model, used to calculate the game outcomes. The game was formulated with strategies defined by the real interest rate and the budget deficit in relation to GDP. Different variants of policies were analyzed, taking into account the best response strategies, Nash equilibria and Pareto-optimality.

In comparison to these previous papers, the present paper concentrates on the analysis of possible game solutions, compared with the real results of the historical strategies in Poland, implemented by the fiscal and monetary authorities. The game is formulated in a different way. For this comparative study, the strategies in the game are formulated as deviations of the fiscal and monetary policies with respect to the historical strategies of the fiscal and monetary authorities. The deviations mean here the changes of the policies towards the more restrictive or more expansive ones with respect to the policies really implemented. Computational experiments have been made in the attempt to answer the question: what can be consequences of these alternative policies and, especially, can the real historical strategies be improved using the game approach. For this reason the best response strategies are calculated for different targets assumed by the fiscal and monetary authorities, then possible Nash equilibria are derived and Pareto-optimality of the game outcomes is checked. To carry out the experiments here reported, a new, updated version of the macroeconomic model was used. The experiments and respective analysis are made for two different time periods: the period of economic expansion of 2004-2005 and the period of global economic crisis of 2008-2009. The model has been estimated using the time series for 2000-2014 for Poland.

The bibliography, dealing with interactions of fiscal and monetary policies and using game ideas is relatively rich, starting from the papers by Blinder (1983) and Nordhaus (1994). Different aspects of possible outcomes of the game and of players' behavior are analyzed in such papers as Bennett & Loayza (2001), Dixit & Lambertini (2001), Lambertini & Rovelli (2003), or Marszałek (2009). There are also papers analyzing the policy mix problems using statistical data, including the case of Poland, see Wojtyna (1996), Darnault & Kutos (2005), Stawska (2014), Libich, Nguyen & Stehlik (2014). An extended list of references can be found in Kruś & Woroniecka-Leciejewicz (2017). The research presented in these papers has in general a descriptive character.

Our research has a normative character. It leads, ultimately, to the construction of a decision support system including the game formulation and respective interactive macro-economic model. It allows for different types of analyses and for the selection of the monetary and fiscal policies, satisfying in the best way the assumed goals of the policies, and having respective stability and Pareto-optimality properties. In the case of Poland there were no publications, dealing with interactions of the fiscal and monetary policies, analyzed with the use of

computational game models.

This paper is organized as follows. The next section, Section 2, presents the formulation of the proposed noncooperative monetary fiscal game. The proposed recursive macroeconomic model is described in Section 3. Section 4 presents the results of model estimation. Simulation experiments for Poland in the periods 2004-2005 and 2008-2009 are presented in Section 5. This section includes the examples of simulation runs and the analysis of the proposed monetary-fiscal game. Section 6 concludes the obtained results.

2. Noncooperative monetary-fiscal game

Relations between the fiscal authority and the monetary authority are described in this study by a noncooperative, static, deterministic game. There are two players i =1, 2: the fiscal authority (the government) and the monetary authority (the central bank). Each player takes decisions independently, taking into account the possible reaction of the counter-player. The strategies of the fiscal authority refer to the budgetary policy and are defined by the deviation Δb of the level of budget deficit in relation to GDP in comparison to the historical one. The strategies range from restrictive to expansive ones and belong to a set B. The strategies of the monetary authority also range from restrictive to expansive ones. They are defined by the deviation Δr of the real interest rate in comparison with the historical one and belong to a set R.

For each player $i = 1, 2$, a function h^i: $B \times R \to R$ is given, defining the outcome of the player i for given strategies undertaken by both players. The outcome of the fiscal authority is measured by the GDP growth rate, denoted by y, where $y = h^1(b, r)$, $b = b_0 + \Delta b, r = r_0 + \Delta r$, where b_0 and r_0 denote, respectively, the historical values of the level of budget deficit in relation to GDP and the real interest rate. The outcome of the monetary authority is measured by the inflation value, denoted by p, where $p = h^2(b, r)$. The functions h^i, i =1, 2, are defined by the model relations. For each player i =1, 2, a preference relation is given in the set of the attainable outcomes. It is assumed here that each of the two authorities tries to achieve a given goal: the fiscal authority – a desired value of GDP growth, the monetary authority – a desired value of inflation.

Outcomes of the game in the discrete form are presented in Fig 1. Payoffs in this figure are denoted in the following manner: y_{ij}– payoff of the fiscal authority (GDP growth rate) in the case, in which the government applies the fiscal strategy F_i and the central bank applies the monetary strategy M_j; p_{ij}– payoff of the monetary authority (inflation) for the same pair of policies. The symbol Δb_i denotes the deviation of budgetary deficit in relation to GDP in comparison with the historical one – corresponding to the i-th fiscal strategy, while Δr_j denotes the deviation of the real interest rate with respect to the historical one, ascribed to the j-th monetary strategy. According to the considered

comparative analysis, presented in this paper, the table of payoff is formulated in a different way than in the previous papers, in which the fiscal policy was represented directly by the budget deficit in relation to GDP and the monetary policy was represented by the real interest rate. In this paper we look for alternative, more effective, policy-mix in comparison to the policies carried out actually in the past. For this reason deviation from the historical policies – the deviations referring to more restrictive or more expansive policies – are considered as inputs in the game.

It is assumed that the fiscal and monetary authorities take their respective decisions independently, and the Nash equilibrium state in such a game is identified with the choice of a given combination of the budgetary and monetary policies, corresponding to these decisions.

Figure 1. The monetary-fiscal game - table of payoffs

		Central bank – the monetary policy ← restrictive … expansive →			
	Strategies	Monetary strategy M_1 (deviation of interest rate from historical Δr_1)	Monetary strategy M_2 (deviation of interest rate from historical Δr)	…	Monetary strategy M_n (deviation of interest rate from historical Δr)
Government – fiscal policy ↓ expansive restrictive ↑	Fiscal strategy F_1 (deviation of budget deficit from historical Δb_1)	p_{11} / y_{11}	p_{12} / y_{12}	… / …	p_{1n} / y_{1n}
	Fiscal strategy F_2 (deviation of budget deficit from historical Δb_2)	p_{21} / y_{21}	p_{22} / y_{22}	… / …	p_{2n} / y_{2n}
	…			…	
	Fiscal strategy F_m (deviation of budget deficit from historical Δb_m)	p_{m1} / y_{m1}	p_{m2} / y_{m2}	… / …	p_{mn} / y_{mn}

3. Recursive econometric model

The here presented model, used to analyze the discussed monetary-fiscal game, is a recursive macroeconomic model, based on the concept of New Neoclassical Synthesis (NNS). In comparison to the basic NNS model (compare, e.g., Gali, 2009) the proposed model takes additionally into account the effects of the fiscal policy – influence of the real budget expenditures. An equation of the output gap is introduced. In comparison to the previous papers of the present authors, the Taylor equation, describing the interest rate, derived by the central bank, is removed. The interest rate is assumed on the basis of historical data, excluding the period of analysis, in which it is given as the input in the game, in the

period of 8 quarters, changed in simulations. After this period, the interest rate is again assumed on the basis of historical data. An additional equation describing expected inflation is also introduced.

3.1. Equation of the output gap (dynamic, inter-period version of the IS curve)

The equation describes an aggregated demand as the result of the optimal decisions made by a representative consumer.

$$x_t = \alpha_0 + \alpha_1 x_{t-1} + \alpha_2 (r_t - \pi_t^e - r_t^n) + \alpha_3 g_t + \varepsilon_{1t}, \tag{1}$$

where:

$x_t = y_t - y_t^n$ is the production gap, x_t, defined as a difference of the current real production y_t and its natural level y_t^n in the equilibrium state with the perfectly elastic prices,

$r_t - \pi_t^e - r_t^n$ is the interest rate gap, i.e. deviation of the real interest rate from its natural value r_t^n; real interest rate is calculated as the difference: the nominal interest rate r_t (WIBOR 1M) minus the expected inflation π_t^e,

$g_t = G_t - G_t^n$: gap of the budget expenditures, deviation of the real budget expenditures G_t from its natural value G_t^n.

Production is measured by the real Gross Domestic Product (GDP). The current value of the production gap depends on its delayed value and on the interest rate gap, where the interest rate gap is defined as the difference of the real interest rate and its natural level r_t^n.

The natural level of the product as well as the natural interest rate r_t^n and the expenditures G_t^n have been calculated using the Hodrick–Prescott filter.

3.2. Inflation equation

The equation is known as the New Keynesian version of the Phillips curve. It presents a function of the aggregated supply based on price decisions of firms in the conditions of imperfect competition (Calvo, 1983). Inflation depends on the expected inflation π_t^e and on the output gap x_t. The equation has the form:

$$\pi_t = \beta_0 + \beta_1 \pi_{t-1}^e + \beta_2 x_t. \tag{2}$$

3.3. Equation of expected inflation

The expected inflation is explained by its delayed value and by the current inflation. The equation has the form:

$$\pi_t^e = \delta_0 + \delta_1 \pi_{t-1}^e + \delta_2 \pi_t \quad . \tag{3}$$

4. Model estimation

The time series for the Polish economy from the period of years 2000-2014 (quarterly data) have been used in estimation. The statistical data have been collected from the following sources: Central Statistical Office of Poland, National Bank of Poland (NBP), and Ipsos group. The NNS-MFG model has been estimated as a system of simultaneous equations using the Three-Stage Least Squares Method (3SLS) in the econometric GRETL package.

The variables, used in the model estimation and the estimation results are presented in graphical form in Fig.2.

The estimation results show an acceptable goodness of fit. All the variables are statistically significant.

Table 1. The variables used in the model estimation

Variable	**Description**
output_gap	The output gap is defined as the difference between the real GDP and the natural level of output presented by the Central Statistical Office in time series according to the principles of the "European System of National and Regional Accounts" (ESA); GDP in constant prices. The natural level is calculated using the Hodrick–Prescott filter.
output_gap_1	The output gap, one period delayed
inflation	Inflation calculated on the basis of the consumer price index
expected_infl	Expected inflation measured as the average inflation level expected in the next year (NBP, Ipsos data)
expected_infl_1	Expected inflation, one period delayed
WIBOR_gap	The interest rate gap measured on the basis of WIBOR 1M. The interest rate WIBOR 1M, nominal, at the beginning of each period (data from Money.pl (http://www.money.pl/))
expend_gap	The gap of the expenditure of the public sector

Equation 1: Estimation 3SLS, observations 2001:1-2014:4 ($N = 56$)

$$output\_gap = \underset{(0.1195)}{0.0274} + \underset{(0.0841)}{0.6853}\, output\_gap\_1 - \underset{(0.1241)}{0.4343}\, WIBOR\_gap + \underset{(0.0622)}{0.1353}\, expend\_gap$$

R-squared 0.647118 Adjusted R-squared 0.624743

Equation 2: Estimation 3SLS, observations 2001:1-2014:4 ($N = 56$)

$$inflation = \underset{(0.1908)}{0.5510} + \underset{(0.0584)}{0.7670}\, expected\_infl\_1 + \underset{(0.0937)}{0.3755}\, output\_gap$$

R-squared 0.759751 Adjusted R-squared 0.750686

Equation 3: Estimation 3SLS, observations 2001:1-2014:4 ($N = 56$)

	coefficient	std. error	z	p-value	
const	0.0272869	0.119475	0.2284	0.8193	
output_gap_1	0.693819	0.0840444	8.255	1.51e-016	***
WIBOR_gap	-0.424272	0.124742	-3,401	0.0007	***
expend_gap	0.137646	0.0620940	2.217	0.0266	**

	coefficient	std. error	z	p-value	
const	0.520982	0.190795	2.731	0.0063	***
expected_infl_1	0.766939	0.0583543	13.14	1.87e-039	***
output_gap	0.375516	0.0936751	4.009	6.11e-05	***

$$expected\_infl = \underset{(0.1026)}{-0.1994} + \underset{(0.0607)}{0.1748} expected\_infl\_1 + \underset{(0.0773)}{0.8673} inflation$$

R-squared 0.941506 Adjusted R-squared 0.939298

	coefficient	std. error	z	p-value	
const	-0.159371	0.102611	-1.553	0.1204	
expected_infl_1	0.174756	0.0607436	2.877	0.0040	***
inflation	0.867254	0.0773378	11.21	3.49e-029	***

5. Simulation experiments

5.1. Simulation assumptions

The output variables are calculated using the proposed model since 2001 according to statistical data for Poland.

In a selected period an impulse, changing the policy mix, is introduced. The instruments of the policy mix, i.e. real interest rate and the budget deficit in relation to GDP are assumed as a given deviation in % points from the historical levels in this period of time. The effects of the changed policy mix are measured by average annual production growth and average annual inflation in the period of 8 quarters since the introduction of changes into the policy mix.

Payoffs of players have been calculated for different values of the strategies changed in the assumed intervals: deviations of the interest rate have been changed in the interval of [2%, -2%] in terms of percentage points and deviations of the budget deficit in relation to GDP – also in the interval [-2%, 2%] in comparison with the historical ones.

The analysis of simulation results focuses on two different periods: 2004-2005 – period of prosperity, and the recession period of 2008 – 2009.

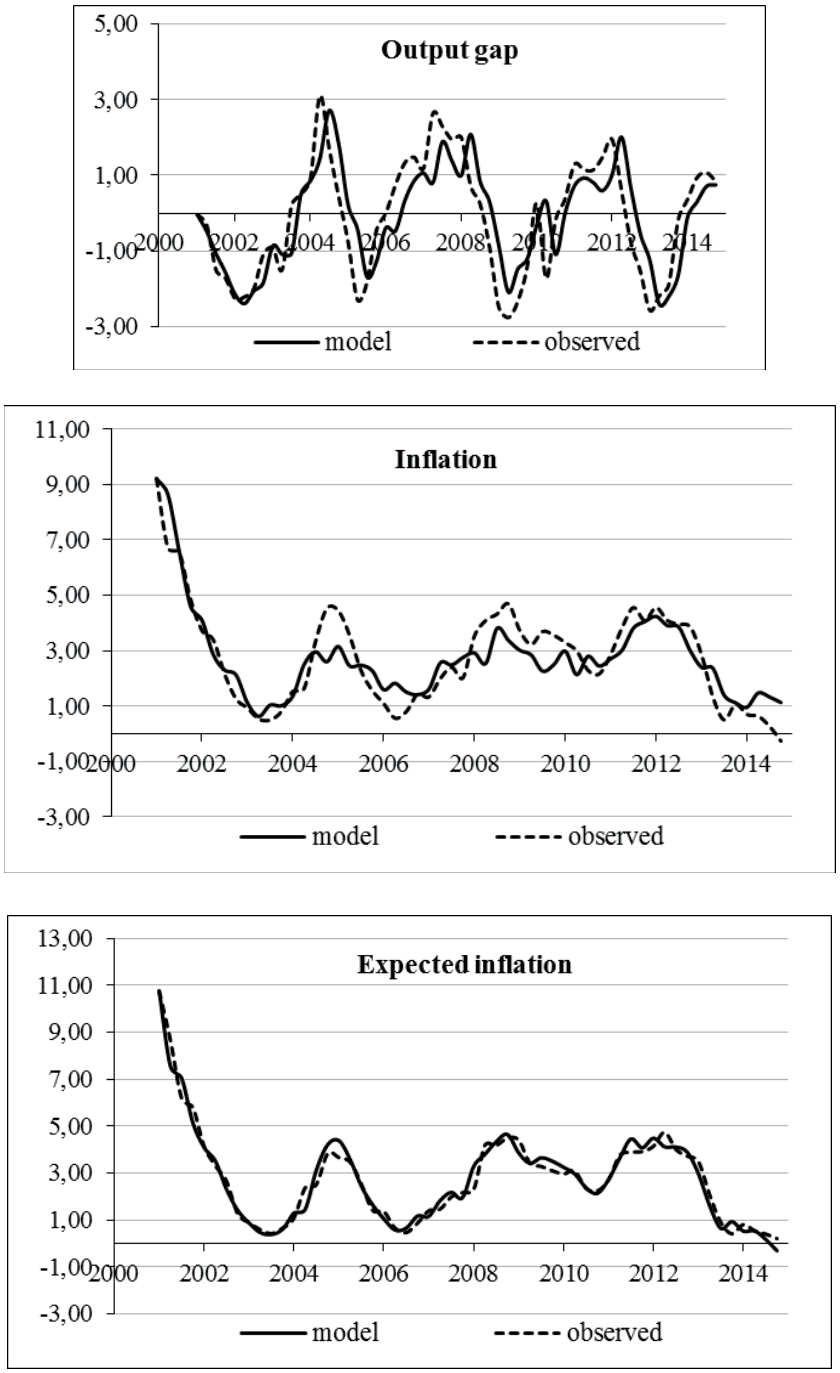

Figure 2. Estimation results

The period 2004-2005 has been assumed in the simulations as an example of the time of economic recovery in Poland. The GDP growth rate in 2004 was 5.4%. The Polish economy has been developing more than two times faster than that of EU-25 countries. The GDP growth rate, very high, at 7% in the first quarter, decreased in the last quarter to roughly 4%. The growth noted in the first and second quarters of the year was the effect of the accession of Poland to EU and the associated increase of demand.

Inflation in Poland in 2004 was under the influence of prices related to the accession to EU as well as to the prices of raw materials, rising on the word markets. Especially the increases of prices of food and crude oil had been observed. In June 2004, inflation exceeded the upper limit of the inflation target. The increase of inflation was accompanied by corresponding inflation expectation. There was a risk that the budget deficit could exceed the second prescribed limit (55% of GDP). The Council of Monetary Policy at the National Bank of Poland (NBP) had decided in 2004 to pursue a more restrictive monetary policy.

Average inflation in 2005 was 2.1%. It was lower than it had been assumed in all the internal forecasts previously prepared in 2004 and 2005. This was the effect of the decrease of inflation, which temporarily increased after the accession of Poland to EU, and of a strong appreciation of Polish currency (PLN) in 2004. Additionally, the real budget deficit of public finance was lower than previously forecasted. Finally, the interest rates could be decreased to the level assumed before the increase undertaken in 2004. While in the first part of 2005 the economic recovery was slower than expected, in the last months of the year a distinct upsurge was observed and inflation was lower than expected. This allowed for pursuing a softened monetary policy.

In 2008, Polish economy was under the impact of strong perturbations, observed on the world markets. The global financial crisis, which took place in that year, was initiated by the subprime mortgage crisis in US. In the first half of the year the Polish economy was in a high growth. A dynamic growth of consumption and investments was observed. In the second part of the year the increasing effect of the word crisis had brought limitation of investments in Poland. The recession in the EU, especially in Germany, which is the most important trade partner for Poland, resulted in a decrease of the GDP growth in Poland. The inflation processes in Poland were determined mainly by the world factors. An increase in food prices and in prices of energy was observed. In 2009, the monetary policy in Poland was pursued in the conditions of recession in the world economy. Since the second quarter of the year an improvement of the economic situation, with curbing of the recession on the world financial markets, was observed.

Polish economy was relatively resistant to the world economic crisis. Poland

was a unique EU country having positive GDP growth in 2009, even though the growth decreased to 1.8% from 5.0% in 2008. The slowdown of economic processes was accompanied by a decrease of employment. The slowdown made worse the situation of the public finance sector. The budget deficit in relation to GDP increased twice, reaching 7.1% in 2009. The Consumer Price Index (CPI) in this year was 3.5%, i.e. by 0.7 % point lower than in 2008. It was on the upper level of deviations from the inflation target of NBP. The raised CPI in 2009 was an effect of the increase in VAT rates and in administrative prices, as well as the depreciation of PLN in the period between July 2008 and February 2009.

In the current state (as of the end of 2018), Polish economy is in a slowdown phase. The indicators of business cycle at the end of 2018, including the composite business cycle indicators as well as PMI index, show that a slowdown in the Polish economy is observed. Lower export orders, and the first, since 2016, decrease of production and decrease of employment in the industrial sector result in the decrease of PMI below 50 points (49.5). The projections of the National Bank of Poland (NBP) for the period between the 4th quarter of 2018 and the 4th quarter of 2020, presented in the Inflation report (November 2018) show that in 2019 - 2020 the GDP growth will successively decrease to below 3.5% at the end of 2020. The consumption demand will be still an important factor of economic growth. It will be the result of increasing incomes of households, due to a better situation on the labor market. According to the report, a subsequent increase of the investment rate is expected due to absorption of the EU structural funds. The lower level of the interest rate will have a favorable impact on the domestic demand. On the other hand, increasing prices of energy and lower dynamics of GDP in the Euro zone will create barriers to the economic growth in Poland. The NBP expects also an increase of inflation (3.2% in 2019 and 2.9% in 2020). The inflation increase will be the effect of the increasing cost and demand pressure. The increase of wages exceeding the increase of labor productivity and the increasing prices of energy will bring about the increase in the cost of production.

The presented methodology can be applied also in this case after the respective model re-estimation.

5.2. Alternative variants to the historical policy mix: more expansive and more restrictive

Three variants of changes of the policies during 2 years (8 quarters), starting from the first quarter of 2008, are considered:

1. A policy more expansive than the policy historically implemented. Real interest rate was assumed 1 percent point lower and the budget deficit in relation to GDP – 1 percent point higher than the historical values.
2. A policy more restrictive than the historical policy. Real interest rate was

assumed 1 percent point higher and the budget deficit in relation to GDP – 1 percent point lower than the historical values.

3. A neutral policy, when the instruments were assumed on their historical levels.

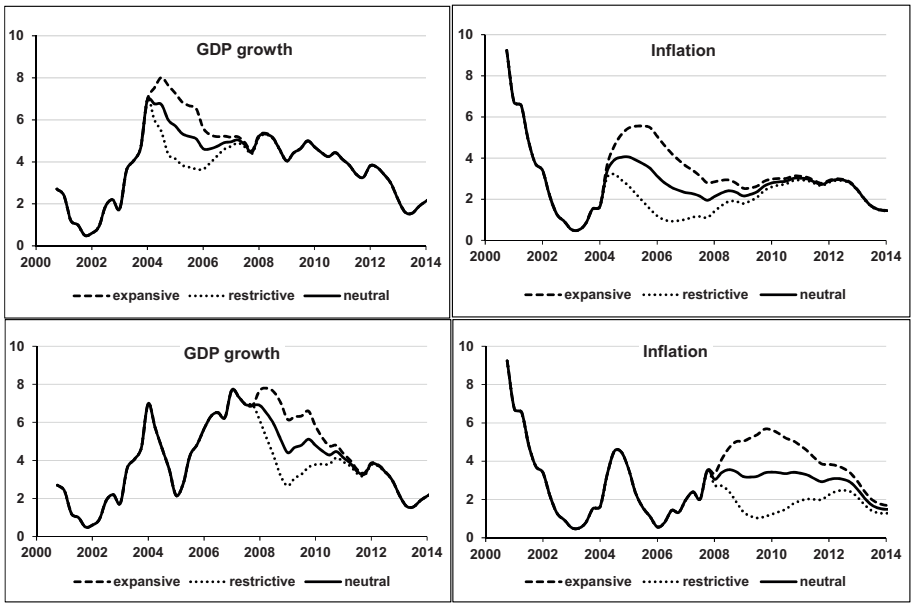

Figure 3. Alternative variants to the historical policy mix in 2004-2005 (upper part of the figure) and 2008-2009 (lower part of the figure): more expansive and more restrictive

It can be observed (see Fig. 3) that the effects of the introduced changes of the policies are temporary, shorter in the case of the GDP growth and longer in the case of inflation. The more expansive policy mix results in a greater GDP growth and in a greater inflation in comparison to the neutral path. The effects of the more restrictive policy are reverse.

5.3. Game payoffs dependent on the strategies

Figures 4 and 5 present the outcomes of the authorities, as dependent on assumed changes of strategies for the period 2008-2009. Inflation (Fig. 4) can be obtained at a low level when a restrictive monetary policy and a restrictive fiscal policy are applied simultaneously. More expansive monetary and fiscal policies lead to an increase of inflation and of the economic growth. On the other hand, more restrictive monetary and restrictive fiscal policies lead to a decrease of inflation and of the economic growth (Fig. 5).

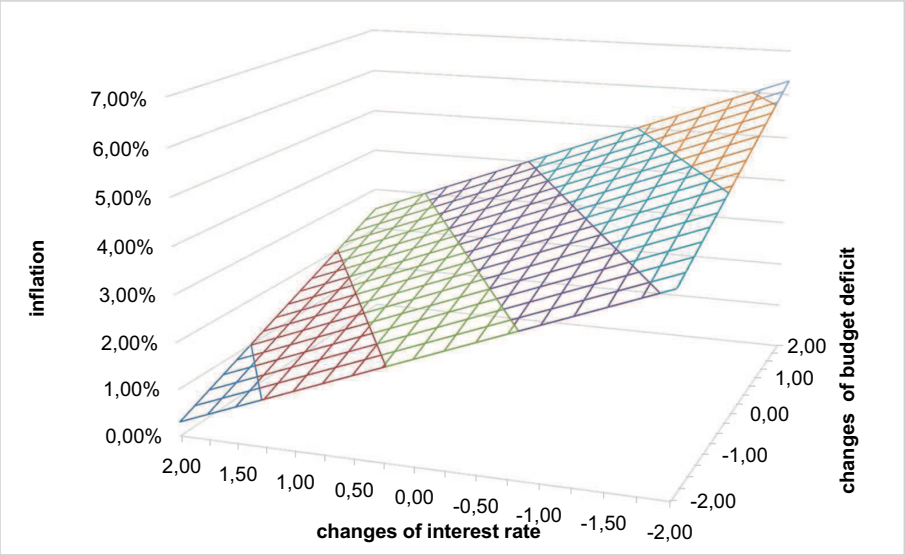

Figure 4. Outcomes of the monetary authority

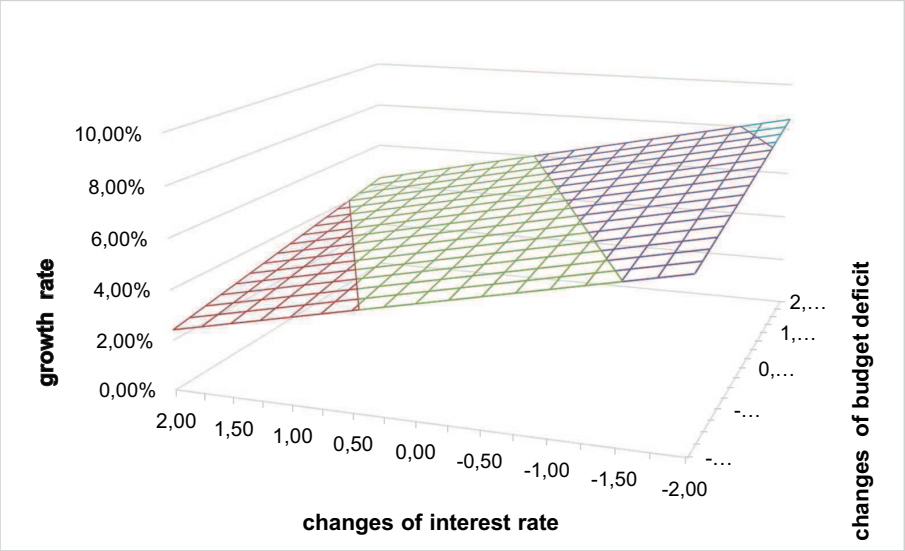

Figure 5. Outcomes of the fiscal authority

5.4. The optimal (best response) strategies

Let the fiscal authority try to achieve the GDP growth rate at the level y^g,and let the monetary authority assume the inflation goal at the level p^g.

Let B and R denote the sets of admissible values of strategies Δb and Δr.

The respective best response strategies can be obtained as solutions of the following two optimization problems:

$$Min|h^1(b,r) - y^g|$$

with respect to the deviation of the budget deficit $\Delta b \in B$, solved for all considered deviations of the interest rates $\Delta r \in R$, in the case of the fiscal authority, where $b = b_0 + \Delta b, r = r_0 + \Delta r$, while b_0 and r_0 denote, respectively, the historical values of the level of budget deficit in relation to GDP and the real interest rate;

and

$$Min|h^2(b,r) - p^g|$$

with respect to $\Delta r \in R$, solved for all $\Delta b \in B$, in the case of the monetary authority.

Examples of the best response strategies, derived for different targets of the authorities, are presented in the following figures for two analyzed periods: 2004-2005 (Fig. 6) and 2008-2009 (Figs. 7 and 8). Figure 6, the upper part (case a) presents the best response strategies of the fiscal authority for the three different targets: GDP growth = 4.5%, 4.75%, 5%, and the best response strategy of the monetary authority for the target: inflation = 2.5%. Figure 6, the lower part (case b) presents the best response strategies of the monetary authority for the three different targets: inflation = 2%, 2.5%, 3% and the best response strategies of the monetary authority for the targets: GDP growth = 4.75% and 5.5%. The Nash equilibria, which are Pareto optimal in the assumed interval of the policy instruments, are also shown.

It can be observed how the level of restrictiveness/expansiveness of the monetary policy depends on the level of restrictiveness/expansiveness of the fiscal policy. A more expansive fiscal policy leads to a more restrictive monetary policy, adopted by the central bank, trying to limit inflation exceeding the inflation target. When the budget deficit is higher, then the required inflation is obtained for the correspondingly higher interest rates. Analogously, if the government carries out a more restrictive budget policy, then the central bank will apply a less restrictive (more expansive) monetary policy, characterized by the relatively lower interest rates.

On the other hand, a more restrictive monetary policy causes, in reaction, a more expansive budget policy. If the interest rate is higher, then the required

growth rate can be achieved by applying a more expansive fiscal policy, supporting a higher growth rate. This means that the government should assume a relatively bigger budget deficit. Inversely, the government can implement a more restrictive fiscal policy for limiting the budget deficit in reaction to a more expansive monetary policy.

The simulation results show how changes of the targets of fiscal and monetary policies influence the best response strategies and the Nash equilibrium state, i.e. the choice of the respective policy mix. More ambitious target of fiscal policy, with a high required economic growth, causes that the best response budget strategy moves in the direction of a more expansive one and vice versa in the opposite case. The higher inflation targets, assumed by the monetary authority cause that the best response strategies of the central bank move in the direction of more expansive monetary policies. In the opposite case, of the lower inflation target, the best response monetary policy moves towards a more restrictive one. Changes of the targets assumed by the fiscal and monetary authorities result in respective positioning of the Nash equilibrium.

There are two cases of the best response strategies in the considered game. The first takes place when the best response strategies cross inside the set of admissible strategies, and the second – when they do not cross in this set. The crossing point in the first case defines the Nash equilibrium. One can easily see that a deviation of any strategy from this point leads to a worse payoff of the respected player (Nash, 1951).

Similar observations can be formulated upon analyzing the simulation results for the period 2008-2009.

The more expansive fiscal policy leads to the more restrictive monetary policy, adopted by the central bank, when trying to limit inflation, exceeding the inflation target. When the budget deficit is higher, then the required inflation is obtained for the correspondingly higher interest rates. Analogously, if the government carries out the more restrictive budget policy, then the central bank will apply a less restrictive (more expansive) monetary policy with relatively lower interest rates. On the other hand, the more restrictive monetary policy motivates the government to choose the more expansive fiscal policy and vice-versa. The lines cross for selected targets only.

The comparison of the instruments and effects of the policy mixes obtained through the game versus the historical ones in the considered periods is presented in Table 2.

The periods of 2004-05 and 2008-09 have been selected intentionally for purposes of analysing the policies alternative with respect to the historical ones. In the economic crisis period of 2008-09 the negative impact of the economic envi-

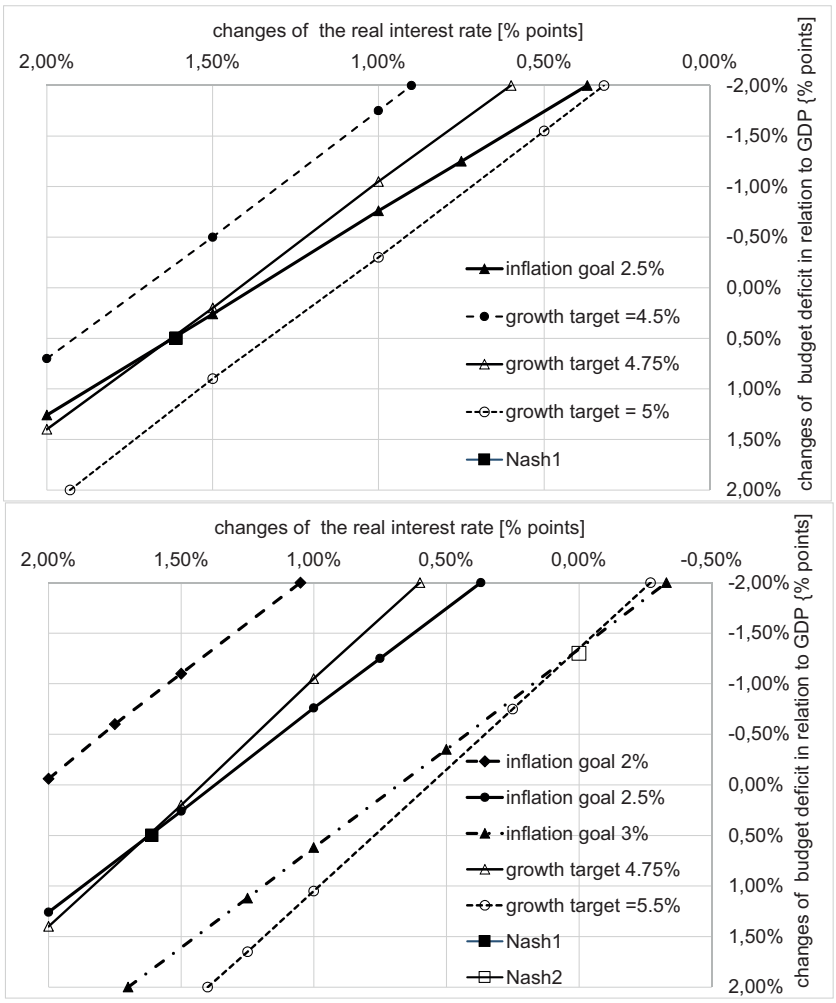

Figure 6. The best response strategies of the authorities (period: 2004-2005): (a – upper part) for different fiscal targets and the monetary target – inflation = 2.5%; (b – lower part) for different monetary and fiscal targets

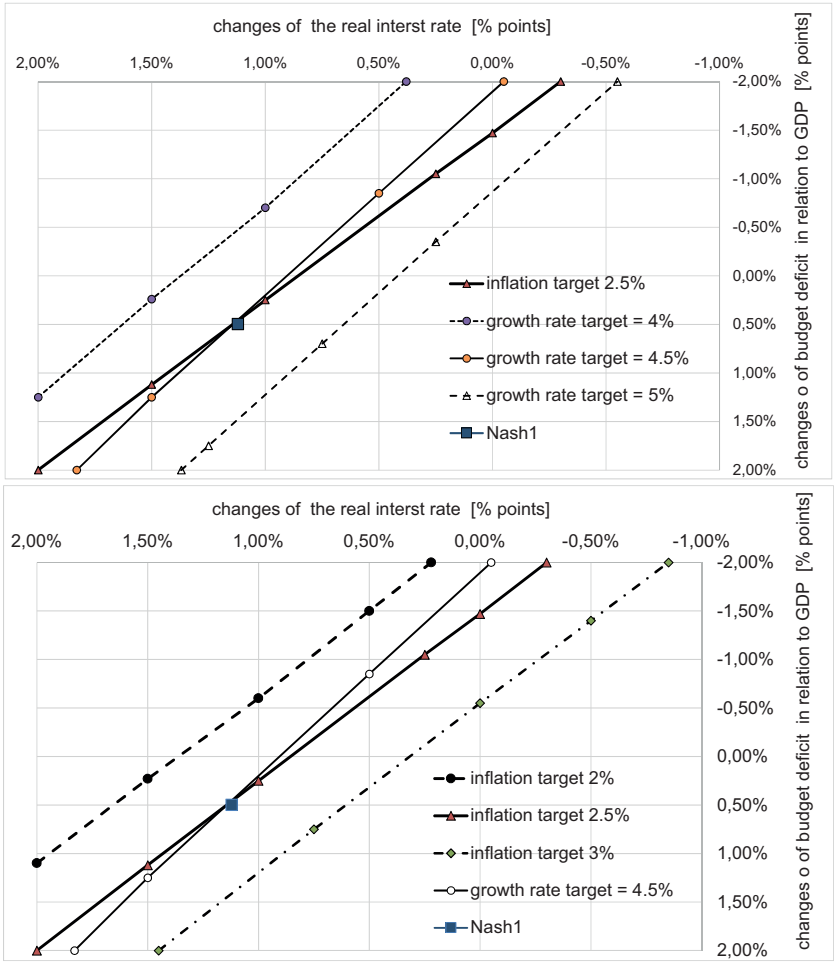

Figure 7. The best response strategies of the authorities (period: 2008-2009): (a – upper part) for different fiscal targets and the monetary target – inflation = 2.5%; (b – lower part) for different monetary targets and the fiscal target – growth rate = 4.5%

ronment on the Polish economy was observed. The model, which is used in the present analysis, does not include directly the factors of economic environment. Therefore, the better results from the game than the data historically observed could be expected. In fact, the calculated Nash equilibrium state indicates that assuming the policy-mix conform to this equilibrium, better payoffs than those historically observed could be obtained. The calculated Nash equilibrium (Nash 1 in Fig. 7) corresponds to 2.5% of inflation and 4.5% of the growth rate, i.e. better than the actual historical ones. Inflation is lower than the historically observed value, equal to 3.83%, and the economic growth rate is higher than the historical 3.29%. The game results have been obtained by applying more restrictive monetary and more expansive fiscal policies.

For comparison, we tried to check also the economic expansion period of 2004-05, in which a positive impact of external factors has been observed, especially related to the access of Poland to the EU, this fact not being explicitly included in the model. The results of the game show that also in this period better results could be obtained by appropriately changing the historical policy-mix. In the period 2004-05 the results at the Nash equilibrium (Nash 1 in Fig. 6): inflation at 2.5% and GDP growth at 4.75% are better than the historical ones. Thus, inflation is lower than the historical 2.81% and the GDP growth rate is higher than the historical 4.36%. These better results have been also obtained for the more restrictive monetary and more expansive fiscal policies.

With respect to Fig. 8, let us explain that arrows illustrate the actions of the authorities, implementing the best response strategies. The case (c) illustrates too ambitious targets of the authorities. The lines presenting the strategies have no common point in the considered set of instruments. This means that the two targets cannot be attained simultaneously. The final state exists for the combination of the most restrictive monetary policy and the most expansive fiscal policy. In the case (d) another example of the targets is shown. The final state is in this case at the most expansive monetary and the restrictive fiscal policy. The real Nash equilibria in the area of admissible intervals of instruments are not Pareto optimal.

6. Final remarks

The paper presents an application of game theory and optimization tools for the analysis of the fiscal and monetary policies. The analysis concentrates on the comparison of the real historical policies, undertaken by the central bank and the government, with the effective strategies, calculated with the use of the proposed game model. A noncooperative monetary-fiscal game and a respective dynamic macroeconomic model, calculating the game payoffs have been implemented in the form of a computer-based system. The system has been used in experimental simulations and analysis of the game outcomes in an interactive

Table 2. Comparison of the game results and the historical (statistical) data in the periods 2004-05 and 2008-09. The results refer to the average annual values during 8 quarters after the impulse of changing the instrument values

		Instruments		**Economic effects / outputs**	
Time period		**Real interest rate**	**Budgetary deficit in relation to GDP**	**Inflation**	**GDP** growth
2004-05	**Statistical data** (historical)	3.20%	376%	2.81%	4.36%
	Nash equilibrium	1.65% (higher than the historical value)	0.5% (higher than the historical value)	2.50%	4.75%
2008-09	**Statistical data** (historical)	1.37%	2.65%	3.83%	3.29%
	Nash equilibrium	1.15%, higher than the historical value	0.5%, higher than the historical value	2.50%	4.50%

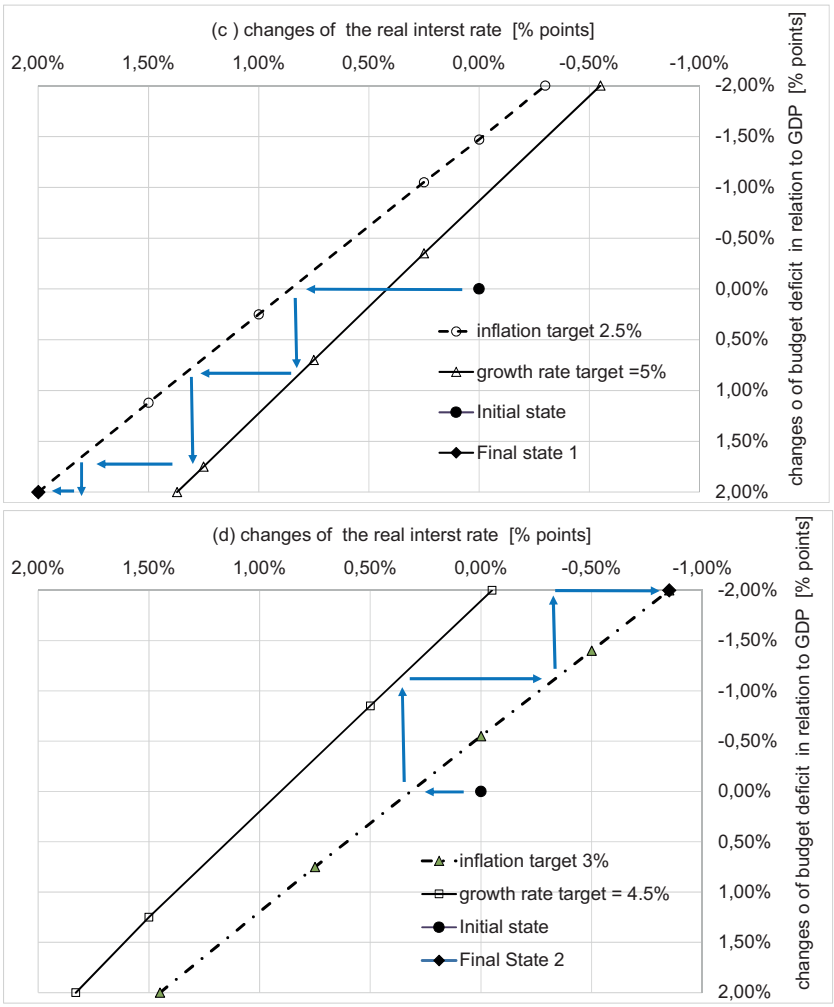

Figure 8. The best response strategies: (c) for the targets: growth rate = 5% and inflation = 2.5%; (d) for the targets: growth rate = 4.5% and inflation = 3%

way. The simulations, which have been performed, include calculations of effects of the policies that are alternative with respect to the historical ones, more expansive and more restrictive ones, as well as derivation of the best response strategies for different targets of the authorities. The historical policies, carried out in different periods of time and their economic effects are compared with the possible strategies, obtained from the analysis of the proposed monetary-fiscal game. The simulations have been carried out for two periods of time: the time of economic expansion of 2004-2005, related to the accession of Poland to the EU, and the period of global economic crisis of 2008-2009.

The simulations include different policy targets of the authorities, moderate as well as ambitious. The possible Nash equilibria have been derived. The computational results show typical cases, when the Nash equilibrium in the game is or is not Pareto optimal. It is shown that very ambitious targets of the authorities, i.e. too high target of the growth rate with respect to the inflation target of the Polish Central Bank (NBP) may lead in the game to the extreme policies of the authorities: a very restrictive monetary policy and a highly expansive fiscal policy. The best response strategies do not cross in the interval of reasonable values of instruments and the respective Nash equilibrium is not Pareto optimal. It has been shown that the appropriate coordination of the policies could lead to better results than the historical ones. In the period of 2004-2005 the coordinated monetary and fiscal policies could lead to the Nash equilibrium with inflation at 2.5% and GDP growth at 4.75%, which are better than the historical ones, i.e. inflation 2.8% and GDP growth 4.4%. In the period of 2008-2009 the calculated Nash equilibrium: inflation at 2.5% and growth rate at 4.5% is better than the historical situation, namely 3.8% of inflation and 3.3% of the growth rate. This shows that better results have been obtained not only for the recession period 2008 –2009, but also for the period of prosperity 2004 – 2005.

The proposed gaming approach can be useful in the analysis of the monetary and fiscal policies, constructed by the central bank and the government. It enables the search for the Pareto-optimal and stable, in the sense of Nash, equilibrium consensus of the authorities in the policy-mix problem. It may also allow for avoiding the selection of the targets, aimed at by the authorities, which could lead to unpredictable conflicting policies. The proposed methodology can be applied also for the analysis of the current and future economic situation in Poland. For this purpose, the model should be re-estimated using the updated statistical data. The targets of the fiscal and monetary policies should be adopted according to the current assumptions, plans, and the forecasts of the authorities. The future planned work includes application of the methodology for the analysis in the case of current and future economic situations and modification of the econometric model. We think that nonlinear relations would describe better the influence of the policy instruments on the dynamic course of the economy. According to the current world trends of studies, the expected

values of the quantities described in the model will be introduced, in the place of their delayed values. Another model extension refers to the description of the external economic factors, including export, and their impact on the business cycle.

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