Decision-making on interest rate of Federal Reserve System (FRS)

Introduction

Decision-making process which is described in mathematical or economic scientific works is shown as it should be, but not as it really happens. Many studies about political decision-making describe it as "muddling through" (Colander, 2005; Lindblom, 1979). Even though there is some influence from theoretical works on practical results, their usage is moderate. There are two reasons: inability to achieve a single correct solution; limited influence on policymakers because other components of the decision-making process may have a greater impact. For example, when it has been done a try to determine the critical level of government debt to gross domestic product (GDP) ratio which can inhibit the growth of debt after the 2008 financial crisis, it has not been achieved a unique solution even whether the debt influence GDP growth, not to mention the critical level and its effect (Cecchetti, Mohanty, and Zampolli, 2011; Herndon, Ash, and Pollin, 2013; Reinhart, Rogoff, and Kenneth, 2010).

The first goal of this work will be examine the facilities for simplification of decision-making process on interest rate, in general, and on interest rate in USA (federal fund rate), in particular. As it will be seen the main facilities are predefined rules which describe the function of Federal Reserve System interest rate (FED fund rate) from some inputs. Such inputs could be inflation, gross domestic product, unemployment, labor force, monetary aggregate, monetary velocity, output gap, etc. However, on practice, Taylor rule is used more often which described dependency between interest rate and inflation and output gap. Therefore, the second task will be explore the quality of Taylor rule from econometric point of view and if its quality is not satisfied than it will be necessary to create additional models which can solve the drawbacks of Taylor rule.

Chapter I. Decision making on interest rate

Alan Greenspan (1997), chairman of the Federal Reserve System during 1987-2006, has noted that the decision-making process in monetary policy should include models, which are based on rules and on the basis of human decision-making. A similar system of decision-making process in monetary policy was implemented by European Central Bank. This system is also based on human decision-making, but it used models for greater discipline (Angeloni, Issing, Gaspar, and Tristani, (2001)).

One of the classic rules that help in monetary policy decision-making has the following equation:

$$R(t) - R^*(t) = \theta\big(X(t) - X^*(t)\big), \quad (1.1)$$

where: $R(t)$ - interest rate in moment of time t[1] that should be determined; $R^*(t)$ - "neutral" level of interest rate; $X(t) - X^*(t)$ - deviation of some factor or factors from the past value, or "neutral" level; θ – rule coefficient which is often determined on a historical sample.

The factors could be different macroeconomic variables: money supply, inflation, GDP, unemployment, etc. In some works (Clarida, Gali, and Gertler, 1999; Orphanides, 2007; Weymark, 1995), it has been conducted a comparative analysis of models of this type and determined that the best rules are the models that use inflation and productivity gap as input:

$$R(t) - R^*(t) = \gamma\big(\pi^a(t) - \pi^*(t)\big) + \delta y(t), \quad (1.2)$$

where: $\pi^a(t)$ - inflation; $\pi^*(t)$ - expected level of inflation; $y(t)$ - productivity gap; γ and δ - rule coefficients; all other symbols are as beforementioned.

The advantage of this rule is that it focuses on maximizing economic activity while maintaining minimal unemployment and preventing huge inflation increase at the same time. The results of large number of studies which was aggregated by Bryant, Peter, and Catherine (1993) showed that the reaction function which is based on (1.2) can achieve better macroeconomic results than a policy that controls the other variables while the information problem is absent.

However, despite some limitations, rule in the form (1.2) has been spread around, and monetary policy decisions are made in the form of Taylor rules. In 1993, Taylor said that US

[1] During the text the mark (t) define that the variables should be taken in moment of time t, and (t-i) in the moment of time t-i.

monetary policy at that time could be described by the rule in the following form (Taylor, 1993):

$$i(t) = 4 + 1.5(\pi(t) - 2) + 0.5(q(t) - q^*(t)),$$

or in the classic form of representation:

$$i(t) = 2 + \pi(t) + 0.5(\pi(t) - 2) + 0.5(q(t) - q^*(t)),$$

where: $i(t)$ - discount rate of the Federal Reserve System (FED fund rate)); $\pi(t)$ - consumer price inflation in US; $q(t)$ - growth rate of GDP; $q^*(t)$ - growth rate of potential GDP.

Taylor rule's standard practice is to determine the coefficients based on historical dynamics of FRS interest rate in some time period and to use estimated equation for other periods of time, thereafter. That rule does not allow calculating the optimal solution for given criteria, and it only estimates FRS interest rate at the economy current state in respect to historic decisions of the Fed.

Through the time, the Taylor rule extended its influence. In his later discussions, Taylor suggested that this rule should be used, ubiquitously, as the basis for monetary policy decision-making process. This assumption was based on the facts that rule described changes in FED fund rate properly. Market participants, without other facilities, agreed to use the rule (Benchimol and Fourçans, 2012; Clarida, Gali, and Gertler, 2000; Hossein, Ai Jun, and Farrukh, 2013; Orphanides, 2007; Samuelson, 1983; Woodford, 2001).

In general the Taylor rule has the next form:

$$i(t) = \pi(t) + r^*(t) + a_\pi\big(\pi(t) - \pi^*(t)\big) + a_q(q(t) - q^*(t)),$$

where: $r^*(t)$ - real interest rate at equilibrium in the economy; a_π and a_q – rule coefficients on which is imposed some restrictions; all the other symbols are the same.

The restrictions which are imposed on rule coefficients are as follows:

• $a_\pi > 0$: increase of inflation by one percent requires increase of nominal interest rates by more than one percent - $1+a_\pi$. Since real interest rates are calculated as the difference between nominal interest rates and inflation than $a_\pi > 0$ may lead to an increase in real interest rates with increasing inflation. The idea that real interest rates should rise to cool the economy with increasing inflation is called Taylor principle (Davig and Leeper, 2007).

• $a_q > 0$: during decrease in real GDP compared with potential GDP, one should reduce the interest rate by a_q that will give economic stimulus for growth.

As beforementioned, prerequisites to use Taylor rule as a basis for making decisions arose in 1999, when the rule described very precise monetary policy of that days and economists thought that it is possible to manage the business cycle of the country only through monetary policy. After the 2008 crisis, the vision is not so much unanimous. First of all, doubt leads to the problem of zero rates, liquidity trap, below which central banks are not willing to go down (classical economic principles based on the fact that the nominal interest rate is greater than zero). Second, it is believed that the situation in global economy is the example that monetary policy could not solve all economy issues alone (Engle, Ghysels, and Sohn, 2013; Gali and Gertler, 2007; Cecchetti, Mohanty, and Zampolli, 2011; Yellen, 2012). However, it does not affect the fact that such rules can help in simplifying the decision-making process.

Also, Taylor rule characterizes by another drawback to which attention is not drawn in literature – model is static: for all inputs, there are no historical dynamics. This is the result of assumption that the policy-makers should use only up-to-date data, but it leads to the fact that economy's position in the business cycle is not important for the rule, what can also lead to inaccurate policy decisions.

Chapter II. Modeling of rule for decision making on interest rate

The classic Taylor rule has the simple structure and consists only of three inputs: constant variable; inflation deviation from two percent level; and growth rate of gross domestic product (GDP) deviation from growth rate of potential gross domestic products, which is knows as output gap. The model which described the dependence of Federal Reserve System interest rate (FED fund rate, FFRate) from 1980 till 2013 has the structure according to the next equation[2] (classic Taylor rule):

$$FFRate(t) = 3.05 + 1.61(Inflation(t) - 2\%) + 0.25(Output\ GAP(t)). \quad (2.1)$$

The equation (2.1) shows that the deviation of inflation from the aim level (two percent) on one percent point requires increasing of FED fund rate on 1.61%. At the same time, each percent point of output gap require increasing in rate only on 0.25% or more than six time less. Constant variable shows the natural level of interest if we are on the optimal levels of inflation (if inflation is equal 2.0%) and growth rate of gross domestic product (output gap is equal 0.0%).

However, this model is not the best, and it has an econometric problem. At first, R^2 is equal only 0.72 and adjusted R^2 is equal only 0.7, in other words, only about 70% of FED fund rate changes are explained by this model; therefore, standard error of regression is equal 2.25% or 43% of average value, in other words, the decision maker can wait on 43% margin error each time when he will make the decision. Additionally, there is high probability that coefficient near output gap variable is equal to zero due to high p-value, 26.15%. It is not possible to say that coefficient is significant on the level less than 26.15% level; therefore, output gap coefficient is insignificant on the 5% level. Finally, Durbin-Watson statistic is

[2] The data are described in Appendix 1 and there are no irregularities with the data; all coefficients in the equations are rounded till the second sign after the point.

equal to 1.06 and Breusch-Godfrey Serial Correlation LM Test shows the probability equal 0.62%, in other words, there is existed positive autocorrelation in the model (correlation of residuals is near 0.5) and autocorrelation problem is significant on the level 1.0% and more. At the same time, there are also some positive qualities of this model: no multicollinearity, no heteroscedasticity, linear in parameters, normally distributed residuals (detailed information is represented in Table 2.1).

Table 2.1

Verification of econometric problems of the model (2.1)

Test	**Results**	**Comments**
Explanatory power	$R^2 = 0.7$	(-) Explanatory power is low.
Standard error of regression	S.E. of regressions = 2.25	(-) Very high average error.
Significance of coefficient	Output gap p-value = 26.15%	(-) One variable should be excluded due to insignificance on the level of 5%.
Autocorrelation problem	Durbin Watson = 1.06 Breusch Godfrey probability = 0.62%	(-) Positive autocorrelation on the level near 0.5, autocorrelation problem is significant on the 1% level.
Multicollinearity problem	BKW[3] singular decomposition shows lowest conditions of eigenvalues equal 0.10.	(+) There is no multicollinearity (0.1 is more than 0.001)
Heteroscedasticity problem	White heteroscedasticity test probability = 74.12%.	(+) Heteroscedasticity problem is insignificant on the level less than 74.12%.
Linear in parametrs	Ramsey RESET test probability = 55.24%	(+) Non-linearity problem is insignificant on the level less than 55.24%.
Normally distributed residuals	Jarque-Bera probability = 54.43%	(+) Non-normality is insignificant on the level less than 54.43%.

Autocorrelation problem is very important and says that in the model is presented omission due to high correlation of residuals. Autocorrelation problem can be solved with

[3] BKW is acronym of the surnames of Belsley, Kuh and Welsch, which proposed two step identification algorithm of multicollinearity problem existence.

using autoregression terms of output (FED fund rate) or using additional output which can nullify presented omissions. Standard structure of Taylor rule does not use lagged terms, therefore, at first, it should be better to improve model with using of additional inputs. It was used follows additional inputs: unemployment (un), labor force (lf), M1 stock (M1S), M2 velocity (M2V), M3 stock (M3S), dummy variable for period beyond USA Saving and Loan crisis in 1990-1995 (D1), and dummy variable for saving glut[4] beyond 2002 (D2). However, all this outputs (except dummies) require usage of lagged terms what is not the part of classical structure of Taylor rule. Therefore, the second edition of our model added only dummy variables:

$$FFRate(t) = 5.49 + 1.27(Inflation(t) - 2\%) - 2.48D1 - 4.2D2. \qquad (2.2)$$

Table 2.2

Verification of econometric problems of the model (2.2)

Test	**Results**	**Comments**
Explanatory power	$R^2 = 0.9$	(+) Explanatory power is moderately high.
Standard error of regression	S.E. of regressions = 1.37	(○) Average error is moderately high.
Significance of coefficient	All p-value is less than 0.1%	(+) All the variables are significant.
Autocorrelation problem	Durbin Watson = 2.02 Breusch Godfrey probability = 86.9%	(+) There is no autocorrelation, autocorrelation problem is insignificant on the level less than 86.9%.
Multicollinearity problem	BKW singular decomposition shows lowest conditions of eigenvalues equal 0.01.	(+) There is no multicollinearity (0.01 is more than 0.001)
Heteroscedasticity problem	White heteroscedasticity test probability = 87.53%.	(+) Heteroscedasticity problem is insignificant on the level less than 87.53%.
Linear in parametrs	Ramsey RESET test probability = 7.86%	(+) Non-linearity problem is insignificant on the level less than 7.86%. If we unify coefficient near dummy variables by summing (d1+d2) then Ramsey RESET test probability could be increased to 57.79%; however, the error will be increased a little.
Normally distributed residuals	Jarque-Bera probability = 33.93%	(+) Non-normality is insignificant on the level less than 33.93%.

[4] Saving glut is the problem of high savings in emerging markets which creates the negative pressure on the interest rate in developed countries. The beginning of this pressure is estimated near 2002.

As it could be seen from the equation (2.2), the output gap is excluded from the model due to insignificance on the 5% level. Also, it is possible to see how big is pressure of saving glut on the modern interest rates in the world and that the natural rate is almost twofold than in equation (2.1). All the other important information about second model is presented in Table 2.2. As the result of the second model estimation, it could be said that the second model is only moderately good due to moderately high error.

The main goal of the third model is decreasing of the error while using also all the inputs with the lagged terms; therefore, there are no prescriptions about the sign of coefficient and structure of the model. The third model has the next equation:

$$\begin{gathered} FFRate(t) = 0.13FFRate(t-5) - 4.37D2 - \\ -3.23e^{-11}M1S(t) + 2.71e^{-11}M1S(t-1) - 10.25M2V(t) + \\ +9.41e^{-12}M3S(t) - 8.42e^{-12}M3S(t-1) + 0.39lf(-1) \end{gathered} . \quad (2.3)$$

Table 2.3

Confidence interval for the coefficients of the model (2.3)

Variable	Coefficient	Low	High
FFRATE(-5)	0.13	0.05	0.21
D2	-4.37	-5.36	-3.38
M1S	-3.23E-11	-3.67E-11	-2.79E-11
M1S(-1)	2.71E-11	2.24E-11	3.18E-11
M3S	9.41E-12	7.29E-12	1.15E-11
M3S(-1)	-8.42E-12	-1.08E-11	-6.02E-12
M2V(-2)	-10.25	-12.52	-7.99
LF(-1)	0.39	0.32	0.47

From equation (2.3), it could be seen that the third model has autoregression terms that are lagged on five years, however, from this results it could be seen that only 13% of FED fund rate 5 years ago influences the FED fund rate today. Also, there is no constant variable and it is impossible to speak about natural level of interest rate. Additionally, it is very interesting that the coefficient near dummy variables of saving glut is almost the same as for the second model. Labor force has positive influence on FED fund rate, but money velocity (M2V) has negative influence. At the same time, M1 and M3 stock has undefined influence: M1 stock has negative coefficient near last terms and positive coefficient near lagged term (but it is lower), M3 stock has reverse situation. However, no coefficient signs contravene the macroeconomic theory[5]. The third model also has multicollinearity problem which could influence the stability of coefficient estimation (confidence interval for third model coefficient is shown in the Table 2.3). All the other important information about third model is presented in Table 2.4.

Table 2.4

Verification of econometric problems of the model (2.3)

Test	Results	Comments
Explanatory power	$R^2 = 0.98$	(+) Explanatory power is high.
Standard error of regression	S.E. of regressions = 0.48	(+) Average error is moderately low.
Significance of coefficient	All p-value is less than 0.4%	(+) All the variables are significant.
Autocorrelation problem	Durbin Watson = 2.18 Breusch Godfrey probability = 55.43%	(+) There is a little negative autocorrelation, autocorrelation problem is insignificant on the level less than 55.43%.
Multicollinearity problem	BKW singular decomposition shows lowest conditions of eigenvalues equal -1.39e^{-19}, and there is the decomposition proportions higher than 0.5	(-) There is multicollinearity problem.
Heteroscedasticity problem	White heteroscedasticity test probability = 73.05%.	(+) Heteroscedasticity problem is insignificant on the level less than 73.05%.
Linear in parametrs	Ramsey RESET test probability = 73.4%	(+) Non-linearity problem is insignificant on the level less than 73.4%.
Normally distributed residuals	Jarque-Bera probability = 49.05%	(+) Non-normality is insignificant on the level less than 49.05%.

[5] The sign of monetary aggregates in models in general is not defined and depends on many factors. For this situation it is possible to expect positive coefficient for monetary aggregates, but we have positive coefficient not for all monetary aggregates inputs. The coefficient near M3 stock shows that it has positive coefficient for changes in monetary 3 stocks. At the same time, M1 stock and M2 velocity has the negative coefficient, but it could be possible due to interdependence between M1 and M3 stock and M2 velocity, and the negative coefficients may balance the positive effect from M3 stock. For labor force all is classic: more labor force, than more employment, than higher inflationary pressure, therefore the interest rate should be increased.

From the econometric point of view the best model, of course, is the second due to absence of any problems, however, its moderately high standard error make its usage on the practice conjugated with additional risk of mistakes. At the same time, the third model is less risky to use on practice for making decisions about FED fund rate due to its more comprehended structure and moderately low standard error. However, the multicollinearity problem says that coefficient of the model could have abrupt changes while reassessment of model coefficient will be done in future. This also creates some risks, but, as for me, this risk is not direct and less significant; therefore the third model is the best to use on practice.

Conclusions

At the current moment, Taylor rule is the main facility which helps market participants to interpret consistency of monetary police in USA or in any other country. However, Taylor rule got that status only due to the absence of other facilities. The main drawbacks of Taylor rule are the follows: Taylor rule is static, Taylor rule use only two independent inputs (output gap and inflation) from one country, and Taylor rule described historical dependence of FED fund rate and rules inputs. The first two drawbacks have been solved in this work; however, the last drawback has not been solved in this work due to necessity of using other mechanisms - the mathematical apparatus of optimization problems, and it can be the aim of other works.

In this work, also, it has been shown that using dynamic version of Taylor rule (with lagged terms) and other inputs, equation (2.3), can help in decreasing standard error of the model. At the same time, the standard form of Taylor rule could show better results, equation (2.2), if the scientists do not forget that there are sometimes not direct but high pressures on interest rates from other countries and if creators of model use dummy variables or data from other countries.

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Appendix I. Data and sources

Observation date	FEDFUNDS	GDPPOT	CPIAUCNS	GDPCA	LNU01300000	UNRATENSA	M2V	MANMM101USA189N	MABMM301USA189S	S&L crysis	Savings glut
1980	13.82	6572.3	77.8	6450.4	63.3	6.9	1.874	395 733 333 333	1 540 350 000 000	0	0
1981	19.08	6713.4	87	6617.7	63.2	8.2	1.932	424 900 000 000	1 679 591 666 667	0	0
1982	13.22	6888.2	94.3	6491.3	63	9.4	1.842	453 000 000 000	1 831 441 666 667	0	0
1983	8.68	7096.9	97.8	6792	63.3	11.4	1.748	503 175 000 000	2 054 783 333 333	0	0
1984	9.56	7309.8	101.9	7285	63.3	8.8	1.814	538 641 666 667	2 219 316 666 667	0	0
1985	8.35	7548.4	105.5	7593.8	64	8	1.802	586 950 000 000	2 416 666 666 667	0	0
1986	8.14	7810.1	109.6	7860.5	64.2	7.3	1.795	666 358 333 333	2 613 533 333 333	0	0
1987	6.43	8076.8	111.2	8132.6	64.7	7.3	1.723	743 450 000 000	2 783 766 666 667	0	0
1988	6.83	8338.8	115.7	8474.5	65.1	6.3	1.773	774 758 333 333	2 933 433 333 333	0	0
1989	9.12	8599.7	121.1	8786.4	65.8	6	1.844	782 191 666 667	3 056 083 333 333	0	0
1990	8.23	8863.0	127.4	8955	66	6	1.852	810 566 666 667	3 223 583 333 333	1	0
1991	6.91	9125.4	134.6	8948.4	65.5	7.1	1.832	858 983 333 333	3 342 183 333 333	1	0
1992	4.03	9381.1	138.1	9266.6	65.7	8.1	1.88	965 941 666 667	3 403 616 666 667	1	0
1993	3.02	9648.1	142.6	9521	65.6	8	1.977	1 078 508 333 333	3 437 950 000 000	1	0
1994	3.05	9931.8	146.2	9905.4	66	7.3	2.054	1 145 216 666 667	3 482 141 666 667	1	0
1995	5.53	10227.0	150.3	10174.8	66.1	6.2	2.163	1 143 083 333 333	3 552 783 333 333	1	0
1996	5.56	10544.3	154.4	10561	65.8	6.3	2.155	1 106 533 333 333	3 722 916 666 667	0	0
1997	5.25	10884.8	159.1	11034.9	66.4	5.9	2.192	1 070 125 000 000	3 909 966 666 667	0	0
1998	5.56	11249.9	161.6	11525.9	66.6	5.2	2.184	1 080 558 333 333	4 189 158 333 333	0	0
1999	4.63	11644.9	164.3	12065.9	66.7	4.8	2.146	1 102 275 000 000	4 497 166 666 667	0	0
2000	5.45	12062.0	168.8	12559.7	66.8	4.5	2.15	1 103 600 000 000	4 769 608 333 333	0	0
2001	5.98	12505.9	175.1	12682.2	66.8	4.7	2.103	1 140 300 000 000	5 179 691 666 667	0	0
2002	1.73	12950.5	177.1	12908.8	66.2	6.3	1.988	1 196 700 000 000	5 562 675 000 000	0	1
2003	1.24	13375.7	181.7	13271.1	66.1	6.5	1.935	1 273 750 000 000	5 950 308 333 333	0	1
2004	1	13749.3	185.2	13773.5	65.7	6.3	1.971	1 344 250 000 000	6 236 108 333 333	0	1
2005	2.28	14080.0	190.7	14234.2	65.4	5.7	2.001	1 371 608 333 333	6 504 608 333 333	0	1
2006	4.29	14411.7	198.3	14613.8	65.5	5.1	2.032	1 374 658 333 333	6 846 850 000 000	0	1
2007	5.25	14757.0	202.416	14873.7	65.9	5	2.004	1 372 600 000 000	7 268 833 333 333	0	1
2008	3.94	15107.0	211.08	14830.4	65.7	5.4	1.94	1 434 858 333 333	7 766 116 666 667	0	1

2009	0.15	15408.3	211.143	14418.7	65.4	8.5	1.734	1 637 716 666 667	8 389 875 000 000	0	1
2010	0.11	15630.7	216.687	14783.8	64.6	10.6	1.733	1 742 316 666 667	8 597 408 333 333	0	1
2011	0.17	15836.2	220.223	15020.6	63.9	9.8	1.719	2 010 050 000 000	9 225 425 000 000	0	1
2012	0.08	16071.5	226.665	15369.2	63.4	8.8	1.634	2 311 875 000 000	10 014 716 666 667	0	1
2013	0.14	16332.3	230.28	15710.3	63.3	8.5	1.574	2 548 758 333 333	10 689 658 333 333	0	1

All the data (except the dummies: S&L crisis, Savings glut) are taken from *http://research.stlouisfed.org/fred2*

- FEDFUNDS - Effective Federal Funds Rate, Percent, Monthly, Not Seasonally Adjusted;
- GDPPOT - Real Potential Gross Domestic Product, Billions of Chained 2009 Dollars, Quarterly, Not Seasonally Adjusted;
- CPIAUCNS - Consumer Price Index for All Urban Consumers: All Items, Index 1982-84=100, Monthly, Not Seasonally Adjusted;
- GDPCA - Real Gross Domestic Product, Billions of Chained 2009 Dollars, Annual, Not Seasonally Adjusted;
- LNU01300000 - Civilian Labor Force Participation Rate, Percent, Monthly, Not Seasonally Adjusted;
- UNRATENSA - Civilian Unemployment Rate, Percent, Monthly, Not Seasonally Adjusted;
- M2V - Velocity of M2 Money Stock, Ratio, Quarterly, Seasonally Adjusted;
- MANMM101USA189N - M1 for the United States, OECD "Main Economic Indicators - complete database", Main Economic Indicators (database), Dollars, Annual, Not Seasonally Adjusted;
- MABMM301USA189S - M3 for the United States, OECD "Main Economic Indicators - complete database", Main Economic Indicators (database), Dollars, Annual, Not Seasonally Adjusted;
- S&L crisis – dummy variable takes ‘1’ for years in period from 1990 till 1995 and describes the period beyond Saving and Loans crisis in USA;
- Savings glut – dummy variable takes ‘1’ for years in period beyond 2002 and describes the period of saving glut in the world.