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Quantitative Determination of Optimal Fiscal and Monetary Policies: A Stochastic Optimal Control Analysis for Iran

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Abstract

This paper analyzes the design of macroeconomic policies for Iran during the fourth development plan (2005-2009). For this purpose, first we develop and design a macroeconometric model for Iran economy. Then, we use the stochastic optimal control algorithm "OPTCON" until determine optimal fiscal and monetary policies as solutions of optimum control problems with a quadratic objective function and the macroeconometric model as a constraint. The results show that, the optimal values of government current expenditures, government capital expenditures, tax revenues and oil revenues as the set of fiscal policies, are greater than those proposed in fourth development plan where as money stock as monetary policy is less than the proposed one. The comparison between the effects of the proposed and optimal macroeconomic policies on goal variables, show that using the optimal policies, will improve the economic growth rate significantly and led to lower inflation and unemployment rate. Also, these optimal policies decrease the ratio of budget deficit to GDP some deal. Therefore, the determination of optimal macroeconomic policies for fifth development plan and remainder of the Iran's twenty years of development prospect bill is suggested.

Keyword: macroeconometric model, optimal fiscal and monetary policies, stochastic optimal control algorithm, fourth development plan of I.R.I

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1- Introduction

The study of economic changes in economics literature shows that requirement of economy policy-making by fiscal and monetary instrument in economic, avoidable to obtain the perceived goals [1]. So that after the great depression through 1929-32, Keynes attempted to justify government intervention in economy by introducing general disequilibrium theory. However, according to "all or nothing demand for money theory", he recommended fiscal policies to improve economic situations.

After three decades, Friedman [2] showed how monetary policies lead to incentive investment and output in the short run. Some economists such as Tobin [3], Peterson and Lerner [4] pointed out that increasing money supply lead to increase in the capital accumulation and economic growth. Robert Mundell [5, 6 & 7] dealt with the impact of fiscal and monetary policies in an open economy. He showed that different exchange rate regimes as well as the degree of capital mobility influence the effectiveness of macroeconomic policies.

In a new classical school framework, unanticipated policies will have real effects, even in a very short period. Thus, until initially of 2000 decade intermediation and policy-making in economy, voided from visionary and tentative battles. Also, we know that carrying out several policies are likely to conflict with the other goals and in this condition cost all or some of other goals, in due to interaction feedback effects distortion. This revealed when intertemporal essence of decision-making is focus. Therefore in spite of substitution ability must optimize control of policy-makers variables. So, especially in middle of 1990 decade, the more of studies related to economic policies, used the optimization models. So determine the policies or the other words optimal fiscal and monetary instrument, state the important policy-making duties each economic system [8].

During the last three decades, Iran’s economy has witnessed high inflation and unemployment, budget deficit and high fluctuations in economic growth. Combating the above problems has been one of the important goals of policy-making in Iran. Therefore, at the end of the imposed war , the Iranian first, second and third development plan were launched. Due to lack of coordinating between the macroeconomic policies introduced some of the main important goals proposed in

these plans were not accomplished. The present paper deals with the quantitative determination of Iran's optimal fiscal and monetary policies in order to obtain the goals of economic growth rate, inflation rate, unemployment rate and the ratio of government budget deficit to GDP with minimum loss during the counting fourth economic plan (2005-2009) under the flexible exchange rate systems.

To do so, first we review the previous empirical studies that utilized stochastic optimal control analysis and algorithm for determination of optimal fiscal and monetary policies. Next, we have designed a nonlinear dynamic macroeconomic system and estimated this middle macro econometric model for Iran economy. Since surveyed the stochastic optimal control approach and "OPTCON" algorithm, calculated the optimal macroeconomic policies and effects of these policies on goal variables of fourth development plan using by the optimal control algorithm "OPTCON". Finally we will compare the optimal monetary and fiscal policies and their effects on goal variables with whatever passed in objectivity and ending paper with concluding remarks.

2- Previous Empirical Studies

During the last two decades, the application of optimal control theory has been widely developed in economic studies. In fact, policy-makers in decision-making process should determine the objectives and constraints. Then, he (or she) should choose the alternative that gives the nearest outputs to objectives. For this reason mathematical models have been used. But, in practice, one is recognize the intertemporal nature of decision process, the presence of uncertainty the imperfect information, the interactions fiscal or money variables and the nonlinearity of economic models. Stochastic optimal control theory is a powerful tool for solving these problems and for this purpose, some stochastic optimal control algorithms were designed [9, 10 & 11]. Stochastic optimal control algorithm "OPTCON" is one powerful these algorithms. So, in section review the previous empirical studies that utilized stochastic optimal control analysis and "OPTCON" algorithm especially for determination of optimal fiscal and monetary policies.

Reinhard Neck [12] in paper namely optimality macroeconomic policies: application to Austria, utilized the optimal control theory for

determination of optimal fiscal and monetary policies to Austria. In Neck' algorithm, applied the money stock, taxation rate and government consumption expenditures as control variables. He showed with scrutiny and comparison of optimization result per actual data that suggestion optimal policies are practicable.

While Neck and Matulka [13] introduced OPTCON algorithm, they solve linear and nonlinear models toward stochastic dynamic optimization problem for delineated optimal fiscal and monetary policies of Austria economy. At non-linear model, control variables were taxation rate, government consumption expenditures and money stock. The purpose of an optimization problem has been the desirable value of production and inflation variables. Those deduced through quantitative determination control variables that specifically adoption of optimal fiscal policies could increase the real national gross production during time.

Neck and Karbuz [14, 15, & 16] preceded the quantitative determination of fiscal policies Austria economy with postulation of monetary policies exogenous. Those designed one non-liner dynamic model for optimization of policy-maker objective function with OPTCON algorithm. In this research the policy-maker targets are access to desirable quantities of economic growth rate, unemployment rate, inflation rate, current account balance and the percentage of budget deficit to GDP. In order to access these goals, government investment expenditures and taxation income net, posed the control variables. Moreover researchers evaluated the results sensitivity into stochastic or deterministic of equations system. Results shown, increase uncertainly degree is costly and in applied condition biased the fiscal policies coefficients.

Neck and Karbuz [17] with optimal control method perused of macroeconomic policies stabilization. In this paper major question was what can fiscal and monetary policies in the 1980s decade, decrease fluctuations and business cycles Austria economy or no. The results show that actual fiscal and monetary policies enjoy the less power stabilization into optimal fiscal and monetary policies.

Neck and Karbuz [18, 19, & 20] scrutinized the sensitivity into results of dynamic optimization with OPTCON algorithm toward goals quantitative. For this, these researchers calculated the optimal fiscal and monetary

policies to Austria economy during 1993-2000. Then those survey sensitivity of dynamic optimization results into the path of target variables to change on quantities of these variables. The results research shown that users of this algorithm should avoid from very optimistic or pessimistic about target of macroeconomic in planning.

Neck and Karbuz [21] utilized the OPTCON algorithm to determination fiscal policies for Austria economy. These researchers via minimization of an intertemporal objective function for a macro econometric model shown that implement optimal fiscal policies, help government to more access of purposed targets.

Weyerstrass [22] analyzed optimal monetary and fiscal policies for Slovenia under different exchange rate regimes. Results of this research that included a Keynesian dynamic system are demonstrator of effect remarkable of exchange rate regime type on production and economic growth trend due implement optimal monetary and fiscal policies.

Weyersrass et al [23] moreover quantitative determination of optimal monetary and fiscal policies for Slovenia economy, aimed that in adoption condition of optimal monetary and fiscal policies, reduce taxation rate on labor force without creating undesirable effects on government budget deficit can be improve the unemployment rate.

Jafari Samimi et al [24] used the OPTCON algorithm to calculate optimal fiscal and monetary policies under fixed, flexible and crawling peg exchange rate regimes for the third five year Iranian development plan. The results of this study show that in the absent of active monetary policy instruments, the government expenditures are greater and the optimal tax revenues are lower than the proposed values in Iran third development plan. However, under a flexible exchange rate regime, the optimal values of government expenditures are lower and the optimal values of tax revenues are greater than that proposed in Iran's third development plan. The study also shows that using optimal macroeconomic policies lead to lower fluctuations in major macroeconomic variables. The main conclusion seems to be is that only under the flexible exchange rate regime, the macroeconomic goals of the plan can be achieved, the flexible exchange rate regime being recommended as a policy instrument for Iran's fourth five year development plan.

Tehranchian and Abdi Rad [25] analyzed the optimality of macroeconomic policies for Iran during the third five year development plan (2000-2004). For this purpose, those developed and used a macro econometric model. These researchers determined optimal monetary and fiscal policies as solutions of optimum control problems with a quadratic objective function and the macro econometric model as a constraint. The results of this paper show the optimal values of macroeconomic policies have deviation from those realities in third development plan. So that, this deviation in variables of government current expenditures, government tax revenues and government oil revenues are loss and in variables of government capital expenditures and money stock as monetary policy are more. Also, the empirical optimization result show that the optimal monetary and fiscal policies could lead to a considerable stabilization of the time path of the rate of economic growth, without creating undesirable effects on inflation and unemployment rates and the ratio of budget deficit to GDP. Also, the results showed using the optimal macroeconomics policies obviation the fluctuations of the main and minor objective variables.

3- The Macroeconometric Model

The constraint to the optimization problem is given by a macro econometric model of the Iran's economy. So, our model is a medium-sized macro econometric model of the open economy of Iran. It consists of 36 equations: 13 behavioral equations and 23 identities. The list of variables is shown in appendix and table1 shows the estimated behavioral equations and identities. The former were estimated by ordinary least squares (O.L.S), using time series data for the period 1960 until 2004 [26]. This model is basically of a Keynesian-Classic type and includes goods, services market and money market from the aggregate demand side and the potential GDP function and labor market from the aggregate supply side. The goods, services market contain private consumption function, private investment function, government consumption function, government investment function, import and export functions. Also, whole of the behavioral equations contain the lagged dependent variables, reflecting adaptive expectations and costs of adjustment.

Private consumption is explained by a simple Keynesian consumption function, depending on disposable income and private investment is influenced by government investment, real long-term interest rate and the change of total domestic demand (an accelerator hypothesis). Government consumption is explained by government current expenditure and government investment depending on real gross domestic product and government capital expenditure. The part of non-oil export from exports of goods and services is a function of the real exchange rate and part of oil export from exports of goods and services is exogenous. Import of goods and services is a function of the real gross domestic product and real exchange rate. Also, function of the nominal long-term interest rate as inverse of money demand, depends on real gross domestic product and nominal money stock.

The labor market is modeled by specifying a wag rate equation and an employment equation, whereas the labor supply is exogenous to the model. So that wag rate is determined by the price level, by labor productivity and the unemployment rate and employment depends on real gross domestic product and real wage rate. Also, from the aggregate supply side, potential output, which is determined by a Cobb-Douglas production function with constant returns to scale, depends on trend employment, the capital stock, and trend time [27]. Trend employment is defined as the labor force supply and trend time is defined as autonomous technical progress.

In order to explore the implications of the exchange rate system, the model contains an exchange rate equation that it is explained by ratio Iran CPI to USA CPI. USA CPI is defined as the proxy of foreign world CPI and it forecasted by an ARIMA (2, 1, 1). Finally, in this model consumer prices level depend on domestic and international factors that those consist of nominal money stock, the relative price of import and the capacity utilization rate. Gross domestic product deflator depends on price level. Also, it noticeable that identities equations defined current statutory of macroeconomic.

Table 1: The equations

Number	Equations
	Behavioral:
1	$CPR = 0.83CPR(-1) + 0.13YDR$ t: (11.79) (3.19) $DW = 2.02$ $R^{-2} = \%99$
2	$INVPR = 0.85INVPR(-1) + 0.22\ INVGR + 0.37\Delta DEMAND - 59.78LTIRR$ t: (10.89) (1.65) (13.06) (-0.26) $DW = 1.43$ $R^{-2} = \%88$
3	$CGR = 0.19CGR(-1) + 0.61GCER$ t: (1.84) (7.85) $DW = 1.93$ $R^{-2} = \%98$
4	$INVGR = 0.24INVGR(-1) + 0.05GDPR + 0.51GMER$ t: (1.98) (3.55) (3.65) $DW = 2.11$ $R^{-2} = \%88$
5	$NOILEXPR = 0.97NOILEXPR(-1) + 0.35ERR$ t: (16.10) (1.51) $DW = 2.10$ $R^{-2} = \%87$
6	$IMPR = 0.79IMPR(-1) + 0.09GDPR - 2.74ERR$ t: (10.08) (2.96) (-1.61) $DW = 1.42$ $R^{-2} = \%82$
7	$AGWN = 0.96AGWN(-1) + 3.81CPI + 0.0069PROD - 3.51UR$ t: (9.90) (2.53) (1.21) (-1.36) $DW = 1.87$ $R^{-2} = \%99$
8	$CPI = 0.55CPI(-1) + 0.000076M3N + 0.12IMPDEF + 0.021UTIL$ t: (6.29) (5.39) (3.56) (0.85) $DW = 1.90$ $R^{-2} = \%99$
9	$EMP = 1.01EMP(-1) + 0.00057GDPR - 0.053AGWR$ t: (75.81) (2.46) (-1.91) $DW = 1.59$ $R^{-2} = \%99$
10	$LTIRN = 0.94\ LTIRN(-1) + 0.0000027\ GDPR - 0.0000028\ M3R$ t: (9.98) (0.91) (-0.62) $DW = 1.71$ $R^{-2} = \%94$
11	$ERN = 0.60ERN(-1) + 3714.20\ PRICERATIO$ t: (3.63) (2.87) $DW = 1.65$ $R^{-2} = \%98$
12	$GDPDEF = 0.95GDPDEF(-1) + 0.19CPI$ t: (16.48) (4.27) $DW = 2.11$ $R^{-2} = \%87$
13	$GDPPOT = 0.48CAPR + 10.76LFORCE + 7177.80TIME$ t: (7.78) (1.65) (0.91) $DW = 1.51$ $R^{-2} = \%98$
	Identities:
14	$GDPR = CPR+CGR+INVR+EXPR-IMPR$
15	$INVR = INVPR+INVGR+SEDIR$
16	$EXPR = OILEXPR+NOILEXPR$
17	$DEMAND = GDPR+IMPR$
18	$GDPN = (GDPR*GDPDEF)/100$
19	$GRGDPR = ((GDPR-GDPR(-1))/GDPR(-1))*100$
20	$GRCPI = ((CPI-CPI(-1))/CPI(-1))*100$
21	$LTIRR = LTIRN-GRCPI$

22	*AGWR = (AGWN/CPI)*100*
23	*M3R = (M3N/CPI)*100*
24	*PROD = (GDPR/EMP)*100*
25	*ERR = (CPIF/CPI)*ERN*
26	*PRICERATIO = CPI/CPIF*
27	*UTIL = (GDPR/GDPPOT)*100*
28	*CAPR =CAPR(-1)+INVPR+INVGR-DEPR*
29	*UN = LFORCE-EMP*
30	*UR = (UN/LFORCE)*100*
31	*GCER = (GCEN/GDPDEF)*100*
32	*GMER = (GMEN/GDPDEF)*100*
33	*TAXRR = (TAXRN/GDPDEF)*100*
34	*DEF = GCEN+GMEN-TAXRN-OILRN-OTHERRN*
35	*DEFRATIO = (DEF/GDPN)*100*
36	*YDR = GDPR-TAXRR*

*t, R^{-2} and D.W are the t statistic, adjusted R and Durbin Watson statistic respectively.

4- The "Stochastic Optimal Control" Approach

Optimal fiscal and monetary policies are calculated using OPTCON, an algorithm for the optimization of an intertemporal objective function subject to the constraints of a dynamic nonlinear multivariable model, developed by Matulka and Neck [28 & 13]. OPTCON determines approximate solutions of optimum control problems with a quadratic objective function and a nonlinear multivariable model. The objective function has to be quadratic in the deviations of the state and control variables from their desired values. The objective function has the following form:

$$L = \frac{1}{2}\sum_{t=1}^{T}\begin{bmatrix} x_t - \overline{x_t} \\ u_t - \overline{u_t} \end{bmatrix}' . W_t . \begin{bmatrix} x_t - \overline{x_t} \\ u_t - \overline{u_t} \end{bmatrix}, \qquad (1)$$

$$W_t = \alpha^{t-1} . \ W, \ t = 1,..., T \qquad (2)$$

Where x_t denotes the vector of state variables, u_t denotes the vector of control variables, $\overline{x_t}$ and $\overline{u_t}$ are the desired values of the state and control

variables, W_t is the matrix containing the weights given to the deviations of the state and control variables from their desired values, respectively, and a denotes the discount factor. The dynamic system has to be given in a state space representation. Although OPTCON can solve deterministic and stochastic optimum control problems, here we confine ourselves to deterministic optimizations only.

So the dynamic nonlinear system is defined as:

$$x_t = f\ (x_{t-1}, u_t, \hat{\theta}, z_t) + \varepsilon_t \tag{3}$$

In this system $\hat{\theta}$, z_t and ε_t are the expected value of the stochastic parameter vector, exogenous variables vector and the matrix of the additive system noise respectively. As inputs of the algorithm, the user has to supply the followings: the system function, the initial value of the state vector, a tentative path for the control variables, the expected value and the covariance matrix of the stochastic parameter vector, the covariance matrix of the additive system noise, the weight matrices of the objective function, the planning horizon, the desired paths for the state and control variables, the tentative path for control and state variables and a discount rate of the objective function. This algorithm is executable in ‘‘GAUSS’’ programming system.

Therefore, we used the "OPTCON" algorithm in order to determine the optimal fiscal and monetary policies for Iran during the fourth development plan.

As the stochastic model equations are estimated by OLS, no full covariance matrix of the parameters is available. In this case, only a limited stochastic optimization can be run with the estimated standard errors of the coefficients and the standard errors of the regression equations taken into account [18, 19]. In order to determine the approximate solutions optimum current government expenditures, capital government expenditures, tax revenues and oil revenues as the set of fiscal policies and also optimum money stock as monetary policy, three “main” and one “minor” objectives are considered. The “main” objective variables are economic growth rate, inflation rate and unemployment rate. Also, the minor objective is ratio of budget deficit to GDP. The values of target for these variables are the values, which targeted in Iran’s fourth development plan. So, the planning horizon for the control experiments has been chosen as 2005 to 2009. After several

experiments sensitivity analysis we hare chosen a discount factor $\alpha = 0.5$, the weight 1000 for main and 10 for minor objective variables. Then, in the weight matrix of the objective function, off diagonal elements were all set equal to zero. In addition, all state variables in the model not mentioned above, got the weight zero.

5- The Results of Optimization

In order to compare the optimal fiscal and monetary policies effects on the main and minor objective function variables with that of the proposed fiscal and monetary policies in fourth plan and the tentative path for state variables, we used $MAPLE_{10}$ program for the simulation of the model and used the GAUSS program to determine the optimal macroeconomic policies. The calculated optimum set of fiscal and monetary policies are compared with those proposed valued in fourth development plan in table 2. The table shows that, the optimal values of government current expenditures, government capital expenditures, government tax revenues and government oil revenues as the set of fiscal policies, are greater than those proposed in fourth development plan whereas money stock as monetary policy is less than the proposed one.

Table 2: The values of optimal and fourth plan control variables (Milliard Rials)

		2005	2006	2007	2008	2009
GCEN	**Optimal**	234758.9	288315.9	363490.2	480971.2	683060.3
	Proposed	222234.1	244457.5	268903.3	295793.6	325372.9
GMEN	**Optimal**	181625.6	269885.9	378293.1	509600.6	650005.6
	Proposed	102820.7	134746.1	171070.4	214373.6	275841
TAXRN	**Optimal**	162780.7	200222.8	257530.1	347187.9	494905.3
	Proposed	117830.4	150397.7	182521.9	218558.7	262631.4
OILRN	**Optimal**	214752.9	306768.2	417368.7	556629.1	728802.1
	Proposed	134764.8	148054.7	166118.1	186117.3	204310.9
M3N	**Optimal**	781960.7	944835.3	1127493.7	1335156.5	1581919.5
	Proposed	814407.7	993577.4	1192292.9	1406905.6	1634279.8

Source: author calculations.

Also, table 3 shows the target values and the results for the most important state variables of the simulation and optimization run,

respectively. The comparison between the effects of the proposed and optimal macroeconomic policies on goal variables, show that using the optimal policies, will improve the economic growth rate significantly and led to lower inflation and unemployment rate. Also, these optimal policies decrease the ratio of budget deficit to GDP some deal.

Table 3:The result of optimization and simulation results (Percentage)

		2005	2006	2007	2008	2009
	Fourth Plan Targets	7.1	7.4	7.8	8.4	9.3
GRGDPR	Simulation Results	2.1	0.7	0.8	1.0	2.4
	Optimization Results	7.1	7.3	7.6	8.1	8.6
	Fourth Plan Targets	14.6	11.5	9.1	7.9	6.8
GRCPI	Simulation Results	14.3	17.1	17.6	17.1	16.1
	Optimization Results	12.9	15.8	16.7	16.2	15.7
	Fourth Plan Targets	11.8	11	10.1	9.3	8.4
UR	Simulation Results	12.2	12.1	12.0	12.0	12.1
	Optimization Results	12.0	11.6	11.0	10.3	9.5
	Fourth Plan Targets	2.5	2.1	1.9	1.7	1.9
DEF%	Simulation Results	2.6	2.3	2.1	2.0	2.2
	Optimization Results	0.6	0.8	0.9	1.1	1.2

Source: author calculations.

6- Concluding Remarks

In this paper we have tried to determine the optimal macroeconomic policies to achieve the major goals of the fourth five year's Iranian development plan (2005–2009), this include economic growth rate, inflation rate, unemployment rate and the ratio of budget deficit to GDP. To do so, after review the previous empirical studies about utilized stochastic optimal control analysis and algorithm for determination of optimal macroeconomic policies, we have defined a dynamic nonlinear system of macroeconomic equations.

Then, estimated this macro econometric model for Iran economy and calculated the effects of macroeconomic policies imposed during the fourth development plan on the above mentioned macroeconomic variables using the simulation technique by $MAPLE_{10}$ program. Thence, surveyed the

stochastic optimal control approach and "OPTCON" algorithm, calculated the optimal macroeconomic policies and effects of these policies on goal variables of fourth development plan using by the optimal control algorithm "OPTCON" under flexible exchange rate regime.

Finally compare the optimal monetary and fiscal policies and their effects on goal variables with whatever passed in objectivity. The empirical optimization result show that the optimum macroeconomic policies may lead to a considerable stabilization of the time path of the rate of economic growth and those will improve the inflation rate, unemployment rate and the ratio of budget deficit to GDP some deal.

Appendix: List of variables

State (or endogenous) variables:	
AGWN	Average gross wage rate per employee, nominal
AGWR	Average gross wage rate per employee, real
CAPR	Capital stock, real
CGR	Government consumption, real
CPI	Consumer price index
CPR	Private consumption expenditures, real
DEF	Budget deficit, nominal
DEF%	Budget deficit as percentage of nominal GDP
DEMAND	Total final demand, real
EMP	Employment; 1,000 persons
ERN	Exchange rate, nominal
ERR	Exchange rate, real
EXPR	Total export, real
GCER	Government current expenditure, real
GDPN	Gross domestic product, nominal
GDPR	Gross domestic product, real
GDPDEF	GDP deflator
GDPPOT	Potential GDP, real
GMER	Government capital expenditure, real
GRCPI	Annual growth rate of CPI (Inflation rate)
GRGDPR	Annual growth rate of real GDP
IMPR	Total imports, real

INVGR	Government investment, real
INVPR	Private investment, real
INVR	Total investment, real
LTIRN	Long-term interest rate, nominal
LTIRR	Long-term interest rate, real
NOILEXPR	Non-oil export, real
M3R	Money stock M3, real
PRICERATIO	Ratio Iran CPI to USA CPI
PROD	Labor productivity
TAXRR	Government tax revenue, real
UN	Number of unemployed persons
UR	Unemployment rate, % of the labor force
UTIL	Capacity utilization rate
YDR	Personal disposable income, real
Non-control exogenous variables:	
CPIUSA	USA CPI Consumer price index
DEPR	Depreciation of fixed capital, real
IMPDEF	Import price level (import deflator)
LFORCE	Labor force; 1,000 persons
OILEXPR	Oil exports, real
OTHERRN	Government non-tax revenue, nominal
SEDIR	Sum of inventory change and statistic errors
TIME	Linear time trend
Control exogenous variable:	
GCEN	Government currency expenditure, nominal
GMEN	Government capital expenditure, nominal
TAXRN	Government tax revenue, nominal
OILRN	Government oil revenue, nominal
M3N	Money stock M3, nominal

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