

ESTIMATING A DSGE MODEL OF THE NIGERIAN ECONOMY

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ABSTRACT

Effective policy formulation requires model that draws significantly on the microeconomic behaviour of agents as well as captures their responses to economic/monetary disturbances. Getting such models has remained a persistent aspiration of both developed and developing economies central banks with mixed results. This paper presents a small-scale DSGE model of the Nigerian economy and sets out the process for its estimation with the aim of aiding monetary policy decisions. Preliminary results obtained from the VAR estimation of the model show that changes in prices are influenced mainly by volatility in real output while exchange rate and inflation account for significant proportion of the variability in interest rate. A major constraint confronted in the study is unavailability of relevant software for the comprehensive estimation of the model. This makes the re-estimation of the model the outstanding task and a major issue to provide conclusive assessment of the relevance of the application of the DSGE model to the Nigerian economy.

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I. Introduction

Recent enthusiasm about the construction of medium-scale dynamic stochastic general equilibrium (DSGE) model, especially among central bank researchers, seems to suggest that succor has finally been found in modeling for policy evaluation. Advocates of DSGE models emphasize their structural microfoundation framework and effectiveness in the analysis of the cyclical properties of the economy (Zanetti, 2007). Whether DSGE models will be given a greater role in the process of policy analysis in the years ahead shall be made clearer soonest. This paper presents and estimates a small scale DSGE model for the Nigerian economy. It however suffices to note that the preliminary results should be interpreted with caution due to limitations imposed by computing facilities inadequacy.

The paper begins with an overview of the Nigerian economy to provide an environmental context for the assessment of the model and its results. Specifically, the trends in macroeconomic aggregates and monetary policy responses in the last two decades were described. Section 3 provides a brief narration of the emergence of DSGE models and surveys the emerging empirical literature on its experimentation. Section 4 presents the theoretical model for the study and the underlying justification for its adoption. In section 5, a pseudo-estimation of the model was carried out and the results analysed. Pseudo, due to unavailability of requisite software programs for actual estimation and simulation. The last section concludes the paper and provides area of further refinement of the model for policy relevance.

II. Background on the Nigerian Economy

Prior to the advent of oil, agriculture constituted the mainstay of the Nigerian economy in terms of total employment, source of government revenue and contribution to the Gross Domestic Product (GDP). A significant proportion of the GDP (about 60 percent) originated from agriculture and foreign exchange was earned mainly through the exports of principal commodities such as cocoa, groundnuts, palm oil, rubber, cotton and timber. The dawn of

petroleum era in the 1970s altered the structure of the Nigerian macro economy significantly. Specifically, the structure of the economy started to be dictated mainly by the growing importance of petroleum, the expanding role of the public sector in the economy and an unsustainable dependence on the external sector.

From almost half in 1970, the contribution of agriculture to the real GDP fell sharply to 28.4 percent in 1975. Since then, the share has been growing steadily up to 2000 when it was 41.9 percent (Table 1). The improvement in the contribution of agriculture to the overall economy was attributed to the structural reforms directed at diversifying the productive base of the economy since 1986 and also to the various policies of the CBN aimed at stimulating the growth of the real sector of the economy.

TABLE 1: Percentage Sectoral Share of Nigeria's Real GDP

Sectors	1970	1975	1980	1985	1990	1995	2000	2005
Agriculture	49.2	28.4	36.2	40.4	39.0	38.8	41.9	41.2
Building and Construction	7.6	8.2	6.4	1.9	1.9	2.0	1.4	1.5
Mining and Oil	10.3	31.7	15.3	15.6	13.2	12.9	28.8	24.3
Manufacturing	7.0	6.5	9.4	8.6	8.1	6.6	5.3	3.8
Services	22.4	20.1	18.7	21.2	25.7	26.3	14.6	13.4
Others	4.5	5.1	14.0	12.3	12.1	13.4	8.0	15.8

Source CBN Statistical Bulletin (2004) and CBN Annual Reports

From 1970 to 1998, the manufacturing sector was a drag on the Nigerian economy because of its sluggish performance. Its contribution to the gross domestic product throughout the period was less than 10 percent. This poor performance of the manufacturing sector can be explained when such factors as the low capacity utilisation, poor effective demand for final products, exchange rates misalignment and input procurement constraints are taken into consideration. In 1970, the value of oil exports, as a ratio of total exports was 57.6 percent. The ratio increased suddenly to 92.6 percent in 1974. Except for the marginal decreases in 1977-78 and the two years following the introduction of the structural adjustment programme

(SAP) in 1986, earnings from oil exports has been accounting for about 97 percent of total export earnings since the early 1980s.

Using the growth in real GDP, the performance of the Nigerian economy has been relatively impressive. From double digit growth of 11.7 percent in 1975, the real GDP grew by about 5 percent in the last two decades. Except in 1995 when growth in prices was 72.8 percent, inflation in Nigeria has been reasonable.

TABLE 2: Annual growth rate of Selected Economic Indicators (Percent)

	1975	1980	1985	1990	1995	2000	2005	2006
Real GDP	11.7	5.48	9.38	8.2	2.15	5.40	6.51	5.63
Broad Money (M2)	67.6	46.1	10.3	40.4	19.4	48.1	24.4	30.6
Inflation	33.9	9.9	5.5	7.5	72.8	14.5	11.6	8.5
Imports	114.2	21.7	-1.6	48.1	33.9	14.2	24.5	23.9
Exports	-15.0	30.9	29.0	89.6	36.4	63.6	38.1	-12.8

Source: CBN Annual Reports

The Nigerian financial sector is made up of a wide array of institutions, which include the regulatory agencies, deposits money banks (DMBs), development and specialized banks, non-depository institutions, and the capital market. Within the regulatory arm of the financial system are the Central Bank of Nigeria (CBN), the Federal Ministry of Finance, the Securities and Exchange Commission (SEC), the Nigerian Deposit Insurance Corporation (NDIC) set up in 1988 in the wake of financial reforms, and the National Insurance Commission (NAICOM) established in 1997. The non-bank financial institutions comprise finance and discount houses, investment companies, bureaux-de-change, insurance companies, and the Pension and Provident Funds.

III. Emergence of DSGE Models and Its Experimentation¹

Policy models have evolved through four generations. The first generation was largely driven by IS/LM framework and involved writing down equations which described the determinants of variables in the national accounting identity for GDP, e.g. investment and consumption. Dynamics were introduced through distributed lag relations. Second generation models introduced much stronger supply side features and also moved towards deriving some of the relationships as the consequence of static optimization problems solved by agents. Dynamics were again introduced by modifying the static relationships with the use of distributed lag ideas (Fukač and Pagan, 2006) (FP). Third generation models responded to the fact that the earlier generation models rarely converged to a steady state solution when simulated. The models become much smaller and emphasis was placed on the need to initiate their construction by designing a steady state that they were to converge to and to fully account for stock-flow interactions.

The third generation models allowed for the possibility that decisions about prices, consumption, investment etc. might be based upon expected future outcomes, rather than just those made about financial variables. In practice a combination of both backward and forward looking elements were incorporated into decision rules with the greater weight being given to the “backward effects”. In most instances, the parameters of the base model were calibrated by utilizing information in “great ratios”, in first moments, and from the attitudes of policy makers and advisers. Even the parameters determined in the second stage of model construction – largely relating to dynamic adjustment – were influenced by attitudes of bank staff about the likely dynamic effects of particular shocks, as well as the evidence on dynamic adjustments in the data through past studies using techniques like VARs.

The fourth generation models distinguished themselves from the earlier ones for two reasons. First, they feature considerable heterogeneity. A variety of labour services are now available, there are many intermediate goods produced, and there may be a number of final goods

¹ This section benefits from Fukač and Pagan (2006).

produced, rather than single good of the previous generation of models. This heterogeneity is often associated with monopolistic and monopsonistic behaviour rather than the competitive markets of the earlier generation models. Second, there is a considerable increase in the degree of intrinsic dynamics, with a large number of constraints upon agents when making decisions, including habit persistence in consumption and labour choices, adjustment costs in investment and labour, capital utilization variations, and wages and prices being adjusted according to various staggered price setting and contractual arrangements. Thus the base model now has much more of the dynamic structure coming from optimal decisions than was the case in the previous models, while still retaining smallness and featuring both forward looking and backward looking behaviour. Fukač and Pagan (2006) describe the micro-macro aggregation procedure of the fourth generation models as both rather clever and good provision of interpretation to some of the aggregate demand functions.

DSGE models emerged from an attempt at making the real business cycle (RBC) paradigm (*a la* Kydland and Prescott, 1982) more realistic with the introduction of imperfections such as monopolistic competition in the goods market, disequilibrium in the labour market, liquidity constraints and explicit role for fiscal and monetary policies (Zanetti, 2007). While virtually all the features of the fourth generation models are intrinsically contained within the DSGE models, the issue of perfect correspondence between the two classes of models still lingers, especially, on the issue of how observable and unobservable shocks are treated.

Smets and Wouters (2003) (SW) convincingly show that modern micro-founded DSGE models with sticky prices and wages along the lines developed by Christiano, Eichenbaum and Evans (2005) (CEE) are sufficiently rich to capture most of the statistical features of the main macro-economic time series. SW further enunciate that applying Bayesian estimation techniques could reduce relatively large models to an estimable system that does not only deliver a more efficient estimate of the structural model parameters but also provide a consistent estimate of the structural shock processes driving recent economic developments, the understanding of which is important input in the monetary policy decision process.

Following SW treatise, experimentations with DSGE models across countries in the last three to four years have been unprecedented, with the emergence of more issues to make the process more policy relevant. Sugo and Ueda (2007) estimated a medium scale DSGE model of the Japanese economy following CEE, SW and Levin et al. (2005). By using actual capital utilization data and modifying the formulation of utilization, Sugo and Ueda succeeded in incorporating a negative correlation between capital utilization and rental costs to explain actual capital utilization rate and found hump-shaped and persistent behaviour of inflation rate in response to a monetary policy shock, which CEE cast doubt upon. DiCecio and Nelson (2007) estimated the DSGE model of CEE on the United Kingdom data and found that price stickiness was an important source of nominal rigidities in the UK than wage stickiness.

Curdia and Finocchiaro (2005) use Bayesian methods to estimate a small open economy DSGE model for Sweden. They explicitly account for the monetary regime change from an exchange rate target zone to flexible exchange rates with explicit inflation targeting, being current experimentation in Sweden. It was concluded in the paper that monetary policy is mainly concerned with stabilizing the exchange rate in the target zone and with price stability in the inflation targeting regime and that expectations of realignment and risk premium are the main sources of volatility in the target zone period. On the other hand, monetary shocks were found to be important sources of volatility in the short run in the inflation targeting period but not in the long run when labor supply and preference shocks become relatively more important. Other DSGE estimation attempts include Edge et al (2007) for the US economy and Smets and Wouters (2004) for the Euro Area.

IV. The Model for the Study

This section introduces the DSGE model used for the study. The model follows the small-scale model in Lubik and Schorfheide (2006), as illustrated in Fukač and Pagan (2006). It has four key equations. An open economy IS curve

$$\tilde{y}_t = E_t \tilde{y}_{t+1} - [\tau + \alpha(2 - \alpha)(1 - \tau)](R_t - E_t \pi_{t+1}) - \alpha[\tau + \alpha(2 - \alpha)(1 - \tau)]\rho_q \Delta q_t + \rho_A dA_t - \alpha(2 - \alpha) \frac{1 - \tau}{\tau} (1 - \rho_{y^*}) \tilde{y}_t^* \quad (1)$$

$$0 < \alpha < 1, \quad \tau^{-1} > 0,$$

an open economy Phillips curve

$$\pi_t = \beta E_t \pi_{t+1} - \alpha(1 - \beta \rho_q) \Delta q_t + \frac{\kappa}{\tau + \alpha(2 - \alpha)(1 - \tau)} \tilde{y}_t + \frac{\kappa \alpha(2 - \alpha)(1 - \tau)}{\tau[\tau + \alpha(2 - \alpha)(1 - \tau)]} \tilde{y}_t^* \quad (2)$$

an exchange rate equation

$$\Delta s_t = \pi_t - (1 - \alpha) \Delta q_t - \pi_t^* \quad (3)$$

and the policy rule

$$R_t = \rho_R R_{t-1} + (1 - \rho_R)[\gamma_1 \pi_t + \gamma_2 \tilde{y}_t + \gamma_3 \Delta s_t] + s_t^R \quad (4)$$

In the equations above \tilde{y}_t is the difference between the log of the level of output (y_t) and the log level of technology (A_t), \tilde{y}_t^* is the log of world output, R_t is the interest rate, π_t is the inflation rate, π_t^* is the world inflation rate, q_t is the log of terms of trade, and s_t is the nominal exchange rate.

Terms of trade was assumed to be an observed exogenous shock evolving as

$$\Delta q_t = \rho_q \Delta q_{t-1} + s_t^q \quad (5)$$

The variables $dA_t, \tilde{y}_t^*, \pi_t^*, s_t^R$ are unobservable shocks, being the growth rate in technology, the world level of output, world inflation and the monetary policy shocks respectively. The first three follow AR(1) processes;

$$dA_t = \rho_a dA_{t-1} + s_t^a \quad (6)$$

$$\tilde{y}_t^* = \rho_{y^*} \tilde{y}_{t-1}^* + s_t^{y^*} \quad (7)$$

$$\pi_t^* = \rho_{\pi^*} \pi_{t-1}^* + s_t^{\pi^*} \quad (8)$$

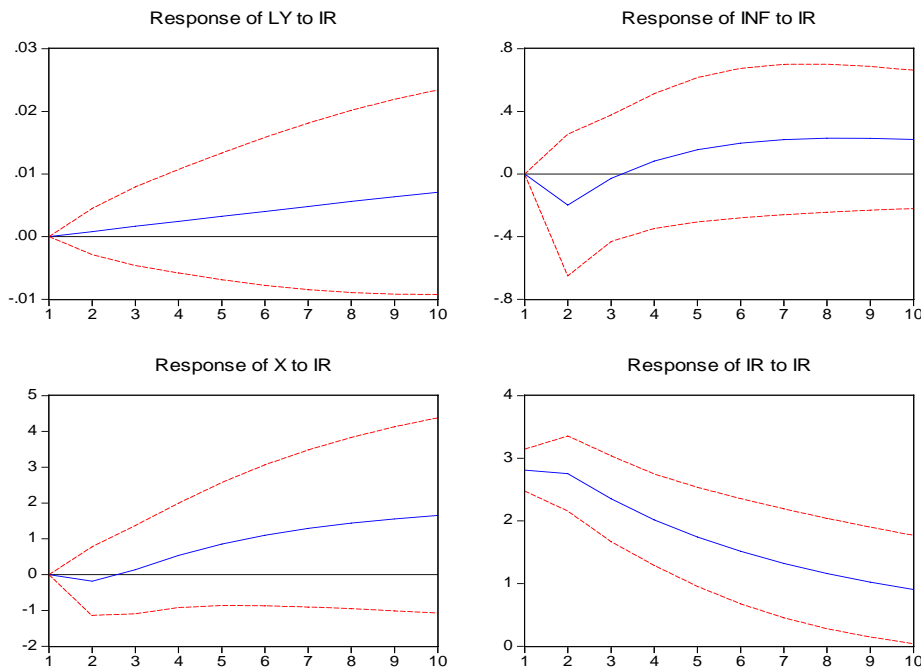
with $\rho_a, \rho_{y^*}, \rho_{\pi^*}$ assumed to lie between zero and unity and $s_t^a, s_t^{y^*}$, and $s_t^{\pi^*}$ being white noise processes. The monetary policy shock s_t^R is taken to be white noise. Since technology is an I(1) process, output will also be, and so the model is made stationary by using

$\hat{y}_t = y_t - \ln A_t$ and $\hat{y}_t^* = y_t^* - \ln A_t$, where $\ln A_t = \ln A_{t-1} + dA_t$ is the log level of technology. Lubik and Schorfheide (2006) estimated the time preference parameter as a function of a real interest rate of 2.5, i.e. $\beta=0.99$. In the empirical analysis, all the variables are represented except the log of terms of trade which is not available

V. Estimation and Analysis

Due to the unavailability of relevant software² for a detailed estimation of the specified model, pseudo-estimation by VAR methodology was carried out. The impulse responses to monetary shock to interest rate show a contraction of inflation in the second quarter and a weak response of real output. Exchange rate was initially sluggish to monetary shock only to respond sharply around the third quarter (Fig. 1).

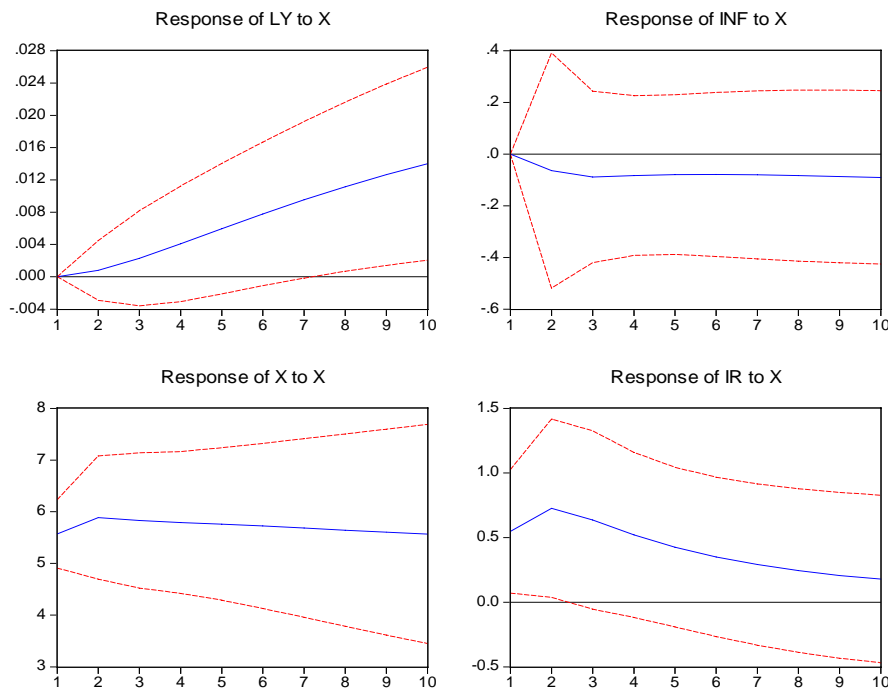
Fig 1: Impulse responses to interest rate shock



² All attempts to get DYNARE and MATLAB based on suggestions from peer review process of initial results proved unsuccessful.

The results from the impulse response to exchange rate shock are mixed. While exchange rate shock weakly depresses inflation, the response of real output was unique, especially after the third quarter. Interest rate response to exchange rate shock was mixed with initial positive reaction in the second quarter and a depressive inverse response thereafter (Fig.2).

Fig 2: Impulse Responses to Exchange Rate Shock



As with standard VAR methodology, the variables were ordered according to their rigidity to monetary shocks. Results from variance composition from the VAR estimation present less than satisfactory outlook. Variability in real output is mainly self accounted for, with all other variables combined influencing only about one percent of variation in real GDP. On the other hand, volatilities in general prices are influenced significantly by changes in real output, especially in the short run. Real GDP accounted for about 10 percent variability in inflation in the first quarter while exchange rate and interest rate exert very weak influences on prices in Nigeria. Inflation was found to be the most important element influencing exchange rate volatility, especially after the second quarter while inflation and exchange rate significantly account for the variability in interest rate (Table 3).

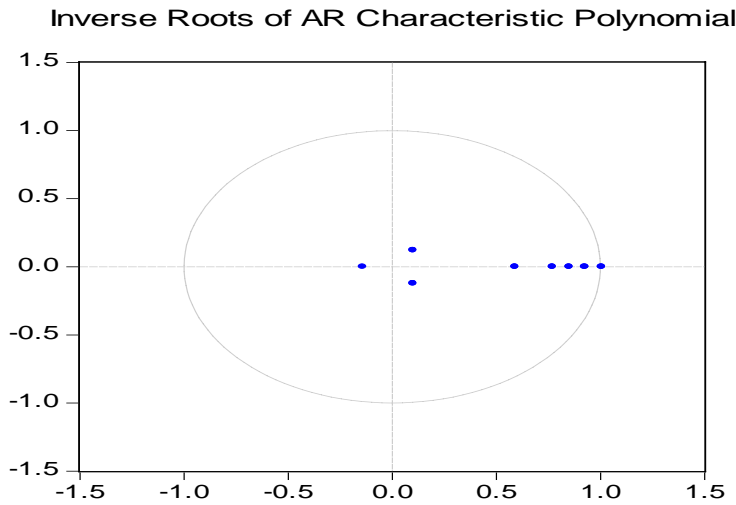
TABLE 3: Variance Decomposition (Percent)

Variance Decomposition of Real GDP:					
Period in Qtrs	S.E.	LY	INF	X	IR
1	0.021	100.0	0.00	0.00	0.00
2	0.038	99.88	0.03	0.04	0.04
3	0.053	99.55	0.13	0.20	0.12
4	0.066	99.01	0.27	0.51	0.21
5	0.077	98.25	0.44	0.98	0.33
Inflation:					
Period	S.E.	LY	INF	X	IR
1	2.625	10.09	89.90	0.00	0.00
2	3.096	8.78	90.75	0.04	0.41
3	3.386	7.90	91.63	0.10	0.35
4	3.569	7.29	92.19	0.15	0.37
5	3.696	6.84	92.44	0.18	0.52
Exchange Rate:					
Period	S.E.	LY	INF	X	IR
1	5.577	0.04	0.20	99.77	0.00
2	8.126	0.08	0.40	99.47	0.05
3	10.048	0.26	0.99	98.70	0.05
4	11.680	0.55	1.57	97.63	0.25
5	13.141	0.95	2.09	96.34	0.62
Interest Rate:					
Period	S.E.	LY	INF	X	IR
1	2.913	0.01	3.44	3.55	93.00
2	4.162	0.04	5.83	4.78	89.34
3	4.903	0.19	7.30	5.12	87.38
4	5.403	0.43	8.51	5.15	85.92
5	5.764	0.72	9.55	5.07	84.66

Ordering: **LY, INF, X, IR**

As shown by the inverse roots of AR characteristic polynomial, the VAR result from the analysis does not satisfy the stability condition (Fig 3). This may not be surprising as the macro variables were found to be weakly cointegrated.

Fig 3: Inverse Roots of AR Characteristic Polynomial



VI. Conclusions and Limitations

The combination of sound micro-founded and theoretically consistent model structure and good forecasting performance suggests that the DSGE models could be further developed as an important tool for both policy analysis and forecasting in central banking. The micro foundations imply that the structural parameters are more likely to be invariant to various policy interventions the policy makers may want to consider. As such one can more easily justify considering projections under different hypothetical monetary policies using these models. This paper presents a small-scale DSGE model of the Nigerian economy and sets out the process for its estimation with a pseudo-estimation of the model by VAR methodology. Preliminary results obtained from the estimation show that changes in prices are influenced mainly by volatility in real output while exchange rate and inflation account for significant proportion of the variability in interest rate. A major constraint confronted in the study is unavailability of relevant software to estimate the model. This makes the re-estimation of the model the outstanding task and a major issue to provide conclusive assessment of the relevance of the application of the DSGE model to the Nigerian economy.

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APPENDIX

Table A1: Descriptive Statistics of the Variables (1970Q1-2005Q4)

	LY	INF	X	IR
Mean	10.033	4.6201	28.461	14.055
Median	10.040	3.3852	4.2000	11.500
Maximum	10.587	20.302	135.20	37.800
Minimum	9.4814	-4.7110	0.5000	4.7667
Std. Dev.	0.2527	4.0238	45.229	7.4053
Skewness	0.2109	1.1023	1.5044	0.7983
Kurtosis	2.236	4.5952	3.5289	2.8387
Jarque-Bera	4.5358	44.12459	55.60526	15.344
Probability	0.1035	0.000	0.000	0.00047

NB: LY is log of Real GDP, INF is Inflation Rate,
X is Exchange Rate of Naira to Dollar and IR is Interest Rate

Table A2: Unrestricted CI Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.2073	32.060	27.584	0.012
At most 1	0.0583	8.2997	21.131	0.884
At most 2	0.0386	5.4330	14.264	0.686
At most 3	0.0028	0.3962	3.8414	0.529

Max-eigenvalue test indicates One CI Eqn at the 0.05 level

* denotes rejection of the hypothesis at the 0.05 level

The Normalized Co-Integrating Vector (s.e. in parentheses)

LY	INF	X	IR
1.00	-1.298	-0.047	0.554
	(0.239)	(0.018)	(0.128)