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The NEDA quarterly macroeconomic model: theoretical structure and some empirical results*

Carlos C. Bautista, University of the Philippines College of Business Administration

Roberto S. Mariano, School of Economics and Social Sciences, Singapore Management University

Bayani Victor Bawagan, National Economic and Development Authority, Philippines

This paper presents the National Economic and Development Authority's (NEDA) quarterly macroeconomic model (QMM) of the Philippines and discusses the results of historical and policy simulations using the model. With its strict adherence to modern macroeconomic general equilibrium analysis, the current model deviates substantially from its predecessor. The core block is based on a general equilibrium macro-model with monopolistic competition à la Blanchard and Kiyotaki [1989] that allows the derivation of the domestic price level (PGDP) and aggregate output (GDP). The real and monetary/external sectors of the model are linked through an open economy IS-LM aggregate demand framework, which embeds the portfolio balance approach to exchange rate determination; the model assumes a fully flexible exchange rate regime.

The model distinguishes between domestic inflation, computed as the PGDP percent change and consumer price inflation (CPI) percent change. The latter is derived econometrically as the weighted average of domestic inflation and imported goods inflation. Expected inflation is assumed to be a weighted average of forward-looking and backward-looking expectations of individuals.

The historical simulation results show the model's adequate tracking ability. Fifteen policy experiments are presented in this paper. For each experiment, an exogenous/policy variable is changed to determine if it has a stagflationary, recessionary, or expansionary effect. The results for all experiments show that their effects on the price level and output conform to predictions of economic theory.

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The model is clearly a work-in-progress as yearly updates are required to maintain the model.

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1. Introduction

This paper presents the theoretical foundations of the National Economic and Development Authority (NEDA) quarterly macroeconometric model (QMM) that was recently revised and updated under the third NEDA-Institutional Strengthening Project (NEDA-ISP 3). Based on a theoretical framework presented in section 2, the following equations or group of equations were estimated and tested for their statistical and forecasting properties:

1. Sectoral quantity equations were estimated as sectoral demand functions. In previous versions, these equations were supply equations.
2. Sectoral price equations, some of which were based on identities in the previous model, were estimated as inverted supply equations.
3. The expected inflation equation was simplified and was provided a theoretical basis that is easier to comprehend. It is an adaptation of the expected inflation specification of the International Monetary Fund's (IMF) MULTIMOD Mark III model.
4. The output gap series estimate that was derived from a "peak-to-peak" method and used in the previous version was dropped from the current model. This drastically simplified the expectations equation and the labor market sector which made use of this estimate.
5. The consumption demand equation was also re-specified—the food and nonfood equations of the previous model were replaced by an aggregate equation. In the revised model, aggregate consumption was assumed to be affected by real disposable income, real money balances, real financial asset holdings, and the real interest rate.
6. The tax equations were all updated and re-specified.
7. The export and import demand equations were estimated using balance of payments (BOP) accounts data; in the previous model, the national accounts were used.

8. In preparation for policy analysis on inflation targeting, the consumer price inflation (CPI) equation was estimated based on the suggested framework detailed below. The CPI is computed as a weighted average of the domestic price index and the imported price index.

Prior to the re-estimation of the model equations, the data were updated and checked for errors in data entry and processing. After the model equations were finalized, static and dynamic historical simulations were conducted to determine how well the model tracked the economy. Policy experiments and ex-ante forecasts were done after the historical simulations. The next section presents the theoretical structure of the model. The third section presents the estimation methods. The fourth and fifth sections discuss the simulation results.

2. Framework

While the previous version of the model makes extensive use of econometric theory-based explanations of equilibrium through cointegration techniques, the current version of the QMM relies on modern macroeconomic theory as the main guide in the estimation of the model. There are two disadvantages in relying on cointegration analysis in specifying a structural macro-model. First, it limits the ability to adopt desirable specifications. For example, a regression of the real exchange rate level on the real interest rate differential, while having a rigorous theoretical foundation, is not permitted because the latter is known to be I(0) while the former is often found to be I(1). Second, the unit root test is known to have weak power over the alternative of linear mean reversion. It is therefore difficult to assert that no relationship exists simply because no evidence of cointegration was found.[1] One may think of the current model's adopted line of macroeconometric model building as a response to the challenge presented in Valadkhani [2004] that called for the use of recent developments in macroeconomic theory in the modeling process.

The core block of the current version is based on a general equilibrium macro-model with monopolistic competition due to Blanchard and Kiyotaki [1989] that allows the derivation of the domestic price level (per capita gross domestic product [PGDP]) and aggregate output (gross domestic product [GDP]). The real and monetary/external sectors of the model are linked through an open economy IS-LM aggregate demand framework, which embeds the portfolio balance approach to exchange rate determination; the model assumes a fully flexible exchange rate regime. Figure 1 shows the structure of the model diagrammatically and how the GE and IS-LM frameworks intersect. The model

[1]The unit root literature is also evolving and, recently, a unit root test against the alternative of nonlinear mean reversion has been developed by Kapetanios, Shin, and Snell [2003], which can potentially reverse results of previous papers.

is constructed to distinguish between domestic inflation, computed as the PGDP percent change and CPI percent change. The latter is derived econometrically as the weighted average of domestic inflation and imported goods inflation. Expected inflation is assumed to be a weighted average of forward-looking and backward-looking expectations of individuals. The next subsections, lifted from the technical appendix of the QMM final report, discuss the theoretical basis of the model in detail.

2.1. General equilibrium with monopolistic competition

2.1.1. Aggregate good production (GDP) and sectoral demands

Recent analysis of the macroeconomy (see Blanchard and Fischer [1989]; Romer [2000]; Walsh [1998]) makes use of a constant elasticity of substitution (CES) aggregation technology, much like the one used in applied general equilibrium analysis. Here, GDP can be thought of as the aggregate good, q, produced under perfect competition and is assumed to be a CES aggregation of individual goods in the economy. Assume n goods in the economy and let $q_i, i = 1,\ldots,n,$ be the ith good. Hence,

$$q\left(\sum_{i=1}^{n}\phi_i^{1/\theta}q_i^{\theta-1/\theta}\right)^{\theta/\theta-1} \tag{1}$$

$\theta > 1$ is the Dixit–Stiglitz substitution elasticity and the $\phi_i s$ are the distribution parameters.

Using (1) in the profit equation, one gets:

$$\pi = p\left(\sum_{i=1}^{n}\phi_i^{1/\theta}q_i^{\theta-1/\theta}\right)^{\theta/\theta-1} - \sum_{i=1}^{n}p_i q_i. \tag{2}$$

Profit maximization under perfect competition yields "input demand" functions for the n goods of the economy:

$$q_i = \left(\frac{p_i}{p}\right)^{-\theta}\phi_i q \quad ; \qquad i = 1,\ldots,n. \tag{3}$$

Figure 1. Structure of the model

	REAL SECTOR	
General equilibrium	Three markets: agriculture, industry, and services.	$p_a,\ p_i,\ p_s$
	Sectoral equilibrium yields prices and quantities.	$q_a,\ q_i,\ q_s$
	General equilibrium allows for the computation of aggregate domestic price level (PGDP) and aggregate output (GDP).	$p = \phi_a p_a + \phi_i p_i + \phi_s p_s$ $q = q_a + q_i + q_s$
Aggregate demand (extended IS-LM)	Four aggregate markets: goods, money, foreign asset, and domestic asset	
IS (goods market)	Demand by domestic residents and foreign demand (which is equal to total available supply in the economy; domestic production plus imports: q + z) is assumed to be used by producers in determining how much to produce.	$(c+i+g)+x$
	Behavioral equations are specified for each demand component.	
	MONETARY/ EXTERNAL SECTOR	
LM (money market)	Equality between money demand and money supply yields the equilibrium real interest rate.	$r = r(\cdot) + \pi$
FX (foreign asset market)	Equality between foreign exchange demand and supply yields the equilibrium exchange rate.	$e = e(\cdot)$
BOP accounts	Identities and bridge equations link the capital account to the money supply process and import and export demands to the real sector.	$z = z(\cdot)$ $x = x(\cdot)$

Figure 1. Structure of the model (continued)

	OTHER SECTORS	
Fiscal accounts	Identities showing details of revenue and expenditure items that enter the real and monetary blocks above.	
Labor sector	Contains aggregated labor supply and demand functions that determined the unemployment rate.	
CPI inflation	CPI is computed as the weighted average of the domestic price index and the import price index.	$cpi = f\left(p, p^{*}\right)$
Expected inflation	This is modeled as a weighted average of expectations of forward-looking and backward-looking individuals.	$\pi^{e} = \eta\pi^{mc} + (1-\eta)\pi_{-1}$ $p-1$

In the literature, equation (3) is interpreted as the demand function faced by the *ith* firm that operates under monopolistically competitive conditions. In setting production levels, the firm anticipates the level of aggregate demand q. Under rational expectations, the anticipated levels correspond to actual values. Thus, given the sectoral price level, the firm can determine the demand it faces on the price-output plane, depending on the level of aggregate demand. Note that this provides a rigorous justification to the Keynesian notion that output produced in the short run is determined by aggregate demand. Taking the logarithm of both sides of (3), an equation that can be estimated by ordinary least squares (OLS) is obtained.

2.1.2. Sectoral production under monopolistic competition

It is assumed that individual goods in the economy $(q_1,\ldots,q_n)$ are produced under monopolistically competitive conditions and the profit of the typical firm in the *ith* sector is:

$$\pi_i = p_i q_i - \left(p c_i \frac{q_i^{1+k}}{1+k} \right) \quad ; \quad i = 1,\ldots,n, \tag{4}$$

where $k > 0$ implies decreasing returns and $1/(1+k)$ is the returns to scale of production; $c_i = c_i\left(w/p, ep^*/p\right)$ is the (minimized) real unit cost function, which shows that output i is produced using labor and an imported input. The profit-maximizing condition is $MR = MC$, hence, from (4):

$$p_i + q_i \frac{\partial p_i}{\partial q_i} = p c_i q_i^k \quad ; \quad i = 1,\ldots,n. \tag{5}$$

Using (3) in (5), the price that is set as a markup over marginal cost is obtained:

$$\frac{p_i}{p} = \mu c_i \left(\frac{w}{p}, \frac{ep^*}{p} \right) q_i^k \quad ; \quad i = 1,\ldots,n, \tag{6}$$

where $\mu = \theta/(\theta-1)$ is the markup over marginal cost. Equation (6) is a set of n sectoral supply functions. Log differentiating (6), one obtains an equation that can be estimated using OLS:

$$p_i = \mu + k q_i + \delta_1 w + \delta_2 \left(e + p^*\right) + \left(1 - \delta_1 - \delta_2\right) p, \tag{7}$$

where the δs are the marginal cost elasticities and a variable υ's percent change is $\upsilon = d\upsilon/\upsilon$. It is clear from (7) that $k = 0$ implies constant returns to scale,

$k > 0$ means decreasing returns to scale and an upward sloping sectoral supply function is derived; $k < 0$ shows increasing returns and a negative price-output relation.

2.1.3. The GDP deflator

To arrive at a generalized expression for the GDP deflator consistent with this general equilibrium framework, substitute (3) in (2). In long-run equilibrium, the zero profit condition holds. Hence, setting the profit equation to zero after the substitution and rearranging yields:

$$p = \left(\sum_{i=1}^{n} \phi_i p_i^{1-\theta} \right)^{1/_{1-\theta}} \tag{8}$$

Note that a value of zero for θ (Leontif technology) leads to a GDP deflator that is computed in the usual fashion: a weighted average of sectoral prices.

2.2. The optimizing CPI

The CPI is normally constructed as a weighted average of consumer prices of food, clothing, energy products, etc. Each of these goods, say, food, is in turn an aggregation of imported goods (like Toblerone) and goods produced domestically using domestic and imported inputs (like bread produced using imported wheat flour and local sugar, salt, yeast, etc.). A detailed breakdown of consumer prices in this manner is difficult to incorporate in a model of this size as it requires a different data set. Instead information that is already available in the model is used to approximate the CPI. In the model, the weighted average of the domestic price index (the GDP deflator) and the price index for imported goods is used to approximate the CPI. The weights used are estimated econometrically. The model below provides a foundation.

Assume a representative consumer, who is also the producer, is able to differentiate a domestic composite good, q, from an imported good, z. The latter is the final consumption goods imports while the former is the good produced domestically using domestic and imported inputs.[2] Hence, the problem is to maximize:

$$u = \left[\alpha^{1/_\theta} q^{\theta - 1/_\theta} + (1-\alpha)^{1/_\theta} z^{\theta - 1/_\theta} \right]^{\theta/_{\theta-1}} \tag{9}$$

subject to

$$\Upsilon = pq + p_z z \tag{10}$$

[2]This model due to Obstfeld and Rogoff [1996] is highly simplified. In practice, only a part of q is privately consumed while the rest are used for investment and public consumption. For those interested, a richer model that relaxes some of the assumptions can be found in Obstfeld and Rogoff [1996], chapter 10.

where Υ is the nominal value of total goods available in the economy and $p_z = ep_z^*$. The first-order conditions yield the import demand function:

$$z = \frac{p_z^{-\theta}(1-\alpha)\Upsilon}{\alpha p^{1-\theta} + (1-\alpha)p_z^{1-\theta}}, \qquad (11)$$
$$= \left(\frac{p_z}{p_y}\right)^{-\theta} \frac{(1-\alpha)\Upsilon}{p_y}$$

where p_y is the consumption–based price index,

$$p_y = \left[\alpha p^{1-\theta} + (1-\alpha)p_z^{1-\theta}\right]^{1/1-\theta} \qquad (12)$$
$$= \left[\sigma\phi_1 p_1^{1-\theta} + \ldots + \alpha\phi_n p_n^{1-\theta} + (1-\alpha)\left(ep_z^*\right)^{1-\theta}\right]^{1/1-\theta}$$

It is the minimum expenditure $\Upsilon = pq + p_z z$ such that $u = u(q,z) = 1$, given p and p_z.[3] The second equality in (12) makes use of (8) and the fact that $p_z ep_z^*$. Note as in the previous subsections that as the Dixit-Stiglitz elasticity $\theta \to 1$, the Cobb-Douglas utility function is obtained; $\theta \to 0$ yields a Leontif utility function and $\theta \to \infty$ shows a linear utility function.

Import demand equation (11) is estimated using OLS. The CPI is estimated econometrically with the GDP deflator and the import price index as the explanatory variable. The former is a weighted average of sectoral prices, which are themselves estimated using the specification shown in equation (7).

2.3. *Aggregate demand (The extended IS-LM framework)*

2.3.1. Goods market

The aggregate demand (AD) is derived by specifying behavioral equations for AD components: private consumption, investment demand, government consumption, and exports and imports (specified in equation 11 above).

$$c = c\left(r - \pi^e, q - \frac{T_y}{p}, \frac{m}{p}, b_t\right). \qquad (13)$$

$$i = i\left(r - \pi^e, q\right). \qquad (14)$$

[3]To derive p_y, substitute the optimal z and q in (10), set $u = 1$ and let $Y = p_y$. An expression for q can similarly be derived from the first-order conditions. Alternative derivations can be found in Walsh [1998].

$$g = g\left(q, \frac{T}{p}, rev, \upsilon_g\right). \tag{15}$$

$$x = x\left(q^*, \frac{p_x/e}{p^*}\right). \tag{16}$$

The AD components (equations [13] to [17]) may be disaggregated further. In the implementation, investment demand is broken down into public and private construction, durable equipment, orchard and breeding, and change in stocks. Substituting (13) to (16) and (11) in the national income accounting identity, $q = c + i + g + x - z$, should yield the IS equation.

2.3.2. Monetary and external sector

The monetary sector consists mainly of the Bangko Sentral ng Pilipinas (BSP) and BOP accounts. Equation (17) is the BSP balance sheet while (18) shows the relation between money supply and reserve money through the money multiplier. The latter is a function of the currency deposit ratio and the reserve deposit ratio.

$$h = e \cdot nfa + nda \tag{17}$$

$$m = \mu \cdot h \tag{18}$$

where $\mu = 1 + cc/cc + rr$, $cc = cu/d = fc(\cdot)/fd(\cdot)$ and rr is the reserve-deposit ratio that is assumed to be exogenous.

The *nfa* component of reserve money in US dollars is assumed to be a function of the available foreign exchange supply, F, and the *BOP* in US dollars:

$$nfa = f_F\left(BOP, F\right). \tag{19}$$

Alternatively, *nfa* can be directly linked to the *BOP* accounts but with an adjustment variable:

$$nfa = KA + adj,$$

where *KA* is the capital account component of the *BOP*. At present, the *nda* is assumed to be fully exogenous. Alternatively, it can be assumed that it is affected by the BSP's open market operations and the change in the government's cash balances with the BSP; this is an area that needs to be explored further.

Equations (20) and (21) below are equilibrium asset price equations derived from the portfolio approach to exchange rate determination (see Herin, Lindbeck, and Myhrman [1976]) for early papers on this approach). The former is an open economy LM curve that represents money market equilibrium. The latter determines the nominal exchange rate that clears the foreign exchange market.

$$r = f_r\left(\frac{m}{p}, q, e, p^e, rp, D_g\right). \tag{20}$$

$$e = f_e(F, q, r) \qquad \text{or} \qquad e = f_e(F, q, r) \cdot e_{-1}. \tag{21}$$

LM equation (20) includes two policy variables: the reverse repurchase rate and the volume of treasury bills issued by the national government. Equation (21) states that the nominal exchange rate depends positively on output and negatively on available foreign exchange and the nominal short–term interest rate.

The balance of payments identity in foreign currency is given by:

$$BOP = KA + Z_x \tag{22}$$

where $Z_x = x_x - z_x$ is the current account balance in foreign currency terms. The capital account equation shows that the net foreign flow is used to finance the current account deficit or the fiscal deficit:

$$KA = f_k(Z_x, B_g). \tag{23}$$

The import and export demand equations in real terms are specified as follows:

$$\frac{ez_x}{p_z} = z_x\left(\frac{p_z}{p_y}, \frac{Y}{p_y}\right). \tag{24A}$$

$$\frac{x_x}{p^*} = x_x\left(\frac{p_x^*}{p^*}, q^*\right) \tag{24B}$$

where $p_x^* = p_x / e$ is the export price in foreign currency terms, p_x is the domestic currency price of exports, and p^* is the foreign GDP deflator. Equations (24a) and (24b) are equivalent to demand equations (7) and (12), respectively. In the empirical implementation, the former set of equations are estimated instead of the latter, and bridge equations are just used to link the national accounts with the BOP accounts:

$$z = f_z\left(\frac{ez_x}{p_z}\right) \quad ; \quad x = f_x\left(\frac{ex_x}{p_x}\right). \tag{25}$$

These equations in (25) are equivalent to (11) and (16).

The fiscal sector shows the government budget accounts and how the deficit is financed. The financing is, of course, inextricably linked to the monetary subsector through its effects on the interest rates and the money supply process.

2.3.3. Inflation expectations formation and other indices

Following IMF's MULTIMOD Mark III, the expectations mechanism is a weighted average of the expectations formed by forward-looking and backward-looking individuals. The former is endowed with rational expectations while the latter forms expectations adaptively.

$$\pi^e = \eta\pi^{mc} + (-\eta)\pi_{-1} \tag{26}$$

π^{mc} is the "model consistent" inflation that can be proxied by the difference between the long-run domestic interest rate and a measure of world equilibrium interest rate (see Laxton et al. [1998]). In the empirical implementation, the one-period-ahead actual inflation proxies for expected inflation, $\pi^e = E_t\pi_{t+1}$. The fitted value of a regression of the form $\pi_t = f(lr_t - libor180, \pi_{t-2})$ is then the expected inflation series that is used by the model.

A monetary conditions index (MCI) and an exchange market pressure index (EMPI) are computed by the model but do not enter into any of the right-hand side of the equations. It must be noted that the MCI has its own drawbacks and must be interpreted with caution (see Batini and Turnbull [2002] a discussion). In the model, the MCI of JP Morgan, where the long-run exports to GDP ratio is used as the weight in the foreign exchange rate component, is modified. The model computes MCI as:

$$\begin{aligned} mci = 1 &+ \left(\log(1/fxr) - (-3.30505352111)\right)^* @movav(totx/gdpd, 12) \\ &+ (tbr91/100 - 0.2676)^* \left(1 - @movav(totx/gdpd, 12)\right). \end{aligned} \tag{27}$$

In the model, the weights are time varying and is a 12-quarter moving average of the exports to GDP ratio.

The EMPI is the sum of the depreciation rate and that component of base money growth attributable to movements in its foreign component (reserve outflows). It is computed in the model as follows:

$$empi = fxr\big/ fxr(4) - 1 - d\left(fxr^{*}bnfax, 0, 4\big/ rm(-4)\right). \tag{28}$$

A good reference on EMPIs is Tanner [2001]. Simulation results for these indices are shown graphically in the last row of Figure 2.

3. Estimation

The QMM model equations were estimated using the OLS. Attempts to correct for varying degrees of serial correlation were made. Hence almost all regressions were performed with autoregressive-moving average (ARMA) disturbances. The estimates were carefully examined to make sure that all coefficients are correctly signed and were based on the theoretical structure presented in the previous section. The present QMM model has a total of 186 variables, of which 104 are endogenous and 82 are exogenous. It has 48 behavioral equations estimated using OLS and 56 identities. Some identities that do not enter the right-hand side of the equations are not included in the count above since they are computed only to generate additional results from the information generated by the model. The period of estimation is from 1981:1 to 2002:4. The EVIEWS 4.1 econometric package is used in the simulation and forecasting exercises presented in the succeeding sections. The OLS estimates are not included in this paper to conserve space. The reader interested in the 104 equation estimates is referred to the final report.

4. Historical simulation results

The simulation period is from 1989:1 to 2002:4. To gauge the simulation performance of the QMM model, the root mean square error (RMSE) and the root mean square percent error (RMSPE) are examined for selected endogenous variables of interest. The root mean square and root mean square percent errors are computed as follows:

$$RMSE = \sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(x_t^{\alpha} - x_t^{s}\right)^2} \quad RMSPE = 100 \cdot \sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(\frac{x_t^{\alpha} - x_t^{s}}{x_t^{\alpha}}\right)^2}$$

Table 1. Simulation statistics

	RMSE	RMSPE		RMSE	RMSPE
MM	0.2	5	DL_FXR	8.8	*
LF	0.4	1.4	CPI85	*	8.8
ISEMP	0.9	6.5	PVAR	*	*
GDPGR	1.9	*	PVSR	*	9.9
FXR	2.1	6	VAR	*	4.4
XINFL	3	*	PCE	*	1.4
INFL	3.1	*	VIR	*	5.7
UR	3.4	*	VSR	*	5.7
PGDPGR	3.9	*	TOTX	*	7.3
TBR91	4.3	*	TOTM	*	7.4
PVIR	8.6	3.6	GDP	*	4.5

* Greater than 10 percent.

For the central variables of the model, the simulation statistics shown in Table 1 seem reasonable, and the model tracks the historical values quite reasonably. The simulation results can be seen graphically in Figure 2.

5. Policy simulation results

Increases in the minimum wage rate, tariff rate, and the crude oil price have stagflationary effects: declining output and inflation. One can imagine a shifting of an upward sloping AS curve to the left for a given position of the AD curve. An increase in any of the following are expansionary as growth and inflation occur: LIBOR90, capital outlays, private construction, government consumption, reserve money or foreign exchange rate. A 100-basis-point increase in the treasury bills rate or in BSP policy rates (RRP) leads to a recession as output and price levels decline. The results for all experiments show that their effects on the price level and output conform to predictions of economic theory. These results are shown in Figure 3.

The QMM model is clearly a work in progress, as regular updates are required to maintain the model. There are, however, two aspects of the model that need to be improved upon. The link between the monetary sector and the BOP/Fiscal sectors has been improved from the previous version but remains rudimentary. While reasonable estimates of linking equations were obtained, the model failed to converge in the simulation exercises. Hence the number of links was severely trimmed down to manageable levels.

Another area of improvement is in expectations formation. The present expectations framework is sufficiently simple but may still be modified. A deterministic exercise on computing for model-consistent expectations can easily be done as one simply writes out the expectation terms using lead operators in the program. Introducing uncertainty, however, makes the problem more complex. Here, one will have to deal with the entire distribution of the stochastic outcomes forecasted by the model.[4] This requires stochastic simulations with future values of endogenous variables, which are not allowed in Eviews, the software used by the model. This is a technical limitation that can be solved either by migrating the model to another software or waiting for the facility to be made available in a future version of the software.

[4] In the present model, model-consistent expectations are assumed rather than computed.

Figure 2. Historical simulation results

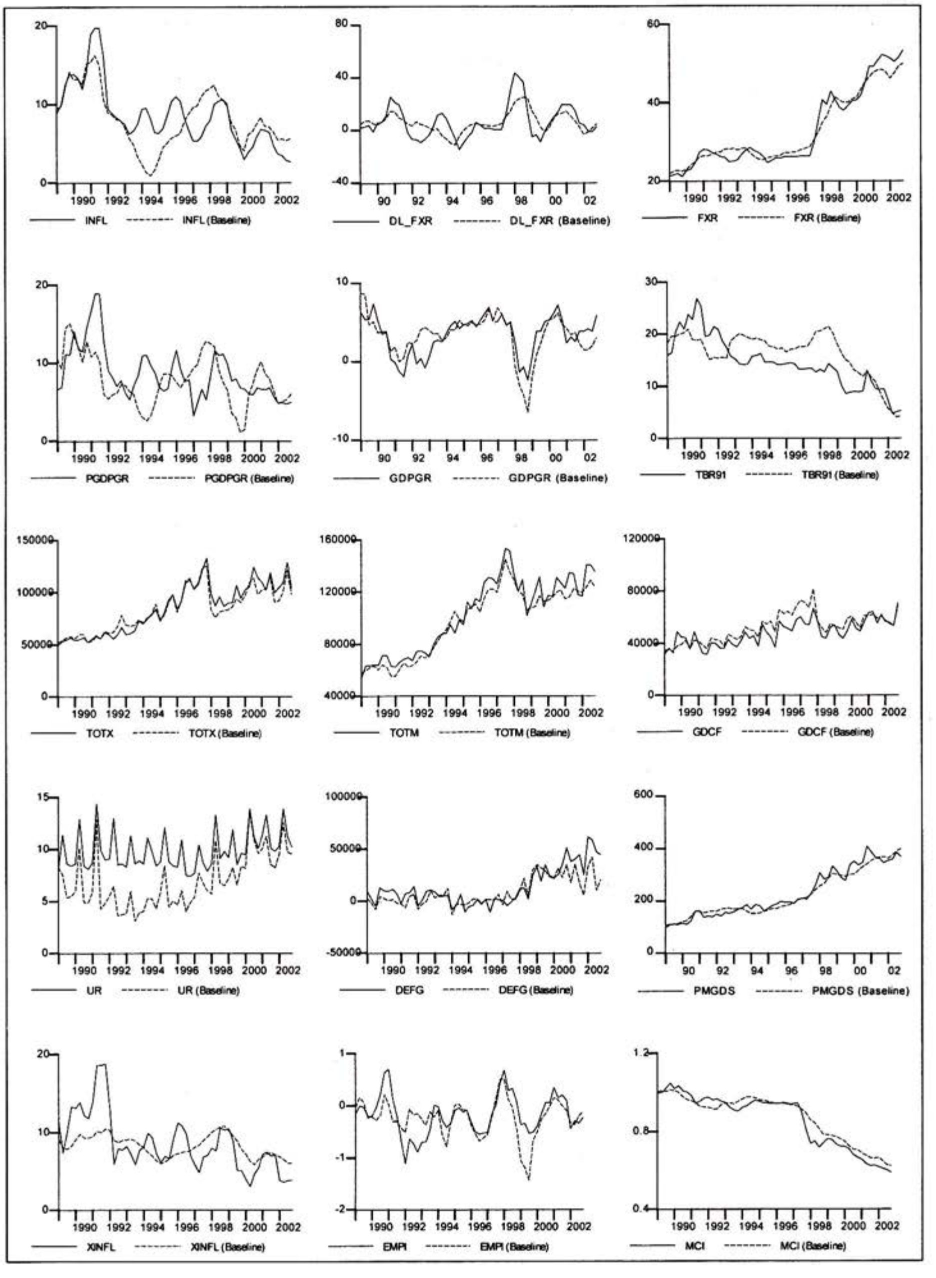
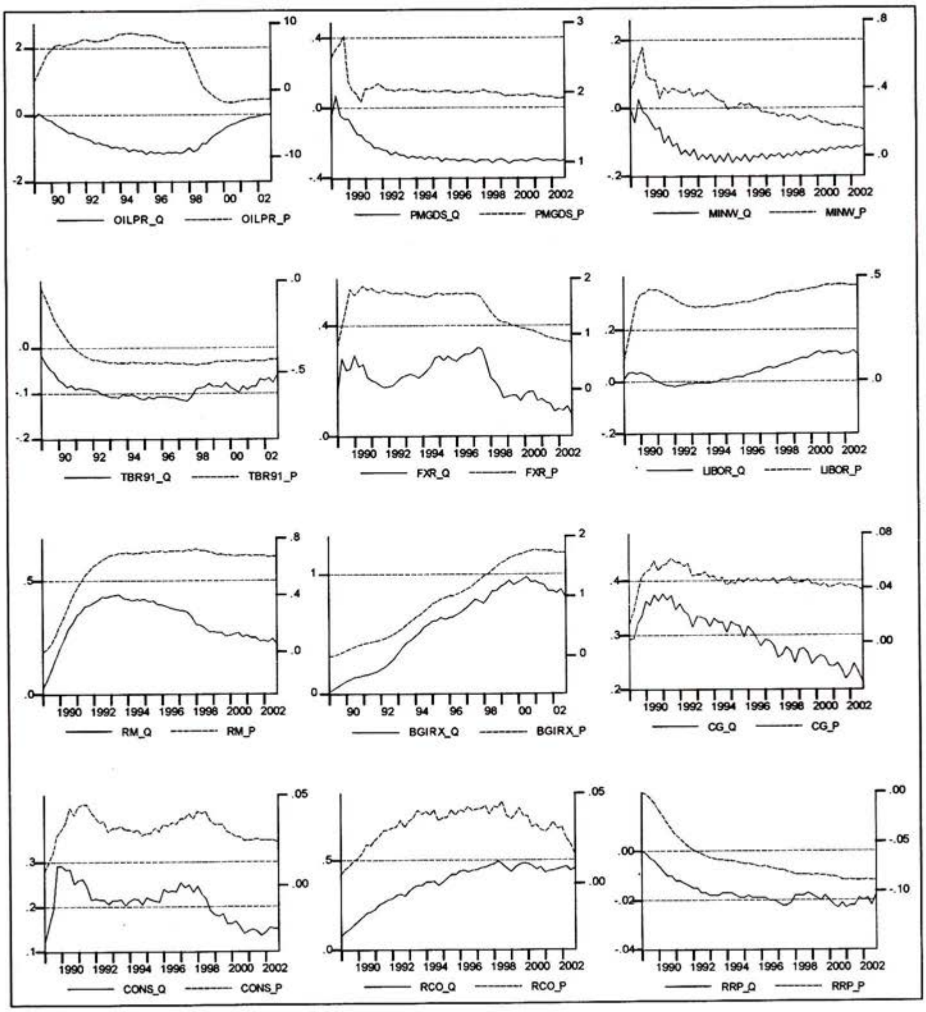


Figure 3. Policy/exogenous shock simulation effects on CPI and GDP (percent change from base value)



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