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Determinants of Inflation, Exchange Rate, and Output in Nigeria

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Abstract

This paper presents a macroeconomic model of the Nigerian economy. The long-run relationships pertaining to the markets for money, foreign exchange, and (non-oil) output are estimated. Subsequently, dynamic equations are estimated for the price level, the real exchange rate, and output. The results are instrumental in explaining the dramatic developments on the foreign exchange market during 1983-86 and 1992-94, the secular depreciation of the real exchange rate since 1985, and the rise and fall of inflation during 1991-97. The methodology could usefully be applied to other economies whose exports are insensitive to exchange rate movements (e.g., other oil-based economies).

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SUMMARY

The key macroeconomic variables for Nigeria are modeled and estimated using co-integration techniques to assess past developments, analyze the response to external shocks, and conduct policy simulations. A theoretical framework is set up by applying the small open economy model to the Nigerian case. The long-term equilibria, or equilibrium correction mechanisms (ECMs), in the markets for money, foreign exchange, and output are estimated using co-integration techniques. The price level is determined by monetary policy, with an excess of money supply over (modeled) money demand driving price rises. The impact of import prices on domestic prices is shown not to be significant. The equilibrium real exchange rate is determined on the balance of payments, taking into account foreign exchange restrictions. Non-oil output is determined by the supply of production factors, the intensity of distortions, and (exogenous) technological progress. Subsequently, using the ECMs, dynamic equations are estimated for the price level, the (real) exchange rate, and output to assess how the economy responds to disequilibria in different markets.

The resulting relationships, which are in line with classical assertions as to the dichotomy between the real and nominal sphere, provide a framework for analyzing some recent major macroeconomic developments. As regards money and prices, the rise (1991-95) and fall (1996-97) of inflation are explained by the stance of monetary policy. Co-integration analysis of the balance of payments block sheds light on the dramatic developments on the foreign exchange market in 1983-86 and 1992-94, as well as the subsequent liberalization of the foreign exchange market and the secular depreciation of the real exchange rate since 1985. The estimated production function (for non-oil output) is used to assess the contributions of factors of production to economic growth over recent decades.

I. INTRODUCTION

This paper presents a macroeconomic model of the Nigerian economy that analyzes the behavior and determinants of three variables important to policy makers: inflation (the price level), the exchange rate, and (non-oil) output. These variables are viewed as clearing the markets for, respectively, money, foreign exchange, and goods.

Models of the determinants of inflation in developing countries usually postulate a money demand function and then specify how expansionary monetary policy (with money supply exceeding money demand) leads to price rises. Models of long-run equilibrium real exchange rates (LRERs) for developing countries have used a variety of potential fundamentals, as in these countries the real processes that can cause large medium- and long-run changes in the real exchange rate (i.e., deviations from purchasing power parity) can differ. The theoretical framework is based on models of small, open economies, such as Edwards (1994), where the LRER is derived from the balance of payments. Agénor (1990) suggests how to adapt the framework to an economy with exchange controls. Traditionally, LRERs for developing countries have been estimated without the use of time-series techniques; instead, a reduced-form equation for the exchange rate stemming from a macroeconomic model has been used (see, for instance, Edwards (1989 and 1994)). Recently, researchers have begun to use co-integration techniques [1] in research on LRERs for developing countries. Elbadawi and Soto (1995) use co-integration techniques to estimate models of the LRER in which the fundamentals include the terms of trade, capital inflows, and export growth, while Loayza and Lopez (1997) use as fundamentals international indebtedness and sectoral productivity measures. Owing to the lack of consistent time series, applications to sub-Saharan African economies (other than South Africa) have been scarce. Toujas (1997) applies the co-integration methodology to the price level and the real exchange rate in Madagascar.

For Nigeria, several quantitative studies into money demand have been carried out (see Teriba (1997) for an overview). Moser (1997a and 1997b) has estimated both money demand and inflation (with money and import prices as the determinants), using the single-equation co-integration technique. When the single-equation technique is used, it is assumed that there is (at most) one long-run relationship among a set of variables. In a vector autoregression (VAR) analysis, the number of long-run relationships in a set of variables is determined empirically. One of the novelties of this paper is the application of the VAR technique for Nigeria. It also appears to be the first empirical investigation into the LRER for Nigeria. The

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[1] Co-integration techniques are particularly useful in estimating long-run relationships, such as the equilibrium real exchange rate, money demand, and potential output. Once a set of long-run equilibrium relationships has been identified empirically, a dynamic model can be estimated, with dynamic equations indicating how the endogenous variables respond to the various disequilibria, or equilibrium correction mechanisms (ECMs). The appeal of the co-integration methodology is that economic theory has a large role to play in explaining the long-run relationships, while short-run behavior is taken to be mainly an empirical matter.

modeling of the price level here, with the difference between money supply and money demand acting as the main driving force, or equilibrium correction mechanism (ECM), is similar to that in Toujas's (1997) work on Madagascar. The economic model for the real exchange rate is different, owing to two particular characteristics of the Nigerian economy: foreign exchange controls (a complication) and oil as the dominant export product (a simplification). In addition, output is here both endogenized and allowed to deviate from potential output. The output gap then forms an additional ECM that (potentially) has an impact on the price level and the real exchange rate. The use of the VAR technique to estimate a model in which the three key macroeconomic variables are endogenized distinguishes this study from earlier macroeconometric work on Nigeria. Although the broad framework for the monetary and the balance of payments sector follows the standard small, open economy approach, the modeling of exchange controls and exogenization of export volumes distinguishes this study from earlier work on other countries.

The results of this study are particularly relevant for policy debates in Nigeria, owing in part to the key feature of the VAR approach used: the dynamic model is derived starting from a very general model structure, with empirical tests determining which theoretical relationships and market-clearing channels are validated empirically. In this way, an attempt is made to answer the important policy questions long debated in Nigeria. Is inflation mainly imported (via higher import prices and exchange rate movements), or predominantly a function of monetary policy? To what extent is the impact of the monetary stance on inflation subject to lags? What is the impact of a fall in oil revenues on the equilibrium exchange rate? How do exchange controls affect the economy? Is output affected by the stance of monetary policy in the short and/or long run? What have been the sources of economic growth?

Long-run equilibrium in the model is characterized by three equilibrium conditions. First, in the long run, the price level is modeled to be determined by monetary policy and import prices.[2] Second, the equilibrium real exchange rate is modeled to be determined by the balance of payments. The supply of foreign exchange to the private sector arises from export revenues, net of public sector imports, debt servicing, and new external borrowing. The supply of foreign exchange, together with the private sector's demand for foreign exchange and the extent of foreign exchange rationing, determines the equilibrium real exchange rate. Import prices in foreign currency are exogenous. The nominal exchange rate is then determined once the price level and the real exchange rate have been determined. Third, potential non-oil GDP is determined by labor supply, the capital stock, a measure of human capital, the degree of distortions, and (residual) technological progress. The three long-run equilibrium conditions, or ECMs, are estimated using the VAR technique. Shocks, external or policy induced, are the cause of temporary disequilibria in any or several of the markets. The manner in which equilibrium in the economy is restored is evaluated by estimating dynamic equations for the price level, the real exchange rate, and output. These dynamic equations quantify how each of the three variables responds to shocks affecting each of the three

[2] The model allows for a long-run effect of import prices on domestic prices. However, this effect is shown empirically not to be significant.

markets, using the information contained in the three ECMs derived from the co-integration analysis, as well as the dynamic explanatory variables.

II. Recent Economic Performance

In the 1970s, following the increases in the world price of oil and with oil production expanding, Nigeria seemed to be on track to prosperity. Oil revenues allowed for large investment programs, and rapidly rising government expenditures led to increasing purchasing power for significant numbers of people. In 1980, with oil export revenues at US$26 billion and a per capita GDP of US$1,480, Nigeria was considered a middle-income country and had easy access to international capital markets. However, in the course of the 1980s, economic weaknesses became apparent. The fall in oil production in 1981 (owing to OPEC quota changes) and the subsequent oil price decrease made it clear how dependent the economy and the government budget had become on oil revenue. Initially, the government sustained its expenditures by increased foreign borrowing, rapidly building up foreign debt (in addition to the buildup of debt by the private sector through trade arrears). However, soon after the 1982 international debt crisis, Nigeria was cut off from the international capital market. The secular decline in oil revenues since the early 1980s has been problematic for Nigeria, in particular during an era of strong population growth. However, government policy has aggravated the unfavorable environment. In the face of falling oil revenues, the government maintained an overvalued exchange rate while resorting to distortionary foreign exchange controls which drove up the parallel market premium to over 100 percent at times and damaged domestic industry and agriculture. Other price and interest rate controls, mandatory credit allocation schemes, and commodity boards further distorted the economy. In the 1970s, Nigeria was a significant exporter of agricultural products. However, by the mid-1990s, agricultural exports had been virtually "crowded out".

Nonpayment of external obligations led to a rapid accumulation of arrears and deteriorating relations with foreign creditors. Several episodes of highly expansionary monetary policy (1987-88 and 1990-94) associated with the monetary financing of budget deficits fueled high inflation. Throughout the 1980s and 1990s, much of public sector investment (which accounted for two-thirds of total investment during the period 1973-90) was directed to wasteful projects, resulting in low returns on investment and meager productivity growth. The implementation of market reforms, a sizable devaluation, and tight fiscal and monetary policies (initially, at least) under a structural adjustment program (SAP) in 1986-90 boosted economic growth. However, the SAP was unpopular, in particular with the vocal urban middle class. For instance, high inflation in 1988 and 1989 was blamed on the sharp devaluation of the naira, instead of on the relaxation of monetary policy in 1987-88. The SAP was subsequently weakened, diluted, and in some cases even reversed. In the early 1990s, with oil export prices (and, hence, government revenues) declining, strong monetary financing of fiscal deficits drove up inflation, which reached 57 percent in 1994. An appreciating real exchange rate and the reimposition of controls on foreign exchange, prices, and interest rates substantially reduced economic growth in the early 1990s.

Since 1995 the macroeconomic environment has improved. Inflation has come down—to about 10 percent in 1997—owing to a tightening of fiscal and monetary policies, and foreign exchange has become available to the private sector at the autonomous foreign exchange market (AFEM), where the exchange rate is allowed to move up or down according to market pressure. After a large devaluation in 1995, the AFEM exchange rate has been broadly stable. Currently, the main constraints on economic growth are fuel shortages, unreliable utilities, and political and economic uncertainty. A resumption of private sector confidence and economic growth is conditional on the removal of these constraints.

III. Theoretical Framework

In this section a theoretical framework will be provided for the long-run equilibria (ECMs) in the markets for money, foreign exchange, and output. The section concludes by indicating how these ECMs are included in the dynamic model.

The economy produces two goods: exportables and nontradables. Exportables (oil) are produced via a highly capital-intensive production process without domestic labor. All labor is employed in the nontradables (non-oil) sector. Identifying the oil sector as the export sector [3] simplifies the analysis a great deal. Both the volume and price of exports can then be treated as exogenous. The only impact of the export sector on the non-oil economy is in the form of foreign exchange revenues flowing to the government and, in part, to the private non-oil sector. The government allocates the net proceeds of oil revenues (after debt service and reserve accumulation) to imports. A substantial part is used for public sector imports (a policy variable). The residual amount is made available to the private sector. Non-oil private sector expenditure (in real terms), D, is spent on domestically produced goods, Y, and non-oil private sector imports, MPR ($D = Y + MPR$).

A. Money and Prices

There is only one asset in this economy: money. Prices are principally determined by monetary policy, as an excess of money supply over money demand leads to excess demand for goods and a rise in the price level. Money supply is assumed to be an exogenous policy instrument, while money demand can be expressed as a function of domestic demand, prices, and opportunity costs. Import prices are also assumed to have an impact on domestic prices. The money-price block then takes the following form:

$$M^d = \mathrm{f}\ (P, D, INF, RDIFF), \tag{1}$$

$$ECMp = M - M^d, \tag{2}$$

$$P = \mathrm{f}(M\text{-}M^d,\ PIM), \tag{3}$$

[3] This is justified on the grounds that oil provides 95 percent of export revenues.

where P is the price level (the non-oil GDP deflator), *INF* denotes the rate of inflation (year-on-year change in the non-oil GDP deflator), *RDIFF* is the differential between the Nigerian three-month deposit rate and the U.S. federal funds rate, *ECMp* is the ECM of the money-price block, and *PIM* is the (domestic currency) price of imports.

B. Balance of Payments and the Real Exchange Rate

The balance of payments identity can be written, in simplified form, as

$$X\$ - (MGPR\$ + MGPU\$) + NFB \equiv dR\,, \tag{4}$$

where *X$* represents exogenous export revenues, *MGPR$* denotes private sector imports of goods, *MGPU$* is public sector imports of goods, *dR* represents the net accumulation of reserves, and *NFB* represents net foreign borrowing, as defined by the equation (all in U.S. dollars). Net foreign borrowing thus includes items that are either exogenous to the model or policy instruments: oil sector imports, imports of services (predominantly factor services in Nigeria),[4] debt-service payments, accumulation of arrears, official borrowing, and private capital flows.[5] The net accumulation of reserves is also assumed to be a policy instrument. Using equation (4), the exogenous real supply of foreign exchange to the private sector (FX^s) can be written as follows:

$$FX^s = (X\$ - MGPU\$ + NFB - dR)/P\$\,, \tag{5}$$

where *P$* is the price of imports in U.S. dollars. Real private sector demand for foreign exchange (FX^d) arises from the demand for imports:

$$FX^d = f(D, RER, (M - M^d))\,, \tag{6}$$

where *RER* is the real exchange rate (the price of imports relative to the price of domestically produced goods) [6] and ($M - M^d$) denotes excess money supply. During the period of analysis (1983-96), the Nigerian authorities made, to varying degrees, extensive use of foreign

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[4] It would have been preferable to base the analysis for Nigeria on total imports, including nonfactor services, of the private sector, but data limitations necessitated the use of imports of goods. There are no source data available for nonfactor services; IMF staff estimates are made using a constant share of imports of goods. According to those estimates, nonfactor services are a small part of total private sector imports.

[5] Private capital flows in Nigeria are small enough, in relation to other balance of payments transactions, to be taken as exogenous.

[6] Nigeria's relative exchange rate is defined as $RER = P\$ * E * (1+T/100) / P$, with *P$* the price of imported goods (in U.S. dollars), E the formal exchange rate (naira per U.S. dollar), T the average import tariff, and P the domestic price level (non-oil GDP deflator).

exchange rationing and import controls. As a consequence, the demand for foreign exchange at the prevailing formal exchange rate usually exceeded supply. For periods during which access to imports was restricted, the premium of the parallel exchange rate (*PAR*) over the formal exchange rate (*E*) measures the excess demand for foreign exchange (see Agénor (1990)).[7] Note that the degree of foreign exchange restrictions--and, hence, the parallel market premium--is a policy instrument. The equilibrium on the foreign exchange market is

$$fx^d = fx^s + c_3 * rho\,, \quad c_3 > 0\,, \tag{7}$$

where fx^d and fx^s are, respectively, real demand for, and supply of, foreign exchange of the non-oil private sector expressed in logarithms, *rho* is the logarithm of (*PAR/E*), with both exchange rates defined in terms of naira per U.S. dollar, and c_3 expresses the relation between excess import demand and the exchange rate premium. In long-run equilibrium, M^d is equal to M. Combining equations (6) and (7), the long-run equilibrium relation for the foreign exchange market can be written as

$$fx^s = c_1 * d - c_2 * rereq - c_3 * rho\,, \quad c_1\,, c_2\,, c_3 > 0\,, \tag{8}$$

with *d* and *rereq* the logarithms of, respectively, real demand and the equilibrium real exchange rate. For our purposes, it is convenient to rewrite equation (8) as follows:

$$rereq = a_1 * d - a_2 * fx^s - a_3 * rho, \quad a_1\,, a_2\,, a_3 > 0\,, \tag{9}$$

Given the supply of foreign exchange and the level of activity in the domestic economy, and depending on the value of the parallel market premium (i.e., the degree of overvaluation of the nominal formal exchange rate), the equilibrium real exchange rate adjusts so as to bring demand for foreign exchange in line with supply. The difference between the actual real exchange rate and its equilibrium value forms the second ECM:

$$ECMrer = rer - rereq\,. \tag{10}$$

[7] Since the first quarter of 1995, Nigeria's formal exchange rate has been allowed to adjust to market forces. Consequently, the premium has been reduced significantly, and it virtually disappeared during 1997.

C. Production Factors and Output

The supply of nontradables is assumed to be a function of labor, capital (physical and human), the degree of distortions, and (residual) technological progress, according to a Cobb-Douglas production function with constant returns to scale. The degree of distortions that reduces potential output is approximated by the parallel market premium (see, for instance, Barro and Sala-I-Martin (1995)).[8] The production function is written as

$$y^s = \alpha_1 * ls + \alpha_2 * k + \alpha_3 * h - \delta * rho + Techn\,, \tag{11}$$

where y^s denotes (potential) non-oil output, *ls* represents the labor supply, *k* stands for the capital stock, *h* is the "stock" of secondary school education, [9] and *Techn* is (residual) exogenous technological progress, with all variables written in lower case expressed in logarithms. The imposition of constant returns to scale implies that the three factor shares (α_1, α_2 , α_3) add to one. In long-term equilibrium, actual output (non-oil GDP) is assumed to grow in line with potential output. However, at any particular time, actual output can deviate from potential output, owing to exogenous shocks or changes in the fiscal and monetary policy stance. This relationship is expressed as

$$Y^d = f\,(Y^s\,, (M\text{-}M^d)\,, RER\,, FX^s)\,, \tag{12}$$

where Y^d is non-oil GDP. An increase in *RER*, that is, a real exchange rate depreciation, would lead to a rise in the share of domestic expenditure spent on domestically produced goods. The output gap, which is the ECM for the goods market used in the dynamic equations, is

$$ECMy = y^d - y^s. \tag{13}$$

With Equations (2), (10), and (13) defining the ECMs, the general form of the dynamic model can now be written as

$$dz = \mathbf{A} * ECM + \mathbf{B} * dx(\mathrm{l})\,, \tag{14}$$

where $dz' = [\,dp\,, drer\,, dy^d\,]$, $ECM' = [\,ECMp\,, ECMrer\,, ECMy\,]$. With 7 variables (P , RER , M , Y , INF , $RDIFF$, $and\, FX^s$)and two lags included for all dynamic terms, dx(l) is a (21 X 1) vector of dynamic terms of all variables, **A** is a (3 X 3) matrix of coefficients, and **B**

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[8] The parallel market premium is, over a long-enough time period, stationary. Although its inclusion does influence the estimated level for output capacity in specific periods, it does not alter the estimated long-run rate of technological progress.

[9] Human capital is approximated by applying the perpetual inventory method to a time series of the secondary school enrollment rate to construct the "stock" of secondary education (see Appendix).

is a (3 X 21) matrix of coefficients. The final dynamic equations reported in Section V resulted from the exclusion of empirically insignificant channels.

IV. Co-integration Analysis

This model was estimated on quarterly data for 1983-96. The sources of the data, the estimation period, and the results of unit root tests are discussed in sections A, B, and C of the Appendix (Appendix Table 2 lists the unit root test statistics).

A. Co-integration Analysis of the Money and Price Block

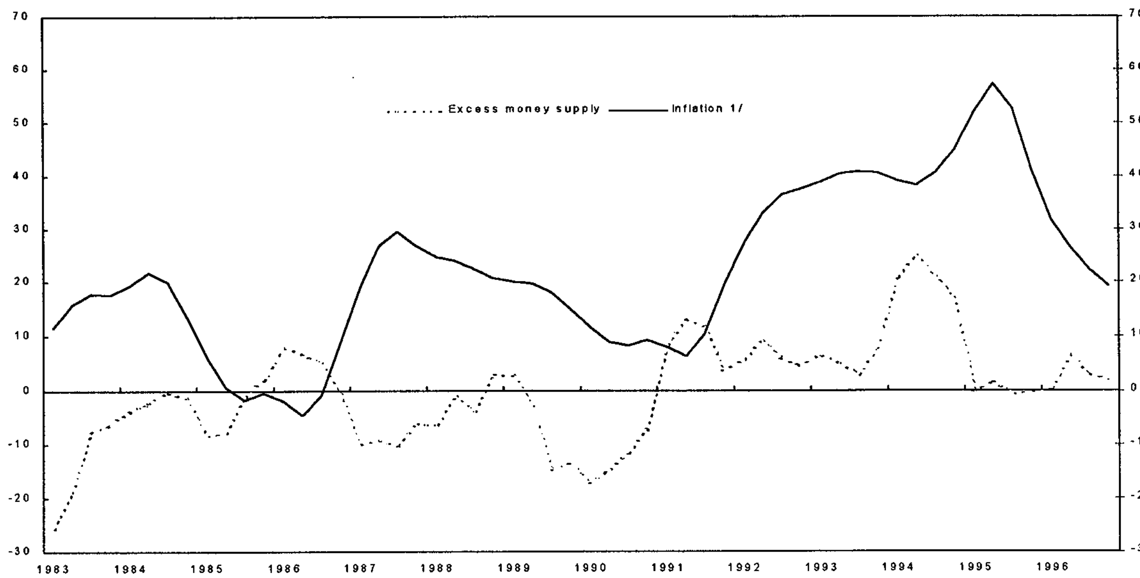
Appendix Table 3 reports the results of co-integration analysis for the set of variables $\{m, p, d, INF, RDIFF, pim\}$. The trace statistic indicates that there are, at most, two co-integrating vectors. Tests on the significance of individual variables indicate that *pim* is not significant in either of the two vectors. Hence, *pim* could be removed from the analysis. This result suggests that in Nigeria the price level is in the long run determined by money growth, while the contribution of import prices is not significant. The restrictions used to reduce the remaining system to a set of two economically meaningful relationships were accepted statistically (see Appendix Table 3). The first relationship is interpretable as an equation for money demand. The second one indicates that *INF* is stationary by itself, confirming the unit root results. The commonly used restriction of homogeneity between money and prices was not accepted; the restriction of homogeneity between money and nominal activity was accepted.[10] The derived demand for money function can be written as:

$$m^d = 0.89 * p + 1.11 * d + 0.0136 * RDIFF . \qquad (15)$$

According to the augmented Dickey-Fuller (ADF) unit root test, the residuals are stationary at the 5 percent significance level. The nonstandard result that the elasticity of money with respect to prices is significantly lower than one suggests that an increase in the price level results in a fall in the demand for real money balances. The elasticity of money demand with respect to non-oil domestic demand was estimated to be 1.1. The semielasticity of money demand with respect to the interest differential is within the range found for other countries, implying that a permanent 1 percentage point rise in the interest differential would lead to an increase in real money demand of 1.4 percent. A dynamic equation for the price level is discussed below. However, having obtained the demand for money function, we can illustrate its relevance for the determination of prices. Figure 1 shows excess money supply (*ECMp*; the actual money stock minus the demand for (nominal) money)) and inflation for the

[10] The imposition of the sum of the coefficients of *d* and *p* being 2.

Figure 1. Nigeria: Monetary Policy Stance and Inflation, 1983:Q1-1996:Q4
(In percent)



Sources: Nigerian authorities; and staff estimates.

1/ As measured by year-on-year change in GDP deflator.

period under investigation. Expansionary monetary policy clearly leads to inflationary pressure; however, the impact of the monetary stance is felt with a lag of several quarters.

B. Co-integration Analysis of the Balance of Payments Block

Co-integration analysis was carried out for the set of variables $\{ rer, d, fx^s, rho \}$.[11] Appendix Table 4 presents the results. Rank testing suggested the presence of one co-integrating vector. Subsequent significance tests on the individual variables indicated that none of the variables could be removed from the co-integrating relationship.[12] The relationship for equilibrium on the balance of payments can be written as:

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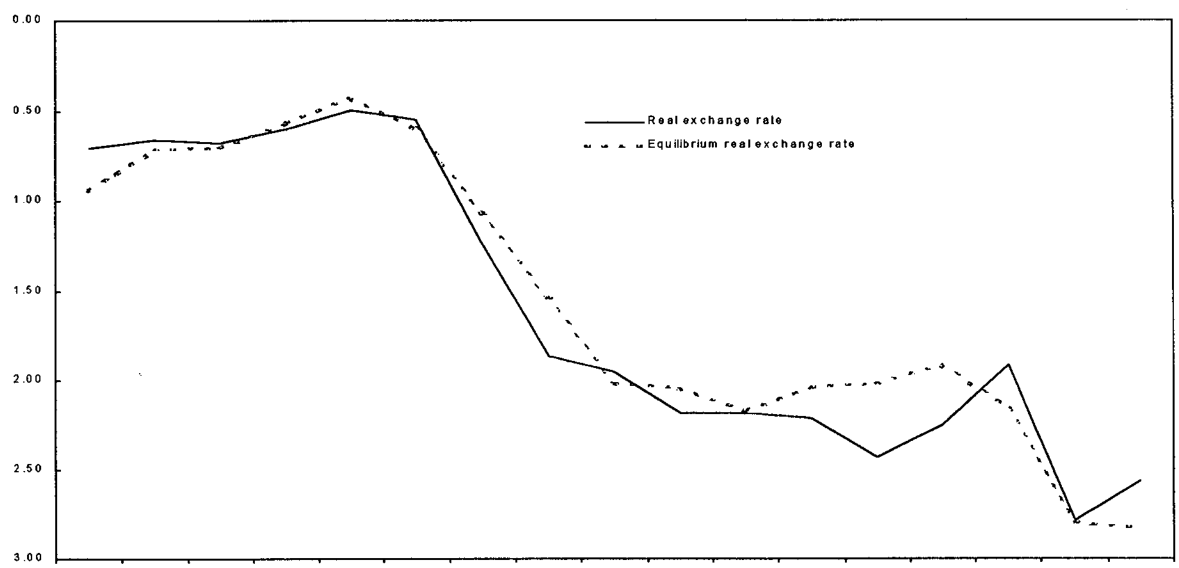
[11] The analysis was initially carried out for the period 1983-96. A repetition of the exercise for the period 1981-1996 rendered a relationship that was, although almost identical, more robust to tests. Therefore, the results for 1981-96 were used in the dynamic model.

[12] As discussed in the Appendix, the unit root tests suggest that fx^s is not unambiguously I(1); hence, fx^s could be the one stationary relationship suggested by the rank testing. However, because none of the other variables can be removed from the identified co-integrating vector and the vector was shown to be stationary, the identified relationship seems to be the one co-integrating vector suggested by the rank testing.

$$rereq = 2.928 * d - 1.652 * fx^s - 0.33 * rho . \qquad (16)$$

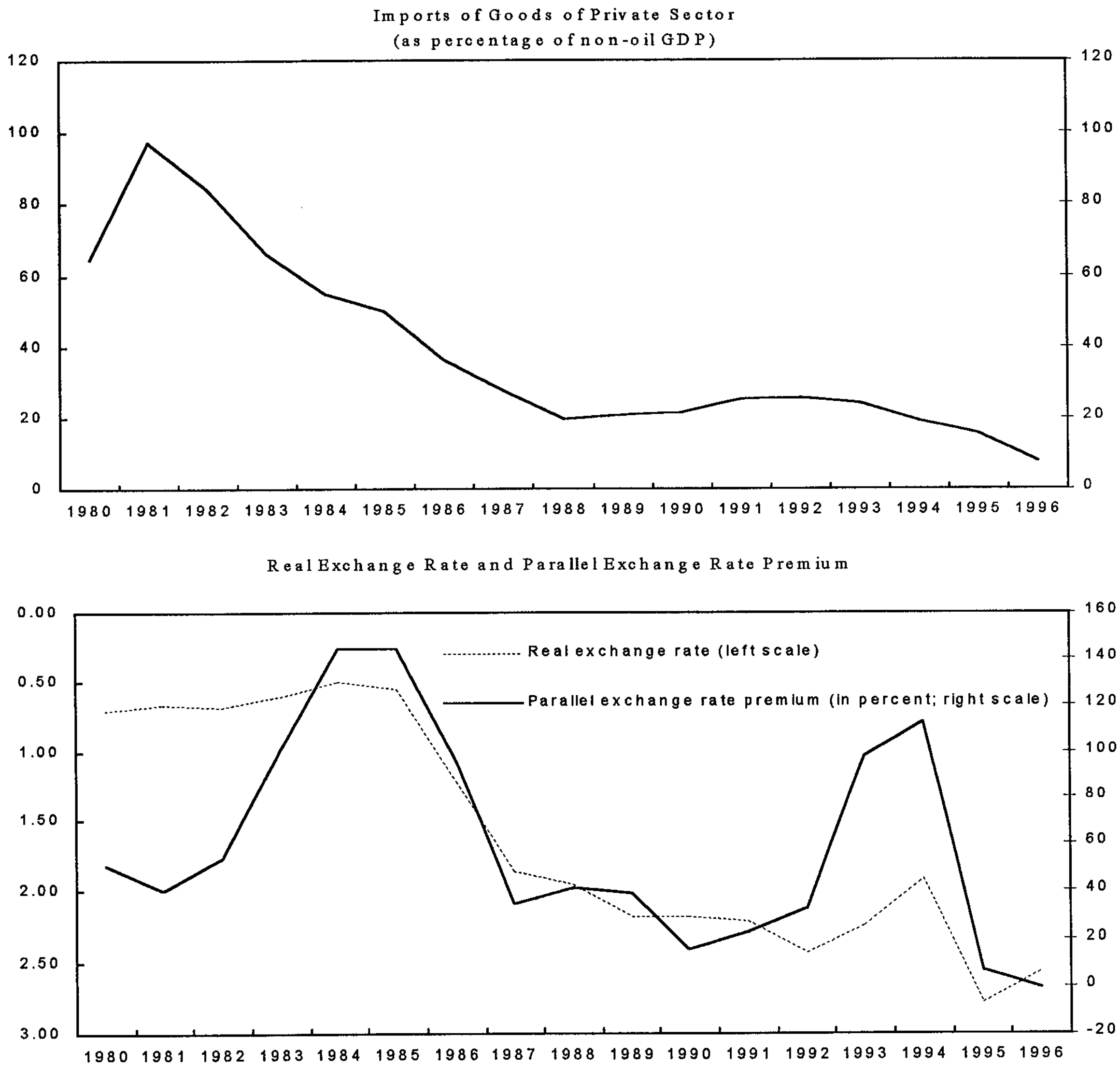
The residuals are stationary at the 5 percent significance level. The coefficients all have the expected sign. If the equation is seen as an import demand function (that is, by rewriting the equation, bringing fx^s to the left-hand side), the elasticity of imports (fx^s) with respect to domestic demand is relatively high (2.93/1.65 = 1.78). The elasticity of imports with respect to the real exchange rate (1/1.65 = 0.61) is in line with results for other countries. The equation suggests that a permanent 1 percent increase in domestic demand, with an unchanged foreign exchange supply and a constant parallel market premium, would require a real exchange rate depreciation of 2.9 percent to dampen the demand for imports. A permanent 1 percent fall in the supply of foreign currency to the private sector would, with an unchanged parallel market premium, require a 1.65 percent depreciation of the real exchange rate, a (1.65/2.9 =) 0.6 percent drop in domestic demand, or a combination of the two. If neither the real exchange rate nor domestic demand is allowed to change, the ensuing shortage of foreign currency would, in the long run, result in a (1.65/0.33 =) 5 percent rise in the parallel market premium. Figure 2 shows the actual and equilibrium real exchange rates (given the manner in which the real exchange rate is defined, a downward movement in the graph implies a real depreciation). Figure 3 (top panel) shows the ratio of the supply of foreign exchange (imports of goods) of the non-oil private sector to non-oil GDP. Combined, the two figures illustrate how the sharp fall in the supply of foreign exchange to the non-oil private sector since the beginning of the 1980s has led to a secular depreciation of the real exchange rate.

Figure 2. Nigeria: Real Exchange Rate and Long-Run Equilibrium, 1980-96
(Logarithmic Scale)



Sources: Nigerian authorities; and staff estimates.

Figure 3. Nigeria: Supply of Foreign Exchange and the Exchange Rate, 1980-96



Sources: Nigerian authorities; and staff estimates.

Two turbulent periods are of special interest: 1983-86 and 1992-94. In the period 1983-86, sharply falling oil revenues put pressure on the foreign exchange market.[13] In a free market, this pressure would have required a sharp depreciation of the real exchange rate. Such action, however, was resisted during 1984-85; instead, the authorities put in place tight restrictions on access to foreign exchange, which led to a rise in the parallel market premium to almost

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[13] Public sector imports have also declined significantly since the early 1980s, although somewhat less dramatic than non-oil private sector imports.

150 percent (bottom panel of figure 3). In 1986, the naira was allowed to devaluate strongly, which reduced the tension and led to a fall in the parallel market premium. In 1993-94, exchange market pressure was resisted in a similar manner, with the parallel market premium rising to over 100 percent. The 1995 devaluation was sufficiently large to remove the tension, and to allow the subsequent liberalization of the foreign exchange market.

C. Co-integration Analysis of Non-oil Output

The production function was estimated in two steps. The first step consisted of formally establishing the presence of a long-run relation between output (*y*), the production factors (*ls*, *k*, and *h*), and the intensity of distortions, as measured by the parallel market premium (*rho*), and to test whether imposing a Cobb-Douglas production function with constant returns to scale and "standard" factor shares was accepted statistically. Subsequently, the contributions to total factor productivity (*TFP)* of distortions and exogenous technological progress (*Techn*) were measured. Appendix Table 5 summarizes the results. Rank testing on the set of variables { *y* , *ls* , *h* , *k* , *rho* } suggested the presence of one or two co-integrating relationship(s). Subsequent investigation indicated that a rank of one could be imposed.[14] Constant returns to scale were imposed (and accepted), and the restriction of a coefficient of 0.6 for *ls* was accepted. Although the imposition of a positive coefficient (i.e., a positive contribution to output growth) for *h* was not accepted statistically, a coefficient of 0.1 was imposed.[15] In the restricted co-integrating vector, *rho* has a significant, freely estimated coefficient with the right sign. The vector (*y* - 0.6**ls* - 0.3**k* - 0.1**h*) represents *TFP*. In a second step, *TFP* was regressed on *Techn* and *rho*. The resulting relationship for potential output can be written as

$$y^s = 0.6 * ls + 0.1 * h + 0.3 * k - 0.07 * rho + 0.016 * Techn\,. \qquad (17)$$

The residuals of this co-integrating vector are stationary at the 1 percent significance level. Note the estimated impact of the parallel market premium on potential output: the coefficient suggests that a 10 percent increase in the parallel market premium would lead to a 0.7 percent

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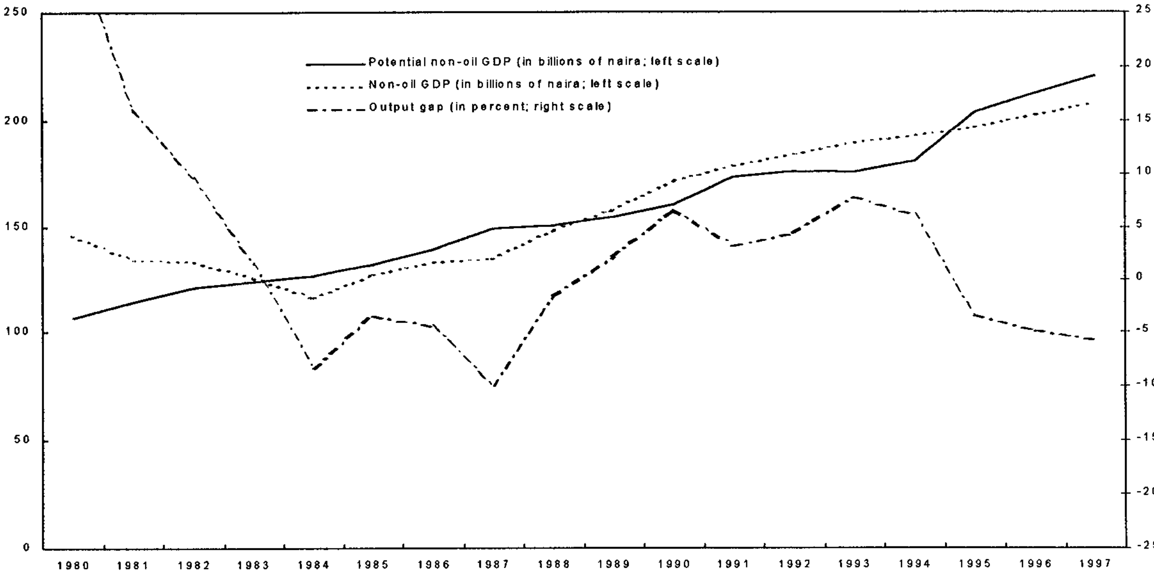
[14] The restricted long-run impact (Π) matrix for a rank of one was not significantly different from the impact matrix for a rank of two. Moreover, the second eigenvector was significantly lower than the first eigenvector.

[15] The possibility of a negative effect of education on growth is not fully discarded by some researchers (see Pritchett (1996)). However, given the unreliability of the data, the relatively short sample period, and the sensitivity of the results of growth regressions for Nigeria to changes in the sample period, here the preferred approach was to impose factor shares in line with mainstream economic theory.

Figure 4. Nigeria: Non-Oil GDP and Potential Output, 1980-97
(In constant 1990 prices)



Sources: Nigerian authorities; and staff estimates.

reduction in potential output. Figure 4 depicts actual and potential non-oil GDP, as derived above. The difference between the two forms the implied output gap.

Ideally, a production function should be estimated over a long period. However, the period over which the production function was estimated here (1982-97) was partly determined by the need to produce a supply function that has economically plausible coefficients and that results in output gaps for the dynamic model estimation period that are not out of line with received wisdom about the business cycle. Equation (17) meets these criteria. As indicated in Figure 4, non-oil GDP fell sharply at the start of the 1980s. Output remained below potential until 1988, but it grew steadily from 1989 onward, owing to expansionary macroeconomic policies. However, with very low capital formation and more intense distortions, potential output remained subdued. When foreign exchange restrictions were reduced significantly in 1995, potential output was boosted. However, restrictive macroeconomic policies have maintained actual output below potential by some 4-5 percent in recent years.

From a longer perspective, it is interesting to conduct a growth-accounting exercise (see Table 1). Average annual growth of non-oil GDP decreased from 3.8 percent during the period 1970-82 to 3.0 percent in the period 1983-97. The growth of the labor force remained roughly constant at some 2.5 percent per year, and the growth rate of the human capital stock increased from 5.5 percent per year in 1970-82 to 7.1 percent in 1983-97. In the period 1970-82, capital formation was very high: the stock of physical capital increased on average by over 13 percent per annum. However, the productivity of capital, in terms of increased output, was very meager during that period.

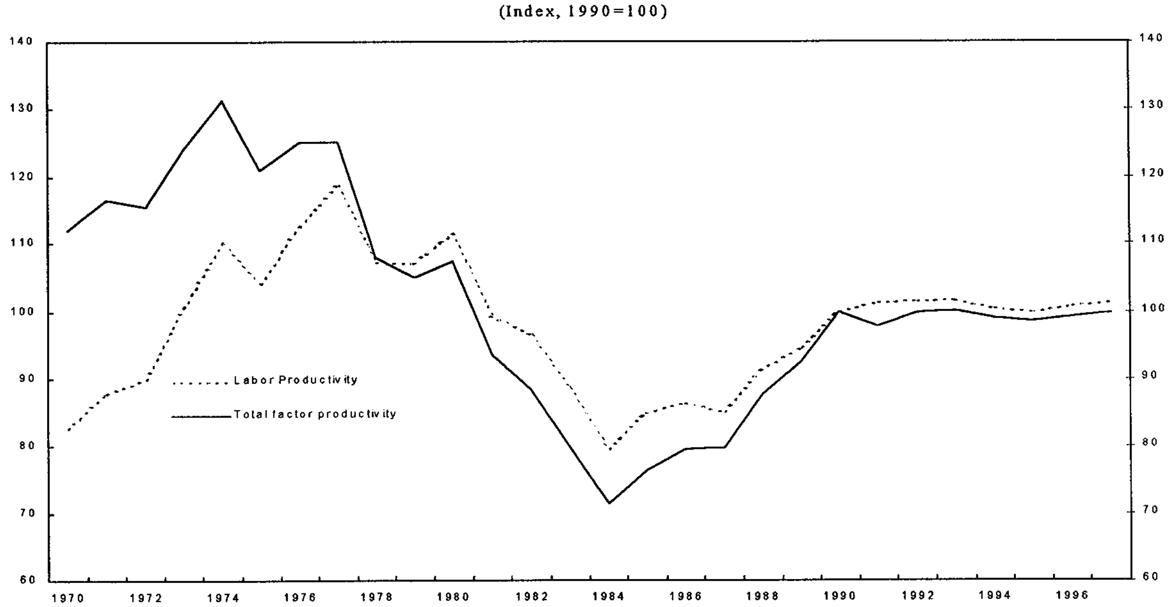
Table 1. Growth of Production Factors and Productivity, 1970-97
(Annual percentage change)

	1970-82	1983-97
GDP	3.81	2.98
Employment	2.49	2.64
Physical capital	13.10	-0.38
Human capital	5.47	7.12
Labor productivity	1.32	0.34
Total factor productivity 1/	-1.96	0.80
Of which: explained by changes in intensity of distortions 1/	-0.01	0.25

Sources: Nigerian authorities; *Penn World Tables; and* World Bank, World Development Indicators.
1/ Based on estimated Cobb-Douglas production function

Although labor productivity grew by some 1.3 percent per year, total factor productivity (as implied by the Cobb-Douglas production function) decreased by almost 2 percent per year. Figure 5 shows that the dramatic fall in total factor productivity continued through 1984. The inefficiency of investments over this period is usually attributed to the often wasteful nature of many public sector investment projects. In the period 1983-97, net capital formation was actually slightly negative. But, as can be seen in Figure 5, the efficiency with which capital was used (and, as a result, total factor productivity) has improved

Figure 5. Nigeria: Productivity, 1980-97
(Index, 1990=100)



Sources: Nigerian authorities; and staff estimates.

substantially since the middle of the 1980s, when structural adjustment policies began to be implemented. As a result, since the trough in 1984, output has been growing at some 4.5 percent per year despite low investment levels.

V. Dynamic Model

Following equation (14), dynamic equations were estimated for the price level, the real exchange rate, and non-oil GDP, using the three co-integrating relationships as ECM terms.[16] The equations displayed below (equations (18), (19), and (20)) are the final versions derived after removing insignificant variables and including dummy variables to account for outliers.

A. Price Level

$$dp = \underset{(17.4)}{1.581} * dp(-1) - \underset{(-12.1)}{1.606} * dp(-2) + \underset{(10.2)}{1.350} * dp(-3) - \underset{(-6.6)}{0.580} * dp(-4) \quad (18)$$

$$+ \underset{(6.0)}{0.113} * ECMp(-1) - \underset{(-2.2)}{0.465} * dy + \underset{(3.2)}{0.571} * dy(-1) - \underset{(-5.7)}{0.248} - \underset{(-4.15)}{0.048} * D861,$$

$R^2 = 0.95$ $\sigma = 0.011$ DW = 1.89

where *ECMp* is excess money supply and *D861* is a dummy [17]. Although the output gap (*ECMy*) was found not to exert a significant effect on prices, the combined effect of the two dynamic terms in output suggests that a rise in output is associated with a short-run increase in the rate of change of the price level. The exchange rate ECM (*ECMrer*) does not exert any impact on prices. This outcome, which is robust, is remarkable in the light of strongly held domestic views that inflation in Nigeria has often been triggered by devaluations of the naira. When a vector representing the purchasing power parity condition (*P - P$*E*) was included as an additional ECM, it was not significant. This result also holds when import prices are valued at the parallel market exchange rate, instead of at the formal exchange rate. The absence of a significant exchange rate impact on domestic prices is in line with the marked reduction in quantitative importance of imports since the start of the 1980s. The ratio of imports to non-oil GDP has fallen to less than 20 percent in recent years (see Figure 3).

Excess money supply has a significant impact on the price level. However, the "speed of adjustment" coefficient indicates that it would take more than two years (nine quarters) before prices are fully adjusted to a shock in excess money supply. These estimation results

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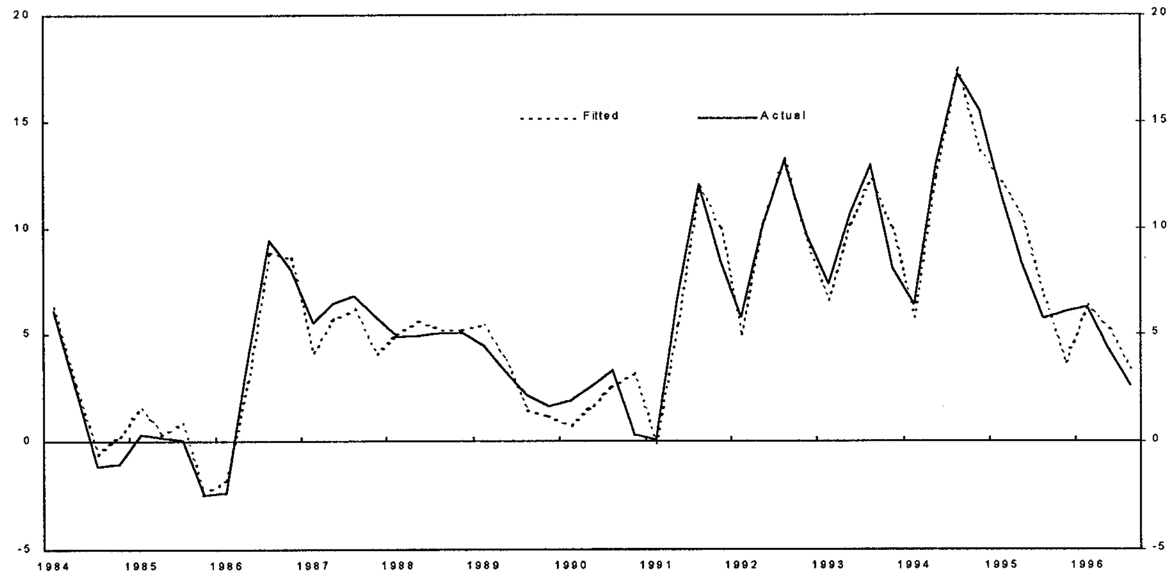
[16] *INF*, which was found to be co-integrated by itself (stationary) in the co-integration analysis for the money-price block, was also included in (lagged) level form. However, it was not found to be significant in any of the dynamic equations.

[17] As mentioned above, dummies are included to let the equations pass the diagnostic tests in the face of outliers. The dummies are not meant to explicitly account for specific events.

Figure 6. Nigeria: Actual and Fitted Values of Price Level, 1984:Q2-1996:Q4
(Quarter-on-quarter change, in percent)



Sources: Nigerian authorities; and staff estimates.

confirm the tentative conclusions drawn from Figure 2: variations in price increases are well predicted by the stance of monetary policy, but the response of prices is subject to lags. The lagged effect means that it is inappropriate to assume a mechanical contemporaneous relationship between nominal income and money. The inclusion of four lagged dependent variables was necessary to avoid serial correlation of the residuals. Since the sum of the coefficients of the lags of the dependent variable is less than one (0.74), no overshooting takes place. The standard deviation (0.011) indicates a fairly good fit, which is shown by the comparison of actual and fitted values in Figure 6. The equation passes all diagnostic tests (see Appendix Table 6).

B. Real Exchange Rate

Neither excess money supply nor the output gap was estimated to have an impact on the real exchange rate. Moreover, neither the change in money supply nor the level of inflation has a significant impact. Hence, surprisingly, the real exchange rate is, even in the short run, affected only by real variables. The lack of impact of the interest differential seems consistent with the modest importance of private capital flows in Nigeria. The balance of payments ECM influences strongly the real exchange rate; the "speed of adjustment" coefficient of 0.16 indicates that, after a shock, the real exchange rate reverts rapidly to the equilibrium value given by the co-integration result (within six quarters). An 10 percent increase in the parallel market premium is estimated to lead to a 2 percent appreciation of the real exchange rate.

$$drer = -0.188 * drho - 0.157 * ECMrer(-1) - 0.875 + 0.800 * D864 \quad (19)$$
$$\quad (-2.3) \qquad (-2.7) \qquad (-2.7) \quad (8.8)$$

$$+ 0.327 * D922 + 0.643 * D951 ,$$
$$(3.8) \qquad (5.4)$$

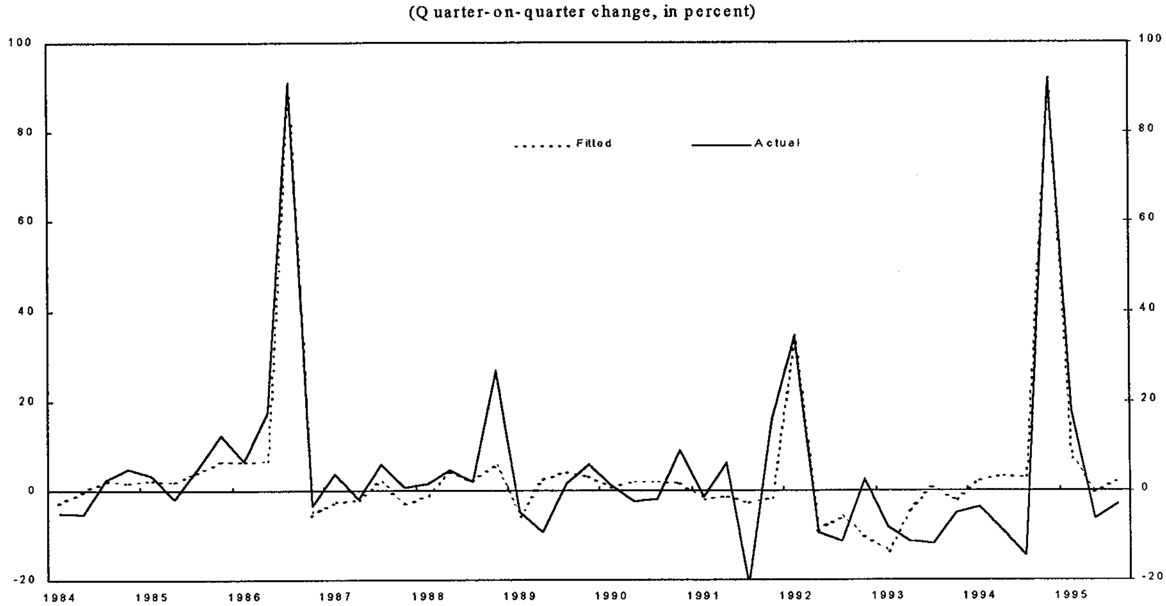
$R^2 = 0.86$ $\sigma = 0.083$ DW = 2.00

The equation posed no specification problems (see Appendix Table 6). Actual and fitted values are shown in Figure 7. The fit is much weaker than for the price equation, as is confirmed by the standard error of 0.083.

C. Non-Oil GDP

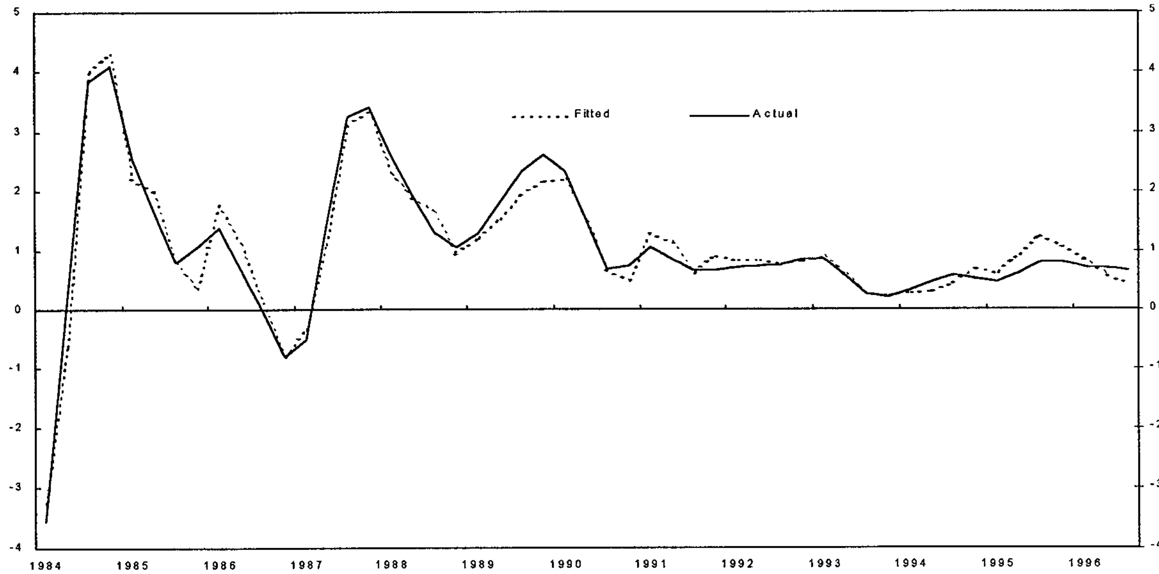
The estimation of the dynamic equation for non-oil GDP generated some interesting results. Neither the monetary nor the balance of payment disequilibrium was estimated to have an impact on short-run variations in output. However, an increase in supply of foreign exchange was estimated to increase output in the short run. Changes in the real exchange rate

Figure 7. Nigeria: Actual and Fitted Values of Real Exchange Rate, 1984:Q2-1995:Q4
(Quarter-on-quarter change, in percent)



Sources: Nigerian authorities; and staff estimates.

Figure 8. Nigeria: Actual and Fitted Values of Non-Oil GDP, 1984:Q2-1996:Q4
(Quarter-on-quarter change, in percent)



Sources: Nigerian authorities and staff estimates.

were found not to have a significant effect on short-run output growth. The final dynamic equation for non-oil GDP is

$$dy = \underset{(21.4)}{1.699} * dy(-1) - \underset{(-12.2)}{1.804} * dy(-2) + \underset{(7.9)}{1.159} * dy(-3) - \underset{(-5.1)}{0.378} * dy(-4) \qquad (20)$$

$$+ \underset{(3.2)}{0.017} * dfx^{s} - \underset{(-4.5)}{0.0388} * ECMy(-1) - \underset{(-3.9)}{0.013} * D854 - \underset{(-4.6)}{0.014} * D871 + \underset{(7.7)}{0.005},$$

$R^2 = 0.95$ $\sigma = 0.0029$ DW = 1.84

where *ECMy*, the output gap, is the deviation of non-oil GDP from potential output, and *D854* and *D*871 are dummies. The correct sign of the coefficient of *ECMy* and its *t*-value imply that output is "attracted" to potential output. But the low value of the coefficient of the output gap implies that deviations of output from potential output can be sustained for extended periods. The coefficient on the dynamic term in the supply of foreign exchange suggests that a 10 percent rise in foreign exchange supply is estimated to increase output by 0.13 percent in the short-run. Figure 8 depicts actual and fitted values (see Appendix Table 6 for specification test results).

VI. Conclusions

A model was estimated that determines three key economic variables in Nigeria—the price level, the exchange rate, and non-oil GDP. After the long-run equilibrium conditions on the market for broad money (monetary ECM), the market for foreign exchange (balance of payments ECM) and the non-oil goods market (output gap) had been determined, a dynamic model was estimated in which the disequilibria in the three markets were allowed to influence the price level, the real exchange rate, and output. The results are in line with classical assertions concerning the dichotomy between the real and monetary spheres. First, the price level is, in the long run, determined by monetary policy, as an excess of money supply over money demand leads to a rise in the rate of inflation, while the long-run effect of import prices is insignificant. Moreover, in the dynamic model, prices do not respond to either the balance of payments disequilibrium or to deviations of output from potential. The price level does, in the short run, respond to variations in output. Second, the long-run equilibrium real exchange rate, the (only) relative price in the model, is determined by the real demand for, and supply of, foreign exchange. A reduced supply of foreign currency requires a real depreciation toward the new equilibrium real exchange rate, so as to dampen the demand for foreign currency stemming from import demand. In the dynamic model, the real exchange rate responds rapidly to the balance of payment disequilibrium, but not to excess money supply or the output gap. Third, the dynamic model for output suggests that, although deviations from potential output can be sustained for prolonged periods, output is attracted to potential output. Although neither the monetary nor balance of payments disequilibrium was estimated to have an impact on the growth of output, an increase in the supply of foreign exchange does lead to a short-run increase in output.

The most remarkable feature of these results is that they are so straightforward. Although the dynamic model specifically allows for the possibility that the three endogenous variables (prices, the real exchange rate, and non-oil output) are affected by the three disequilibria relationships, all three variables are attracted to the one long-run equilibrium that mainstream economic theory suggests.

This framework could usefully be applied to other economies—in particular, to other countries whose exports are relatively insensitive to exchange rate movements (e.g., other oil-based economies).

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Definitions and Unit Root Test Statistics of Variables

A. Descriptions and Sources of Data

Mnemonic	Description	Source
M	M2	*International Financial Statistics* (*IFS*), country desk
Y[1]	Non-oil GDP, constant 1990 prices	*IFS*, country desk
YN[1]	Non-oil GDP, current prices	*IFS*, country desk
P[1]	Non-oil GDP deflator, 1990 = 100	100**YN/Y*
INF[1]	Inflation	100*(*P-P*(-4))/*P*(-4)
R	Three-month deposit rate	*IFS*, 69460L..ZF...
*R**	U.S. federal funds rate	*IFS*
RDIFF	Interest rate differential	*R-R**
E[1]	Formal exchange rate up to January 1995--official rate; from February 1995 onward--autonomous foreign exchange market (AFEM) rate	*IFS*, country desk
PAR[1]	Parallel market exchange rate	*World Currency Handbook/ Currency Alert*
rho	Parallel market premium	log(*PAR/E*)
MGPR$[1]	Private sector imports of goods, in U.S. dollars	*IFS*, country desk
FX$[s]	Supply of foreign exchange to private sector	*MGPR$*
Pcomm$	Commodity price index, 1990 = 100	IMF, Commodity Prices Database
PXGind$	Price deflator of exports of goods of industrial countries, 1990 = 100	IMF, World Economic Outlook database
P$	Price of imports (goods), in foreign currency	0.5*(*Pcomm$+PXGind$*)
T	Trade-weighted import tariff	Adenikinju and Chete (1996) and World Trade Organization (WTO)
Pim[1]	Price of imported goods, in domestic currency	*E*P$**(1+*T*/100)
MGPR[1]	Private sector imports of goods, In domestic currency	100*8.04**MGPR$/P$* (8.04=1990 exchange rate)
FX[s]	Supply of foreign exchange, 1990 domestic prices	*MGPR*
D[1]	Domestic demand	*Y + Fxs*
RER[1]	Real exchange rate	*E**(1+*T*/100)**P$/P*
LS	Labor supply (thousand persons)	World Bank, World Development Indicators database: SL.TLF.TOTL.IN
SS	Secondary school enrollment rate	World Bank, World Development Indicators database: SE.SEC.ENRR

Mnemonic	Description	Source
H	Stock of educational capital	0.96*H_1+0.04*(.25*SS_1+ .25*SS_2+.25*SS-3+.25*SS_4)
Kaplab	Capital-labor ratio	*Penn World Tables*
K	Capital stock	*Kaplab*LS*
Techn	Exogenous technological progress	Trend variable
TFP[1]	Total factor productivity	Y-0.6**LS*-0.1**H*-0.3**K*

[1] Denotes an endogenous variable.

B. Estimation Period and Frequency

The long-run relationships for the money-price block and the balance of payments block, as well as all dynamic equations, were estimated using quarterly data for the period 1983-96. For this period, the necessary data are available on a reasonably consistent basis. Most of the data were taken from *International Financial Statistics*. However, for many variables, data for recent periods were overwritten with data from the IMF's Nigeria desk. Variables for which no quarterly data exist (non-oil GDP, the non-oil GDP deflator, private sector imports, and import tariffs) were interpolated. Data on production factors were available from the World Bank's World Development Indicators database and the *Penn World Tables* only on an annual basis. Therefore, the production function for non-oil output was estimated using annual data for the period 1982-97. Data on the capital stock,[18] the labor force, and the secondary school enrollment rate were available through 1995; estimates for 1996 and 1997 were made using data on investment and population growth. The time series for the "stock" of human capital was constructed using the perpetual inventory approach. The annual time series for potential output resulting from the estimation of the production function was interpolated into a quarterly series for the estimation of the dynamic equations.

C. Unit Root Tests

Co-integration analysis was used to identify the long-run equilibrium relationships in the system of variables. A set of nonstationary variables is said to be co-integrated if there exists at least one linear combination (a co-integrating vector) of these variables that is stationary (I(0)). A necessary condition for the result to hold is that the maximum order of integration of the variables is one. The Johansen method can be used to determine the number of co-integrating vectors among a set of I(1) variables. The order of integration of the

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[18] The capital stock data available refer to the total capital stock, including the capital employed in the oil sector. Using these data to proxy the capital stock in the non-oil sector assumes that the growth of the capital stock in the non-oil sector is highly correlated with capital growth in the oil sector (note that no such assumption has to be made regarding the levels of the capital stock). This approach, although heroic, was in the end preferred over the construction of a time series for the non-oil capital stock using available non-oil investment data, as the quality of these data is rather poor.

individual variables was determined using the augmented Dickey-Fuller (ADF) test. Appendix Table 2 reports the test statistics for the original level variables (in log form for all variables except *INF*, *RDIFF*, and *rho*) and first differences. The larger the test statistic, the less likely it is that the series is stationary. The test results for the level variables suggest that all variables are at least I(1), that is, not stationary, at the 1 percent significance level; however, fx^s and *INF* were found to be stationary at the 5 percent and 8 percent significance level, respectively. The first differences of all variables are I(0), at the 5 percent significance level, implying that none of the variables is integrated of an order higher than one.[19] The fact that fx^s and *INF* are not unambiguously I(1)—that is, they could be I(0)—had to be taken into account in the co-integration analysis.[20]

[19] Although *P* is, strictly speaking, I(2) rather than I(1) at the 5 percent significance level, the test statistic (-2.5) is close to the critical value (-2.9). Moreover, *P* was found to be I(I) when the unit root test was repeated over a longer period.

[20] A stationary variable forms a co-integrating relationship on its own. Ignoring the stationarity of variables included in a co-integration analysis leads to an overestimation of the number of "proper" co-integrating vectors and could distort the identification process.

Table 2. Order of Integration: Unit Root ADF Test Statistics

	Level		First Difference	
	Lag	Test statistic	Lag	Test statistic
rho	0	-1.10	0	-6.39 **
M	4	1.53	0	-5.51 **
E	0	2.19	0	-5.59 **
RER	0	0.60	0	-6.67 **
D	0	-0.34	2	-2.62 **
P_{im}	0	3.05	0	-5.55 **
Y	4	1.96	5	-2.39 *
P	4	2.37	3	-2.44 1/
FX^s	2	-2.21 *	2	-2.73 **
RDIFF	1	-0.95	0	-5.22 **
INF	3	-2.62 1/	5	-4.24 **
Y 2/	0	2.11	0	-4.46 **
LS 2/	0	37.77	0	-3.84 ** 1/
K 2/	1	0.64	0	-2.09 *
H 2/	1	-0.12	1	-2.14 *
RHO 2/	0	-1.27	0	-3.77 **

Notes: Variables are as defined in the text. The estimation period is 1983:Q1-1996:Q4 for the quarterly data (first group) and 1975-97 for the annual data (second group). Asterisks * and ** denote rejection of the null hypothesis of a unit root at the 5 percent and 1 percent significance levels, respectively.

1/ Constant included.

2/ Annual data.

Table 3. Co-integration Analysis of Money and Price Level, 1983:Q1-1996:Q4

General system (including import price)

Hypothesis	r = 0	r <= 1	r <= 2	r <= 3	r <= 4	r <= 5
Trace statistic 1/	131.80 **	73.01 *	41.58	15.12	3.94	0.34
95 percent critical value	94.20	68.50	47.20	29.70	15.40	3.80
			Standardized eigenvectors			
Normalize, weak exogeneity	*m*	*p*	*d*	*INF*	*RDIFF*	*pim*
and coefficient of *pim* in first	1.000	-0.836	-1.651	-2.280	-0.006	0.000
vector = 0	-0.997	1.000	1.310	-0.261	0.016	-0.071

Restriction

Coefficient *pim* in second vector = 0: chi-square (1) = 2.5 [0.1138].

Reduced system (excluding import price)

Hypothesis	r = 0	r <= 1	r <= 2	r <= 3	r <= 4
Trace statistic 1/	120.90 **	56.13 **	28.54	10.70	0.57
95 percent critical value	68.50	47.20	29.70	15.40	3.80
			Standardized eigenvectors		
	m	*p*	*d*	*INF*	*RDIFF*
	1.000	-0.757	-0.887	-11.490	0.001
	-1.243	1.000	2.078	0.069	0.033
			Standardized impact coefficients		
	m	*p*	*d*	*INF*	*RDIFF*
	-0.010	0.001	-0.003	0.025	-0.379
	0.116	-0.046	-0.031	-0.027	-3.082

Restrictions

d is weakly exogenous for both vectors, *RDIFF* is weakly exogenous for first vector: chi-square (2) = 6.5 [0.0386]*.
Coefficients of *m* and *p* in second vector are 0: chi-square (2) = 1.31 [0.5194].
Coefficients of *d* and *RDIFF* in second vector are 0, coefficient of *INF* in first vector is 0: chi-square (3) = 2.17 [0.5379].
m is homogenous in (*p* +*d*): chi-square (1) = 0.03 [0.8625].

			Standardized eigenvectors		
	m	*p*	*d*	*INF*	*RDIFF*
Chi-square (7) = 12.477 [0.0859]	1.000 [0.00]	-0.886 [0.03]	-1.114 [0.00]	0.000 [0.00]	-0.014 [0.00]
	0.000 [0.00]	0.000 [0.00]	0.000 [0.00]	1.000 [0.00]	0.000 [0.00]
			Standardized impact coefficients		
	m	*p*	*d*	*INF*	*RDIFF*
	-0.081 [0.06]	0.164 [0.03]	0.000 [0.00]	0.133 [0.03]	0.000 [0.00]
	0.119 [0.07]	0.027 [0.03]	0.000 [0.00]	-0.241 [0.03]	3.770 [2.83]

Unit root testing vector {*m* - 0.886 * *p* - 1.114 * *d* - 0.0136 * *RDIFF*}: *t*-statistic = -3.4258 * (stationary at 5 percent).B25

Notes: Variables are as defined in the text. Asterisks * and ** denote rejection of the null hypothesis at the 5 percent and 1 percent significance levels, respectively. Numbers between square brackets denote standard errors.
1/ Adjusted for the number of degrees of freedom.

Table 4. Co-integration Analysis of Real Exchange Rate 1981:Q1-1996:Q4

Hypothesis	$r = 0$	$r <= 1$	$r <= 2$	$r <= 3$
Trace statistic 1/	61.89 **	25.39	7.06	2.21
95 percent critical value	47.20	29.70	15.40	3.80
		Standardized eigenvector		
	rer	*d*	fx^s	*rho*
	1.000	-2.642	1.845	0.272
	[0.00]	[0.41]	[0.12]	[0.11]
Restrictions				
d and *rho* are weakly exogenous.				
		Standardized eigenvector		
Chi-square (2) = 4.837 [0.0891]	*rer*	*d*	fx^s	*rho*
	1.000	-2.928	1.652	0.333
	[0.00]	[0.40]	[0.12]	[0.11]
		Standardized impact coefficients		
	rer	*d*	fx^s	*rho*
	-0.074	0.000	-0.145	0.000
	[0.07]	[0.01]	[0.03]	[0.08]

Testing significance

rho	Chi-square (1) = 6.4 [0.0114]*
d	Chi-square (1) = 24.7 [0.000]**
rer	Chi-square (1) = 37.1 [0.000]**

Unit root testing vector $\{rer - 2.928 * d + 1.652 * fx^s + 0.333 * rho\}$: t-statistic = -3.241 * (stationary at 5 percent).

Notes: Variables are as defined in the text. Asterisks * and ** denote rejection of the null hypothesis at the 5 percent and 1 percent significance levels, respectively.
Numbers between square brackets denote standard errors.
1/ Adjusted for the number of degrees of freedom.

Table 5. Co-integration Analysis of Non-Oil GDP and Estimation of Production Function, 1982-97

Estimation Cobb-Douglas production function

Hypothesis	$r = 0$	$r <= 1$	$r <= 2$	$r <= 3$
Trace statistic 1/	108.20 **	49.41 *	26.97	13.46
95 percent critical value	68.50	47.20	29.70	15.40

Standardized eigenvector

y	*ls*	*h*	*k*	*rho*
1.000	0.059	0.054	-0.274	-0.025
[0.00]	[0.17]	[0.06]	[0.08]	[0.01]

Restrictions

ls and *k* are weakly exogenous: chi-square (1) = 2.49 [0.287].
Constant returns to scale exist (coefficients of *ls*, *h*, and *k* add to -1): chi-square (1) = 5.77 [0.016]*.
Coefficient of *ls* = -0.6: chi-square (1) = 3.97 [0.046]*.
Coefficient of *h* = -0.1: chi-square (1) = 33.5 [0.000]**.

Standardized eigenvector (constrained)

y	*ls*	*h*	*k*	*rho*
1.000	-0.600	-0.100	-0.300	0.043
[0.00]	[0.00]	[0.00]	[0.00]	[0.01]

Define: total factor productivity $(TFP) = y - 0.6 * ls - 0.1 * h - 0.3 * k$.

Estimation of total factor productivity

Regress *TFP* on *rho* and *Techn*

$$TFP = -0.071 * RHO + 0.016 * Techn - 0.741$$
(-1.8) (3.8) (-7.2)

$R^2 = 0.73$ SE = 0.090 DW = 0.82

Unit root testing vector $\{y - 0.6 * ls - 0.1 * h - 0.3 * k + 0.071 * RHO - 0.0158 * Techn - 0.741\}$:
t-statistic = -3.03** (stationary at 1 percent).

Notes: Variables are as defined in the text. Asterisks * and ** denote rejection of the null hypothesis at the 5 percent and 1 percent significance levels, respectively. Numbers between square brackets denote standard errors. Numbers between parentheses denote t-statistics.
1/ Adjusted for the number of degrees of freedom.

Table 6. Diagnostic Tests for Dynamic Equations

	Price Level	Real Exchange Rate	Non-oil Output
AR 1-4[1]	F(4,38) = 1.099 [0.37]	F(4,37) = 2.279 [0.079]	F(4,38) = 2.881 [0.04]*
ARCH 4[2]	F(4,34) = 0.968 [0.44]	F(4,33) = 0.111 [0.98]	F(4,34) = 0.585 [0.68]
Normality[3]	χ^2 (2) = 1.900 [0.387]	χ^2 (2) = 4.491 [0.106]	χ^2 (2) = 4.083 [0.13]
χ_i^2 [4]	F(15,26) = 0.379 [0.97]	F(7,33) = 0.477 [0.84]	F(12,31) = 1.814 [0.09]
$\chi_i * \chi_j$ [5]		F(8,32) = 0.501 [0.85]	
Reset[6]	F(1,41) = 0.053 [0.82]	F(1,40) = 5.633 [0.02]*	F(1,41) = 1.025 [0.32]

Note: Asterisks* and ** denote rejection of the null hypothesis at the 5 percent and 1 percent significance levels, respectively.

[1]Test for serial correlation of residuals (H_0: no autocorrelation).

[2]Test for autoregressive conditional heteroscedasticity (H_0: no heteroscedasticity).

[3]Test for normality of distribution of residuals (H_0: normality).

[4]Test for heteroscedasticity (H_0: no heteroscedasticity).

[5]White's cross-product test for heteroscedasticity (H_0: no heteroscedasticity).

[6]Test for general misspecification of equation (H_0: no misspecification).