Center For Economic Research on Africa
School of Business
Montclair State University
Upper Montclair, New Jersey 07043

On the Simultaneous Interactions of External Debt, Exchange Rates, and Other Macroeconomic Variables: The Case of Nigeria

April 1991

(pdf version October 2000)

Richard Ajayi, Ph.D.
Department of Finance and Business Economics
School of Business Administration
Wayne State University
Detroit, Michigan 48202

Abstract

Using a two-stage least squares simultaneous equation model, estimates of key monetary and real variables in the Nigerian economy over the 1975-1986 period show that the exchange rate of the naira is significantly and positively related to changes in the real price of world oil, and that the size of Nigeria's external debt exerts no statistically significant influence on the naira exchange rate. Policies designed to affect Nigeria's foreign exchange rate should thus concentrate more on developments in the world price of oil rather than on the size of external debt.

***

Technical Assistance in the preparation of the current version of this document has been provided by Monica Mocanasu, graduate assistant in the Department of Economics and Finance of the School of Business, Montclair State University.

Introduction and Background

Several attempts have been made by scholars especially in connection with the verification of the purchasing power parity (PPP) theory, to establish empirical relationships between the exchange rates, relative prices, income, and interest rates. While these studies focus mainly on the developed countries, they merit a brief overview. Thomas (1973) presents results of a regression (using logs) of the exchange rate on relative prices and finds that the relationship between relative prices and the exchange rate is not significantly different from unity for France, but is significantly less than unity for Canada and Spain. This implies that a one-percent change in relative prices results in the same percentage change in the exchange rates in the case of France. In the case of Canada and Spain, a one percent change in the relative price is not matched by a similar change in their exchange rates. Specifically, the PPP theory holds for France but not for Canada or Spain. His second regression of the exchange rate or relative prices, relative incomes, and relative interest rates shows that for France the relationship between relative prices and the exchange rate is significantly less than unity. This second model incorporates more explanatory variables than the first model and results in a different conclusion about the responsiveness of the exchange rates to relative price changes for France. Hodgson and Phelps (1975) and Kohlhagen (1978) also estimate similar models with mixed results.

These examples show that several early models of exchange rate determination produced mixed results within the same model specification and across different models. Furthermore, no single model exists that can capture the dynamics of exchange rate behavior across different countries.

Cornell and Shapiro (1985) present indirect evidence on the behavior of the real interest rate by examining the correlations between changes in nominal interest rates and exchange rates. Their empirical evidence supports the view that monetary shocks affect the real interest rates. In his own case, Hardouvellis (1985) observes simultaneous increases in long-term interest rates and in the value of the dollar after an announced larger than anticipated money stock by the Federal Reserve. These two studies reinforce the fact the relation between exchange rates and nominal interest rates. depends on the extent to which variations in nominal rates are dominated by changes in the real rates or by expected inflation. If short-run changes in interest rates are due primarily to fluctuations in the real rate, then these should be associated with an appreciation of the domestic currency. On the other hand a rise in nominal rates that reflects expected inflation should be accompanied by a depreciation of the domestic currency.

Several other empirical studies in connection with the monetary and asset models of exchange rate determination are well documented in the literature. The basic building blocks of the monetary approach indicate a close association between monetary developments and exchange rates, and link domestic income and interest rates with their foreign counterparts (Dornbusch, 1980 and Somanath, 1984).

Most asset models come with a number of simplifying assumptions about the role of wealth, country size, nature of expectation and the degree of substitutability between assets (Penati, 1983 and Pippenger, 1984). However, most of the theoretical and empirical discourse on the variability of exchange rates in recent years have featured "traditional" variables considered as determinants of exchange rates. Traditional variables include current account balances, monetary aggregates, interest rates, inflation, income, and measures of expectations. Also the vast majority of available theories relate assymmetrically to the advanced economies of the western world. These include Dornbush, (1976); Frankel, (1979); Branson, (1983); Dornbush, (1983); Boughton, (1984): So, (1986): and Huang (1987). Studies related to developing economies incorporate current account balances (Khan and Knight, 1983), external shocks (Khan, 1986), and effect of domestic monetary and fiscal policies (Kincaid, 1984: Dornbush, 1985: Edwards, 1987; and Mussa, 1987).

The question of the effect of the size of external debt and the world price of oil as factors in exchange rate determination, especially in the context of the developing economies, has received only token attention. Yet the issue of developing countries, debt and their implications for world financial stability can no longer be overlooked. And in like manner, developments about the world oil price situation provide important signals about future directions of the economies of developed and developing countries.

This study is an attempt to fill two gaps in the literature. First, a simultaneous equation model 'of exchange rate determination is adopted. Simultaneous bias problems involved in treating incomes, interest rates, and prices as independent variables in single equation models raise questions about conclusions from such studies. Efforts are made to correct these problems by utilizing a two-stage least square technique (2SLS) to estimate the parameters of the simultaneous model proposed. Second, this study tests the hypotheses that the size of external debt and the world price of oil are significant factors in exchange rate determination.

A Simultaneous Equation Model

The simultaneous equation model is presented in the following equations:

$$D_t = D_{t-1} + CAD \quad (1)$$

$$RR = R – P \quad (2)$$

$$CAD = a_o + a_1 (P/P^*) + a_2(Y/Y^*) = a_3L \quad (3)$$

$$e_X = b_o + b_1 (M/M^*) + b_2 (R/R^*) + b_3 (Y/Y^*)$$

$$+ b_4L + b_5D \quad (4)$$

$$Y = c_o + c_1RR + c_2 (M/P) + c_3G + c_4e_X \quad (5)$$

$$R = \alpha_o + \alpha_lY + \alpha_2 (M/P) \quad (6)$$

$$P = \beta_o + \beta_leX + \beta_2 P^* \quad (7)$$

Where:

D_t	=	current external debt
CAD	=	current account deficit
ex	=	exchange rate defined as domestic currency units per unit of foreign currency
P	=	domestic price level
M	=	money supply
R	=	nominal interest rates
RR	=	real interest rates
Y	=	real income
G	=	Government expenditure
L	=	world price of a barrel of crude oil, in $U.S. dollars
P	=percentage change in P	

The asterisks denote foreign variables.

The first expression is an identity expressing current debt as the sum of last period debt and the current account deficit. The second expression is also an identity decomposing the nominal interest rate into the real rate plus expected rate of inflation.

The third equation attempts to capture the major determinants of the current account deficit by expressing it as a function of relative prices, relative incomes, and the price of oil. This is similar to Galbis (1975) who expresses the current account as a function of national income, foreign income and the foreign exchange rate. It is hypothesized that CADS > 0, CAD2 > 0, and CAD< 0. The subscript i=1,2,3... denotes first partial derivative ol the dependent variable with respect to the ith independent variable. A relatively higher price level at home will tend to reduce exports or increase imports thus increasing the current account deficit. A relatively higher domestic real income, *ceteris paribus*, results in higher imports and a worsening current account deficit. Finally, a higher price of oil is expected to have an adverse impact on the CAD for net oil exporters and positively for net oil importers.

The fourth equation is a modified version of the monetary model of exchange rates [Johnson (1973, Frenkel (1976), Backus (1984)]. In addition to the usual variables such as relative money aggregates, relative interest rates, and incomes, it incorporates the external debt and the world price of oil as explantory variables in exchange determination - see Ajayi and Choi (1988). We hypothesize that $e_{x1} > 0$, $e_{x2} > 0$, $e_{x3} <> 0$, $e_{x4} < 0$ and $e_{x5} > 0$. A faster relative growth of money supply in the domestic economy results in domestic currency depreciation (an increase in ex) via inflation. In an economy with low inflation and no restrictions on capital mobility, a higher domestic interest rate results in capital inflows and an appreciation of the domestic currency. However, in many developing economies with high inflation expectations and restrictions on capital mobility, a higher relative domestic interest rate reflects inflation expectations and has a negative impact on the domestic currency values (or a positive impact on e_x).

The sign of the responsiveness of the exchange rate to real income differentials may be ambiguous. This is because the monetary model of exchange rates posits that an increase in real income raises the demand for money and thereby induces domestic currency appreciation. On the other hand, according to the asset approach, higher levels of real income increase import demand, worsen the balance of payment deficits and result in domestic currency depreciation. The sign of this parameter will therefore depend on whether our model is consistent wit the monetary or the asset views. Increases in the world price of oil should result in domestic currency appreciation (depreciation) for net exporter (importer) countries. And as for the external debt parameter, an increasing level of external debt should have a negative impact on the value of the domestic currency (or a positive impact on ex), since the external debt represents cumulative current account deficits.

The fifth equation expresses real national income as a function of real interest rates, the real money supply, government expenditures, and the foreign exchange rate. This is adapted from Bilson (1975) who proposed Y = f (R, e_x, Y* G, T), where T = taxes. It is hypothesized that Y1 < 0, Y2 > 0, Y3 > 0 and Y4 > 0. A higher real interest reduces investment spending and this results in lower national income. A sustained increase in money growth leads to a reduction in interest rates and an increase in national income and inflation. Also an increase in government spending leads directly to an increase in national income while a depreciating exchange rates (an increase in, e_x) should increase export receipts and thus increase national income provided that export demand responds sufficiently to the exchange rate depreciation.

In the sixth equation, the nominal interest rate is expressed as a function of the level of real income and the real money supply. We hypothesize that $R_1 < 0$ and $R_2 < 0$.

Equation seven states the purchasing power parity theory which establishes the relationship between the relative prices and the exchange rates. A higher exchange rate (a depreciating domestic currency value) should be associated with a rising price level. Also a rising price level abroad should have a positive impact on domestic price level via increasing export demand.

The Identification Problem

A two stage least squares estimation technique will be employed to estimate the parameters of the equation system. The 2SLS provides a very useful estimation procedure for obtaining the values of the structural parameters in exactly or over-identified equations. We shall therefore examine the system of equations (3) to (7) for identification. We shall employ a rule for identification called the "Order Condition". The condition states that if an equation is to be identified, the number of predetermined variables of the system excluded from the equation must be greater than or equal to the number of included endogenous variables minus 1. (Pindyck and Rubinfeld, 1981). By this condition all the equations in the system are over-identified. It is therefore possible to estimate the structural parameters from the reduced form model.

The model is estimated for the case of Nigeria and the data cover the period 1975-1986. We are interested in the exchange rate policy for a developing country in an era of generalized floating among the major currencies of the world. The choice of 1975 as a starting period is justified on the grounds that generalized floating which started in 1973 has, by 1975, become fairly well tested.

Data Sources

Quarterly data for the period were obtained from the *International Financial Statistics* (I.M.F.), *World Debt Tables* (World Bank), and *Annual Reports of the Central Bank of Nigeria*. Data definitions are as follows:

e_x	=	Naira per unit of the dollar
M	=	Currency in circulation and demand deposits (M1)
Y	=	Industrial production index
R	=	Treasury bill rates
DEB	=	Cumulative current account balances
L	=	U. S . dollar price of a barrel of Saudi Arabian Crude oil
CAD	=	Current account deficits
INT	=	R/R*
INCOME	=	Y/Y*
PRICE	=	P/P*
REALM	=	M/P
MONEY	=	M/M*
P	=	[(P-LAGP)/LAGP] x 100.

The asterisks denote equivalent U.S. variables.

Estimation Results

Estimation results are reported in Tables I and II. Table I shows 2SLS results for the equations of the system. As a result of first order autocorrelations observed in Table I correction measures were taken to resolve the problem. Further corrections for second and higher order auto-correlations were implemented for many equations of the system when these became necessary from the result of the first order corrections. The correction technique involves implementing an autoregressive procedure along with the unconditional least squares (ULS) option. The ULS method employed Gauss-Marquardt algorithms to minimize the error sum of squares for all observations.[1] The estimates of standard errors calculated with ULS method takes account of the joint estimation of the

[1] The Gauss-Marquardt algorithm involves minimizing the sum of squares and maximizing the log-likelihood respectively. The relevant optimization is performed simultaneously for both the regression and the Autoregressive Parameters. See SAS/ETS User's guide, version 5, SAS Institute, 1984.

autoregressive and regression parameters and may give more accurate standard error values than many other methods.[2]

Table II reports the final estimation results for all the equations in the system. Most of the signs of the parameter estimates for the exchange rate model turned out as predicted. Consistent with the monetary model of exchange rates, the coefficient of money is positive and significant in the exchange rate model. A relatively higher money growth in Nigeria has a statistically significant negative impact on the external value of the Naira. The relative interest rate parameter is however small, positive, and statistically insignificant. This means that this variable is not a significant factor in the determination of the value of the naira.

In the case of relative income the coefficient is positive and statistically insignificant. The fact that this coefficient is positive is consistent with the asset model of exchange rates. However since this variable is statistically insignificant, our expectation of an ambiguous sign for this variable remains credible.

It is interesting to note that the oil price sign is negative and statistically significant. This means that an increase in the world oil price is associated with an appreciation of the Nigerian naira. We therefore fail to reject the hypothesis that the world oil price level is a significant factor in the Nigerian exchange rate determination. Nigeria, as an oil-exporting country, should enjoy large increases (decreases) in export revenues as the world price of oil skyrockets (tumbles). The positive effect of such increased export revenues on the external value of the naira is confirmed in this model.

The coefficient of the external debt factor presents quite a surprise. It is positive, as expected, but very small and statistically insignificant. This leads to a rejection of our hypothesis that the size of the external debt is a significant factor in the Nigerian exchange rate determination. Given Nigeria's current debt crisis and the massive depreciation the naira has experienced over the period under study, it is hard to explain the insignificant contribution of external debt in the exchange rate determination.

---

[2] In the presence of autocorrelation, the ordinary least squares parameter estimates are not efficient and the standard error estimates are biased. The SAS autoreg procedure makes necessary transformations to produce better estimates in these cases. Several estimation options are available including Maximum Likelihood estimates (ML), Unconditional Lease Square estimates (ULS), and the Yule-Walker estimates (YW). The ULS method minimizes the error sum of squares for all observations and is also referred to as nonlinear least-square (NLS) or exact least-squares (ELS). The maximum likelihood methods estimate simultaneous equations system en block (full-information) or separate equations of a simultaneous equations system (limited information). See Hatanaka (1974) for a full discussion of several estimators.

A further investigation of the data however, reveals a substantial (80%) correlation between debts and oil prices. The model was subsequently re-estimated with the inclusion of one of the two variables and the exclusion of the other. However, the oil price remained statistically significant while the debt factor was still insignificant. It is quite possible that our model, as specified, does not fully capture the effects of external debt on exchange rates. On the other hand Nigeria may be a typical among the LDCs in its basic characteristics and economic structure. Either way, the issue of external debt in exchange rate determination remains an interesting question that warrants further research.

While the exchange rate model remains the major focus in this investigation the results of parameter estimates for other models of the system deserve an overview. Of the remaining four equations in the system, the CAD is the least satisfactory. It has three explanatory variables of which two (Income and L) are significant but their signs are at variance with our prediction. The price variable has the expected positive sign but it is not statistically significant. Overall, the CAD model has an R2 of 82% and a D.W. of 1.78, but these cannot diminish the model's lackluster performance and the possibility of the presence of specification errors in its construction.

The domestic real income (Y) model is the least satisfactory in the system. The real money parameter has the expected sign but it is not statistically significant. The other three variables are either statistically significant but lack the expected signs or have the expected signs but not significant. The domestic interest rate and domestic price models are the remaining two. Their parameter estimates have expected signs and their overall statistics are satisfactory.

Conclusion

Previous studies of exchange rate determination have featured traditional variables such as income, money supply, prices and interest rates. The questions of the role of external debt and the world price of oil in exchange rate determination have so far received little attention. Also most models of exchange rate determination are single equation models which ignore the simultaneous relationship between their independent variables.

In this study, we have taken explicit account of this simultanenity by employing a 2SLS technique to estimate the parameters of the simultaneous equation model proposed. In addition, we tested the hypotheses that the size of the external debt and the world price of oil are significant factors in exchange rate determination. The empirical results indicated that the price of oil has a positive and statistically significant impact on the external value of the Naira while the size of the external debt has a negative but statistically insignificant impact on the external value of the naira.

In general, the exchange rate model estimated within a simultaneous context displayed higher parameter values as well as higher t-values than the same model estimated as a single equation model. . Also in comparison to Bilson (1979), who estimated a similar single equation model, the current. model displays much higher parameter estimates.

The results suggest that in the management of exchange rates for Nigeria the monetary authorities must, in addition to the traditional variables of exchange rate determination, pay particular attention to the developments in the world price of oil and, to a lesser extent, the level of the country's external debt.

Table I

2SLS Results

Model	Variables	Parameter Estimates	T-Statistic	R^2	DW
CAD	C	-750.57	-4.089	0.72	0.92
	Price	1188.06	0.699		
	Income	-91.37	-6.78		
	L	-51.55	-4.179		
EX	C	2.26	2.016	0.32	0.40
	Money	0.0147	0.768		
	INT	-0.4098	-0.741		
	Income	0.0708	1.64		
	L	-0.05	-0.582		
	DEB	0.000068	0.781		
Y	C	92.23	2.575	0.58	1.10
	RR	0.5601	0.737		
	REALM	2.65	1.568		
	G	-0.01286	-2.651		
	EX	-0.6507	-0.088		
R	C	19.22	9.895	0.49	0.74
	Y	-0.022	-0.801		
	REALM	-0.589	-3.823		
P	C	3.18	-0.104	0.76	0.29
	EX	92.07	5.429		
	P*	0.856	6.434		

Table II

Autocorrelation-Corrected 2SLS Results

Model	Variables	Parameter Estimates	T-Statistic	R^2	DW
CAD	C	739.47	-2.1550	0.82	1.78
	Price	395.41	0.5030		
	Income	-88.76	-4.8450		
	L	51.19	2.7840		
EX	C	1.65	5.0020	0.97	1.66
	Money	0.00687	3.8760		
	INT	0.02026	0.3640		
	Income	0.00133	0.4420		
	L	-2.00371	-2.3930		
	DEB	0.000009	0.7860		
Y	C	155.37	9.0890	0.81	1.62
	RR	-0.519	-0.6009		
	REALM	-0.4467	-0.6228		
	G	-0.0125	-2.5620		
	EX	-8.558	-1.9603		
R	C	20.688	7.7590	0.78	1.64
	Y	-0.0796	-3.9610		
	REALM	-0.2533	-3.0500		
P	C	8.906	0.0032	0.96	1.83
	EX	11.372	0.9390		
	P*	0.072	0.5400		

References

Ajayi, R. and Choi, J. Jay, "Debt, Oil and Exchange Rates in Monetary and Asset" Models: The Case of Mexico," In *U.S. Mexican Economic Relations: Prospects and Problems,* Khosrow Fatemi, Ed., Praeger, 1988, pp. 53-59.

Backus, David, "Empirical Models of Exchange Rate: Separating the Wheat from the Chaff," *Canadian Journal of Economics*, XVII,no. 4, Nov. 1984, pp. 824-46.

Backus, David, "Rational Expectation and the Exchange Rate: Theory and Estimation," Paper presented at the American Economic Association Annual Meetings, Dec. 30, 1975 Dallas, Texas.

Backus, David, "Recent Development in Monetary Models of Exchange Rate Determination," *IMF Staff Papers*, no. 26, 1979,
pp. 201-23.

Boughton, James M., "Exchange Rate Movements and Adjustment in Financial Markets: Quarterly Estimates for Major Currencies, *IMF Staff Papers*, vol. 31, no. 3, Sept. 1984, pp. 445-68.

Branson, William H., "Macroeconomic Determinants of Real Exchange Risk," In R.J. Herring, Ed., *Managing Foreign Exchange Risk*, Cambridge University Press, 1983.

Cornell, Bradford and Shapiro, Allan C., "Interest Rates and Exchange Rates: Some New Empirical Results," *Journal of International Money and Finance,* 1985, 4, pp. 431-442.

Dornbush, Rudiger, "Expectations and Exchange Rate Dynamics," *Journal of Political Economy,* vol. 84, no. 6, Dec. 1976,
pp. 1161-1176.

Dornbush, Rudiger, "The Theory of Flexible Exchange Rate Regimes and Macroeconomic Policy," *Scandinavian Journal of Economics*, 2, May 1976, pp. 255-275.

Dornbush, Rudiger, *Open Economy Macroeconomics*, Basic Books Inc., Publishers, New York, 1980.

Dornbush, Rudiger, "Flexible Exchange Rate and Interdependence," *IMF Staff Papers*, vol. 30, no. 1, March 1983, pp. 3-30.

Dornbush, Rudiger, "External Debt, Budget Deficits, and Disequilibrium Exchange Rates," In G.W. Smith and J.T. Cuddington (Eds.), *International Debt and the Developing Countries*, The World Bank, Washington, D.C., 1985.

Edwards, Sebastian, "Sequencing Economic Liberalization in Developing Countries," *Finance and Development,* vol. 24, no. 1, March 1987, pp. 26-29.

Edwards, Sebastian, "On the Mark: A Theory of Floating Exchange Rate Based on Real Interest Differentials," *American Economic Review*, Sept. 1979.

Frenkel, Jacob A., "A Monetary Approach to the Exchange Rate: Doctrinal Aspects and Empirical Evidence," *Scandinavian Journal of Economics*, vol. 78, no. 2, May 1976, pp. 200-224.

Galbis, Vicente, "Monetary and Exchange Rate Policies in a Small Open Economy," *IMF Staff Papers*, vol. 22, July 1975,
pp. 313-343.

Hardouvelis, Gikas A., "Exchange Rates, Interest Rates, and MoneyStock Announcements: A Theoretical Exposition," *Journal of International Money and Finance*, 1985, 4, pp. 443-454.

Hodgson, John a. and Patricia Phelps, "The Distributed Impact of Price Level Variations on Floating Exchange Rates," *The Review of Economics and Statistics*, Feb. 1975, pp. 58-64.

Huang, Roger D., "Expectations of Exchange Rates and Differential Inflation Rates: Further Evidence on Purchasing Power Parity in Efficient Markets," *Journal of Finance,* vol. 42, no. 1, March 1987, pp. 69-79.

Johnson, Harry G., "The Monetary Approach to the Balance of Payments," In H. Johnson, *Further Essays in Monetary Economics,* Cambridge, MA: Harvard University Press, 1973.

Khan, Mohsin S., "Developing Country Exchange Rate Policy Responses to Exogenous Shocks," *IMF Staff Papers,* vol. 30, no. 4, Dec. 1986, pp. 84.

Khan, Mohsin S., and Knight, M.D., "Determinants of Current Account Balances of Non-oil Developing Countries in the 1970s: An Empirical Analysis," *IMF Staff Papers*, vol. 30, no. 4, Dec. 1983, pp. 819-42

Kincaid, Russell G., "A Test of the Efficiency of Exchange Rate Adjustments in Indonesia," *IMF Staff Papers*, vol. 31. no. 1, March 1984, pp. 62-92.

Kohlhagen, Stephen W., "The Performance of Foreign Exchange Markets: 1971-74," *Journal of International Business Studies,* Fall 1975.

Mussa, Michael, "Macroeconomic Policy and Trade Liberalization: Some Guidelines," *The World Bank Research Observer,* vol. 2, no. 1, Jan. 1987, pp. 61-77

Penati, Alessandro, Expansionary Fiscal Policy and the Exchange Rate: A Review," *IMF Staff Papers,* vol. 30, no. 3, Sept. 1983, pp. 542-69.

Pippenger, John E., *Fundamentals of International Finance*, Prentic-Hall Inc., 1984.

Pindyck, R.S. and Daniel Rubinfield, *Econometric Models and Economic Forecasts,* McGraw-Hill, 2nd Ed., 1981.

So, Jacky C., "The Behavior of Foreign Exchange Rates ...Comment," *Journal of International Business Studies,* vol. 27, no. 3, Fall 1986, pp. 165-175.

Somanath, V.S., "Exchange Rate Expectation and the Current Exchange Rate: A Test of the Monetarist Approach," *Journal of International Business Studies*, Spring/Summer 1984, pp. 131140.

Thomas, Lloyd B., "Behavior of Flexible Exchange Rates: Additional Tests From the Post War I Episode," *Southern Economic Journal*, Oct 1973 (a), pp. 167-82.

"Speculation in the Flexible Exchange Revisited -Another View," *Kyklos* (FASC.1), 1973 (b), pp. 143-49.