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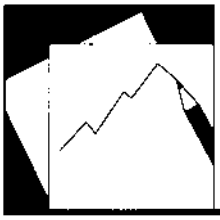

IMF Working Paper

Investigating Inflation Dynamics in Sudan

Kenji Moriyama

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Middle East and Central Asia Department

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Abstract

This paper investigates inflation dynamics in Sudan using three different approaches: the single equation model, the structural vector-auto regression model and a vector error correction model. This is the first study in a low-income and a post-conflict country that uses these three separate techniques to understand inflation dynamics. The use of these approaches is particularly useful to check the robustness of the estimated parameters in the model for a country with limited data coverage and possible structural breaks. The estimated results suggest that money supply growth and nominal exchange rate changes affect inflation with 18-24 months time lag.

10B
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I. INTRODUCTION

1. Inflation projection is one of the most important topics in the policy dialogue between country authorities and the IMF. This is especially the case for low-income and post-conflict countries where institutions and capacity are usually weak, making it particularly difficult to predict inflation. Although many low-income and post-conflict countries have recently enjoyed solid economic growth, some are now experiencing inflationary pressures caused by higher commodity prices, strong capital inflows, and rapid credit growth.

2. Recently, there have been several studies of inflation in low-income countries. These suggest a link between money supply, nominal exchange rate, and inflation. For example, Barnichon and Peiris (2007) used a panel co-integration method to verify the effects of money and the output gap on inflation in Sub-Saharan African countries. Blavy (2004) and Nassar (2005), applying a co-integration and error correction model, confirmed the long-run relation between consumer prices and money supply in Guinea and Madagascar, respectively. Mwase (2006) used a structural vector auto regression (SVAR) model to examine the pass-through effect of nominal exchange rate depreciation on inflation in the late 1990s in Tanzania.

3. However, studies on inflation dynamics in post-conflict countries have been sparse, largely reflecting limitations in data quality and coverage, as well as structural breaks in the economies. This paper examines the determinants of inflation in Sudan, looking in particular at the impact of money supply growth and nominal exchange rate developments on inflation, using three different estimation methods: single equation model, recursive SVAR, and vector error correction model (VECM). Comparing the results based on the three different estimating methods helps check the robustness of the estimated parameters for a country with limited data coverage, data quality problems, and possible structural breaks.

4. The estimated regressions provide the elasticities of inflation to money supply growth and nominal exchange rate appreciation, which give the magnitude of changes in money and nominal exchange rate on inflation. The results should be treated with caution given the limitations in data quality, the relatively low number of observations, and possible structural breaks. Nevertheless, they could help construct a monetary program in the short and medium term based on more solid economic analysis. The analysis could also assist the central bank in constructing and implementing its monetary policy framework—incorporating quantitative economic studies, particularly, the relation between inflation, money supply, and nominal exchange rate, which are generally considered to be most important determinants of inflation.

5. This paper is organized as follows. Section 2 provides background information on inflation, monetary, and exchange rate developments in Sudan. Section 3 discusses the model on which the estimated regressions are based. Section 4 presents the results of estimating the regressions, particularly, the effects of money supply and nominal exchange rate on inflation

using the three different methods. The elasticities of inflation to money supply and inflation in the short and medium term—critical information to construct the monetary program— are also computed from the estimated regressions. The last section discusses the policy implications and conclusions of the analysis.

II. BACKGROUND

6. Until the mid-1990s, the available monetary policy instruments for the Central Bank of Sudan (BOS) was limited.[2] Historically, to effect changes in monetary policy, the BOS set statutory reserve requirements only on local currency deposits; used a liquidity financing window, which functioned both as an overdraft and lender-of-last-resort facility; fixed minimum profit margins on Murabaha[3] contracts and minimum customers' share under Musharaka[4] contracts; and conducted foreign currency operations as a tool to control liquidity.

7. Since 1997, the BOS has gradually dismantled restrictions and liberalized the financial system, with the intention to encourage interbank activities and lending. At the same time, the BOS has introduced new instruments of indirect monetary policy management and has modified the existing instruments, including (i) the introduction of a reserve requirement on foreign currency deposits and the reduction of that requirement on local currency deposits; (ii) the introduction of Central Bank Musharaka Certificates (CMCs) and the elimination of long-standing, cost-free loan facilities to banks and public enterprises; (iii) the opening of a financing window with uniform rules of access, which simultaneously serves as general financing, lender-of-last-resort, and overdraft purposes; and (iv) the unifying and reduction of the minimum profit margins under the Murabaha contracts. Also, with a view to strengthening monetary management and analysis, the BOS established a Monetary Policy Committee—a key steering body for monetary policy.

8. The BOS has used broad money as the policy target since May 2002, and has established several analytical units to determine and implement short-term monetary policy, where reserve money is considered to be the operational target in its monetary policy framework. However, the monetary policy framework implemented by the BOS has been vague. In principle, targets for broad money and reserve money growth should be set

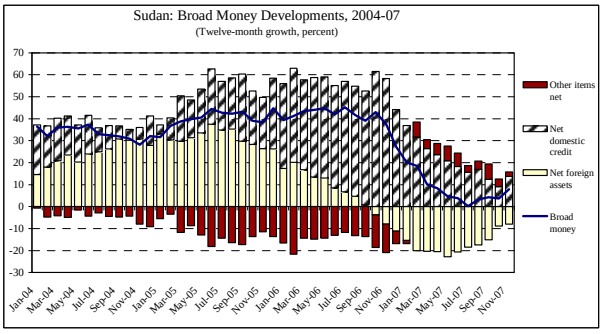
[2] For a more detailed discussions, see Kireyev (2001).

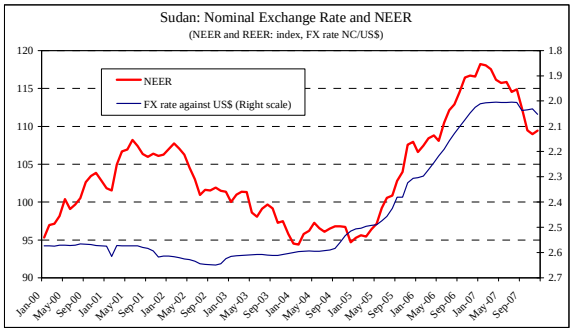
[3] Murabahah is a trade financing contract. Typically, an islamic bank purchases a product (commodity, raw material, etc.) to supply an entrepreneur who does not have his own capital to do so. The bank and the entrepreneur agree on a profit margin which is added to the cost of the product. Payment is delayed for a specific period of time during which the entrepreneur produces the final product and sells it to the market. In the contract, the bank must take the ownership of the product on sale. For details, see Iqbal and Mirakhor (2007).

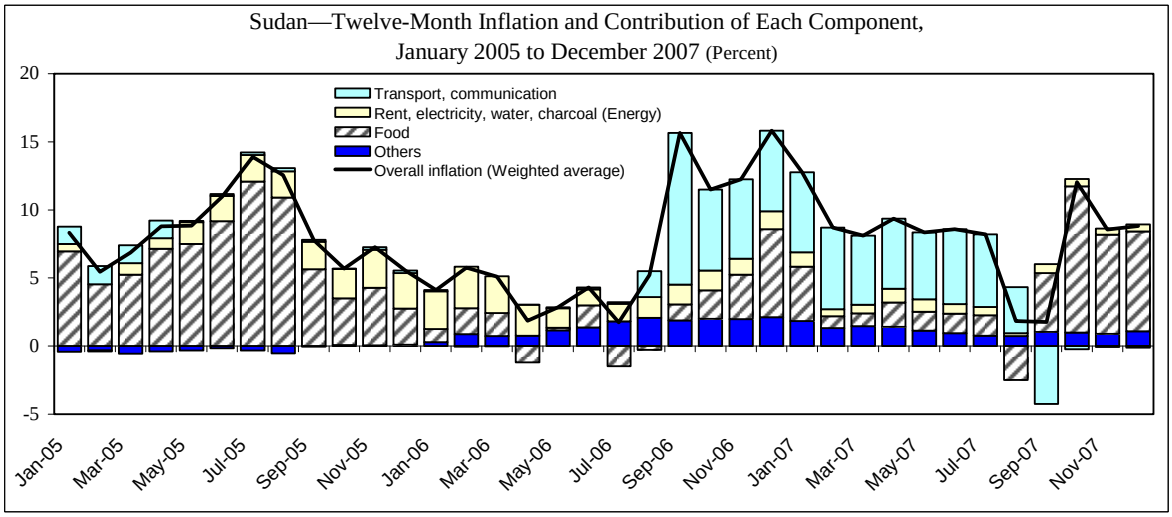
[4] Musharakah is a form of partnership contract where two or more people combine their capital to share the profits and losses, and where they have similar rights and liabilities. For more details, see Iqbal and Mirakhor (2007).

consistent with money demand growth (accounting for financial deepening), real economic growth, and inflation. However, to date, the BOS has neither a model nor the estimated parameters of the relation between monetary aggregates, nominal exchange rate, and inflation based on economics—which would be essential pillars in constructing and implementing its policy framework.

9. Monetary policy in recent years has been accommodating, with a loose fiscal policy and strong capital inflows after 2005. Broad money growth rate (12-month) was over 40 percent during 2005 and 2006 (left chart below). Such an accommodating monetary stance has resulted in inflationary pressures—nonfood, nonenergy and non-transportation[5] (others in the chart on inflation below)—on the economy, despite the sharp nominal appreciation of the Sudanese dinar/pound by about 20 percent against the U.S. dollar, and the trade-weighted nominal effective exchange rate (NEER, right chart below).







10. Since the second half of 2006, the BOS started to sell foreign currency to the market to mop up liquidity. Even after the nominal exchange rate of the dinar against the U.S. dollar

[5] The spike in inflation in transportation sector after September 2006 was caused by the one-off cut in fuel subsidy in August 2006.

was stabilized, the BOS continued to intervene in the market to maintain exchange rate and macroeconomic stability, and to ensure a smooth conversion to the new Sudanese pound. This policy was costly in terms of international reserves—net international reserves declined sharply from US$2.3 billion, equivalent to 2.8 months of imports, in August 2006 to about US$0.6 billion, equivalent to 0.6 months of imports, in May 2007—and led to a sharp decline in money supply growth during the second half of 2007. Since the completion of the currency conversion in mid-2007, the BOS has put more priority on rebuilding international reserves and allowing greater exchange rate flexibility, leading to a decline in the nominal value of the pound vis-à-vis the U.S. dollar by over 3 percent and much wider day-to-day fluctuations.

11. The slowdown in broad money growth and relative stability of the pound through most of 2007 has helped to reduce inflationary pressures. Inflation excluding food, energy, and transportation components declined from 16.5 percent (12-month) in December 2006 to 7.8 percent in December 2007.

III. MODEL

12. The structural approach to time series modeling uses economic theory to model the relationship among variables. Economic theory, however, does not provide sufficient information on the dynamic specification of the relationship between variables. Moreover, estimation and inference may be distorted by the existence of endogenous variables on both the left- and right-hand sides of the equations. These problems lead to alternative, nonstructural approaches to modeling the relationship among several variables, for example, the error correction model, the vector auto-regression (VAR) model, and the vector error correction (VEC) model, which are used in this paper.

13. In the short to medium term, inflation is posited to be affected by monetary innovations, exchange rate changes, foreign inflation, and aggregate demand shocks. Money supply shocks affect prices as they generate excess supply/demand conditions in the money market. Similarly, domestic prices are impacted via pass-through effects from fluctuations in the nominal exchange rate and imported goods' prices. Lastly, the Phillips curve suggests that aggregate demand, measured by non-oil GDP, would impact inflation at least in the short and medium run. While the price of oil could (given Sudan's substantial oil exports) impact domestic prices through a wealth effect that raises aggregate demand, oil revenue management in Sudan suggests that such a wealth effect would be captured to some extent by the accumulation of international reserves in the central bank, implying some of the effect could be captured by money supply developments.

14. The model is based on two basic relations: (i) the composition of the overall price index; and (ii) the quantity theorem of money.

First, the overall price index consists of domestic price (P_d) and foreign price (P_*) components.

$$P = P_d^{\alpha} (EP_*)^{1-\alpha} \quad (1)$$

where α is the share of the domestic component and is assumed to be constant over time, and E is the nominal exchange rate. Equation (1) suggests that overall inflation is a function of domestic inflation, nominal appreciation/depreciation, and foreign inflation. Nominal appreciation would reduce inflation given other conditions (the pass-through effect), while an increase in foreign prices would result in a higher overall price index (imported inflation).

Second, the domestic prices component is assumed to follow the quantity theorem of money.

$$MV = P_d Y \quad (2)$$

Where M is money supply, V is the velocity, and Y is real (non-oil) GDP. Equation (2) implies that increasing the money supply would lead to higher prices given the money demand as a function of the velocity and real GDP. Because velocity usually has a negative time trend ($\theta < 0$, as velocity typically declines with financial deepening) taking the natural logarithm of equation (2) gives

$$p_d = m - y + \theta t + \eta \quad (3)$$

where small letters indicate natural logarithm value and η indicates any disturbances of the velocity other than the time trend component.

15. Taking the natural logarithm of equation (1) and combining it with equation (3) gives overall inflation as a function of money supply, real GDP, nominal exchange rate, and foreign inflation, which is the regression to be estimated in this paper:

$$p = F(e, m, y, p_*; Z) = X\beta + Z\gamma + \varepsilon \quad (4)$$

where $X = (e, m, y, p_*)$, Z is a set of control variables (if necessary) including time trend, and ε is an error term. Coefficients for money supply and nominal exchange rate should capture the effects of monetary policy and import prices, respectively, on inflation. The set-up of the model suggests a positive effect of money supply, a negative effect for that of nominal exchange rate, and a positive effect for that of foreign deflator.

16. This paper uses three approaches to estimate equation (4), given the results of the unit root test.[6] The first is the *single-equation model* with the first difference of each variable including the error collection component, incorporating an idea that the deviation from the long-run relation affects the speed of inflation adjustment. The second approach is the structural (recursive) *vector auto regression* (VAR) *approach* developed by McCarthy (2000),[7] assuming the recursive relation among the disturbance terms of the system. The third approach is the *vector error correction model* (VECM) assuming the existence of co-

[6] See Appendix I and Table 1.

[7] McCarthy's original paper used quarterly data for eight variables (oil price inflation, the output gap, exchange rate change, import price inflation, Producer Price Index (PPI) inflation, CPI inflation, short-term interest rate, and money growth) to estimate the pass-through rate of nominal appreciation on import price inflation assuming a recursive structure of an economy.

integration vector(s), capturing the long-run relation among the variables, and the deviation from the long-run relation affects the speed of inflation adjustment.

17. The short- and medium-term elasticities of inflation to money supply and nominal exchange rate are computed from the impulse responses[8] of the estimated regression, where the elasticities are obtained by dividing the cumulative impulse responses of CPI inflation after j months by the cumulative response of the money growth (nominal exchange rate changes) shock after j months (Leigh and Rossi 2002; Gueorguiev 2003).

IV. DATA ISSUES AND RESULTS

18. Sudan presents a particular challenge with respect to data. In general, there is tension between long time-series (which gives a greater degree of freedom to estimate a regression) and the likelihood for longer series to contain structural breaks in the data. This possibility is especially critical for Sudan, where there have been numerous structural changes, including the greater integration of the South following the Comprehensive Peace Agreement (CPA) in 2005, the introduction of a new monetary policy framework in 1997, and the start of oil production in 1998. Although it is reasonable to assume that structural breaks accompanied such events, restricting the data period to exclude these breaks does not allow for sufficient observations to yield efficient estimates. Appendix I discusses data used in the analysis.

19. This section presents the estimated results of equation (4) using the three approaches: the single equation model, the structural vector auto regression (VAR) model, and the vector error correction model (VECM) assuming the co-integration relation among the regressors. Regressions include a dummy for the monetary policy framework change and a fuel subsidy cut dummy during Q3 2006 to control exogenous structural changes.

A. Single-Equation Model

20. Regression based on the single-equation model is derived by taking the first difference of equation (4).

$$\Delta p_t = \Delta x_t \beta + z_t \gamma + \varepsilon_t \qquad (5)$$

where $x_t = (e_t, m_t, y_t, p_t^*)'$, z is a set of control variables, and Δ indicates the first difference. Equation (5) suggests that inflation depends on money supply growth, real GDP growth, nominal exchange rate appreciation/depreciation and foreign inflation in the same period. There are two variations to equation (5). One is to add the lag of inflation, intended to incorporate the adjustment costs to change inflation. The other is to add the error correction component which consists of the lag of price index, money supply, real non-oil GDP, nominal exchange rate, and foreign prices. The error correction component is expected to

[8] Impulse responses trace the effect of a one-time shock to one of the innovations (or error terms in the VAR system) on current and future values of the endogenous variables in the VAR system.

capture the idea that inflation depends not only on the contemporary developments of the factors but also on the deviation of inflation from that implied by the long-run relation among the variables, suggesting that developments of explanatory variables in the past would also affect the current inflation rate.

21. The estimated regressions, assuming AR(1) process in the error term with applying the Cochrane-Orcutt method, are presented in Table 2. The main results are summarized as follows:

(a) Nominal appreciation/depreciation (Δfx) affects inflation in all specifications, suggesting the existence of the pass-through effects on inflation. Also, the estimated coefficient of foreign inflation (Δp^*) is marginally significant in the specifications with the error correction component (specifications (iii) and (iv)), implying that some of the inflation in Sudan is imported.

(b) Error correction component is significant (specifications (iii) and (iv)). Adding the error correction component makes the effect of contemporary money supply growth on inflation insignificant (compare (i) and (iii), and (ii) and (iv), respectively). This observation may suggest the time lag of the effects of monetary policy on inflation, i.e., a change in money supply would affect inflation after several quarters. The error correction component may, therefore, include the accumulated effects of money supply change in the past.

(c) Sign of the estimated coefficients of variables in the error correction component is in line with the model discussed previously: the increase in money supply raises price level; the nominal appreciation reduces price level (the pass-through effects); and higher foreign prices leads to an increase in overall price level (the imported inflation).

22. The elasticities of inflation to money supply and nominal exchange rate based on specification (iv) suggest that a permanent increase in money supply growth and nominal appreciation by one percentage point would raise inflation by 0.32 and -0.63 over 12-months and 0.48 and -0.73 over 24-months, respectively (Table 3), with most of the response of inflation completed within two years.

23. The estimated elasticities may, however, be biased because the specification misses one important fact—money is neutral in the long run as suggested by the quantitative theory of money, equivalent to assuming that the sum of the estimated coefficients of money (m_{-1}) and nominal exchange rate (fx_{-1}) is one in equation (5) (or specification (iv) in Table 2) in a small open economy with free capital mobility. The estimated elasticities with the constraint in Table 2 suggest that a permanent increase in money supply growth and nominal appreciation by one percentage point would raise inflation by 0.46 and -0.26 over 12-months and 0.71 and -0.34 over 24-months, respectively (Table 3). Compared to the estimated regression without the restriction, adding the constraint increases the elasticity of money supply, while the elasticity of inflation to nominal exchange rate declines, suggesting money

supply growth would affect inflation through nominal depreciation caused by the change in money supply growth.

24. The estimated elasticities may also be biased because the regression is based on a single-equation model and thus does not take into account interrelation among the variables. Considering the interrelation using the vector auto regression model (VAR) would, therefore, help mitigate such biases in the single-equation model.

B. Structural Vector Auto Regression Model (SVAR)

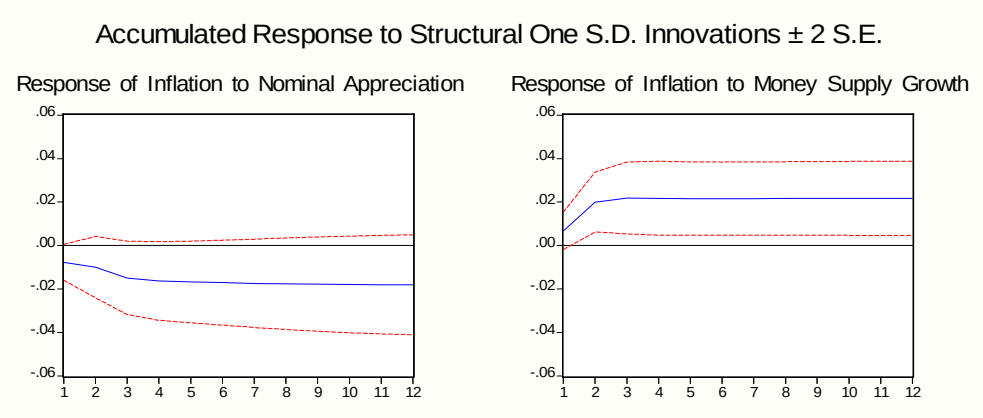
25. This model follows McCarthy (2000) by assuming the recursive structure of the economy (Appendix II): (i) foreign inflation is exogenous to the system and thus affects all disturbances to real GDP growth, nominal appreciation/depreciation, money supply growth, and inflation; (ii) demand shocks to GDP (u^y) affect disturbances of the variables other than foreign inflation; (iii) money supply shocks affect the disturbances of nominal appreciation/depreciation and inflation; (iv) nominal appreciation/depreciation shock does not affect money supply shocks, reflecting a common and reasonable assumption that the central bank can set money supply growth as a policy variable.

26. The length of lag is selected based on the Schwarz Information Criterion (SIC) (Table 4). The estimated structural VAR gives the impulse responses of inflation to money supply growth and nominal appreciation, and the elasticities of inflation to money supply growth and nominal appreciation (Table 3).

27. The main results of the model are summarized as follows:

(a) Both the nominal depreciation and the increase in money supply growth would result in higher inflation, while the response of inflation to nominal appreciation is marginally significant. Most of the adjustment of inflation would be over within one year (see the impulse response charts below).

(b) The estimated elasticities of inflation to money supply and nominal exchange rate are 0.57 and -0.23 for 12-months, and 0.57 and -0.25 for 24-months, respectively. Although the signs of the elasticities are consistent with those the theory implied, their magnitude is different from the magnitude based on the single-equation model, but similar to the results with the long-run constraint. The difference may be caused by ignoring the long-run relation (the error correction component), which was significant in the single-equation model, and the time lag of monetary policy on inflation (the impulse responses are based on the estimated model with lag one).



28. To check the latter hypothesis, the structural VAR model with 2 lags (the second smallest SIC value in Table 4), has also been estimated. Under this assumption, the estimated elasticities to money supply and nominal exchange rate are 0.26 and -0.48 for 12-months and 0.21 and -0.63 for 24-months, respectively. This result—that the elasticity to nominal exchange rate is larger than that to money supply—is similar to that based on the single-equation error correction model (ECM), in line with the time-lag effects of monetary policy.

C. Vector Error Correction Model (VECM)

29. In the system of the VECM, equation (4) is expressed as follows.

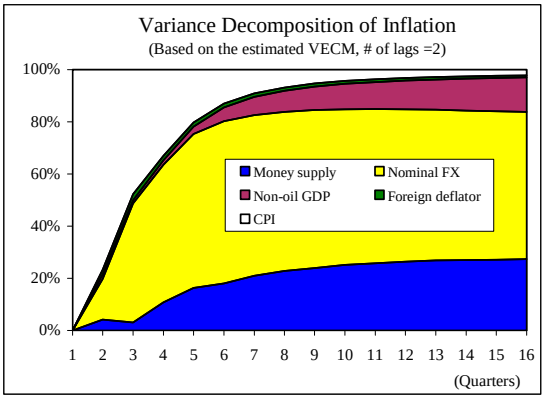
$$\Delta x_t = \phi(L)\Delta x_t + x_t^{'}\delta + z_t\gamma + \varepsilon_t \qquad (7)$$

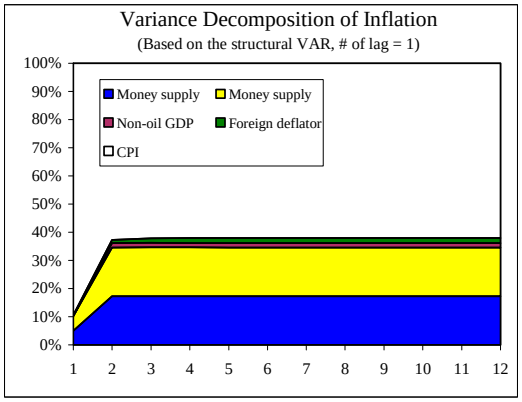
where $x_t = (e_t, m_t, y_t, p_t^*)'$, Δ indicates taking the first difference, and $\phi(L)$ is the coefficients matrix (matrices) for lag operators L. δ is the co-integration vector(s) capturing the long-run relation among the variables in the system. The lag length for the system (7) is selected to be 2 based on the Schwarz Information Criterion (SIC) (Table 4).

30. The results of a co-integration test (the Johansen test, Table 5) suggest two co-integration vectors. The estimated coefficients of the two co-integration vectors are mostly significant in the system, suggesting that the deviation from the long-run relation affects inflation. The elasticities of inflation to money supply and nominal exchange rate derived from the impulse responses based on the estimated VEC system are 0.15 and -0.41 for 12-months, and 0.34 and -0.99 for 24-months, respectively (Table 3). These results are in line with those based on the single-equation model and the structural VAR with two lags, implying the elasticity to nominal appreciation is larger than that to money supply, while the results of the single equation with the long-run constraint imply that money supply could affect inflation through nominal exchange rate fluctuations in an open economy.

31. The variance decomposition based on the estimated VEC system—separating the variation in inflation into the component shocks to the VEC system—suggests that more than 80 percent of CPI inflation fluctuations in Sudan in recent years could be explained by money supply (about 25 percent) and nominal exchange rate (about 55 percent) fluctuations

(left chart below). This is a remarkable improvement in explanatory power compared to the structural VAR model (right chart below). The decomposition chart based on the VEC system suggest that most of the adjustment of inflation would be over 18-24 months after the shocks. This period is longer than the one based on the structural VAR, reflecting the consideration on the long-run relation in the VEC system.





V. POLICY IMPLICATIONS AND CONCLUSIONS

32. The results presented in the previous section—based on the three different estimating methods to check for robustness—can be summarized as follows:

(i) Both money supply and the nominal exchange rate affect inflation in Sudan. These results are robust. The nominal exchange rate appears to have a stronger impact on inflation than money supply when the time lag of the effects of monetary/exchange rate policy is taken into account in the model with the error correction component, co-integration vector(s) and longer lags in the system.

(ii) The long-run relationship implied by the error correction term and the co-integration vectors significantly affects inflation dynamics in Sudan—consistent with the time lag of the effects of monetary/exchange rate policy on inflation. The estimated elasticities and the variance decomposition suggest the time lag is from 18 to 24 months.

(iii) The estimated elasticity of inflation to money supply is substantially lower than one. However, The estimated elasticities with the long-run constraint in the single-equation model also suggest that money supply growth may affect inflation through nominal exchange rate fluctuations generated by the change in money supply.

(iv) The sum of the elasticities of inflation to money supply and nominal exchange rate is not far from one in the long run, broadly confirming the simple quantity theory of money in an open economy. This observation suggests that the estimated results would be useful for monetary program over the short to medium term.

33. These observations are consistent with recent inflation developments in Sudan. Stable food prices contributed to keeping overall CPI inflation low during the second half of 2005 and throughout 2006, despite faster monetary growth since early 2005. The nominal appreciation of the dinar/pound by about 20 percent vis-à-vis the U.S. dollar during 2005 and 2006 helped mitigate inflationary pressures through lower import prices. Also, inflation developments, excluding food, energy, and transportation (including level shift caused by the fuel subsidy elimination) suggest a decline in money supply growth as a result of sharp appreciation of dinar/pound after the second half of 2006 appears to have lessened inflationary pressures during 2007.

34. The large elasticity of inflation to the nominal exchange rate estimated in the previous section is consistent with the authorities' view on the relationship between the nominal exchange rate and macroeconomic stability in Sudan. Since the beginning of 2007, the BOS has intervened by selling foreign exchange to stabilize the nominal exchange rate—even at the cost of a sharp decline in international reserves.[9] Although the authorities recognize that exchange rate flexibility is necessary to rebuild reserves, they have also emphasized that smoothing short-term volatility in the nominal exchange rate is important from the viewpoint of macroeconomic stability.

35. The pronounced relationship between the nominal exchange rate and inflation could be another reason why the authorities put more emphasis on nominal exchange stability—over and above concerns about the negative impact of depreciation on capital inflows. The high degree of elasticity of inflation to the nominal exchange rate suggests that nominal depreciation as a result of allowing exchange rate flexibility would cause higher inflation, leading to a sharp decline in investment because of a surge in the user cost of capital.[10] Such huge fluctuations in investment would hurt macroeconomic stability, even without the reversal of capital inflows.

36. Given the relation between oil prices and the real exchange rate, the BOS should fine tune its policy to focus more on maintaining stable inflation. Although the results presented in this paper should be treated with caution given the limitations on data and possible structural changes, the estimated relation between inflation, money supply, and nominal exchange rate should help the BOS construct and implement its monetary policy framework based on economic theory and empirical results rather than the current vague framework.

[9] IMF (2007).

[10] Hassett and Hubbard (1999). The surge in the user cost of capital by an increase in inflation is caused by (i) rising nominal interest rate and (ii) (accounting) depreciation is based on the nominal value of capital stock at installment, implying that inflation would reduce the benefits of tax allowances on depreciation.

APPENDIX I: Data Issues

The data in this paper spans Q1 1995 to Q2 2007. This series excludes the large devaluation of the domestic currency in 1994 (by about 45 percent from Q2 to Q3). A dummy variable is included to capture the 1997 change in the monetary policy regime. Also, a Q3 2006 dummy is inserted to capture the level change in price level caused by the reduction in the domestic fuel subsidy.

All data used to estimate the regression in this paper is on a quarterly basis. The consumer price index (seasonally adjusted) is taken from the International Financial Statistics (IFS). Money supply, defined as money plus quasi-money, is from IFS, where the X-12 ARIMA method is used to compute the seasonally adjusted series of money supply. Quarterly non-oil GDP data is estimated by the linear projection of annual non-oil GDP from the World Economic Outlook (WEO) and IMF staff estimates.[1] Foreign inflation is proxied by the world GDP deflator, given as the imports weighted average, taken from Global Economic Environment (GEE).

There are several possible choices for a proxy of the nominal exchange rate to estimate the pass-through effects on inflation.[2] Although nominal effective exchange rate (NEER), which is the trade weighted average of nominal exchange rate, is easy to use for estimating regressions, it may not be a good proxy for import prices because export data is also used to estimate NEER. This paper, therefore, uses the import weighted average of the nominal exchange rate (calculated by the author from the Direction of Trade Statistics) and the nominal exchange rate (from the INS) as a proxy for the imported price index.

In general, macroeconomic variables such as CPI, money supply, GDP, nominal exchange rate, and GDP deflator are considered to be I(1) process, i.e., they have unit root. The results of the unit root tests are broadly in line with the existence of unit root (Table 1).

[1] Non-oil GDP data is based on IMF (2007).

[2] Sudan lacks an import price index, which is typically used to estimate such pass-through effects.

APPENDIX II: Structural Model Assumptions

These assumptions presented in the text can be described as a linear system of five equations.

$$\Delta p_t^* = E_{t-1}\Delta p_t^* + u_t^{p^*}$$
$$\Delta y_t = E_{t-1}\Delta y_t + a_1 u_t^{p^*} + u_t^y$$
$$\Delta m_t = E_{t-1}\Delta m_t + a_2 u_t^{p^*} + a_3 u_t^y + u_t^m$$
$$\Delta e_t = E_{t-1}\Delta e_t + a_4 u_t^{p^*} + a_5 u_t^y + a_6 u_t^m + u_t^e$$
$$\Delta p_t = E_{t-1}\Delta p_t + a_7 u_t^{p^*} + a_8 u_t^y + a_9 u_t^m + a_{10} u_t^e + u_t^p$$

where Δ indicates the first difference and E represents the conditional expectation operator. In addition, let us assume that the conditional expectations in the set of equations can be replaced by linear projections of lags for the five variables in the system (the choice of lag is based on SIC). These assumptions would lead to the following recursive (structural) VAR system.

$$y_t = A(L)y_{t-1} + Bu_t$$

where $y = (\Delta p^*, \Delta y, \Delta m, \Delta e, \Delta p\ )'$, $u = (u^{p^*}, u^y, u^m, u^e, u^p)'$ and

$$B = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ a_1 & 1 & 0 & 0 & 0 \\ a_2 & a_3 & 1 & 0 & 0 \\ a_4 & a_5 & a_6 & 1 & 0 \\ a_7 & a_8 & a_9 & a_{10} & 1 \end{bmatrix}.$$

Table 1. Unit Root Tests 1/
(t-statistics. Null: Unit Root)
(*First Difference*)

	ADF test 2/	DF test 3/	PP test 3/
CPI	-1.450	-3.456 **	-3.737 **
Broad money	-6.014 ***	-6.004 ***	-6.081 ***
Non-oil GDP	-3.088	-3.154 *	-3.221 *
Trade weighted FX	-5.733 ***	-4.864 ***	-8.784 ***
Foreign deflator	-3.032 **	-2.167	-2.926 **

1/ * indicates 10 percent, ** indicates 5 percent, and *** indicate 1 percent significance, respectively.
2/ Augumented Dickey-Fuller Test.
3/ Dickey-Fuller GLS Test.
4/ Phillip-Perron test

Table 2. Estimated Regressions 1/ 2/ 3/

	(i)	(ii)	(iii)	(iv)
Δp_{-1}		0.201		-0.064
		(2.14)		(-0.48)
Δm	0.139	0.187	-0.015	-0.022
	(1.50)	(2.12)	(-0.14)	(-0.20)
Δy	0.433	0.187	1.004	1.065
	(0.86)	(0.41)	(1.73)	(1.71)
Δfx	-0.104	-0.137	-0.207	-0.200
	(-1.80)	(-2.46)	(-3.17)	(-2.96)
Δp^*	-3.883	-2.480	7.505	7.667
	(-1.10)	(-0.78)	(1.50)	(1.48)
Error Correction term			-0.307	-0.313
			(-2.85)	(-2.88)
p_{-1}			1.000	1.000
m_{-1}			-0.729	-0.755
			(-3.02)	(-2.89)
y_{-1}			-0.513	-0.510
			(-0.66)	(-0.64)
fx_{-1}			0.877	0.884
			(5.76)	(5.50)
p^*_{-1}			-7.178	-7.833
			(-1.82)	(-1.69)
Adjusted R^2	0.904	0.929	0.930	0.921

1/ AR(1) process is assumed in the error term. Cochrane-Orcutt method is used.

2/ Time trend, fuel subsidy cut dummy and after 1997 dummy are added.

3/ Number in parenthesis is t-statistics.

Table 3. Elasticities of Inflation to Money Supply and Nominal Exchange Rate

(Based on **the single-equation model**)

	6 months	12 months	18 months	24 months	30 months	36 months
Money Supply	0.19	0.32	0.41	0.48	0.52	0.55
Nominal Exchange Rate	-0.53	-0.63	-0.69	-0.73	-0.75	-0.77

(Based on **the single-equation model with the long-run constraint**)

	6 months	12 months	18 months	24 months	30 months	36 months
Money Supply	0.30	0.46	0.60	0.71	0.81	0.89
Nominal Exchange Rate	-0.21	-0.26	-0.30	-0.34	-0.37	-0.39

(Based on **the structural VAR**)

	6 months	12 months	18 months	24 months	30 months	36 months
Money Supply	0.49	0.57	0.57	0.57	0.57	0.57
Nominal Exchange Rate	-0.15	-0.23	-0.24	-0.25	-0.25	-0.25

(Based on **the VECM**)

	6 months	12 months	18 months	24 months	30 months	36 months
Money Supply	0.08	0.15	0.26	0.34	0.39	0.44
Nominal Exchange Rate	-0.12	-0.41	-0.70	-0.99	-1.18	-1.24

Table 4. Schwartz Information Criterion (SIC) and Akaike Information Criterion (AIC)

(*Structural VAR*)

# of lags	SIC	AIC
1	-27.90	-29.46
2	-27.54	-30.07
3	-27.29	-30.79
4	-26.31	-30.79
5	-26.85	-32.31

(*Vector Error Correction Model*)

# of lags	SIC	AIC
1	-28.00	-29.98
2	-28.15	-31.12
3	-27.50	-31.44
4	-27.36	-32.27
5	-27.81	-33.70

Table 5. Johansen Co-Integration Tests 1/

Unrestricted Co-integration Rank Test (Trace)

Hypothesized # of Co-integration(s)	Eigenvalue	Trace Statistic	5% Critical Value	P-value
None	0.777	146.477	88.804	0.000 *
At most 1	0.543	74.463	63.876	0.005 *
At most 2	0.368	36.872	42.915	0.176
At most 3	0.170	14.863	25.872	0.586
At most 4	0.116	5.913	12.518	0.471

Unrestricted Co-integration Rank Test (Maximum Eigenvalue)

Hypothesized # of Co-integration(s)	Eigenvalue	Max-Eigen Statistic	5% Critical Value	P-value
None	0.777	72.014	38.331	0.000 *
At most 1	0.543	37.591	32.118	0.010 *
At most 2	0.368	22.009	25.823	0.147
At most 3	0.170	8.950	19.387	0.730
At most 4	0.116	5.913	12.518	0.471

1/ * indicates 5 percent significance.

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