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PRICE AND EXCHANGE RATE DYNAMICS IN KENYA: AN EMPIRICAL INVESTIGATION (1970-1993)

NJUGUNA S. NDUNG'U

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Price and exchange rate dynamics in Kenya: An empirical investigation, (1970-1993)

Njuguna S. Ndung'u
University of Nairobi

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Abstract

The paper investigates the relationships between domestic and foreign price levels and the exchange rate and other macro-variables. In the first part, the real exchange rate is estimated as a cointegrating vector that spans the variables in a purchasing power parity relation. An exchange rate pass-through equation is estimated, and it is seen that the rate of inflation is affected largely by the pass-through effects from exchange rate changes and the world rate of inflation.

In the second part, real income, domestic credit and foreign exchange reserves are incorporated. Since we find cointegration among the variables, the variables are used in the Granger non-causality tests in their log differences and the long-run relationships, the cointegrating vectors. The results show that exchange rate and the rate of inflation drive each other; foreign exchange reserves, domestic credit and the exchange rate drive each other; and domestic credit drives the rate of inflation with no reverse effects.

However, in the dynamic analysis, the exchange rate and the rate of inflation are dominant in accounting for their own innovations and are little aided by the shocks in other variables. Introducing money supply growth instead of domestic credit does not significantly alter the results.

I. Introduction

Inflation has been a major issue in Kenya since the 1980s. Since the 1970s, the rate of inflation has varied, at times moving to double digit, but it was not until the late 1970s and from the 1980s that inflation was considered a serious problem. The rate of inflation has risen tremendously, while at the same time the exchange rate has continuously depreciated since the early 1980s. The Kenya shilling was pegged to the sterling pound from 1966; the peg was changed to the US dollar in 1971 and to the special drawing right, (SDR), in 1975. In December 1982, the peg was changed to a standard basket of currencies and allowed to crawl in real terms. The adoption of a crawling peg exchange rate in 1982 compounded the inflation problem. This implied that the exchange rate would adjust itself to inflation rate differentials between Kenya and its major trading partners. Thus inflation in Kenya is seen to also depend on the exchange rate regime in operation.

Taken more broadly, by adopting a crawling peg exchange rate, most researchers have argued, the authorities decide to live with relatively high inflation (Edwards, 1993). The rate of inflation and the exchange rate regime in operation are closely related. The adoption of a crawling peg exchange rate, say some researchers, may imply that the economy loses a nominal anchor that could control inflation and so the rate of inflation could become uncontrollable (see Adams and Gros, 1986). This is because the exchange rate and money supply are indexed to the price level. Adams and Gros (1986) show that a real exchange rate rule can lead to a complete monetary accommodation. On the other hand, Blejer and Leiderman (1981) have shown that by following an exchange rate rule a country could determine its long-run rate of inflation independent of the rest of the world. Durevall (1993) has shown that these contradictory results arise from the assumptions made about the functioning of the money market and that following a real exchange rate rule is not sufficient to induce the loss of money as a nominal anchor.

Some researchers have also argued that exchange rate changes and the rate of inflation affect each other to produce an inflation-devaluation spiral or even a vicious circle in flexible exchange rate regimes (Bond, 1980; Kenen and Pack, 1980), or pass-through effects from the exchange rate changes and the foreign price level (Klein, 1990). These effects may thus worsen the domestic rate of inflation.

The literature on exchange rate pass-through suggests that the exchange rate and the foreign price level affect the domestic price level, while the vicious circle hypothesis maintains that the exchange rate changes constitute an independent source of inflationary pressure and that the exchange rate and the price level should drive each other (Bilson, 1979; Bond, 1980; Kenen and Pack, 1980).

The pass-through effects from both the exchange rate changes and the foreign price level depend upon the structure of the economy. The strength of the pass-through effects depends on the price elasticities (Kenen and Pack, 1980). On the other hand, loss of the nominal anchor could imply that shocks to the rate of inflation will have lasting effects, pushing the rate of inflation to a higher level and depreciating the exchange rate. In this case, exchange rate movements, money supply growth, changes in foreign exchange reserves and the rate of inflation will drive each other.

The experience of Kenya in the early part of 1993, when the exchange rate and the domestic price level were severely unstable, is a good example. This was a period when an aid embargo was taking effect, and accelerating money supply growth, fiscal deficits and a foreign exchange squeeze compounded the problem of inflation and exchange rate depreciation. Understanding this situation requires an understanding of the links among these macroeconomic variables.

This paper tries to answer the following questions: Do exchange rate movements and world rate of inflation drive the domestic rate of inflation? Do the exchange rate, world rate of inflation, real income growth, changes in domestic credit and foreign exchange reserves drive the domestic rate of inflation? Do these variables drive each other? Does a shock in these variables have temporary or permanent effects on the domestic rate of inflation? What variables are relatively more important in driving the domestic rate of inflation?

The paper is organized as follows: In the first part we study the dynamics of the domestic price level, the exchange rate and the foreign price level in an unrestricted vector autoregressive (VAR) model. Even though the VAR model allows us to analyse the links among the variables without the need to develop a structural economic model, the model reflected by these three variables has a theoretical base. Thus it may allow us to analyse the real exchange rate and measure the size of the pass-through effects among other interpretations (see, for instance, Edwards, 1989; Klein, 1990; Elbadawi, 1993). The second part of the paper extends the VAR to study the effects of domestic credit, foreign exchange reserves and real output on the rate of inflation. In this section we ask ourselves whether the rate of inflation drives or is driven by any of the variables in the system.

The analytical part has three stages: In the first stage we perform multivariate cointegration analysis to determine the number of cointegrating vectors spanned by the variables. From this stage of the analysis, we will determine whether the real effective exchange rate has been stationary (that is, whether the exchange rate and the domestic and foreign price levels cointegrate) besides identifying other cointegrating vectors. In the second stage, the identified cointegrating vectors will be used together with the variables in log differences in a multivariate Granger non-causality test. This will help us determine which variables drive each other. Finally, in the third stage we use the estimated VAR model to decompose the innovations in all the variables into portions that can be attributed to the other variables. This will help us compare the relative importance of the variables in accounting for their own innovations and those of the other variables.

Macroeconomic background

In the first decade of Kenya's independence, the 1960s, the rate of inflation averaged 3% and was thus considered to be of less policy concern. Inflation began rising in the second decade, however, and was accompanied by devaluation and changes in the exchange rate peg (from the pound to the dollar to the SDR).These changes, along with external price shocks, balance of payments crises, accelerating money supply growth and the expanding budget deficit, produced an economic crisis.

Table 1: Indicators, 1973-1982

YEAR	73	74	75	76	77	78	79	80	81	82
TOT	100	90	82	95	127	108	102	94	81	77
INFL	9.3	18	19.2	13.5	14.9	17	8	13.8	11.8	21
KSH/SDR	8.3	8.8	9.7	9.7	9.7	9.7	9.7	9.7	12	14
GE/GDP	18.4	18.4	20.6	20.5	29.4	23.4	25	25.4	25.3	24
GD/GDP	4.3	6.5	7.9	5.3	5.7	8.3	6.5	9.3	10.9	15
MS/GDP	30.3	26.9	28.0	28.6	32.8	33.7	35.2	30.1	29.5	31
DC	100	110	122	163	235	266	322	330	364	426
DC SHARES										
PUBLIC	22	22	33	33	28	27	29	25	33	43
PRIVATE	78	78	67	67	72	73	71	75	67	57
PRICES										
NONT/MF	103	121	130	130	127	131	133	136	133	133
EXP/MF	95	109	120	143	188	147	148	159	158	156
GDP	100	103	106	111	120	129	135	141	149	154

Source: Central Bureau of Statistics: Economic Survey, various; Ndung'u (1993, Tables 2.3 and 2.4 p. 15-16).

Where TOT is terms of trade index, 1973=100; INFL is the rate of inflation; GE is government expenditure; GDP is gross domestic product; GD is central government deficit (all in current prices); MS is money supply (M2); DC is the index of domestic credit; SDR is the exchange rate to the SDR; NONT/MF is the relative prices of non-traded to manufactured goods; and EXP/MF is the relative price of export to manufactured goods.

In reaction to the crisis, and in an effort to contain the external shocks on the balance of payments, control instruments were introduced. These included selective restrictions on bank lending, licensing of foreign exchange transactions, quota restrictions on most imports and direct price controls on goods. The restrictions on domestic credit were later lifted, but controls on foreign exchange, imports and domestic prices were modified and made more restrictive every year. They acted as an easier response in controlling balance of payments and inflationary pressures.

Table 1 shows an expansionary period. The exchange rate was fixed most of the time and there were discrete devaluations. The government deficit to GDP ratio increased tremendously — by 1982 it was almost 15%. Money supply to GDP ratio, on the other hand, was over 30%, while domestic credit increased by over 300%.

Table 2: Major indicators 1983 - 1993

YEAR	83	84	85	86	87	88	89	90	91	92	93
TOT	72	85	71	79	65	68	61	55	63	61	66
INF	5	9	11	6	11	13	15	18	20	28	46
SDR	15	18	20	23	25	27	29	34	40	50	91
GE/GDP%	32	33	34	37	40	38	38	38	37	43	60
GD/GDP%	4	5	5	6	7	5	5	5	4	5	7
DC(73= 100)	459	521	555	750	875	907	992	1212	1411	1725	2228
MS/GDP %	32	32.6	30.4	34.9	35.1	33.0	32.7	34.6	36.5	43.5	45.4
DC SHARES											
PRIVATE %	61	61	62	56	53	59	64	57	58	65	67
PUBLIC %	39	39	38	44	47	41	36	43	42	35	33
GDP(73= 100)	159	159	168	177	185	195	205	213	218	219	261

Source: CBS: Economic Survey, various; and Ndung'u (1993, Table 2.5, p. 19).
Variables are as defined in Table 1

From this table we see that terms of trade shocks were prevalent, with the rate of inflation rising from 9.3% to 19.2% between 1973 and 1975, to over 20% by 1982. Following the trend in the rate of inflation were the ratios of government deficit to GDP and of money supply to GDP, and the index of domestic credit. The relative prices also show a strong upward trend. This trend was not halted, and government spending, money supply and domestic credit were significantly affected by the 1976-1977 commodity boom. By the decade that followed, the economy was in serious disequilibrium and required a major adjustment and stabilization effort. The control regimes, especially, needed to be overhauled, since they not only created distortions in the economy but were also subject to abuse and increased rent-seeking activities. Domestic credit, even though it included a tremendously expanded share of the public sector in total, was almost stable, save for the last year. This implies that there was no serious trend in the public sector crowding out the private sector.

Table 2 shows a period of deflation. The GD/GDP ratio was checked and never went to 7%; the GE/GDP was highest in the later years. As is evident from this table, the rate of inflation slowed between 1984 and 1986, but started rising thereafter. The exchange rate, on the other hand, continued to depreciate against the SDR and had depreciated by about 70% in nominal terms by 1992. This is also a decade when an active exchange rate policy was pursued, in form of a crawling peg system. Other variables continued to have a strong upward trend; domestic credit, for instance, increased four-fold in this decade. The government was absorbing a sizeable amount of it; this shows an accelerating public sector crowding out the private sector.

Between 1980 and 1982, the Kenya shilling was devalued by about 20% in real terms measured against the SDR, before the new exchange rate policy was adopted. Since then, the shilling has lost ground against the major currencies, depreciating from 15.2 to the SDR in 1983 to about 91 in 1993. The partial, followed by complete, liberalization of the exchange rate and decontrol of imports and foreign exchange transactions in 1993 witnessed the spectacular depreciation of the Kenyan currency and a sudden upsurge of the domestic rate of inflation. Since then, the economy has stabilized and the exchange rate appreciated through the end of 1994; it stabilized and then depreciated slightly in April/May 1995.

The government attributed the sudden rise in the rate of inflation in 1992 to the following factors (Economic Survey, 1993):

- The increased money supply, which grew by 35% in 1992.
- Business imports financed by the use of foreign exchange originating from the Foreign Exchange Bearer Certificates (Forex-Cs) and foreign exchange retention accounts in commercial banks. The depreciation of the Kenya shilling raised the unit cost of imports.
- Inadequate supply of essential commodities due to erratic weather conditions and price decontrol on most commodities, which raised the prices of food items sharply.
- Expectations of continued high inflation, which emanated from foreign exchange shortages, price decontrol and multi-party political activity in 1992. These influences resulted in higher wage claims.
- A strong rise in consumer demand originating from expenses incurred during the campaigning exercise leading to elections in 1992.

What the government fails to mention is the escalating budget deficit, which inevitably, due to the aid embargo, had to be financed by printing money. This was responsible for the money supply expansion. These factors combined to push the rate of inflation strongly upwards while at the same time strongly depreciating the exchange rate, at least up to the middle of 1993. In an attempt to mop up this excess liquidity, the treasury discount rate shot up, pushing the rate of inflation and exchange rate devaluations. This mopping-up exercise also entailed further crowding out of the private sector by the public sector.

Literature survey

The determinants of inflation in Kenya, as in Africa and Latin America as a whole, have become an important area of research. Most scholars studying inflation in Kenya have come up with similar conclusions, differences in methodological approaches notwithstanding (see, for example, Killick and Mwega, 1989; Mwega, 1990; Cannetti and Greene, 1991; Ndung'u, 1993). These studies are also similar to those of London (1989) and Chhibber (1991) on a cross-section of African countries and Durevall (1993) for Brazil, among others.

In these studies, there is an explicit recognition of the exchange rate devaluations as a force behind the upsurge of inflation (see Chhibber, 1991, and London, 1989, for a cross-section of evidence on African countries). The question that has not been adequately addressed is the relevant money supply aggregate that causes inflation. Thus, Killick and Mwega (1989) and Mwega (1990) have used M1, M2 and M3. They show that inflation is driven by money supply with no reverse effects. Cannetti and Greene (1991) have used M1 with the results that inflation weakly drives money supply growth, and money supply growth drives exchange rate changes, but with no reverse effects in either of these cases. Ndung'u (1993) has used monetary base and M3. His results show that monetary base growth and the rate of inflation drive each other, while M3 growth is driven by the rate of inflation with no reverse effects. His study shows that the monetary aggregate used in the inflation model makes a difference in how the rate of inflation affects and is affected by other variables. For example, the study finds that when monetary base is used, the rate of inflation drives and is driven by monetary base growth and changes in the rate of interest. Furthermore, the model with monetary base encompasses the inflation model that uses M3. These results are supported by the fact that the money multiplier is unstable, which is the link between monetary base and a broader monetary aggregate, M3 (Ndung'u, 1994).

Two studies on Kenya are closely related to our proposed study: Canetti and Greene (1991) and Ndung'u (1993). Canetti and Greene analysed a VAR with inflation, money (M1) supply growth and exchange rate changes. Unit root tests showed that the variables were integrated of the first order, but were not cointegrated, using the two-stage Dickey-Fuller tests. As such the VAR was estimated with variables in first-differences. Bivariate causality tests for Kenya showed that exchange rate changes affect the rate of inflation with no feedbacks and money supply growth and the rate of inflation do not affect each other. In trivariate causality tests, their results showed that exchange rate changes and the rate of inflation did not affect each other, inflation had a weak effect on monetary expansion, and monetary expansion affected exchange rate changes with no reverse effects. In the variance decomposition of the forecast error of inflation, the results showed that neither monetary expansion nor the exchange rate devaluations had a dominant role in accounting for the innovations in the rate of inflation. Inflation explained the largest portion of its own innovation followed by the exchange rate changes and monetary growth.

One may argue that their VAR model did not include sufficient information. This they acknowledge. At least, foreign prices, output and the rate of interest might have been crucial information excluded. The results obtained are thus dependent on the information set, especially the F-tests in the Granger causality tests (for details of problems with Granger causality tests, see Surrey, 1989; Ndung'u, 1993).

The information set included in their model might also suggest why they found no cointegration among the variables. It should be noted that cointegration among a group of variables is a confirmation of the theory tying them together (long-run relationships); put differently, economic theory helps us to identify the cointegrating vectors among a group of variables. For example, inclusion of the foreign price level could have produced a real exchange rate cointegrating vector, or inclusion of output could have produced a cointegrating vector reflecting velocity of money, if velocity were stable over time in Kenya. If the theory tying variables together is correct, then cointegration analysis helps us in confirming it (see Cuthbertson et al., 1992, p. 129).

Additionally, lack of cointegration among the variables meant modelling variables in their first-differences in the VAR model. This robbed the model of the long-run dynamics, so that the results presented should be treated as short-run responses. The result that inflation accounts for 69% of its own innovations might suggest that there is a very strong inflation inertial component in Kenya (or price stickiness, which could be a more plausible interpretation). This might not necessarily be the case.

Ndung'u (1993) used a VAR with money supply (monetary base was compared with M3), the domestic price level, exchange rate index, foreign price index, real output and the rate of interest. Multivariate cointegration analysis was carried out and the identified cointegrating vectors were used together with the variables in log-differences in Granger non-causality tests. Unlike Canetti and Greene (1991), it is found that monetary base growth and the rate of inflation drive each other, on one hand, and the rate of inflation and exchange rate changes drive each other, on the other. Interest rate changes and the rate of inflation drive each other when monetary base is used in the model. The rate of inflation was also found to drive M3 growth with no feedback effects. Variance decomposition of the forecast error in the domestic price level showed that the price level was weak in accounting for its own innovations and those of other variables. The exchange rate, interest rate, money supply and the foreign price level, in order of importance, accounted for innovations in the price level. The exchange rate accounted for over half of the innovations in the price level. However, the analysis was carried out with the variables in levels with the assumption that the system could be re-written in an error-correction form. The problem here could be that the variances might not be stable, even though there are no restrictions imposed in the system.

These two studies thus arrive at different conclusions, due partly to the information sets included and partly to some methodological differences. What is missing, however, is the effect of the balance of payments on the rate of inflation and whether domestic credit is more important in causing inflation since it is more policy determined and relevant. The present study intends to fill this gap by analysing the external sector — that is, the dynamics between the price level and the exchange rate — and to update the information set to include foreign reserves, domestic credit and other fundamental variables as in Ndung'u (1993). In this study we intend to investigate whether inflation drives or is driven by the exchange rate changes, domestic credit or foreign reserves, among other macroeconomic variables in the VAR model.

II. Theoretical and econometric models

The concept of the real exchange rate

The real exchange rate model we use in this paper is adapted from Edwards (1989) and Elbadawi (1993), but we do not extend our study to include real exchange rate equilibrium. Elbadawi (1993) starts from the domestic nominal absorption. He derives a supply function of non-traded goods relative to GDP as a function of export prices, import prices and non-tradeable goods prices. These prices, invoking a small-country assumption, can be considered exogenous and the real exchange rate, which can be formulated in different ways, is given as:

$$RER = P_N / EP_X P_M^{-1} \tag{1}$$

Where RER is the real exchange rate, P_N is the price of non-tradeable goods, P_X is the dollar price of exports, P_M is the dollar price of imports and E is the nominal exchange rate. Edwards (1989), on the other hand, defines the real exchange rate as:

$$RER = EP_T / P_N \tag{2}$$

where P_T is the world price of tradeable goods, computed as an index of prices of exports and imports, and P_N is the nominal price of tradeables.

In most empirical work, proxies for P_T (which is a composite index for P_X and P_M) and P_N have been used. In our present study we use the wholesale price index for Kenya's main trading partners to proxy P_T, and E will be represented by multilateral nominal exchange rate index. Both these indexes will be weighted by import shares, while P_N will be proxied by the domestic consumer price index (CPI). We choose this formulation of E to follow Edwards' (1989) argument that multilateral real exchange rates provide a measure of the degree of competitiveness of a country relative to a group of its trading partners.

One problem presented by the definition of RER in Equations 1 and 2 when applied to Kenya is that they impose a purchasing power parity (PPP) assumption. In Kenya, the PPP relation cannot hold because the exchange rate was fixed from the 1970s to the 1980s, an exchange rate rule was adopted in the 1980s and early 1990s, and only in 1993 was the exchange rate allowed to float. Secondly, the CPI is a proxy for non-tradeable goods, but it contains both tradeable and non-tradeable goods. To take this into account, we use an unrestricted version of Equation 2 where we do not impose the PPP relation. In this way we interpret the RER as real effective exchange rate, following Edwards (1989), but in our case it will define a stationary linear combination of these variables consistent with an equilibrium real exchange that is data-based. This formulation, however, assumes a constant terms of trade. This is the idea expounded in the next sub-section.

Econometric models

In this section we formulate the econometric models to be used in the study. The real exchange rate is formulated as a stationary cointegrating vector that spans the PPP relation. We further extend this formulation to include real income, domestic credit and foreign exchange reserves in the VAR.

The exchange rate pass-through equation

We use an exchange rate pass-through equation of the form:

$$CPI_t = \alpha_0 + \alpha_1 EX_t + \alpha_2 WP_t \tag{3}$$

where CPI is the domestic price level, EX is the multilateral nominal exchange rate index and WP is the foreign price index (both EX and WP are trade weighted). The variables are in logs. Equation 3 can be reorganized and by omitting a constant would resemble the Equation 2 computation of real effective exchange rate (but we do not in our case impose a purchasing power parity relation). We do not assume that adjustments in Equation 3 are instantaneous, so that we rewrite it in an autoregressive distributed lag form:

$$CPI_t = \alpha_0 + \Sigma_{i=1}^{k} \alpha_{3i} CPI_{t-i} + \Sigma_{i-0}^{k} \alpha_{4i} + EX_{t-i} + \Sigma_{i=0}^{k} \alpha_{5i} WP_{t-i} + \epsilon_{1t} \tag{4}$$

where ε_{1t} is a white noise process[1] and k is the lag length.

Equation 4 expresses the domestic price level in the form of its own past values and present and past values of the multilateral exchange rate and the foreign price index. Equation 4 contains variables that are non-stationary (we assume that they are integrated of the first order[2] and thus become stationary after first-difference). This allows us to reparameterize Equation 4 into an error-correction formulation. By adding and subtracting terms appropriately we obtain:

$$\begin{aligned} \Delta CPI_t = \alpha_0 + \Sigma_{i=1}^{k-1} \alpha_{6i} \Delta CPI_{t-i} + \Sigma_{i=0}^{k-1} \alpha_{7i} \Delta EX_{t-i} + \Sigma_{i=0}^{k-1} \alpha_{8i} \Delta WP_{t-i} \\ + \alpha_9 [EX - \beta_1 CPI + \beta_2 WP]_{t-k} + \epsilon_{2t} \end{aligned} \tag{5}$$

where $\alpha_{6i} = (\alpha_3\text{-}1)_i + \alpha_{3,i+1} + ...+ \alpha_{3,k-1}$ for i = 1,...,k-1 and

$\alpha_{j,i} = \alpha_{j,i} + \alpha_{j+1,i+1} + ...+ \alpha_{5,k-1}$ for j=3,4,5 and i= 1,...,k-1 and $\alpha_9 = \alpha_{4,i} + \alpha_{4,i+1} +...+ \alpha_{5,k}$ for i=0,...,k and $\beta_1 = (\alpha_{3,i} + \alpha_{3,i+1} +...+ \alpha_{3,k})/a_9$ and $\beta_2 = (\alpha_{5,i} + \alpha_{5,i+1} +...+ \alpha_{5,k})/\alpha_9$ and ε_{2t} is a white noise process with the usual properties.

The term in brackets represents the error-correction term that is formulated to reflect the equilibrium real effective exchange rate. This term forms the long-run part of Equation 5, while the variables in the log-differences will form the short-run part. We have let the parameters of the error-correction term, β_1 and β_2, be different from unity since we do not expect the purchasing power parity relation to hold in Kenya, and hence we determine the size of these parameters empirically. The error-correction term shows that when the nominal exchange rate is devalued to maintain long-run equilibrium, inflation increases; when the nominal exchange rate is over-valued, inflation decreases. The error-correction coefficient, α_9, shows the amount of disequilibrium or strength of adjustment that is transmitted each period to the domestic rate of inflation (since we will analyse the error-correction term in a multivariate setting, there will be several α's, corresponding to each variable, that will show which of the variables adjust strongly in case of disequilibrium in the equilibrium real effective exchange rate).

Domestic credit and balance of payments effects

The theoretical model used in this section is adapted from Durevall (1993). His model derives from Adams and Gros (1986) and Blejer and Leiderman (1981). Adams and Gros (1986) have shown that a real exchange rate rule leads to a loss of control of the domestic rate of inflation. The reason given is that monetary and exchange rate policies are two equivalent but mutually exclusive ways of determining the rate of inflation in the long run (this is partly why we looked at price and exchange rate dynamics in the previous section). They argue that the adoption of a real exchange rate rule may serve to index both the nominal exchange rate and through the balance of payments the money supply to the price level; that is, there is no exogenous nominal anchor to tie prices down (Adams and Gros, 1986). In Blejer and Leiderman (1981), the rate of inflation is determined by excess creation of domestic credit so that the rate of inflation and domestic credit are policy determined variables. They argue that the adoption of a real exchange rate rule does not entail a loss of a nominal anchor; domestic credit is the nominal anchor in this model. They thus conclude that by adopting a real exchange rate rule, a country can determine its own rate of inflation. But Edwards (1993) argues that by adopting a real exchange rate rule, a country agrees to live with high inflation.

Durevall (1993) argues that the fundamental difference between the two models is the assumption made about the relative reaction of international reserves and inflation to changes in domestic credit. Thus in Adams and Gros (1986), money is determined by demand in the long run, so that before money affects inflation, a decrease in domestic credit leads to a compensating inflow of reserves. In Blejer and Leiderman (1981), on the other hand, money is determined by supply, thus a reduction in the supply of domestic credit leads to a slow down in inflation as well as an increase in reserves. Ndung'u (1993) shows that inflation in Kenya is driven by monetary base growth, exchange rate changes and changes in the rate of interest.

We depart from Ndung'u (1993) by incorporating domestic credit and international reserves into the VAR model. Thus, in this section, we investigate the following questions: Do domestic credit and foreign reserves drive or are they driven by the rate of inflation? What variables bear the burden of adjustment when the exchange rate is misaligned? What are the effects of the exchange rate and output on the rate of inflation in this extended model?

The econometric analysis begins by specifying a VAR model of the form:

$$B\,(L)\,X_t = v_t \tag{6}$$

where X_t = { CPI, DC, RES, EX, WP, GDP } where CPI is the domestic price index, DC is domestic credit, RES is international reserves in domestic currency terms, EX is a trade-weighted index of multilateral effective exchange rate, WP is trade-weighted foreign price index and GDP is real income. B(L) is a 6 x 6 matrix with the lag operator L and B_o =I. The v's are the innovation process for X, with $E(v_t\, v'_t) = \Sigma$ and $E(v_t\, v_{t-i}) = 0$ for $i \neq 0$. Once we estimate Equation 6, it is inverted so that each variable is expressed as a linear combination of its own innovation and the lagged innovation of all other variables:

$$X_t = [\,B\,(L)\,]^{-1} v_t \tag{7}$$

In order to analyse the dynamics in the model, the contemporaneous covariance matrix, Σ,needs to be decomposed into variable specific shocks, that is, it has to be orthogonalized. This is achieved by expressing the contemporaneous model as:

$$\varepsilon_t = Hv_t \tag{8}$$

such that $H\,\Sigma\,H' = I$, where I is an identity matrix. This ensures that the innovations v_t will be mutually orthogonal. The added problem is that there is no unique way of orthogonalizing Σ, or of choosing H, the orthogonalized moving average representation of the system. In this study, we will adopt Sims' recursive Choleski decomposition of Σ, where the matrix H is taken to be triangular with positive elements on the diagonal. We shall, however, check the correlation matrix to see if the conclusions might change with a different method of decomposition.

Empirical implementation

In the two preceding sections, will conduct the empirical investigations in three steps. In the first step we will study the data, determine the order of integration and test for cointegration. In this empirical step, we will thus determine the number of cointegrating vectors spanned by the variables in the system in these two empirical parts of the study.

In the second step, the identified cointegrating vectors will be included in the statistical model as error-correction terms. The variables will thus enter the model in log-differences form and in stationary linear combinations. This is because the error-correction terms are computed in a multivariate framework that allows every variable to enter in the short-run equation and to affect the short-run movements of the variable via α's, the adjustment coefficients. This thus justifies the inclusion of the error-correction terms with the variables in log-differences.[4] We will then carry out a multivariate Granger non-causality test (GNC) (Granger, 1969, 1980). When carrying out the GNC tests for a particular variable, we shall consider that in addition to entering the model in rates of change, it will also be part of one or several error-correction terms. By following this approach we shall pay more attention to the long-run information in the data, get more efficient estimates and make sure that the standard distributions for statistical inference are valid since all the variables are stationary.

Finally, we use the estimated VAR model to decompose the innovations in the variables into portions that can be attributable to innovations in the other macroeconomic variables. In this way we will be able to judge, for example, the relative importance of other variables in causing inflation.

III. Empirical results

Data

The study will use quarterly series from 1970 to 1993. But since Kenya started to have an active exchange rate policy in the early 1980s, the sample size is likely to be very small if partitioned between the two periods. The sample period will thus include periods of fixed exchange rate, periods of a real exchange rate rule and a year of dual exchange rate. The data to be used will include the domestic price level, which will be proxied by the weighted consumer price index (CPI). For the exchange rate (EX) and the foreign price level (WP), we will construct trade weights for the major trading partners and then construct indices for these two variables. The trade weights will be based on import shares. These three variables will form the PPP relationship and will show whether the real effective exchange rate is a stationary linear combination of these three variables.

The other variables will include domestic credit (DC), foreign reserves in domestic currency terms (RES) and real national output (GDP) — to be interpolated from annual to quarterly. The presence of DC is intended to capture the effects from balance of payments and the rate of inflation. The major task will be to determine whether DC drives inflation because DC is more policy relevant and policy determined in the class of monetary aggregates. Foreign reserves, RES, are supposed to react to changes in domestic credit. As we have seen in the brief literature surveyed, some researchers hold that if money is determined by demand or supply in the long run, there will be two mechanisms to the rate of inflation, a direct and an indirect one. These effects depend on the assumption made about the relationship between RES, DC and money supply. In addition to RES and DC, real income is added, which also directly affects the domestic rate of inflation and may have direct effects on DC.

We first conduct a descriptive analysis of the data for the first part of the study. Table 3 shows the distribution of the data. We see that the variables do not follow a normal distribution. The second step is to test for a unit root in the variables. The results of the unit root tests are shown in Table 4.

As can be seen from this table all the variables are non-stationary and could possibly be integrated of order one. This is confirmed by their respective graphs (not reported). These results will be confirmed in the next section, where the Johansen Procedure is applied.

Table 3: Data distribution

	Mean	SD	Skewedness	E.Kurtosis	Normality
EX	4.582	.564	1.088	.261	49.546[.000]
CPI	4.201	.830	.226	-.948	7.118[.0255]
WP	4.201	.4779	-.978	-.486	71.042[.00]

SD is the standard deviation.

Table 4: Unit root tests*

Variable	IDW	DF	ADF**	Order of integration
EX	.0136	.581	.646	I(1)
CPI	.003	2.623	-.247	I(1)
WP	.009	-1.005	-1.560	I(1)

Where IDW is the integrated Durbin-Watson test statistic; DF is the Dickey-Fuller test and ADF is the Augmented Dickey-Fuller test. The critical values at 5% level are -3.46 (for both DF and ADF) and 0.78 for the IDW test.

* The auxiliary regression included a constant, trend and four lags.

** The augmented test, ADF, was run recursively, RADF, to identify breaks or shocks in the variable (the t-value graphs are shown later for all the variables). In all cases there were shocks hitting EX and CPI; the ADF tests are reported after these shocks were modelled (see also Appendix A). This is because the Dickey-Fuller test procedure does not require the errors to be serially uncorrelated or homogenous. Shocks in the variables will contribute to the low power of this class of tests (see the recursive t-values graphs in the appendix).

Cointegration analysis of the equilibrium real effective exchange rate

The basic questions we intend to ask are whether the multilateral exchange rate index, the domestic price level and the world price level drive each other, and whether the domestic price level and the multilateral nominal exchange rate are driven by the world price level.

We start by investigating whether these variables are cointegrated, since they already have been seen to have a unit root. In this investigation we use the multivariate cointegration test, the Johansen Procedure. In the Johansen Procedure (see Johansen, 1988, and Johansen and Juselius, 1990, 1992), we want to estimate the equilibrium real effective exchange rate as a cointegrating vector spanned by these three variables. In the first stage, the analysis was conducted assuming all variables are endogenous in order to determine the number of cointegrating vectors in the data. Three lags and seasonal dummies were included. In addition, a number of dummies were used in order to catch the outliers in the residuals of each equation, since the maximum likelihood estimation method requires approximately Gaussian errors (this also follows from the results of the RADF tests). Some of the dummies coincide with either devaluations, exchange rate regime changes or international prices shocks. We show the test statistics in Tables 5 to 8.

Table 5: Test for stationarity

Variable	EX	CPI	WP
$\chi^2(2)$	11.84	15.32	20.96

The test for stationarity follows a χ^2 distribution with 2 degrees of freedom; the critical value at 5% level is 5.99. As can be seen the test is significant for all the variables, hence the variables are non-stationary. The next test determines whether any of the variables can be excluded from the analysis, since we have assumed that the variables form a theoretical relationship, the PPP relation. If a variable could be excluded from the analysis, then either the theory tying the variables is flawed or the data are wrong.

Table 6: Test for exclusion

Variable	EX	CPI	WP
$\chi^2(1)$	6.39	11.60	11.83

The test for exclusion follows a χ^2 distribution with one degree of freedom; the critical value at 5% level is 3.84. The test is significant for all the variables, reflecting the fact that all the variables are important in the analysis. We essentially wanted to test whether any of the variables in the system are irrelevant and thus invalidate the cointegration analysis. The test for weak exogeneity is presented in Table 7.

Table 7: Test for long-run weak exogeneity

Variable	EX	CPI	WP
$\chi^2(1)$	10.96	7.88	2.32

This test also follows χ^2 with 1 degree of freedom. It can be seen that WP is not significant, hence it is weakly exogenous and in line with the small-country assumption of price-taking behaviour. Thus world prices do not adjust domestically and the result is in line with the small-country assumption. This implies that we can re-run the procedure while WP is conditioned as weakly exogenous.

Table 8: Tests for residual mis-specification

Equation	B-PQ$\chi^2(20)$	ARCH$\chi^2(3)$	Normality$\chi^2(2)$	LM Test $\chi^2(3)$*
ΔEX	20.263	0.798	1.467	1.115
ΔCPI	16.801	0.456	57.468	2.118
ΔWP	26.136	1.845	70.190	8.838
5% Level	31.410	7.815	5.991	7.82

Where B-PQ is the Box-Pierce test for residual autocorrelation; ARCH is the autoregressive conditional heteroscedasticity test for heteroscedastic residuals; and Normality is the Jarque-Bera test for the distribution of the residuals.
* Since the CAT programme of the Johansen Procedure does not give the Langrangean multiplier test (LM) the residuals from the equations were generated and regressed on themselves, the three variables in the system lagged three steps and the cointegrating vector lagged one step. This test is significant for the world inflation at 5% level but not at 1%. We thus proceed under the assumption that serial correlation is not a serious problem. The last row shows the critical values of the tests at the 5% level.

Table 9: Cointegration test and the estimated β- and α-vectors

	Eigenvalues	and Trace	Test
H_0	r=0	r≤1	r≤2
λ	.264	.097	.000
T(r)	37.919	9.460	.012
95%	34.91	19.96	9.24
	β - Vectors		
Variable	β_1	β_2	β_3
EX	1.00	1.00	1.00
CPI	-1.088	-.762	-.676
WP	.890	.659	.330
	α - Vectors		
Equation	α_1	α_2	α_3
ΔEX	-.116	.048	-.002
ΔCPI	.079	.054	-.000
ΔWP	.029	-.020	-.003

Where λ are the eigenvalues, r is the cointegrating vector and T(r) is the trace test.

From Table 8 we see that the residuals from the ΔCPI and ΔWP equations are not normally distributed, but the other two tests are not significant for all the equations' residuals. Perhaps the most critical tests are the B-PQ and LM for serial correlation; they are not significant in any equation at 1% level. We thus proceed under the assumption that the residuals are approximately a white noise process. The next step is to present the cointegration test; this is shown in Table 9.

From these results we see that there is one significant cointegrating vector that spans the variables in the system, where EX, CPI and WP form a stationary linear combination.

In the second stage, we estimated two endogenous variables, while WP was conditioned as weakly exogenous, as the test for long-run weak exogeneity showed, in order to improve on the formulation. This produced the final cointegrating vector presented in Table 10.

Table 10: Final cointegration vector

	EX	CPI	WP
β	1.00	-1.157	.877
	ΔEX	ΔCPI	ΔWP
α	-.117	.091	-

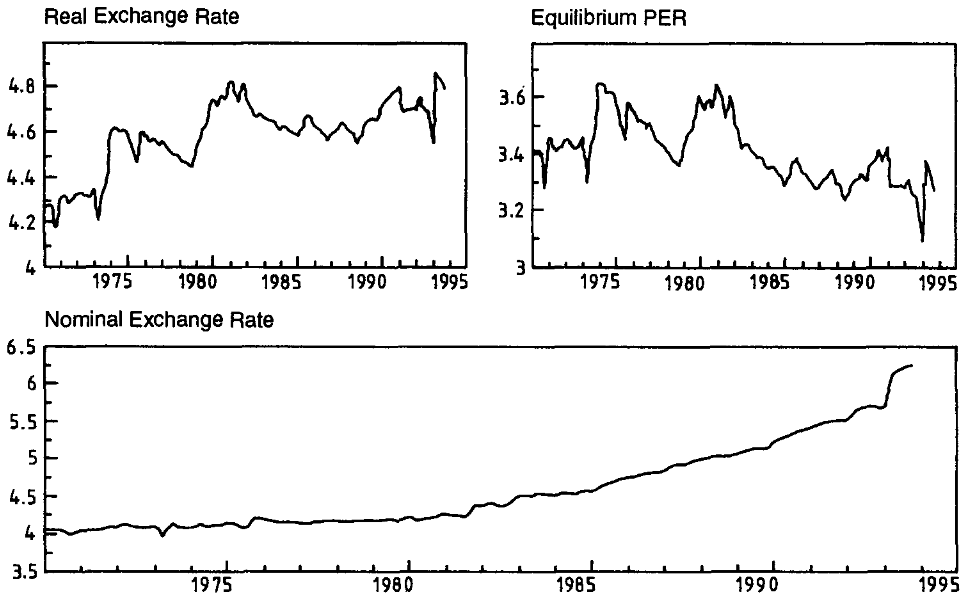
The major difference is that the short-run adjustment, α, for WP is absent. This is in line with the small-country assumption; that is, we do not expect the world price level to adjust domestically.

The final vector now defines our data-based equilibrium real effective exchange rate, which shows that the multilateral nominal effective exchange rate index, the consumer price index and the world price index cointegrate. We see that the short-run adjustments are not very strong for EX and CPI. This is reflected by the α-vector, which represents weights with which the cointegration vector enters in each equation. The nominal effective exchange rate adjusts faster than the CPI in the short run. Since the variables are in logs, we can interpret these adjustment coefficients, the α's, in percentages. Thus, when the nominal effective exchange rate moves out of the long-run trend of the real effective exchange rate, the nominal effective exchange rate depreciates by 11.7%, while the rate of inflation increases by 9% and the world rate of inflation does not domestically adjust. We show the cointegrating vector and the trade weighted nominal and equilibrium effective exchange rates in Figure 1.

As can be seen, the nominal exchange rate rises faster in the crawling and dual exchange rate period. The real effective exchange rate has a trend effect; the cointegrating vector is fairly stationary, but shows a depression with the massive devaluation of 1992-1993. We believe this graph portrays a fair approximation of the trends in these rates in Kenya.

Having identified the cointegrating vector (EREER), now our ECM term, the next step is to determine how these variables drive each other. This is done through the Granger non-causality (GNC) tests. The results are shown in Table 11. From these results, we see that exchange rate changes and the domestic rate of inflation predict each other. The world rate of inflation does not predict the domestic rate of inflation, but does predict exchange rate changes. The real effective exchange rate does not predict the domestic rate of inflation but predicts exchange rate changes.

Figure 1: Real exchange rate, data-based equilibrium real exchange rate and nominal exchange rate



We can thus conclude that both the domestic rate of inflation and exchange rate changes drive each other, while the world rate of inflation and the real exchange rate affect the domestic rate of inflation through exchange rate changes. The strength of the causation between the domestic rate of inflation and exchange rate changes could perhaps be assessed by decomposing the forecast error variance. That is, we use the VAR model to decompose the innovations in the variables into portions that can be attributed to other variables. The results are shown in Table 12 and 12a.

Table 11: Granger non-causality tests*

Equation → Variables ↓	ΔCPI	ΔEX
ΔCPI, ECM_{t-1}	.000	.000
ΔEX, ECM_{t-1}	.022	.000
ΔWP, ECM_{t-1}	.297	.033
ECM_{t-1}	.729	.001

* The test was performed with lags 1-4 for ΔEX and ΔCPI and lags 0 to 4 for ΔWP, and the lagged error-correction mechanism term, ECM, which is the REER. The figures are probability values from F-test.

Table 12: Decomposition of the forecast error variance (%): Inflation (ΔCPI)

STEPS	ΔWP	ΔEX	ΔCPI
2	.21	.64	99.15
4	.56	3.06	96.38
8	.83	4.13	95.05
12	.79	5.14	94.07
18	.81	5.89	93.30
24	.83	6.14	93.03
30	.84	6.23	92.93
36	.84	6.26	92.90

Table 12a: Decomposition of the forecast error variance (%): Exchange rate changes (ΔEX)

STEPS	ΔWP	ΔEX	ΔCPI
2	4.67	95.23	.10
4	4.84	83.19	11.96
8	7.04	79.79	13.17
12	7.29	79.09	13.62
18	7.27	78.67	14.04
24	7.28	78.55	14.18
30	7.27	78.50	14.22
36	7.27	78.49	14.27

From these results, we see that the rate of inflation is relatively stronger in driving the exchange rate changes than the reverse effects it gets from exchange rate changes. The results also suggest that neither of the variables is dominant in accounting for the other's innovation. The rate of inflation only accounts for about 14% of the innovations in exchange rate changes, while the world rate of inflation accounts for about 7%; the rest comes from own innovations, that is, the exchange rate movements, about 78%, at the end of the forecast horizon. On the other hand, the rate of inflation accounts for over 90% of its own innovation, aided only by exchange rate changes, 6%, and less than 1% from world inflation. This supports the GNC tests, which showed that in this model, the world rate of inflation affects the domestic rate of inflation via exchange rate changes.

The final step is to estimate a pass-through equation. We enter variables in first-differences lagged six periods and then let the model hinge on the long-run solution, the cointegrating vector (ECM) lagged one step. In this way the ECM reflects the impact on inflation of having the real effective exchange rate out of its long-run trend. This term, therefore, reflects attempts to correct such errors and its coefficient can be interpreted as the strength of adjustment or the amount of disequilibrium transmitted each period to the rate of inflation.

Table 13: General model results

Lags	0	1	2	3	4	5	6
ΔCPI		263*	.018	.0997	.048	-.027	-.029
ΔEX	.128**	-.040	.001	-.038	-.0123	.062	.103*
ΔWP	-.023	.038	.040	-.021	.035	.056	.037
ECM		.008					
Constant	-.019						
Dummy1	.026*						
Dummy2	.048**						
Q_1	.003						
Q_2	-.003						
Q_3	-.003						

where * indicates significance at 5% level and ** at 1% level; Q_i are seasonal dummies; Dummy 1 and 2 reflect dummies in 1979:4 and 1982:1.
R^2=.65 F(26,49)=3.49[.000] s.e.=.1062 DW=1.86 n=76

Model tests:
AR 1-5 F(5,44) = .399[.872]
ARCH 4 F(4,41) = .682[.608]
Normality $\chi^2(2)$= .741[.691]
RESET F(1,48] = .661[.420]

The general statistical model results are shown in Table 13. Using the general-to-specific estimation procedure, the general model was reduced until we arrived at the preferred model. From the general model results, we see that the ECM is not significant. This is not surprising, since in the GNC tests we found that the real effective exchange rate does not drive the rate of inflation. Similarly, the world rate of inflation is not significant even though some lags have a potential for being significant during the reduction process.

These results were achieved after the sample size was restricted to 1990 third quarter (1990:3). There were huge outliers at the end of the sample and we found it inappropriate to include dummies at the end of the sample. In addition the parameters tended to be very unstable. The model thus tended to break down when the period 1990:4 to 1993:4 was included. We therefore report the results for the period before the instability, 1990:3, and also include two dummies for 1979:4 and 1982:1 and then proceed to reduce the model. The model tests are not significant starting with the AR test for autocorrelated residuals, the ARCH test for heteroscedastic errors, the Jarque-Bera normality test for the distribution of the residuals and the RESET test for the regression specification. The latter was significant at 5% but not at 1% (see Table 14).

In the preferred model lagged inflation, current and lagged exchange rate changes, lagged world inflation, and dummies are significant variables in the pass-through equation.

To test the validity of the model, we re-estimated the model recursively and without dummies. The results that emerged showed that the parameters of the model were relatively stable except for the 1982 period. The recursive graphs are shown in (Figures 2 and 3).

Figure 2: Recursive graphs for coefficient values

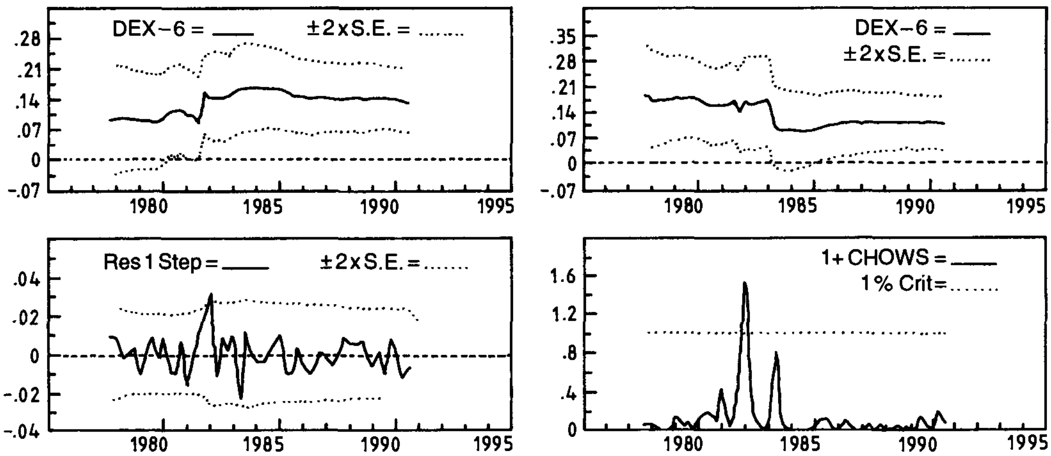


Figure 3: Recursive graphs, coefficients values and residuals tests.

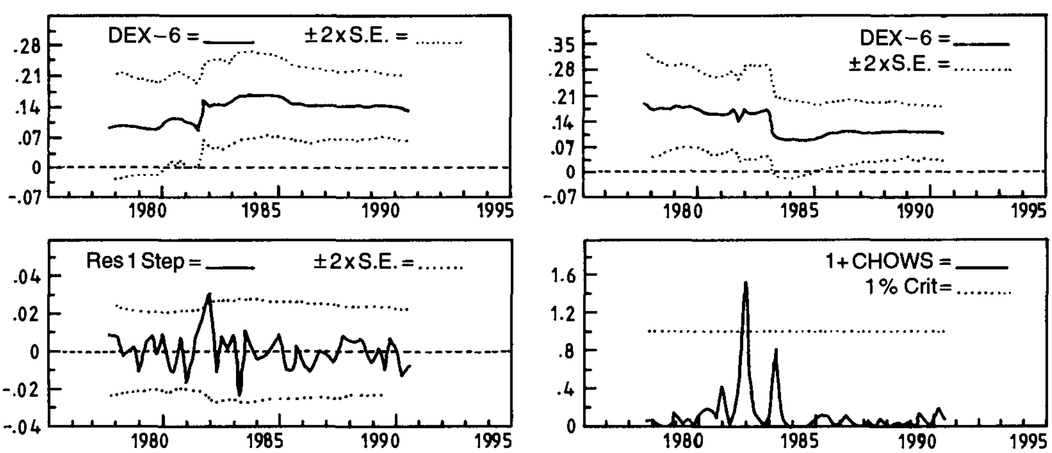


Table 14: The preferred model results

Variable	Coefficient	t - ratio	t-prob.Value
Constant	.012	3.405	.0012
ΔCPI_{t-1}	.226	2.396	.0196
ΔEX_t	.140	4.373	.000
ΔEX_{t-5}	.067	1.821	.0734
ΔEX_{t-6}	.102	3.082	.0031
ΔWP_{t-2}	.073	2.187	.0324
ΔWP_{t-5}	.080	2.400	.0193
ΔWP_{t-6}	.067	2.061	.0435
Dummy1	.028	2.434	.0178
Dummy2	.046	4.104	.0001
Q_1	.004	1.290	.2018
Q_2	-.002	-.460	.6470
Q_3	-.003	-.972	.3347

R^2 = .59 F(12,63) = 7.540[.000] s.e. = .01013 DW = 1.71 n=76

Model tests:
AR 1 - 5 F(5,58) = .343[.8840]
ARCH 1-4 F(4,55) = .480[.7501]
Normality $\chi^2(2)$ = .110[.9466]
Heteroscedastic F(19,43) = 1.43[.1641]
RESET F(1,64) = 4.994[.0290]*

The one-step residuals and the Chow test show some break in 1982, which is also reflected by the coefficients. This is the period when a crawling peg exchange rate policy was adopted and the analysis thus shows a structural break in the trend of the rate of inflation. Thereafter the coefficients are relatively stable. We thus confirm the observation in the literature that adopting a real exchange rate rule changes the profile of the rate of inflation.

We can now solve for the pass-through equation, to obtain:

$$\Delta CPI = .016 + .399\Delta EX + .284\Delta WP$$

This equation shows the pass-through effects from the exchange rate changes and the world rate of inflation to the domestic rate of inflation. It shows that a 1% devaluation has a pass-through effect of 0.4% to the domestic rate of inflation; that is, it increases the rate of inflation by 0.4%. On the other hand, an increase of 1% in the world rate of inflation increases the domestic rate of inflation by 0.28%. By any standards these are large pass-through effects, whose combined effect reflects the experiences that Kenya underwent in 1993, where prices mimicked exchange rate devaluations.

Table 15: Data distribution

Var.	Mean	S.D.	Skew.	E.Kutos.	Norm.
EX	4.58	.56	1.09	.26	49.55[.00]
CPI	4.20	.83	.23	-.95	7.12[.026]
RES	8.13	.65	-.09	-.64	1.50[.47]
GDP	11.05	.99	-.23	-1.05	9.11[.011]
DC	9.82	1.04	-.21	-1.04	8.53[.014]
WP	4.20	.48	-.98	-.49	71.04[.00]

Table 16: Unit root tests*

Var.	IDW	DF	ADF	Integration order
EX	.014	.581	.646	I(1)
WP	.009	-1.005	-1.560	I(1)
CPI	.003	2.623	-.247	I(1)
DC	.004	-2.021	-2.519	I(1)
GDP	.002	-2.249	-2.183	I(1)
RES	.096	-1.99	-3.429	I(1)

* The auxiliary regressions were run with a constant, trend and four lags.

Table 17: Testing for stationarity

Variable	EX	CPI	WP	DC	RES	GDP
$\chi^2(4)$	23.22	13.15	22.46	16.56	13.92	15.68

Incorporating domestic credit and foreign exchange reserves

The first task is to look at the data distribution.[5] This is shown in Table 15. For the normality test (Norm) the figures in parentheses are the probability values. We notice that foreign exchange reserves is the only variable that follows a normal distribution. The next step is to test for a unit root in the variables. The results are shown in Table 16. In testing for the unit root tests, it was clear that some variables had undergone shocks in the period of the study, especially with the exchange rate and the domestic price level, as earlier shown.

This conclusion was drawn from running the recursive ADF (RADF), whose t-values are shown in Appendix A. This helped us in observing whether there are shocks or structural breaks in the series. In the case where the series were being affected by shocks or breaks, the unit root tests would be biased unless we modelled the shocks or structural breaks in the series (see Perron, 1993, 1994). As it turned out, the exchange rate and the domestic price level were being affected by shocks and this could have led to wrong conclusions about their level of integration, as the t-value graphs show. This called for modelling the shocks in the series by adding dummy variables. Interestingly, the shocks to the exchange rate and the price level coincide with discrete devaluations of 1973, 1981 and 1992 and the price shocks of 1982 and 1993. The ADF test results in Table 16 take the effects of shocks into account.[6]

All the variables seem to be non-stationary and coupled with their respective graphs (not reported); they are integrated of the first order, I(1). International reserves, RES, seem to border an I(0) process when we use the ADF test, but this is refuted by its graphical analysis and the results in Table 17 when a maximum likelihood procedure is used instead in the cointegration analysis.

The basic idea behind cointegration analysis is that although macro variables may tend to move up or down over time, groups of variables may tend to drift together. If there is some tendency for some linear relationships to hold among a set of variables over long periods of time, then cointegration helps us to discover it (see Johansen and Juselius, 1990, 1992; Juselius, 1991). In the first stage of the analysis all the variables were assumed endogenous and we ran the Johansen Maximum Likelihood Procedure in order to determine the number of cointegrating vectors in the data. The results of the test for stationarity of the variables is presented in Table 17.

The test follows a χ^2 distribution with 4 degrees of freedom; the critical value at the 5% level is 9.488. As can be seen the test is significant for all the variables, confirming their non-stationarity.

The next test, shown in Table 18, is on residual mis-specification to determine whether the residuals from the specified equations are a white noise process.

Table 18: Residual mis-specification tests*

Equation	B-P $\chi^2(19)$	ARCH $\chi^2(4)$	Normality $\chi^2(2)$	LM $\chi^2(4)$**
ΔEX	13.79	1.66	1.56	4.668
ΔCPI	21.33	4.12	13.62	12.62
ΔWP	21.37	2.50	19.06	4.681
ΔDC	20.29	4.26	12.70	0.794
ΔRES	16.60	4.11	11.28	8.954
ΔGDP	16.94	9.69	10.13	6.969
5% Level	30.14	9.49	5.99	9.49

* Four lags were used in each equation; the inflation equation shows serial correlation at 5% but not at 1%.

**Since the CATS program of the Johansen Procedure does not give the LM test for serial correlation, the residuals for each equation were generated and regressed on their lags, and lags of the other regressors in the system plus the cointegrating vectors lagged one step and the LM test calculated.

Table 19: Cointegration tests and the estimated β- and α-vectors

	Eigen -	Values	and	Trace	Test
H_0	r=0	r≤1	r≤2	r≤3	r≤4
	.575	.481	.280	.041	.035
T(r)	176.37	97.57	37.27	7.11	3.24
95%	102.14	76.06	53.12	34.91	19.96
		β -	Vectors		
Variable	β_1	β_2	β_3	β_4	β_5
EX	1.00	1.00	1.81	1.00	1.00
CPI	-1.158	-.884	-1.065	-.366	-1.023
DC	.057	-.474	-1.441	.249	1.503
RES	.078	.354	1.00	.028	.559
GDP	.146	.640	.631	-.820	-2.220
WP	.461	.103	-.036	.894	.924
		α -	Vectors		
Equation	α_1	α_2	α_3	α_4	α_5
ΔEX	-.207	.138	.001	.052	-.003
ΔCPI	.184	-.006	-.026	.038	-.007
ΔDC	.307	.082	.037	.016	-.044
ΔRES	-1.160	-.712	.055	.150	-.185
ΔGDP	.008	-.007	.006	.015	.001

Table 20: Final cointegration vectors

Variable	EX	CPI	DC	WP	TEST*
β-vector	1.00	-1.234	.212	.564	$\chi^2(1)$=.02[.90]
Equation	ΔEX	ΔCPI	ΔDC	ΔWP	
α-vector	-.097	.168	.346	-	
Variable	EX	DC	RES	GDP	TEST*
β-vector	-.841	1.00	-.675	.565	$\chi^2(1)$=1.7[.190]
Equation	ΔEX	ΔDC	ΔRES	ΔGDP	
α-vector	-.033	-.175	.985	.003	

* The two vectors were obtained when we imposed two restrictions on one β-vector at a time. This exclusion test follows a χ^2 distribution with 1 degree of freedom. The figures in the brackets are the probability values.

As before in the three-variable case, the normality test is significant except for the exchange rate changes equation. The same case applied in the previous section; there are huge outliers at the end of the sample. The ARCH test is significant for the real income growth equation but not for the other equations. The B-PQ test is not significant for any of the equations and the LM test is significant for the inflation equation at 5% but not at 1% (the critical value at 1% level is 13.28). We thus proceed under the assumption that the residuals are approximately a white noise process.

In the second stage, we re-estimated the system with world price level conditioned

Table 21: GNC tests (probability values)

VARS. ↓Equation →	LAGS	ΔCPI	ΔEX	ΔDC	ΔRES
ΔCPI, ECM1	1-4	.000	.000	.187	.009
ΔEX, ECM1, ECM2	1-4	.001	.286	.002	.163
ΔDC, ECM1, ECM2	1-4	.009	.051	.100	.010
ΔGDP, ECM2	0-4	.027	.000	.000	.048
ΔRES, ECM2	1-4	.006	.056	.024	.007
ΔWP, ECM1	0-4	.312	.815	.968	.366
ECM1, ECM2	1	-	.072	.102	-
ECM1	1	.047	.334	.240	-
ECM2	1	-	.025	.033	.131

as weakly exogenous in order to improve the results. The cointegration tests are shown in Table 19. From the cointegration tests, we find that we have two significant vectors. We tested various combinations of variables that form these two vectors and then chose the most significant of them and also those that encompassed the data.

The chosen vectors are shown in Table 20, together with the respective test statistics. We do not intend to give these vectors a structural interpretation. In the first cointegrating vector (ECM1), the exchange rate, the price index, the international price level and the domestic credit cointegrate. From the way this vector appears, it shows that increase in domestic credit will appreciate the real exchange rate. This is the statistical result and may seem contradictory, but can be interpreted as the results of the speed of reaction of foreign reserves. We also notice that domestic credit adjusts very fast, more than the price level and the exchange rate in case of any disequilibrium; this is reflected by the size of its α-coefficient. In the second vector (ECM2), domestic credit, exchange rate, international reserves and real income cointegrate. From these results we see that the burden of adjustment is borne by international reserves, whose adjustment is almost complete and instantaneous. Domestic credit adjusts slowly while the exchange rate and the real income are the slowest. In fact, real income seems exogenous in this vector.

The next stage is to use these vectors in a multivariate Granger non-causality test (GNC), together with the variables in first-differences to determine which variables drive each other. Finding cointegration is proof that the variables predict each other at least in one direction. When carrying out the GNC tests for a particular variable, we consider that in addition to entering the model in rates of change, it is also part of one or both error-correction terms — that is, the cointegarting vectors. By following this procedure we pay attention to the long-run information in the data, get more efficient estimates and make sure that the standard distributions for statistical inference are valid since all variables are stationary. The results of the GNC tests are reported in Table 21. From the GNC tests, we notice that in the first equation the rate of inflation is predicted by its own lagged values, exchange rate changes, real income growth, growth of domestic credit and international reserves, but not by the world rate of inflation. The first error-correction term also predicts the rate of inflation.

In the second equation, we see that exchange rate changes and the rate of inflation drive each other, but exchange rate changes are not predicted by their lagged values. Exchange rate changes are predicted by growth in domestic credit, real income, international reserves and the error-correction terms. In the third equation, domestic credit growth and exchange rate changes are seen to drive each other and growth of domestic credit is predicted by real income growth, rate of change of international reserves, the second error-correction term and a weak effect coming from its own lagged values. In the final equation, changes in international reserves are predicted by the domestic rate of inflation, changes in domestic credit, real income growth and own lagged effects. There are reverse effects between changes in international reserves and domestic credit on the one hand and the rate of inflation and changes in international reserves on the other.

The results of the GNC tests have established that:

- The rate of inflation and exchange rate changes drive each other.
- Domestic credit predicts the rate of inflation without significant reverse effects (at 18.7%).
- The domestic rate of inflation and changes in reserves drive each other.
- Exchange rate changes and the rate of change of domestic credit drive each other.
- The rates of change of domestic credit and international reserves drive each other.

These results can be summarized below for the four equations:

$$\begin{array}{cccc} \Delta EX & & \leftrightarrow & \Delta DC \\ \updownarrow & \nwarrow & \swarrow & \updownarrow \\ \Delta CPI & & \leftrightarrow & \Delta RES \end{array}$$

The double arrow heads show the variables that drive each other. The system does not seem to have a nominal anchor.

Perhaps these results could be modified by using money supply, M2, instead of domestic credit to incorporate net foreign assets that also affect the exchange rate. After incorporating M2 into the system, the flow chart shows the following results.[7]

$$\begin{array}{cccc} \Delta EX & & \leftrightarrow & \Delta M2 \\ \updownarrow & \nwarrow & \swarrow & \updownarrow \\ \Delta CPI & & \leftrightarrow & \Delta RES \end{array}$$

The results are almost the same except that money supply growth drives the exchange rate without reverse effects.

To describe the relative importance of each variable in accounting for its own behaviour and that of the other variables over time, we have decomposed the forecast error variance for the variables in the system. Real income was assumed pre-determined; we thus do not show its innovation because it is an interpolated variable. We report the results in Appendix B for a forecast horizon of 36 quarters.

Since the results are sensitive to a particular ordering of the variables we have used the results of the GNC test, where the world rate of inflation was put first (in the equation formulation it was made to depend only on its lagged values and the error-correction term). International reserves were put second, domestic credit was third, exchange rate was fourth and the domestic rate of inflation was last.

Variance decomposition of the rate of inflation shows that about 69% is explained by own innovations, 23% by shocks in the exchange rate changes and about 6% by shocks in the foreign rate of inflation. Other variables are of minor importance. For the exchange rate changes, none of the variables in the system is dominant in accounting for its innovations. Thus about 81% is explained by own innovations, and 14% by shocks to the domestic and foreign inflation rates. Changes in domestic credit account for only 4%. Changes in domestic credit and international reserves are the only variables that are not dominant in accounting for their own innovations. The bulk of their innovations is explained by shocks to the domestic rate of inflation and exchange rate changes. Changes in international reserves is the only variable in the system that is weak in accounting for both its own innovations and those of the other variables. These results show a situation where there is no anchor to the system; ΔCPI and ΔEX drive the other variables and shocks to the other variables drive ΔCPI and ΔEX.

IV. Conclusion

In the first part of this paper we looked at the dynamics of the domestic price level, the exchange rate and the foreign price level. We estimated an equilibrium real effective exchange rate that encompasses different exchange rate regimes, estimated as a cointegrating vector that spans these three variables. This equilibrium real effective exchange rate was compared with the nominal and real effective exchange rates and showed periods of over-valuation during the fixed exchange rate regime; the real rate declines slightly in the real exchange rate rule regime. The floating (or partial float) covers only one year and creates a depression. This reflects the stiff devaluation in 1993 and thus lowers the real rate, but quickly returns to its original level.

Further analysis showed that the rate of inflation and exchange rate changes drive each other, while the foreign rate of inflation and the real effective exchange rate drive the nominal effective exchange rate changes. Even though the pass-through equation does not take into account the experiences of the 1991-1993 period, we come to the conclusion that the pass-through effects are large, which perhaps explains why the domestic rate of inflation has followed the developments in the external sector.

In the second part of the paper, we identified two significant cointegration vectors that spanned the data. However, we did not attempt to give the cointegrating vectors a theory-based interpretation but rather chose a linear combination of variables that were most significant. These vectors helped us in performing the GNC tests with stationary variables both in log-differences and in stationary linear combinations. The results showed that inflation was predicted by exchange rate changes and changes in international reserves with strong reverse effects. That is, these variables drive each other. Inflation was predicted by domestic credit and real income growth. Exchange rate changes were predicted by changes in domestic credit with reverse effects, while changes in domestic credit and international reserves drove each other. When money supply growth was incorporated, it showed that it drives the exchange rate changes and the rate of inflation with no reverse effects.

In the dynamic analysis, the results showed that the rate of inflation and exchange rate changes were dominant in accounting for their own innovations and were little aided by shocks in the other variables. This was not the same with the growth in domestic credit and international reserves. Thus, for the growth of domestic credit and international reserves, the domestic rate of inflation and exchange rate changes were dominant in accounting for their innovations. Shocks to these variables were transmitted to the innovations in exchange rate changes and inflation. The system may thus portray a picture consistent with a loss of a nominal anchor to halt the process.

The large pass-through effects, the results that inflation and exchange rate changes drive each other, and the indication that the domestic credit growth predicts the rate of inflation without strong reverse effects may explain the acceleration of inflation and currency devaluation between 1990 and 1993. In this period, domestic credit increased by more than 500%. This increase must have produced a spiral from the rate of inflation, to exchange rate changes, to other variables and then back to domestic credit. This is because domestic credit growth and changes in international reserves drive each other, while at the same time these variables have feedback effects with the rate of inflation. This paper therefore concludes that the exchange rate and the domestic price level are important variables in macroeconomic stability, and that exchange rate changes together with the rate of inflation drive each other and other macro variables. The point is strengthened by the difficulties encountered in estimating a pass-through equation; that is, the model broke down when the period of exchange rate instability (and hence inflation), 1990-1993, was included.

The results in this paper show that the domestic rate of inflation and exchange rate movements feed into each other. The foreign rate of inflation and the real effective exchange rate drive nominal exchange rate movements. The pass-through effects from exchange rate and foreign price level are found to drive the domestic price level. In the second part of the empirical analysis, it is seen that inflation is driven by exchange rate movements and changes in foreign exchange reserves with strong reverse effects.

Exchange rate movements and changes in domestic credit drive each other. Furthermore, changes in foreign exchange reserves and domestic credit drive each other. When money supply growth is incorporated into the analysis instead of domestic credit, because money supply includes net foreign assets, it is seen to drive the rate of inflation and exchange rate movements with no reverse effects.

These results may help to explain the acceleration of inflation and currency devaluation in the early 1990s. In this period, domestic credit increased by more than 500%. This increase may have produced a spiral from the rate of inflation to the exchange rate changes and to other variables and then back to domestic credit. The exchange rate pass-through equation could not predict inflation movements in this period. The results thus rely on the causality and variance decomposition analysis. The failure of the simple pass-through equation to account for inflation movements in this period may imply a need to specify a comprehensive structural model. In general the results in this paper show that the four variables in the system, the exchange rate, domestic credit (or money supply), foreign exchange reserves and the rate of inflation, form a causal structure that is consistent with loss of a nominal anchor in the system. A shock in any of the variables in this system is likely to spill over into all the other variables with reverse effects. This may explain why over-accumulation of foreign exchange reserves in 1993-1994 led to an appreciation of the currency and a slowdown in the rate of inflation. Similarly, increase in domestic credit will affect the level of reserve, exchange rate and inflation. However, regime shifts (which makes money supply and exchange rate exogenous or endogenous not at the same time and in different periods), controls and shocks hitting the economy may imply a more complicated causal structure than this simple analysis could uncover.

Appendix A: t-values for the recursive augmented Dickey-Fuller tests

Figure A1: Exchange rate

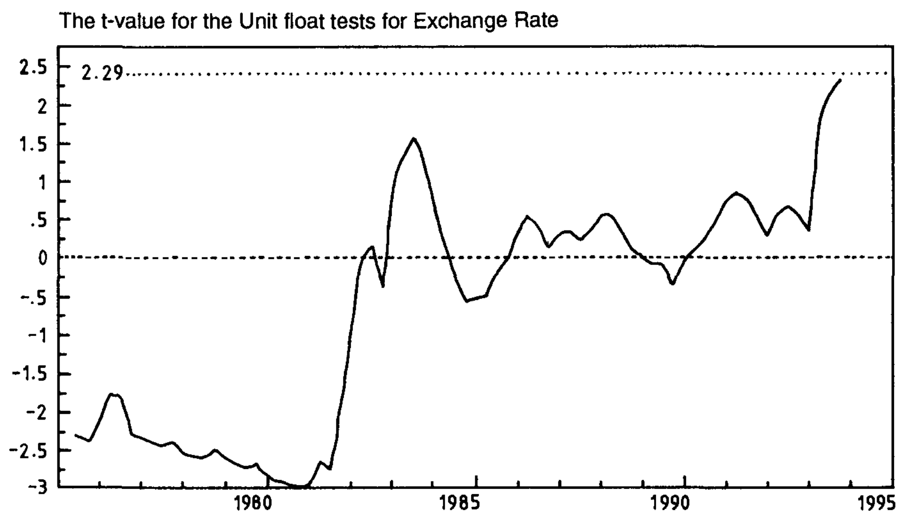


Figure A2: Inflation

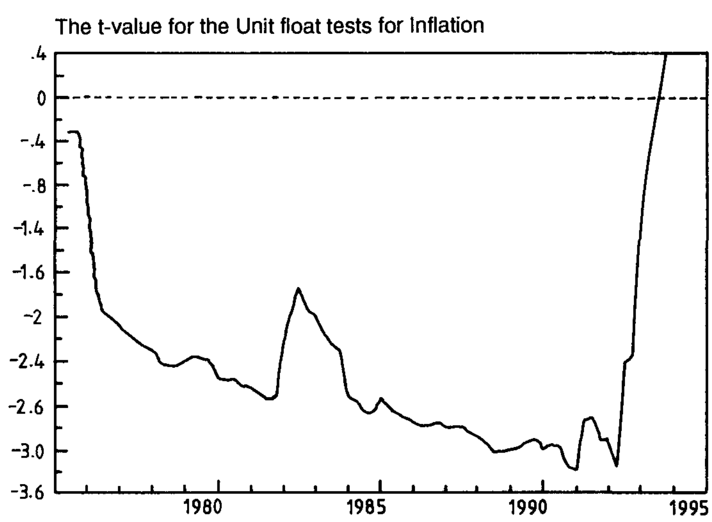


Figure A3: Real income

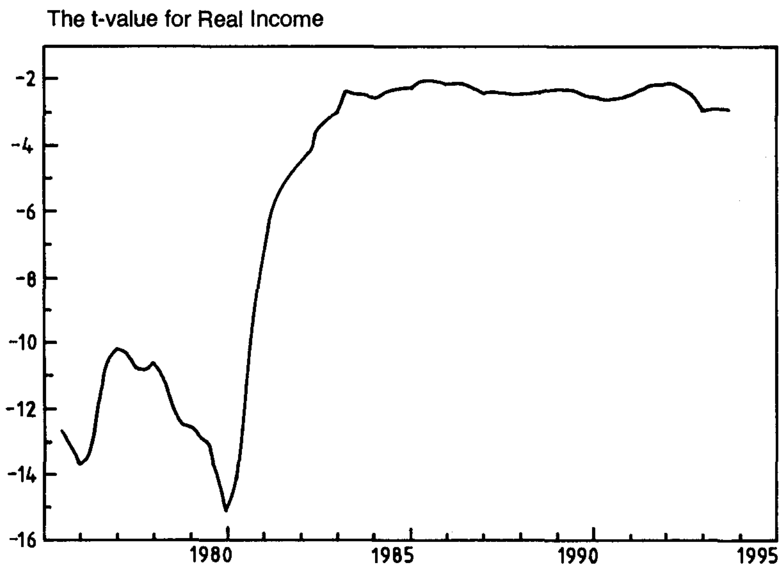


Figure A4: Reserves

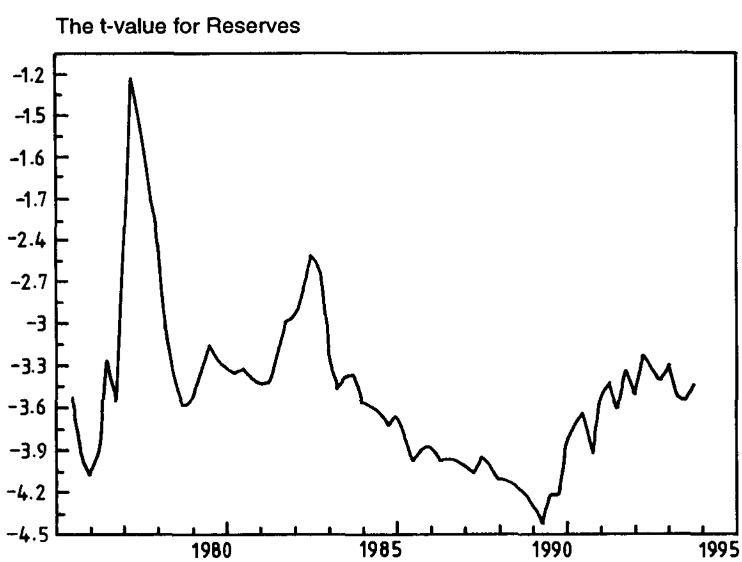


Figure A5: World prices

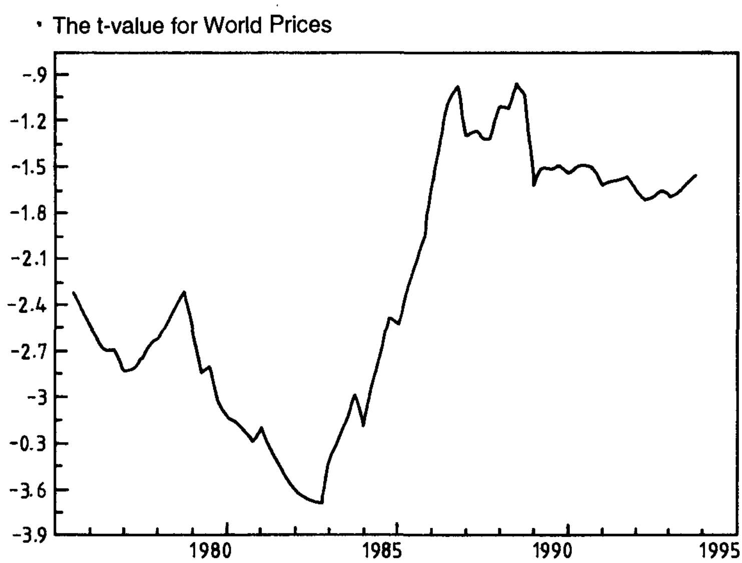
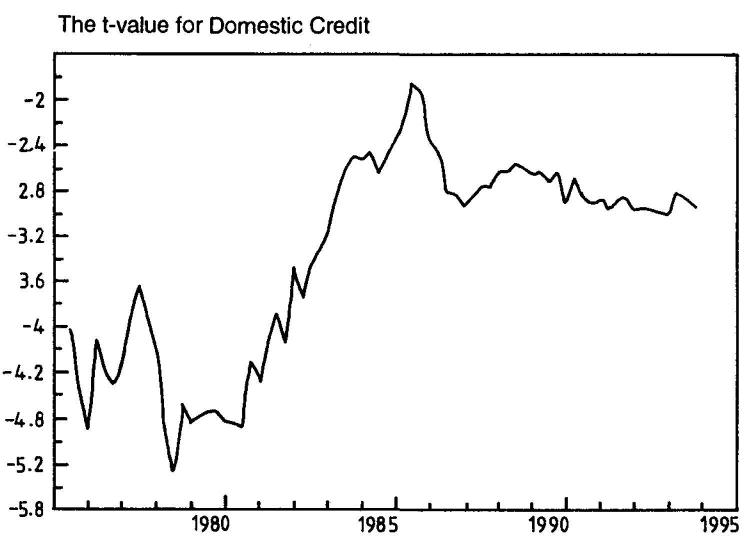


Figure A6: Domestic credit



Appendix B: Decomposition of forecast error variance (%)

The rate of inflation (ΔCPI)

Steps	ΔWP	ΔRES	ΔDC	ΔEX	ΔCPI
2	3.33	.05	.28	13.73	82.61
4	3.45	.08	1.43	16.63	78.42
8	4.86	.09	1.55	19.14	74.35
16	5.69	.12	1.78	22.11	70.30
36	5.89	.12	1.99	23.21	68.79

Exchange rate changes (ΔEX)

Steps	ΔWP	ΔRES	ΔDC	ΔEX	ΔCPI
2	5.24	.03	4.60	86.95	3.17
4	6.71	.04	4.33	85.89	3.03
8	6.79	.04	4.36	83.68	5.13
16	7.06	.04	4.39	81.79	6.73
36	7.16	.04	4.42	80.96	7.42

Changes in domestic credit (ΔDC)

Steps	ΔWP	ΔRES	ΔDC	ΔEX	ΔCPI
2	6.39	.12	67.09	24.86	1.52
4	7.62	.11	39.95	49.40	2.91
8	7.06	.11	34.14	49.60	9.10
16	6.77	.11	28.59	45.01	19.49
36	6.84	.12	27.71	44.83	20.49

Appendix B....continued

Changes in international reserves (ΔRES)

Steps	ΔWP	ΔRES	ΔDC	ΔEX	ΔCPI
2	14.43	1.35	6.81	75.34	2.06
4	9.65	.77	5.55	75.52	12.50
8	6.46	.55	5.29	51.48	36.22
16	5.46	.52	4.53	40.86	48.64
36	5.41	.52	4.70	39.81	49.57

Notes

1. The rate of inflation rose from 9.3% in 1970 to about 21% in 1982 and to about 46% in 1993. During the crisis period of 1992-1993, the monthly rate of inflation, measured by the three-month annualized inflation rate, rose dramatically, reaching to 101% in June 1993.

2. A mean zero stochastic process is white noise if its elements are mutually uncorrelated (see Hendry, 1995, p.39-43).

3. A variable is said to be integrated of the nth order, I (n), if it requires to be differenced n times to render it stationary, that is integrated of order zero, I (0).

4. Granger, Konishi and Ramey (1993) use the same approach; they also go further and use several lags of the error correction terms.

5. This section follows from the data section in Part III, but is separated to avoid confusion in the discussion of the results and reference.

6. The Johansen Maximum Likelihood Procedure also takes this into account since the dummies are added to the equations to take care of outliers.

7. The reformulated cointegrating vectors, when we include money supply, are:
   ECM1 = EX - 1.182CPI + .213GDP + .565WP
   ECM2 = M2 - 1.013CPI - .705RES
   These were chosen as the most significant vectors after testing for various combinations of variables.

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AFRICAN ECONOMIC RESEARCH CONSORTIUM

P.O. BOX 62882
NAIROBI, KENYA

TELEPHONE (254-2) 228057
225234 215898 212359
332438 225087

TELEX 22480

FAX (254-2) 219308

E-MAIL aerc@elci.gn.apc.org
or aerc@form-net.com

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