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Real Exchange Rate Response To Capital Inflows: A Dynamic Analysis For Ghana

by

Maxwell Opoku-Afari, Oliver Morrissey and Tim Lloyd

Centre for Research in Economic Development and International Trade, University of Nottingham

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Abstract

One of the most challenging problems in developing countries such as Ghana is exchange rate management, that is, 'getting the exchange rate right' especially in the context of exchange rate misalignment. The major research and policy question is *what constitutes the equilibrium real exchange rate* (ERER) and how can it be measured? Acknowledging the importance of fundamentals in determining the equilibrium real exchange rate, the paper concentrates on the effects of capital inflows (by decomposing capital inflows into official inflows, 'permanent' inflows and 'non-permanent' inflows). Vector Autoregressive (VAR) techniques are used to model the long-run equilibrium real exchange rate in Ghana, and based on a multivariate orthogonal decomposition technique, the equilibrium steady state path is identified which is used in estimating misalignments. As predicted by the Dutch Disease theory, results indicate that capital inflows tend to appreciate the real exchange rate in the long-run. Capital inflows is the only variable generating real appreciation in the long-run; technology change, trade (exports) and terms of trade all tend to depreciate the real exchange rate. The only variable that has a significant (depreciating) effect on the real exchange rate in the short-run is trade, implying that changes in exports are the major driver of exchange rate misalignment. It is also shown that the real exchange rate is slow to adjust back to equilibrium, implying policy ineffectiveness or inflexibility.

JEL Classification: F31, F35, O11, O55

Keywords: Capital Inflows, Aid, Real Exchange Rate, Ghana

Outline

1. Introduction
2. Theory of Long-run Equilibrium Real Exchange Rate
3. Trends in Real Exchange Rate and Fundamentals in Ghana
4. Empirical Model
5. Estimation and Test Results
6. Equilibrium Real Exchange Rate
7. Conclusions and Implications

1. INTRODUCTION

Exchange rate management, or 'getting the exchange rate right', is a challenging macroeconomic policy issue. There has been a broad consensus in policy circles in developing countries that the overriding objective of exchange rate policy should be to avoid persistence in misalignment, which is a common problem in most developing countries. However, in order to manage misalignments it is necessary to successfully identify what constitutes the equilibrium real exchange rate, and this continues to pose a fundamental difficulty in the modern literature on the real exchange rate (RER).[1] Various studies have tried to estimate the equilibrium RER based on a standard theory which says that the equilibrium RER is a function of observable macroeconomic variables (the fundamentals), and that the actual exchange rate approaches the equilibrium rate over time. Most of these studies measure the equilibrium RER as a static equilibrium instead of treating it as a steady state relation. In the latter case, the equilibrium follows a dynamic path and permanent changes in the fundamentals alter the equilibrium level at each point in time.

An important factor in identifying the equilibrium real exchange rate is the role of capital inflows, which are one of the fundamentals determining the real exchange rate. According to Dutch Disease theory (Corden and Neary, 1982), excessive capital inflows lead to real appreciation of the exchange rate via its impact on both the tradable and non-tradable sectors of the recipient economy. However, the extent of appreciation as a result of capital inflows depends to a large extent on the 'degree of reversibility' of the particular inflow in question. Some inflows are more prone to reversal (or more likely to be associated with outflows) and therefore will have different effects on national income and the real exchange rate than other flows that are less reversible (or more permanent in nature). This suggests a merit of decomposing capital inflows according to their degree of reversibility. Unlike most empirical studies, which use aggregate capital inflows, this study decomposes capital inflows.

Capital inflows are important for Ghana as, like many developing countries, it has become dependent on foreign aid (the major inflow), mainly for budgetary support but also as a means of supporting the local currency. The aid/GDP ratio in Ghana has increased from an average of

1 Strictly, RER is defined as the real effective exchange rate in this paper unless otherwise stated.

4% before the structural adjustment programme (SAP in mid 1980s) to almost 12% by 2000. Similarly, the ratio of aid to government expenditure has increased from some 11% prior to SAP to almost 45% by 1998 (see Table 1). One of the neglected effects of capital inflows is the loss of international competitiveness as a result of real exchange rate appreciation (for Ghana, see Younger, 1992), an issue we do consider.

Table 1: Selected Aid Intensity Indicators for Ghana (%)

	Aid/GDP	ResGDP	Aid/Inv	Aid/M	Aid/Gov	FDI/ GDP	Aid per capita
1970-79	2.77	21.07	31.16	5.33	6.83	0.85	8.32
1980-84	3.76	22.91	79.68	16.65	11.21	0.25	14.09
1985-89	8.71	8.23	78.50	35.46	62.14	0.13	32.93
1990	9.57	12.82	66.17	34.65	72.15	0.25	37.83
1991	13.37	10.95	84.10	49.46	95.27	0.30	57.54
1992	9.56	9.48	74.59	31.20	53.65	0.36	38.85
1993	10.36	9.46	46.55	26.87	49.24	2.10	38.10
1994	10.04	10.03	41.90	25.71	48.68	4.28	32.81
1995	10.12	11.14	50.29	28.74	47.25	1.66	38.10
1996	9.44	12.38	43.65	25.39	44.82	1.73	37.05
1997	7.17	7.72	29.44	17.52	45.12	1.21	27.19
1998	9.39	8.42	40.82	22.98	44.66	0.75	37.97
1999	7.84	7.72					
2000	11.74	21.00					

Notes: ResGDP is the Resource gap to GDP ratio measured as (Imports-Exports)/GDP; Aid is expressed relative to Investment (Inv), imports (M) and government expenditure (Gov).
Source: Author's own calculations with data from the OECD's CD-ROM on Geographical Distribution of Financial Flows to Developing countries.

This paper concentrates on the effects of capital inflows in determining the equilibrium real exchange rate (ERER), and hence misalignments. We develop a dynamic model (using VAR and Structural VAR methods) to estimate the ERER based on the fundamentals. This is in line with the popularly held view that the ERER is a steady state relation and thus moves along a steady state path. This will be particularly helpful to policy makers in Ghana, as most still use the static purchasing power parity (PPP) concept of equilibrium, which has not received much empirical support.

The paper is organised as follows. Section 2 provides a brief review of the existing literature and the theoretical framework employed for determining the long-run equilibrium real exchange rate. Section 3 describes the data and trends for Ghana. Section 4 identifies the empirical model, while Section 5 presents the co-integration methodology and discusses the results. Section 6 briefly considers measurement of exchange rate misalignment. The final section concludes with some policy recommendations.

2. THEORY OF LONG-RUN EQUILIBRIUM REAL EXCHANGE RATE

Theoretically, the real exchange rate (RER) that prevails in an economy at any point in time is perceived as a short run phenomenon. The RER may change if the economy is shocked by dynamic forces that affect the short run equilibrium, thereby leading to disequilibrium in the long-run. In this case, the sustainability of the RER depends on whether the observed RER was the result of a sustainable long-run macroeconomic equilibrium. This brings to bear the importance of determining the factors that support the RER in the long-run.

The long-run equilibrium real exchange rate is that RER that is compatible with steady-state equilibrium for the economy's net international creditor position, conditioned on the permanent values of a variety of policy and exogenous variables. These permanent values need to be identified and their direction of influence explored. This way of defining the long-run equilibrium real exchange rate highlights the permanent variables, which will be referred to here as the fundamentals (as in the literature). This implies that permanent changes in any of these fundamentals may lead to changes in the long-run ERER, which follows a steady-state path. We follow Montiel (1999) in deriving the long run equilibrium real exchange rate.

Montiel (1999) considers two composite good markets, tradables and non-tradables. To analyse these markets, he defined the internal balance (IB) as the condition where the non-tradables goods market clears in the current period and is expected to be in equilibrium in the future (consistent with Edwards, 1989), that is,[2]

$$y_N(e) = c_N + g_N = (1-q)ec + g_N \qquad (1)$$

and $\partial Y_N / \partial e < 0$

where y_N is the supply of non-tradable goods given full employment, e is the real exchange rate, c is total private spending, with q being the proportion of this total private spending on traded goods and g_N represents government consumption of non-traded goods. The above shows the IB position where the real exchange rate is inversely related to consumption. This follows from the fact that, if we start from an initial equilibrium IB position, then an increase in private spending (c) results in an excess demand for non-tradable goods at the initial real exchange rate. To restore equilibrium, a real appreciation is required, promoting supply of non-tradable goods and increasing demand for tradable goods.

Similarly, Montiel (1999) defined the external balance (EB) as the current account balance that is compatible with long-run sustainable capital inflows:

$$\dot{f} = y_T(e) - g_T - (q + t)c + z + rf \qquad (2)$$

where $\dot{f}$ is change in net foreign assets over time, f is total net foreign assets, r is the real yield on the foreign assets (measured in traded goods), $y_T(e)$ is the production of traded goods locally, g_T is government consumption of traded goods, c is total private consumption with q representing the proportion of private consumption on traded goods, t captures transaction costs associated with private spending, with z and rf capturing net aid inflows and external debt service respectively.

Equation (2) posits that EB is given by the trade balance (that is, domestic output of traded goods net of local consumption of these goods), net aid inflows and less costs on foreign debt. In equilibrium, where $\dot{f} = 0$, this gives the EB locus along which we have a relationship between consumption and the real exchange rate. This shows a positive relationship between

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2 Assuming that all production of non-traded goods is consumed by both governments and households.

consumption and RER because, assuming we started from an equilibrium position (initial EB), then an increase in private spending would generate a current account deficit at the original real exchange rate. To restore equilibrium the RER must increase (depreciate). The depreciation would then switch demand towards non-traded goods and supply towards traded goods. As established so far, whereas an increase in private spending in IB yields an appreciation of the real exchange rate (that is increase in the supply of non-traded goods), a similar shock in EB yields a depreciation and promotes an increase in the supply of traded goods. The overall effect of the two markets, that is IB and EB, produces the equilibrium real exchange rate that is consistent with the fundamentals determining the RER.

Setting the right hand side of equation (2) to zero and combining with equation (1) yields the desired equilibrium real exchange rate:

$$e^* = e^*(g_N, g_T, r^* f^* + z, t^*) \qquad (3)$$

$$e_1 < 0, e_2 > 0, e_3 < 0, e_4 > 0.$$

where * denotes steady state values of endogenous variables. The steady state variables were solved by Montiel (1999) by assuming that the economy faces an upward sloping supply curve of net external funds and that households optimise over an infinite horizon. By recognising that the transactions costs per unit, t , is endogenous and depends on the ratio of money holdings to private spending, hence on the nominal interest rate (which is given in the long run by the rate of time preference and the domestic inflation rate), the final expression for the equilibrium real exchange rate is given as:

$$e^* = e^*(g_N, g_T, z, r_w, p_T) \qquad (4)$$

where r_w is the world real interest rate and p_T is the rate of inflation in the domestic price of traded goods (the rate of time preference is suppressed). As is clear from the above, the nominal exchange rate does not appear among the fundamentals as at most it would only have a transitory effect on the real exchange rate. Equation (4) then states that the real exchange rate consistent with both internal and external balance is a function of fundamentals, perceived to be exogenous, and policy variables.

Empirical applications of the model estimate a version of equation (4), although the variables included as fundamentals differ across studies. Edwards (1994) and Baffes *et al* (1999) include policy variables such as terms of trade, trade policy and productivity shocks as fundamentals. They also include macroeconomic imbalances (such as devaluation), thus allowing for nominal devaluation in the equilibrium equation. Various studies have attempted to estimate the determinants of the real exchange rate (RER) and the effects of RER misalignment in both developed and developing countries. Van Wijnbergen and Edwards (1989), White and Wignaraja (1992), Younger (1992), Olofsgard and Olausson (1993) have all provided support for the hypothesis that capital inflows lead to real exchange rate appreciation. It is also evident that excessive inflows come with macroeconomic management problems (Younger, 1992, for Ghana). Recent work has used cointegration techniques to determine the existence of a long-run equilibrium model and estimate the long-run steady state parameters. As noted by Baffes *et al* (1999), the cointegration technique gives a clearer picture of how the fundamentals determining the RER may move permanently, thus altering the equilibrium value. This supports the claim by Edwards (1989) that the equilibrium is not static but follows a dynamic path. Relevant studies include Elbadawi (1994), Elbadawi and Soto (1997), Ghura and Grennes (1993), Sackey (2001), Stein (1992) and Baffes *et al* (1999).

3. TRENDS IN REAL EXCHANGE RATE AND FUNDAMENTALS IN GHANA

The study uses annual data from 1966 to 2000. Opoku-Afari (2004) provides full details on measures of the real exchange rate in Ghana. A brief description of the data and how they affect the real exchange rate is provided below (see Appendix A for sources and definitions).

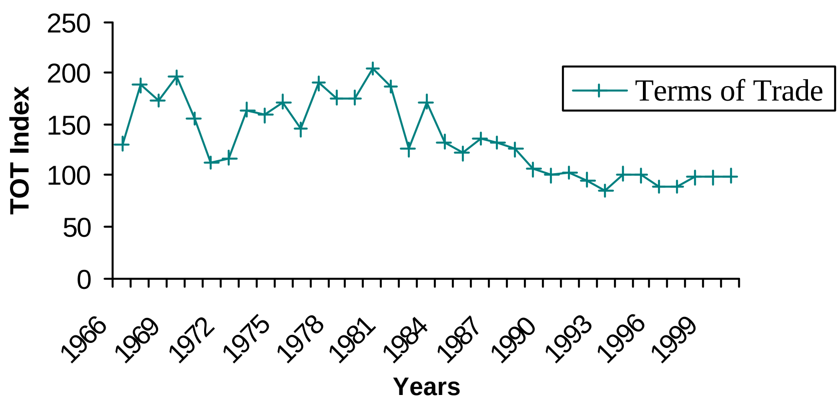
Terms of Trade (TOT) measure the relative price of exports to imports and capture the influence of external demand and supply factors in the tradables sector. An improvement contributes to increases in real wages and thus allows inter-sector shifts in mobile factors of production to the tradables sector. This, in the context of the Dutch Disease theory, will lead to real exchange rate appreciation. There are both income and substitution effects. The income effect of an improvement in terms of trade is that more is spent on all products, resulting in higher prices of non-tradables, causing appreciation in the real exchange rate. The substitution effect leads to a decrease in prices of imported goods and services, falling demand for non-tradables, hence depreciation of the RER. If the income effect associated with the TOT improvement is stronger than the substitution effect, an appreciation of the RER will occur, otherwise the RER will depreciate. This renders the *a priori* expectation of the impact of this fundamental on RER inconclusive. The TOT is defined as:

$$TOT = P_x^* / P_m^* \tag{5}$$

where P_x^* and P_m^* are the foreign prices of exports and imports respectively.

The trends in terms of trade in Ghana are depicted in the Figure 1. It is obvious from the above plot that the period before the SAP was one of relatively favourable terms of trade (in spite of a sharp deterioration in 1971/1972). On the other hand, the period after the SAP has witnessed a steady fall in Ghana's terms of trade. During the same period Ghana's real exchange rate witnessed a continuous depreciation, suggesting that the income effect determines the impact of TOT on the real exchange rate.

Figure 1: Trend in Ghana's Terms of Trade

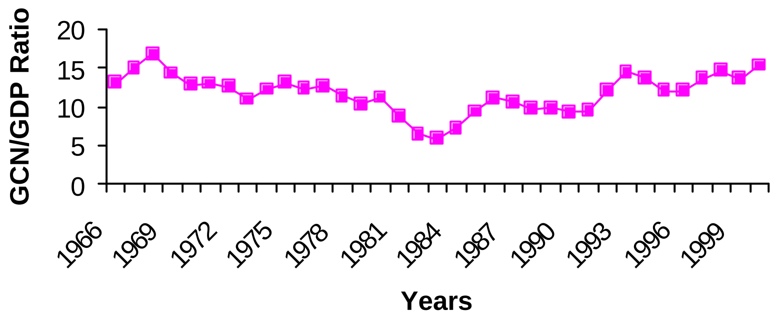


Government Consumption measured relative to GDP captures the propensity to consume (invest in) non-tradable goods. This is essential in explaining the Dutch Disease hypothesis and thus in explaining trends in real exchange rate. An increase in consumption in the non-tradables sector as a result of capital inflows causes further appreciation of the real exchange rate. Due to the unavailability of data on government consumption of non-tradables, we used the ratio of total government consumption (excluding capital expenditures) to GDP as a proxy in line with other studies (Edwards, 1989). That is:

$$GCN_t = \frac{GC_t}{GDP_t} \qquad (6)$$

where *GC* is total government expenditure and GDP is gross domestic product.

Figure 2: Trends in Government Consumption



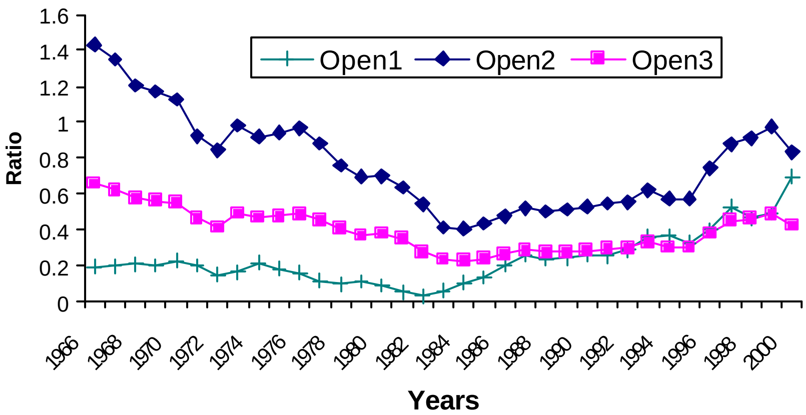
Source: Authors own calculations using data from World Development Indicators CDROM (2002)

Figure 2 shows that period prior to the SAP (pre-1983) witnessed steady decline in government consumption in the non-tradables sector, which theoretically should lead to depreciation of the real exchange rate (*ceteris paribus*). However, the real exchange rate trend shows a steady appreciation in this period, leaving the actual impact of consumption to be determined empirically. On the other hand, after the SAP, the variable showed an upward trend coinciding with the period of massive capital inflows into the Ghanaian economy. This supports the claim in the literature that marginal propensity to consume in the non-tradables sector with capital inflows is relatively high. The post-SAP period was, however, characterised with initial real exchange rate depreciation (as devaluation was an early condition of the SAP), and later a steady appreciation, supporting the Dutch Disease Hypothesis.

A measure of *Openness* is used to capture distortions in trade policy and the extent of liberalisation. Trade policy restrictions tend to reduce the degree of openness and thus implicitly increase the prices of imports and cause prices in the non-tradables sector to increase, leading to real appreciation. An increase in openness will cause depreciation in the real exchange rate. For the purposes of our study we followed Baffes *et al* (1999) and measure the degree of openness using three proxies (Open1, Open2 and Open3).[3] As all measures are based on trade volumes rather than policy, we interpret them as an import capacity measure, trade volume measure and import absorption measure respectively. This is contrary to how many studies interpret these openness measures, but we feel that policy issues are not captured in these measures.

Figure 3 shows that openness measures have declined steadily over the period prior to the SAP (pre-1983) and, not surprisingly, this period was characterised by continuous appreciation of the real exchange rate. This trend seems to have reversed after the SAP but has not returned to the 1960's level except for the Open1 measure. Thus, imports have recovered and indeed increased, but exports do not appear to have reached their 1960s levels. This particular observation is very important in the sense that it helps us to determine which measure is most appropriate for our study, as discussed below.

Figure 3:Trends in Degree of Openness in Ghana

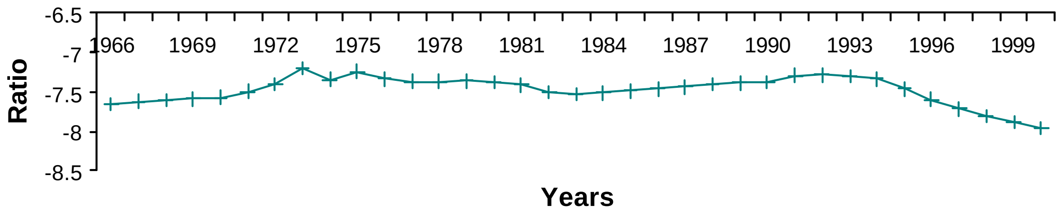


Source: Authors own calculations using data from World Development Indicators CDROM (2002)

3 Open1 is defined as the imports/GDP ratio; Open2 is (imports plus exports)/GDP and Open3 is defined as imports to domestic absorption (DA) ratio (where DA is defined as GDP plus imports minus exports).

Technological Change could be product-augmenting or factor-augmenting and the effects will be different across sectors, and hence on the on real exchange rate. We measure technological change by capturing total factor productivity (TFP) from the Solow-residual growth accounting method (see Appendix A). This captures the part of growth that is not attributable to growth in either capital or labour. With improvements in productivity, incomes will increase and generate increase in demand for non-tradables. The resulting increase in the price of non-tradables would appreciate the RER. This, however, encourages an increase in supply of non-tradables, the price of non-tradables will fall and cause depreciation in the RER, if supply increases sufficiently. The trend in this variable is shown in Figure 4. We observe that after the initial improvement in technology in the 1960s up till 1974, this variable began to deteriorate slowly prior to the SAP and then recovered. The recovery was short-lived as a pattern of deterioration emerged after 1992. The impact of these developments is a matter to be determined empirically.

Figure 4:Trends in Total Factor Productivity (TFP) in Ghana



Source: Authors own calculations (see Appendix A).

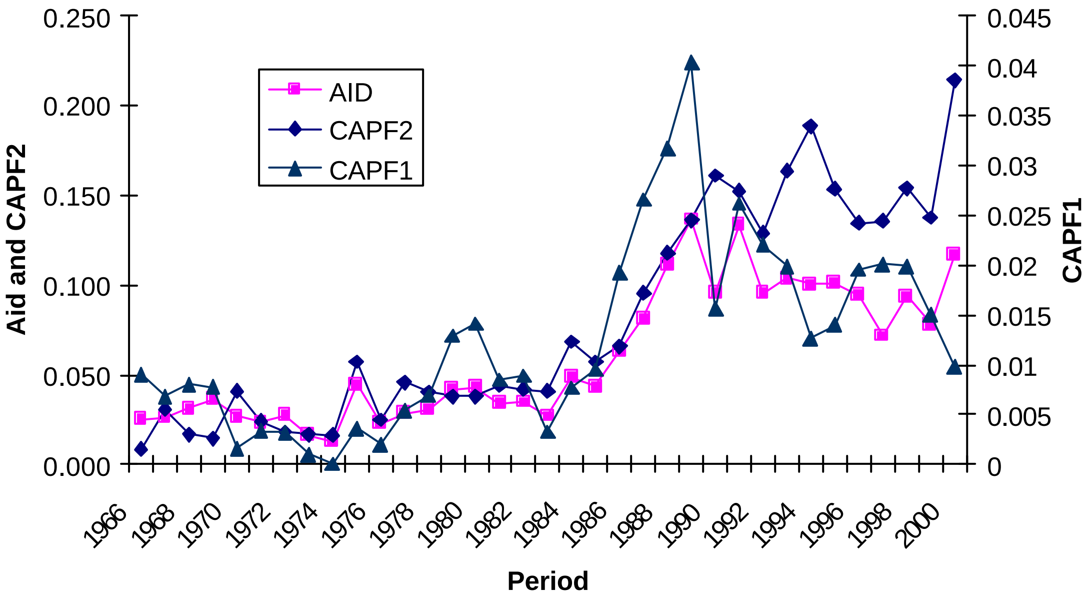
Capital Inflows are the focus of this paper. As noted in the literature on the Dutch Disease (Corden and Neary, 1982), the impact of capital inflows on real exchange rate appreciation depends on the degree of reversibility of the capital inflow, and consequently the medium to long run impact on national income. Following from this, it is obvious that treating capital inflows as one aggregate measure is inappropriate. It will be useful for policy analysis to see how different measures of capital inflows impact on real exchange rate. We decompose capital inflows into three broad measures:

1) Those inflows that require repayment, mainly aid loans excluding grants (*L*) and foreign debt (*D*) as well as non-FDI private capital inflows and other official inflows (*OOF*).[4] These components together measure capital inflows that are reversible and thus 'non-permanent'. This measure is termed CAPF1.

2) The second measure is made up of those inflows we will term as 'permanent' and is made up of aid grants (*G*), remittances (transfers) and foreign direct investments (FDI). Putting these together will give us the inflows that are not immediately reversible. These are termed CAPF2.

3) Finally, we consider separately official inflows, comprising aid grants and loans (*G* and *L*), denoted as AID in our estimations.

Figure 5: Trends in Capital Inflows



Source: Authors own calculations by using data from the OECD (2000).

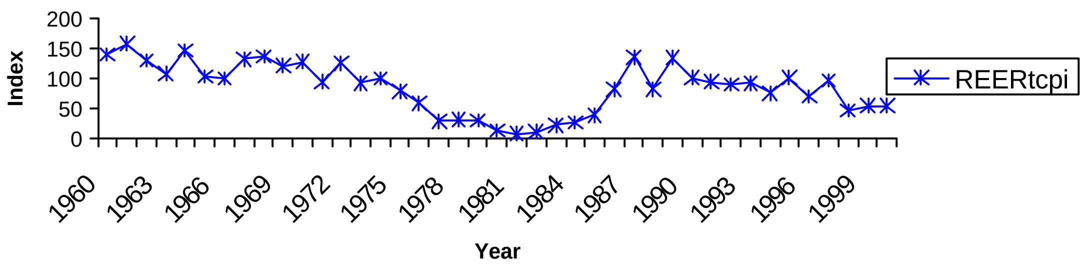
An increase in these variables is expected to lead to an appreciation in the real exchange rate (the extent of appreciation depends on the degree of reversibility of the inflow). A careful

4 Other official inflows (OOF) are either not development motivated, or if development motivated have a grant element below 25%. They include official export credits, official sector equity and portfolio investment, and debt re-organisation undertaken by official sector at non-concessional terms (irrespective of the nature or identity of the original creditor).

examination of these measures shows a broadly common pattern of behaviour with a stable capital inflow during the pre-1983 (SAP) period. After the SAP in 1983 we saw increases in inflows. It is interesting to note that the appreciation of the real exchange rate in the face of falling inflows could be mainly due to the long period of controls (control of foreign exchange rate market and also price controls). However, after the SAP, and the reforms in the foreign exchange market, the currency depreciated to reflect its true value. The actual impact of the inflows on real exchange rate is reflected in the 1990s where excessive inflows were accompanied by persistent appreciation of the real exchange rate (with brief periods of depreciation).

Real effective exchange rate is what we use for the RER, measured as the nominal effective exchange rate (NEER) multiplied by the ratio of a trade-weighted wholesale price index of Ghana's trading partners and the consumer price index in Ghana. Note that RER has been defined in a way that an increase implies depreciation and a fall implies appreciation. The Real Effective Exchange Rate (REER) is defined as $REER = NEER\left[{}^{P_T}\!/\!{}_{P_{NT}} \right]$ where P_T is the price of tradables, P_{NT} is the price of non-tradables and *NEER* is the nominal effective exchange rate. A plot of the computed RER for Ghana is shown below.

Figure 6:Trade Weighted Real Effective Exchange Rates for Ghana: (1990=100)



Source: Authors own computations using data from Direction of Trade Statistics and World Development Indicators CDROM. An upward movement here represents depreciation and a downward movement represents an appreciation

4. EMPIRICAL MODEL

The multivariate approach to co-integration analysis as initiated by Johansen (1988) is used in this study. This is achieved by the use of Vector Autoregressive (VAR), systems of dynamic equations that examine the inter-relationships between economic variables using minimal assumptions about the underlying structure of the economy (see Johansen, 1988; Hamilton, 1994; Harris, 1995). VAR methods are appropriate because all the fundamentals together determine the ERER. To achieve a dynamic steady state relation, we need a method of estimation that will allow for the interdependence and inter-relations of all the identified fundamentals in arriving at the ERER. This is exactly what the VAR technique provides in this context. In addition, we avoid the *a priori* assumption of endogeneity and exogeneity of variables, which has a high potential of affecting inferences made in the analysis.

Assuming the data are I(1), we may write the VAR in error correction form as:

$$\Delta Z_t = \Pi Z_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta Z_{t-i} + m_0 + f D_t + e_t \qquad \textbf{(7)}$$

where $\Gamma = -I_i + A_1 + ... + A_i$ (I_i is a unit matrix) and A_i ($i = 1,........, p$) are coefficient vectors, p is the number of lags included in the system, and e_t is the vector of residuals which represents the unexplained movements in the variables (that is the influence of exogenous shocks). Δ refers to differenced variables, which are I(0) and stationary, m_0 represents the constant term and the D_t captures seasonal dummies and intervention dummies as defined below. As noted in Harris (1995), this way of specifying the system contains information on both the short and long run adjustment to changes in Z_t through the estimates of Γ_i and Π respectively. Of paramount interest in the VAR analysis is the $\hat{\Pi}$ vector which represents a matrix of long-run coefficients, defined as a multiple of two $(n \times r)$ vectors, a and b' i.e. $\Pi = ab'$.

The b' vector represents the co-integrating vectors showing the combinations of long-run relationships amongst the variables while a is a vector of loadings of the co-integrating vectors, denoting the speed of adjustment from disequilibrium. Finding the existence of co-integration is the same as finding the rank (r) of the Π matrix. If it has full rank, the rank $r = n$, and we have n co-integrating relationships, that is, all the variables are I(0).

We estimate the error correction VAR(k) model as: [5]

$$\Delta X_t = a\,(b', b'_{tot}, b'_{tfp}, b'_D, b_0)\begin{pmatrix} X_{t-1} \\ LTOT_{t-1} \\ TFP_{t-1} \\ Ds83_{t-1} \\ t \end{pmatrix} + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} +$$

$$\sum_{i=0}^{k-1} g_i \Delta LTOT_{t-i} + \sum_{i=0}^{k-1} d_i \Delta TFP_{t-i} + \sum_{i=0}^{k-1} j_i \Delta Ds83_{t-i} + m_0 + \Phi D_t + e_t \qquad \textbf{(8)}$$

where $Ds83_t = \begin{Bmatrix} 0: & 1966-1983 \\ 1: & 1984-2000 \end{Bmatrix}$ is a shift dummy which caters for the transitory shock with a level shift in Ghana in 1983. This will then measure the effect of SAP reform and/or liberalisation on the real exchange rate in Ghana, treated as a weakly exogenous variable in our estimations to be able to capture its long lasting effect (see Juselius, 2003, for the rational behind treating shift dummies as weakly exogenous variables). Similarly, D_t contains the intervention dummy representing the transitory shocks observed in 1974 in our *TFP*, *TOT* and *AID* variables, given as $Dt74 = \begin{pmatrix} 1: & 1974 \\ -1: & 1975 \end{pmatrix}$ otherwise zero. The plots of the standardized residuals without the dummies show that we had outliers with large residuals in these years.[6] These dummies were found to reduce the residuals to a satisfactory level. The shift dummy was treated as a weakly exogenous variable since it is clear that the transitory shock also had permanent effect in the data.[7]

5 The information criteria and likelihood ratio tests indicated that two lags seemed optimal. The choice of two lags also reflects the relatively small sample size (see Appendix).

6 It is also evident from the plots of variables that none had a linear trend, hence the absence of a trend term in our model. In the light of this, we restricted the constant term to the co-integration equation. Deterministic components (trend, constant and dummies) have a different meaning and interpretation in dynamic models and asymptotic distributions of the rank test depend very much on the correct specification of the model with trend, constant or dummies. We do not allow accumulation of the constant term effect to have a trending effect in our model. The justification for this type of estimation is in Juselius (2003: 99).

7 A careful examination of the data points to breaks associated with shocks in 1974 and institutional reforms in 1983, both are incorporated with dummy variables. Major shocks and reforms are likely to have a fundamental impact on economic behaviour and need to be included in the systematic part of the model. Ignoring this problem is likely to bias estimates and result in invalid inference (Juselius, 2003: 45). However, if an ordinary intervention does not appear as an outlier, it is possible to treat it as a random shock.

Two other variables are treated as weakly exogenous (by assumption) and restricted to enter only the co-integration equation. These are the terms of trade (*TOT*) and total factor productivity (*TFP*). The decision to assume *a priori* weak exogeneity for these two variables was based on economic reasoning rather than statistical tests. In the case of Ghana, *TOT* can be seen as determined outside the Ghanaian economy. Ghana is a small open economy and thus has little or no influence on the price of its exports or imports. Similarly, with relatively low technology levels, little can be done to initiate technological change and *TFP* can also be treated as exogenous. Arguably for Ghana, aid could have been treated as a weakly exogenous variable, but when this was tested weak exogeneity was rejected (see Appendix B). This leaves our endogenous variables (in logs) represented by $X_t = \begin{pmatrix} LREER_t \\ LOpen_t \\ LKA_t \end{pmatrix}$, where LKA is used to capture capital inflows. The three different measures of capital inflows are introduced separately, yielding three versions of the same model. We tested for mis-specification and also the significance of dummies and weakly exogenous variables (see Appendices B and E).

5. ESTIMATION AND TEST RESULTS

The first step in estimating the model is to determine the appropriate lag length of the VAR(k). We used the model reduction approach and, as mentioned, the optimal lag length was found to be two (that is $k = 2$).[8] This lag level was sufficient to remove any serial correlation, satisfy the normality and mis-specification tests, with the benefit of not significantly affecting the degrees of freedom. We performed a trace test to help determine the rank of our VAR(2) model. This was used with other criteria to help identify the number of co-integration relations present. The choice of rank one (the same for all three inflow measures) is supported by the economic hypothesis that these variables together determine the long-run ERER.

8 Note that the criteria used are only valid under the assumption that the model is correctly specified. Potential specification problems, such as permanent shocks or level shifts in the data and non-constancy of parameters, should be corrected before choosing the lag length. Hence, we introduced the dummies and account for the weakly exogenous variables in our model before estimation.

Table 2: Trace Test Analysis

p-r	Eigen Values	Trace Test Statistic	CV (95%) without dummy	Corrected CV (with dummy)
3	0.7248996	88.21	58.6*	69.4*
2	0.6617872	41.91	37.3	48.2
1	0.3175013	12.22	19.1	30.3

Notes: The corrected critical value (CV) is adjusted for the inclusion of shift dummy and weakly exogenous variables. The standard 95% critical values are not valid with the inclusion of the dummy and weakly exogenous variables. Using a simulation programme in RATS, this was corrected and the actual distribution of the trace test is reported in the last column.

After imposing a rank of one, we had a unique relationship and thus the identification became relatively easy. Normalising the only existing co-integration relation on the *LREER* variable (measuring the real effective exchange rate), we identified a co-integrated relation among the fundamentals and RER itself. The relation between these variables translates into a relation explicitly for the long-run equilibrium real exchange rate for Ghana by assuming causality between the fundamentals and real effective exchange rate. This assumption of causality is based on the theoretical hypothesis of the long-run equilibrium exchange rate and not statistically tested. The identification of the long-run relation was direct as we have only one co-integrating relation, which is clearly identified as the long-run equilibrium exchange rate relation. Table 3 gives a simplified form of all three estimations (see Appendix E for details).

From Table 3, it is clear that all variables are significant in the long-run relation. The shift dummy variable to capture the shocks in 1983 is very significant, implying the SAP and liberalisation had a strong and positive impact on the RER (that is, led to real exchange rate depreciation in Ghana). All the adjustment coefficients (reported in Appendix Table E8) are significant and error correct any disequilibrium in the long run relation (the RER has about 96% correction in a year, consistent with Sackey, 2001 and Elbadawi, 1997). The near unity adjustment coefficient corroborates our earlier results in the single equation estimation reported in Appendix C (an indication of robustness of our models). The implication is that in all three equations an increase in misalignments (measured as deviation of actual from equilibrium, in this case increase represents undervaluation) will lead to a fall in short run real exchange rate (appreciation), thus restoring equilibrium. The short-run real exchange rate adjusts to deviations in long run real exchange rate. All the variables have long-run feedback in the identified relation with a speed of adjustment ranging from 11% to 98%. Similarly, all the variables have significant t-ratios.

Table 3: Long-Run Equations (Normalised on REER)

	Model with Aid	**Model with CAPF1**	**Model with CAPF2**
LOPEN	0,83 (7,62)	0,99 (6,93)	1,57 (2,18)
LAID	**-1,34** (3,51)		
LCAPF1		**-0,46** (4,54)	
LCAPF2			**-2,14** (4,82)
LTOT	1,7 (3,43)	-1,22 (2,54)	-0,84 (3,11)
TFP	1,11 (2,77)	1,82 (1,98)	4,53 (1,99)
Ds83	1,62 (3,89)	1,67 (6,53)	3,13 (5,67)
Trend	-0,13 (2,26)	-0,13 (2,68)	0,03 (3,61)

Notes: Figures in parenthesis are the t-ratios with standard normal distributions. We used total trade weighted real exchange rate. We estimated using exported weighted as well as import weighted indices. As in Ghana exports are determined on international markets and Ghana is a price taker, in effect the fundamentals do not significantly affect the export or import weighted real exchange rate.

It is important to note that in all three different versions of the model, all the variables were consistent in terms of sign with slight variation in magnitude, with the exception of terms of trade which led to depreciation of the real exchange rate when aid is used but appreciation when either ‘permanent’ or ‘non-permanent’ inflows are used. A possible explanation for this difference in the impact of terms of trade may be that aid inflows support production rather than consumption, so that the substitution effect outweighs the income effect, causing depreciation. The other measures of capital inflow may encourage increased consumption, hence the income effect outweighs the substitution effect, causing appreciation in the long run. These findings are consistent with our findings in the single equation estimation (Appendix C).

The coefficients confirm our expectation that the degree of reversibility matters, i.e. we find that decomposition of capital inflows is not trivial. Permanent inflows (CAPF2) have an elasticity of 2 (a 2% appreciation for a 1% increase in inflows) as against 0.5 for 'non-permanent' inflows (CAPF1) and 1.3 for aid (Table 3). This effect is significant and supports the Dutch Disease hypothesis.[9] Furthermore, non-permanent capital inflows (loans, other non-FDI inflows, equities and portfolio investments) have the lowest real appreciation impact. This corroborates our results in the single equation estimation. This finding is contrary to that of (Sackey, 2001), who found a depreciation effect of aid on real exchange rate and thus concluded that the Dutch Disease is not supported in Ghana. However, unlike Sackey (2001), we model the effect of the structural break in 1983 and use the nominal effective exchange rate rather than the bilateral nominal exchange rate in computing the real exchange rate.

Total factor productivity (measuring technological change) leads to real depreciation of the exchange rate in the long-run and is consistent with theoretical priors. This implies that the supply-side effect of improved technology (productivity) outweighs the demand-side effect. Excess supply causes prices of non-tradables to fall and leads to the depreciation of the local currency. This result is contrary to most empirical evidence as most studies have found technological progress causing appreciation in the real exchange rate, implying the demand-side effect of the improvement dominates. However, with the depreciation of the real exchange rate, there is an indication that, in the long-run, technological progress does have a supply side effect in Ghana, thus causing a fall in the prices of non-tradables hence the depreciation in the RER.[10] The coefficient on TFP is highest in the specification using permanent inflows,

9 This suggests that the aid used to finance government spending had a greater impact on increasing the price of non-tradables than tradables.

10 The contrary results of appreciation of technological change on real exchange rate may also be attributed to the way of measuring technological change. In most studies, real GDP growth has been used as a proxy for technological change (Edwards, 1994). According to the Solow-growth

suggesting that FDI (a component in CAPF2) includes technology transfer that has supply side effects that depreciates the real exchange rate.

Whereas an improvement in the terms of trade depreciates the real exchange rate with an elasticity of 1.7 in the aid equation, in both the permanent and non-permanent equations the effect is an appreciation (elasticities of 0.8 and 1.2 respectively). In the case of aid inflows, the substitution effect outweighs the income effect (suggesting an interaction between official inflows and terms of trade in affecting RER). A significant proportion of permanent inflows are private (remittances and FDI), which tend to increase spending and reinforce the income effect (and cause appreciation). The same may be true, to a lesser extent, for non-permanent inflows. Trade volume is also associated with a real depreciation of the exchange rate; this appears to be driven by the trend in exports, and is robust to using different measures of capital inflows.

Short-run analysis

We use the residual covariance matrix to identify the short-run structure. For the identified structure to represent the dynamics in the data, the residual covariance matrix should not be highly correlated. The findings should be interpreted cautiously as we have relatively short time series. Table 4 presents the parsimonious short run model for aid inflows (Appendix E presents the results for other measures of capital inflows). With a high $p-value$ of about 0.48, we could not reject the null hypothesis of the 22 over-identifying zero restrictions imposed on the variables found to be insignificant in the initial estimation. The only variable that appears to have a significant effect (depreciation) on the equilibrium exchange rate in the short run is trade volume, thus causing misalignments. This finding was also corroborated when we identified the short-run model using CAPF1 and CAPF2 (see Appendix E). For all three inflow measures, results for the short run are broadly consistent with those found using the single equation method (Appendix C). It follows that real exchange rate appreciation as a result of excessive capital inflows appears to be a long run phenomenon in Ghana. In the short run, misalignments are driven by trade volume (export revenue) changes.

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accounting model, the problem of using total GDP is that it includes changes in productivity attributable to capital and labour. We account for this by measuring growth in total factor productivity.

Table 4: Parsimonious Short-run Model with AID

	$\Delta LREER$	$\Delta LOPEN1$	$\Delta LAID$
$\Delta LREER$	1	0	0
$\Delta LOPEN1$	0	1	0
$\Delta LAID$	0	0	1
$\Delta LREER_{t-1}$		**0.341** (4.90)	
$\Delta LOPEN1_{t-1}$	**0.185** (2.12)		
$\Delta LAID_{t-1}$			**-0.494** (-4.80)
$\Delta LTOT$			
$\Delta LTOT_{t-1}$			
ΔTFP			
ΔTFP_{t-1}			
$dt74$		**0.265** (2.51)	**-0.769** (-5.08)
$\Delta ds83$	**0.269** (2.35)		
$\Delta ds83_{t-1}$	**1.147** (3.23)	**-0.756** (-3.16)	
ECT_{t-1}	**-0.748** (-7.10)	**-0.225** (-2.84)	
$e_{\Delta LREERtcpi}$	1	0.234	-0.167
$e_{\Delta LOPEN1}$	0.234	1	0.084
$e_{\Delta LAID}$	0.167	0.084	1

Notes: The model was identified using the full information maximum likelihood (FIML) estimation technique as in PcGive 10.3

*LR test of over-identifying restrictions: $c^2(22) = 21.647\,[0.481]$

The extent of depreciation due to trade volume changes is higher in the permanent capital inflow model than in both non-permanent and official inflow models. The error correction terms in all estimations are significant, as is the effect of SAP reforms (the shift dummy). Short-run deviations in real effective exchange rate in Ghana, i.e. misalignments, are driven by trade, and equilibrium is restored after a relatively long period. Furthermore, as imports are relatively stable, changes in trade volume are driven by exports.

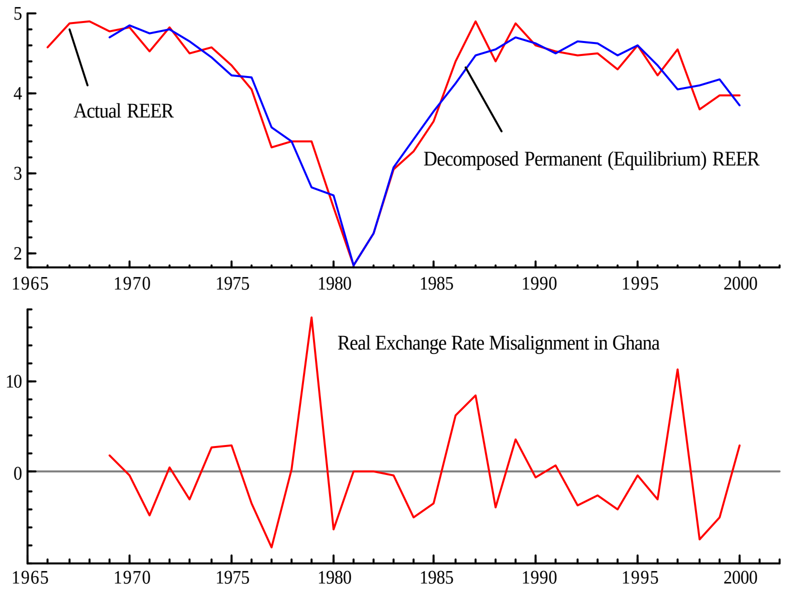
6. EQUILIBRIUM REAL EXCHANGE RATE

An extension of the above VAR analysis is to retrieve the equilibrium real exchange rate, which will help us to compute the misalignment. In the framework of the co-integrated VAR, the obvious decomposition technique is multivariate orthogonal decomposition (Gonzalo and Granger, 1995). We can estimate the equilibrium RER by allowing only the innovations from the permanent component of the fundamentals to affect the long-run forecast of the RER, making use of the duality property between the $C-Matrix$ and the Π matrix (see Appendix D for details). The identified C-Matrix represents the permanent component. Multiplying this vector by the vector of endogenous (observed) variables in the system provides the permanent component at each point in time for the vector of endogenous variables (the real effective exchange rate and its fundamentals). This procedure has been used to estimate the equilibrium real exchange rate as a steady state relation (Juselius, 2003). This equilibrium relation is plotted along side the actual (observed) in Figure 7. Misalignment is defined as:

$$RER_{mis} = \frac{RER - ERER}{ERER}$$

where RER_{mis} is real exchange rate misalignment, RER is the observed real exchange rate and $ERER$ represents the permanent component of the actual RER using the orthogonal decomposition techniques (Appendix D). The vertical scale of the lower panel of figure 7 measures the percentage misalignment while the horizontal scale measures the period.

Figure 7: Equilibrium Real Effective Exchange Rate and Misalignment



During the period under consideration and based on official capital inflows (aid),[11] we clearly observe that the real effective exchange rate in Ghana has persistently been misaligned but not always by much. This supports the claim by Edwards (1988) that real exchange rates in developing countries are persistently misaligned and pose a major problem for exchange rate management. One can identify policy effects on the pattern of misalignment in Ghana. During periods when inflation was high, we can identify appreciation of the real exchange rate as a result of increases in the price on non-tradables. This is evident prior to the implementation of the SAP in 1983, prior to multi-party elections in 1992 and prior to the 2000 general elections (the latter episodes suggest a political business cycle).

This method of measuring misalignment is limited. For example, the estimated model indicates alignment between 1981 and 1983, but the balance of payments accounts for Ghana during

11 We use aid inflows to derive the equilibrium RER and misalignment for comparison with other studies. Using CAPF1 and CAPF2 does not change the pattern or trend of misalignment.

those years reveals a severe and unsustainably high deficit, which necessitated foreign exchange reforms as part of the SAP. The implication is that, for policy purposes, one should combine evidence from the balance of payments account with signals from estimated models before making a policy judgment on the direction of misalignment and its consequent policy response.

7 CONCLUSIONS AND IMPLICATIONS

This paper examines the real effects of capital inflows on the Ghanaian economy by looking at how the real effective exchange rate (RER) responds to changes in its fundamentals, particularly the effect of changes in different types of capital inflows aid, permanent and non-permanent inflows). The analysis was motivated by the Dutch Disease theory and the theory of long-run determinants of the equilibrium real exchange rate. *A priori* expectation based on theory is that in the long-run large capital inflows would lead to overheating in the economy, an increase in the demand for and price of non-tradables, thus leading to a fall in the RER (that is real appreciation). We tested this hypothesis for Ghana using annual data over the period 1966-2000.

The paper contributes to the empirical literature in the following way:

- The use of the VAR method to model the data addressing problems of endogeneity and exogeneity, and of interaction and interdependence between the fundamentals in determining their impact on RER.
- Using the multivariate orthogonal decomposition methodology to estimate the equilibrium real exchange rate (in Ghana) and its misalignment. Fitted values include both the transitory and permanent components of the innovations in the fundamentals and thus do not measure the true equilibrium values. Our approach treats equilibrium as a steady state relation rather than a static equilibrium and offers improved measures of equilibrium RER and misalignment.
- By decomposing capital inflows we have been able to establish the impact of different types of inflows on the real exchange rate in both the long and short run. This is valuable for policy purposes.

Our study establishes that there is a long run relationship between RER and its fundamentals (co-integration relation) with all the variables being significant in the co-integrating space including the shift dummy (a measure of SAP and liberalisation). Capital inflows, however measured, do not have a short run effect on the real exchange rate in Ghana. Short-run deviations from the long-run (mis-alignments) are driven by changes in trade volume (changes in exports mainly). This is particularly important for policy in managing exchange rate misalignments in Ghana. However, capital inflows (all measures) have a significant appreciation effect on the real exchange rate in the long-run, confirming the Dutch Disease hypothesis in Ghana. The extent of appreciation in the long-run was slightly greater for the permanent inflows than for the non-permanent inflows.

The study also establishes that the direction of misalignment of the cedi has been greatly influenced by policy actions in Ghana. Significant among these periods were periods before and during the SAP and the periods prior to the two democratic elections in 1992 and 2000. Nevertheless, capital inflows are the most significant driver of the real effective exchange rate along the long-run equilibrium path, i.e. capital inflows move the real effective exchange rate to a new equilibrium level (with appreciation). The estimated model will allow Ghanaian policy makers to assess how fundamentals contribute to overvaluation or undervaluation. This provides direction to policy decisions in an attempt to correct the misalignment and manage the exchange rate.

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APPENDICES

APPENDIX A: Data Sources and Definitions

Terms of Trade (*TOT*) are from the World Bank African Development Indicators (2002 CD ROM) and are defined as an index (1995 = 1000) of relative prices of exports to imports.

Openness (*Open*) is measured as exports plus imports as a ratio of GDP, with data from the World Bank African Development Indicators (2002 CD ROM).

Technological Change (*TFP*) is estimated from a simple Cobb-Douglas production function involving only two factors (capital and labour) by assuming constant returns to scale. The labour share is defined as the average labour income as a ratio of GDP and the capital coefficient is defined by factor shares. We assumed a labour share of 0.77, implying a capital coefficient of 0.23, following Brown (1972) and Leith (2000). The rather low level of the capital coefficient may be explained by excess capacity in state owned enterprises and mining facilities. Total factor productivity (TFP) is estimated as the residual from the growth accounting equation (details available on request). Data for the estimation were drawn from the World Bank Development Indicators 2002.

Capital inflows as defined in three different versions in the paper was based on data from the *Geographical Distribution of Financial Flows to Aid Recipients* (OECD/DAC, CD ROM)

Real Effective Exchange Rate (*RER*) was measured as nominal effective exchange rate multiplied by the ratio of a trade-weighted wholesale price index of Ghana's trading partners and the consumer price index in Ghana. Full details are in Opoku-Afari (2004). The data are from the *Direction of Trade Yearbook* (various editions) and the IMF *International Financial Statistics* (various editions).

APPENDIX B: Unit Root, Weak Exogeneity and Exclusion tests

From Table B1, it is clear that all our variables are non-stationary. This allowed both the constant term and the shift dummy to be restricted to the co-integrating space.

Table B1: Multivariate Unit Root Tests for Variables

Test of Stationarity of Variables used in the Estimations								
LRER	*LOPEN*	*LAID*	*LTOT*	*TFP*	*Ds83*	Constant	$c^{2}(v)$	P-Value
1	0	0	0	0	-0.725	-4.467	9.58(4)	0.04
0	1	0	0	0	-1.383	1.882	14.10(4)	0.01
0	0	1	0	0	-1.655	3.779	8.64(4)	0.07
0	0	0	1	0	0.594	-5.050	13.08(4)	0.01
0	0	0	0	1	-0.011	-0.100	20.07(4)	0.00

Notes: The null of the test is that the variables are stationary, implying a rejection means they are non-stationary. The tests include the constant term and the shift dummy. The trend was not included, as the data revealed no linear trends.

We assumed that *TOT* and *TFP* were weakly exogenous to the system. This implies that the cumulated errors of these variables will form part of the random walk component in the Granger representation, as expressed through the equation for the common stochastic trend $a_{\underline{1}}' \sum_{i=1}^{t} e_i$. We checked whether any of the variables treated as endogenous were really weakly exogenous and thus could serve as a common stochastic trends driving the system. Results in Table B2 reject the null of weak exogeneity for all the variables. On the issue of the significance of each variable in the co-integrating space, we rejected the null of excluding the variables from the co-integrating space, implying all the variables are significant and important in explaining the long-run relation identified. (see Table B2).

Table B2: Weak Exogeneity and Long-Run Variable Exclusion Tests

	Variable Exclusion and Weak Exogeneity Tests				
		Weak Exogeneity Tests		Variable Exclusion test	
Rank=1		$c^{2}(5) = 3.841$	P-Value	$c^{2}(5) = 3.841$	P-Value
	LRER	9.719	0.002	3.960	0.046
	LOPEN1	14.459	0.000	3.292	0.069
1 Degree(s)	LAID	7.531	0.006	7.259	0.007
of Freedom	LTOT			3.525	0.060
	TFP			3.967	0.046
	DS83			11.077	0.001
	Constant			3.294	0.070

APPENDIX C: Results of Single Equation Estimations

The empirical model for our single equation estimation was based on:

$$A(L)LREER_t = b_0 + l_i(L)LOpen_t + d_i(L)LGCN_t + g_i(L)LTOT_t + f_i(L)TFP_t + y_i(L)KA_t + d_i Ds83_t + a t + m_t \quad \text{(C1)}$$

where the L in parenthesis is the polynomial lag operator and KA captures capital inflows. In line with our objective, all three measures of capital inflows are estimated separately. These will be reported as equations (1-3) in tables C1 (long-run) and C2 (short-run). Trend was introduced into the model to capture the trend in RER and OPEN (particularly, increased imports after SAP) following from the upward adjustment in exchange rate market after the reforms in 1983. It was found out to be significant in the model. We selected a lag length of two based on the AIC and SIC statistics in the analysis of the lag structure in our preliminary estimations. In all our estimations, cointegration was found at 5% or 10% level of significance.

Table C1: Solved Static Lon-run Models $LREER_t$

	Model with Aid	**Model with CAPF2**	**Model with CAPF1**
Constant	17.01***	14.25***	16.14***
LOpen	1.10***	1.17***	1.32***
LTOT	-1.37**	-0.85*	-1.28**
TFP	0.95*	1.51**	2.10*
LGCN	-0.48	-0.29	-0.64
LAID	-0.48**		
LCAPF2		-0.69**	
LCAPF1			-0.10*
Ds83	0.55**	0.84**	0.71*
Trend	-0.12***	-0.13***	-0.11***
Wald Test	162.78***	145.39***	176.26**
Unit Root Test	-6.531***	-6.639***	-6.718***

Notes: *, **, and *** indicate rejection of the null hypothesis at 10, 5, 1 per cent respectively. The Wald test is a test of the null hypothesis that all of the long-run coefficients (except the constant term) are zero. The Unit Root Test allows for a level shift in the variables. The simulated critical values for unit roots test based on 35 observations and 5 right hand side variables including a constant and trend are –5.168 (10%), -5.581(5%) and –6.437(1%).

Table C2: Short-run Parsimonious Model for $\Delta LREER_t$

	Model with Aid	**Model with CAPF2**	**Model with CAPF1**
Constant	-0.12***	-0.13***	-0.13***
$\Delta LREER_{t\_1}$	0.16**		
$\Delta LOpen1$	1.42***	1.27***	1.52***
$\Delta LOpen1_{\_1}$	-0.55**	-0.36*	-0.41**
$\Delta LOpen1_{\_2}$	-0.43***		
$\Delta LGCN_{\_1}$			-0.89
$\Delta LAID$	0.28**		
$\Delta CAPF1$			0.07*
$\Delta LCAPF2_{\_1}$		0.12*	
$\Delta Ds83_{-1}$	1.16***	1.35***	1.23***
$ECM_{\_1}$	-0.87***	-0.88***	-0.95***
R^2	0.76	0.70	0.74
$F-Statistic$	13.26[0.000]	11.97[0.000]	11.87[0.000]
$AR\ 1-2test$	1.2876[0.2951]	1.5060[0.2420]	1.0472[0.3671]
$ARCH\ 1-1test$	0.18980[0.667	0.4699[0.4996]	0.0041[0.9498]
Normality Test	1.3435[0.5108]	3.6224[0.1635]	3.3300[0.1892]
Hetero Test		0.7999[0.6222]	0.4739[0.8888]
Re*set Test*	1.9145[0.1792]	0.1175[0.7347]	0.3222[0.5755]

Notes: *, **, and *** indicates rejection of the null hypothesis at 10, 5, 1 per cent respectively. Numbers in parenthesis are the respective probabilities

APPENDIX D: Multivariate Orthogonal Decomposition Procedure

The duality between the identified Π-Matrix in the cointegration analysis and the C-Matrix (the long run impact matrix) is used to decompose the observed real exchange rate (RER) into transitory and permanent components (Gonzalo and Granger, 1995). The permanent component then represents the equilibrium real exchange rate (ERER) while the transitory components capture deviations from equilibrium.

In our proposed approach, given that x_t represents a vector of I(1) series, then assuming a VAR(1) model (for simplicity):

$$\Delta x_t = ab' x_{t-1} + m + e_t \ , \quad t = 1,.....,T \qquad \text{(D1)}$$

with an initial value x_0. We note that $a_\perp$ has full rank and dimension $n \times (n-r)$ so that $a' a_\perp = 0$ and rank $(a, a_\perp) = n$. Now by making use of the unique relationship between $a, b, a_\perp, b_\perp$: we derive, where $(b' b_\perp) = 0$:

$$b_\perp (a_\perp' b_\perp')^{-1} a_\perp' + a (b' a)^{-1} b' = I$$

The above identity can then be used to decompose any vector and thus it is applied on the n-dimensional vector x_t:

$$x_t = b_\perp (a_\perp' b_\perp)^{-1} a_\perp' x_t + a (b' a)^{-1} b' x_t \qquad \text{(D2)}$$

where,

$$b' x_t = (I + b' a) b' x_{t-1} + b' m + b' e_t$$

(D3)

and

$$a_\perp' x_t = a_\perp' x_0 + \sum_{i=1}^{t} a_\perp' (e_i + m) \cdot \qquad \text{(D4)}$$

By substituting the above equations (D3) and (D4) into equation (D2), we get an expression for x_t in a moving average form given as:

$$x_t = C \sum_{i=1}^{t} e_i + Cm t + Cx_0 + Y_t \qquad \text{(D5)}$$

where Cm measures the slope of the linear trend in x_t, Cx_0 measures the initial values and Y_t represents the stationary process in x_t. Define $C = b_\perp (a_\perp' \Gamma b_\perp)^{-1} a_\perp'$. If we represent $\tilde{b}_\perp = b_\perp (a_\perp' \Gamma b_\perp)^{-1}$ then we can rewrite C as $C = \tilde{b}_\perp a_\perp'$.

The decomposition of the C matrix is similar to that of the Π matrix (and establishes the duality property between the C-Matrix and the Π matrix), except that in the Π matrix form, b determines the common long-run relations and a the loadings, whereas in the moving average representation $a_\perp'$ determines the common stochastic trends driving the long-run relation out of equilibrium and $\tilde{b}_\perp$ defines the loadings (Juselius, 2003). The common stochastic trends are the variables $a_\perp' \sum_{i=1}^{t} e_i$. Ability to determine the common stochastic trends will also help us to identify whether the shocks are permanent or transitory and thus will help us in determining which shocks have long-run impact on variables in the system.

Decomposition

Given the C-Matrix, it is then assumed that transitory shocks (r) have no long-run impact on the variables in the system (i.e. the transitory shocks define zero columns in the C-Matrix), while permanent shocks (n-r) have a significant long-run impact on the variables of the system (defined as non-zero columns in the C-Matrix).

As $a_{\perp}$ represents the common stochastic trends, this multiplied by the error term (or shock e_t) will represent the total shocks in the system. This total shock can also be decomposed into permanent and transitory shocks by employing a similar identity like that used to derive the stochastic trend as follows:

$$a(a'\Omega^{-1}a)a'\Omega^{-1} + \Omega a_{\perp}(a_{\perp}'\Omega a_{\perp})^{-1}a_{\perp}' = I_n$$

The above then can be applied on the shock, e_t, to decompose it as follows:

$$e_t = \underbrace{a(a'\Omega^{-1}a)^{-1}}_{loading} \underbrace{a'\Omega^{-1}e_t}_{Transitory-shock} + \underbrace{\Omega a_{\perp}(a_{\perp}'\Omega a_{\perp})^{-1}}_{loading} \underbrace{a_{\perp}'e_t}_{permanent-shock}$$

with the transitory shock being independent in the sense that:

$$Cov(a'\Omega^{-1}e_t, a_{\perp}'e_t) = a'\Omega^{-1}\Omega a_{\perp} = a_{\perp}'a = 0$$

By ensuring independence, we have been able to establish the orthogonality of the decomposition where the transitory component does not Granger-cause the permanent component. This ensures that the long-run relation is affected by only the permanent components of its fundamental determinants. Thus cointegration among a set of variables allows for the presence of time varying equilibrium with a unique property: the permanent part which is I(1) describes the long-run properties of the relationship among the variables while the transitory part (which will be I(0)) represents the deviations over time from the permanent part and represents departures of the fundamentals from the steady state values. This implies, with a shock e_t, the loading on the transitory part gives a transitory change whereas the loading on the permanent part gives a permanent change $\tilde{b}_{\perp}$.

In a similar fashion, this decomposition technique can be applied to the vector of endogenous variables (as is done for the errors) and the permanent part provides the permanent component at each point in time for the vector of endogenous variables (i.e. the RER and its fundamentals). This approach was used to estimate our ERER and hence misalignment.

APPENDIX E

Table E1: Model Reduction Results

Model Reduction Results(Started from Lag 3 down to 1)							
Model	T	P		Log-Lik	SC	HQ	AIC
SYS(1)	31	72	OLS	85.42	2.465	1.444	-0.866
SYS(2)	31	54	OLS	62.88	**1.925**	0.281	**-0.973**
SYS(3)	31	36	OLS	22.04	2.566	**0.244**	0.900

Table E2: Multivariate Unit Root tests for Variables

Test of Stationarity of Variables used in the Estimations								
REER	LOPEN	LAID	LTOT	TFP	Ds83	Constant	$c^2(v)$	P-Value
1	0	0	0	0	-0.725	-4.467	9.58(4)	0.04
0	1	0	0	0	-1.383	1.882	14.10(4)	0.01
0	0	1	0	0	-1.655	3.779	7.64(4)	0.07
0	0	0	1	0	0.594	-5.050	13.08(4)	0.01
0	0	0	0	1	-0.011	-0.100	20.07(4)	0.00

Table E3: Misspecification Tests

	Where R=1					
	Multivariate Statistics					
Log(Sigma)		-12.141				
Information Criteria	SC	-6.296				
	HQ	-7.945				
Trace Correlation		0.818				
Test for Autocorrelation		ChiSqr (9)	P-Value			
LM(1)		14.42	0.11			
LM(4)		12.48	0.19			
Test for Normality		8.65	0.14			
	Univariate Statistics					
	Mean	Std Dev	Skew ness	Kurtosis	Maximum	Minimum
DLREER	0.000	0.200	1.137	4.48	-0.30	0.59
DLOPEN1	0.000	0.123	0.078	2.92	-0.23	0.31
DLAID	-0.000	0.130	0.645	2.86	-0.20	0.35

The test for Skewness and Kurtosis were reported because VAR estimates are more responsive to deviations to normality due to Skewness than to excess Kurtosis. The trace- correlation coefficient measures the overall measure of goodness of fit as the R^2 in the case of linear regression model (as in CATS by Juselius and Hansen, 1995).

Table E4: Weak Exogeneity and Long-Run Variable Exclusion tests

		Variable Exclusion and Weak Exogeneity Tests			
		Weak Exogeneity Tests		Variable Exclusion test	
Rank=1		$c^2(5) = 3.841$	**P-Value**	$c^2(5) = 3.841$	**P-Value**
	LREER	**9.719**	**0.002**	**3.960**	**0.046**
	LOPEN	**14.459**	**0.000**	**3.292**	**0.069**
1 Degree(s)	**LAID**	**7.531**	**0.006**	**7.259**	**0.007**
of Freedom	**LTOT**			**3.525**	**0.060**
	TFP			**3.967**	**0.046**
	DS83			**11.077**	**0.001**
	Constant			**3.294**	**0.070**

Table E5: Identified Long-Run Equation (Aid)

	Eigen Vectors (Transposed)						
	LREER	LOPEN	LAID	LTOT	TFP	Ds83	Trend
b_1	-3.088	2.554	4.145	5.253	3.419	5.022	-0.416
	Normalised b_1 (Transposed)						
	LREER	LOPEN1	LAID	LTOT	TFP	Ds83	Trend
b_1 t-ratio	1.000	-0.827 *(-7.62)*	1.342 *(3.51)*	-1.701 *(-3.43)*	-1.107 *(-2.77)*	-1.626 *(-3.89)*	0.135 *(2.26)*
	a_{1i}						
DLREER	-0.977 *(-8.57)*						
DLOPEN	-0.367 *(-4.62)*						
DLAID	-0.114 *(-2.12)*						

Figures in parenthesis are the t-ratios with the standard normal distributions. The a 's have the normal asymptotic distribution and thus all of them are significant. Similarly, the t-ratios for the estimated b 's have the normal asymptotic distribution. This applies to all the other equations.

Table E6:Identified Long-Run Equation (CAPF1)

	Eigen Vectors (Transposed)						
	LREER	LOPEN	LCAPF1	LTOT	TFP	Ds83	Trend
b_1	-3.44	3.42	-1.58	-4.20	6.25	5.73	-0.46
	Normalised b_1 (Transposed)						
	LREER	LOPEN1	LCAPF1	LTOT	TFP	Ds83	Trend
b_1	1.000	-0.99	0.46	1.22	-1.81	-1.67	0.13
t-ratio		*(-6.93)*	*(4.54)*	*(2.54)*	*(-1.98)*	*(-6.53)*	*(2.68)*
	a_{1i}						
DLREER	-1.06						
	(-8.19)						
DLOPEN	-0.35						
	(-3.65)						
DLCAPF1	0.31						
	(1.94)						

Table E7: Identified Long-Run Model (CAPF2)

	Eigenvectors (Transposed)						
	LREER	LOPEN1	LCAPF2	LTOT	TFP	DS83	Trend
b_i	1.23	-0.71	2.66	1.04	-5.61	-3.87	-0.04
	Normalised b (Transposed)						
	LREER	LOPEN1	LCAPF2	LTOT	TFP	DS83	Trend
b_i	1.000	-0.57	2.15	0.83	-4.53	-3.13	-0.03
t-ratio		(-2.18)	(4.82)	(3.11)	(-1.99)	(-5.67)	(-3.61)
	a_{ij}						
$\Delta LREER$	-0.38						
	(-7.73)						
$\Delta LOPEN1$	-0.19						
	(-7.55)						
$\Delta LCAPF2$	-0.10						
	(-2.09)						

Table E8: Parsimonious Short-Run Model (CAPF1)

	$\Delta LREER$	$\Delta LOPEN1$	$\Delta LCAPF1$
$\Delta LREER$	1	0	0
$\Delta LOPEN1$	0	1	0
$\Delta LCAPF1$	0	0	1
$\Delta LREER_{t-1}$		**0.24** (3.07)	
$\Delta LOPEN1_{t-1}$	**0.41** (2.41)		0.71 (1.63)
$\Delta LCAPF1_{t-1}$			**-0.23** (-2.47)
$dt74$			**-2.89** (-7.45)
$\Delta ds83$	**0.77** (3.01)	**-0.39** (-1.86)	
$\Delta ds83_{t-1}$	**1.53** (4.01)	**-0.81** (-3.19)	
ECT_{t-1}	**-0.96** (-7.49)	**-0.22** (-2.54)	
$e_{\Delta LREERtcpi}$	1	0.54	-0.22
$e_{\Delta LOPEN1}$	0.54	1	-0.18
$e_{\Delta LCAPF1}$	-0.22	-0.18	1

*LR test of over-identifying restrictions: $\chi^2(20) = 20.737\,[0.4128]$

Table E9: Parsimonious Short-run Model (CAPF2)

	$\Delta LREER$	$\Delta LOPEN1$	$\Delta LCAPF2$
$\Delta LREER$	1	0	0
$\Delta LOPEN1$	0	1	0
$\Delta LCAPF2$	0	0	1

$\Delta LREER_{t-1}$		**0.19** (2.71)	
$\Delta LOPEN1_{t-1}$	**0.63** (2.83)	**-0.34** (-3.05)	
$\Delta LCAPF2_{t-1}$			
$\Delta LTOT$			
$\Delta LTOT_{t-1}$			**0.89** (3.26)
ΔTFP			
ΔTFP_{t-1}			**-2.73** (-4.56)
$\Delta ds83$	**0.95** (3.30)	**-0.56** (-4.02)	
$\Delta ds83_{t-1}$	**1.36** (3.07)	**-1.50** (-7.34)	**-0.47** (-1.64)
ECT_{t-1}	**-0.32** (-5.89)	**-0.19** (-7.39)	**-0.12** (-2.88)
$e_{\Delta LREERtcpi}$	1	0.18	-0.09
$e_{\Delta LOPEN1}$	0.18	1	-0.15
e_{LCAPF2}	-0.09	-0.15	1

*LR test of over-identifying restrictions: $c^2(17) = 16.764[0.4705]$

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