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Dynamics of the Real Exchange Rate, Inflation, and Output Growth: The Case of Malawi

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Abstract

This paper investigates the temporal causality and dynamics of real exchange rate, inflation, and output growth in Malawi, controlling for monetary growth and foreign exchange accumulation. The relationships among these variables are examined using quarterly data and the bounds testing approach to cointegration analysis. A long run relationship among the variables is observed, with the real exchange rate as the dependent variable, which is found responsive, in the long run, to the growth rate of output but not to inflation. Analysis of short-run dynamics reveals that the real exchange rate was influenced by output growth and inflation. The Granger causality analysis in a multivariate setting points to causation running from the real exchange rate to inflation and from each of these to output growth. The lagged error correction term, where included, emerged significant, providing evidence for the presence of long-run causality running interactively through it from the other variables as a group to the real exchange rate. Taken together, the results indicate the relevance of domestic economic activity, monetary policy, and foreign exchange availability for the evolution of the real exchange rate, which, in turn, is observed to have played a role in influencing domestic inflation and output growth in Malawi.

Keywords: exchange rate, inflation, output growth, Malawi, Africa

1. Introduction and Background

Exchange rate policy has been implemented independently, or as a part of structural adjustment and stabilization programs sponsored by the World Bank and the International Monetary Fund (IMF), in many developing countries in response to balance of payments problems believed to have been caused partly by overvalued exchange rates. Correcting overvalued exchange rates through devaluations and allowing the exchange rate to fluctuate in response to conditions in the foreign exchange market were increasingly utilized as countries adopted outward-looking policies and embark on a path toward export-led growth. Whether the policy change would succeed in boosting external competitiveness would rest on whether real depreciation was achieved. The latter would depend, among others, on inflation performance.

Although the sources of inflation in developing countries are many and their relative importance varies from one economy to the other, currency devaluation is commonly found in the list of its determinants (e.g. Loungani & Swagel, 2001; Yiheyis, 2005; Barnichon & Peiris, 2007). This suggests that the effect of nominal devaluations on the real exchange rate would partly be offset by induced relative inflation. At the same time, exchange-rate changes are expected to be influenced by inflation performance, each and the relations between them conditioned by output growth, which, in turn, is influenced by the aforementioned two variables.

This study seeks to empirically examine the causality and dynamics of real exchange rates, inflation and output growth in the context of Malawi where a series of exchange-rate adjustments took place, and where inflation and real exchange rate volatility were observed over the past several decades. In the 1970s and 1980s, the country pursued inward-looking policies with fixed exchange rate arrangements viewed by policymakers as a shelter against the vagaries of investors' sentiments in the foreign exchange market (Ndaferankhande & Ndhlovu, 2006) (Note 1). Accordingly, the Malawi Kwacha was fixed to the British Pound Sterling until 1973 and then to a weighted average of the pound sterling and the US dollar, followed by a peg to the IMF Special Drawing Rights

(SDR) between 1975 and 1984. As the SDR appreciated substantially and the balance of payments (BOP) problems continued to worsen, the Kwacha was delinked from the SDR and re-pegged to a basket of seven currencies (Note 2). However, the new peg was unable to prevent the volatility of the Kwacha, as reflected in its frequent devaluations, totaling six between 1983 and 1994.

The frequent devaluations were heavily influenced by the economic crisis the country experienced in 1979 and 1980 and the subsequent adoption of the structural adjustment program (SAP) under the auspices of the IMF and the World Bank. The objectives of SAP included, among others, liberalization of trade and foreign exchange in the country (Chirwa et al., 2008). The Kwacha, which was overvalued and had led to a rise in a parallel market for foreign exchange, was depreciated by almost 100 percent and started to float in 1994.

The exchange rate policies the country adopted, characterized as "stop-reverse-and-go", is said to have "resulted in larger real exchange rate volatility, lower growth, less economic diversification, higher inflation than the comparator countries [included in the study's sample] in 1990-2010, and repeated periods with foreign exchange shortages and rationing" (Maehle et al., 2013, p. 9). It is further held that the unpredictable and large real effective exchange rate volatility caused by such stop-and-go policies can be more damaging to growth and development than the high frequency volatility associated with floating exchange rates.

However, the extent to which the said changes in the real exchange rate influenced, or were influenced, by output growth and inflation is yet to be sufficiently explored using alternative estimation methods. The present study investigates the dynamics and temporal causality of these variables in the context of Malawi, applying the bounds testing approach to cointegration analysis to quarterly data spanning 1980-2011. As outlined above, the study period covers fixed and floating exchange rate arrangements, allowing a comparative study of the relationships among the aforementioned variables under different exchange rate regimes. The study, therefore, will contribute to the body of empirical evidence on the temporal causality and dynamics of real exchange rates, inflation and output, from which lessons for policy may be drawn not only for Malawi but also for other developing countries sharing similar characteristics.

The remainder of the paper is organized as follows. The next section outlines the theory underlying the linkages among the variables of interest and reviews the related empirical literature. Then the estimating model and methodology are described and the time series profile and properties of the variables overviewed, followed by a discussion of results in the fifth section. The final section summarizes and concludes.

2. Related Literature

2.1 Linkages among the Real Exchange Rate, Inflation, and Output Growth

2.1.1 Exchange Rates and Inflation

Currency depreciation is expected to influence domestic price formation by raising the domestic-prices of imports and import-competing goods and, indirectly, by engendering cost-push effects and changing inflationary expectations (e.g. Dornbusch, 1988; Taylor, 1990; Agénor & Montiel, 2008; Mohanty & Klau, 2002). The sources of the cost-push effect include induced increases in (a) the domestic-currency price of imported inputs, (b) unit labor costs due to implicit or explicit indexation mechanisms, and (c) the interest costs of financing working capital. A reverse causality is expected under a flexible exchange rate regime. Rising domestic inflation relative to its foreign counterpart would directly engender a nominal depreciation, as the latter, absent reserve adjustment, would be required to maintain external balance (Note 3). Given the foreign price level and the nominal exchange rate, and where relative purchasing power parity does not hold, domestic inflation would, by definition, lead to real appreciation.

2.1.2 Real Exchange Rate and Output

A depreciation of the real exchange rate is expected to stimulate aggregate demand through its positive effect on net exports if the Marshall-Lerner condition is met, or through expenditure-switching and reducing effects (e.g. Dornbusch, 1988). In the presence of excess capacity, output will increase, assuming a positive supply response. In the absence of these conditions and partly due to the adverse cost-push effect previously mentioned, devaluation could also be contractionary (Krugman & Taylor, 1978; Lizondo & Montiel, 2008). Causation from output to exchange rates is typically assumed in exchange rate determination models in which it is one of the major arguments, entering positively or negatively depending on the model (e.g. Krueger, 1983; Frankel & Mussa, 1985) (Note 4).

2.1.3 Inflation and Output Growth

Output growth is expected to affect inflation, although the effect is ambiguous a priori, as it partly depends on the source of output growth—whether it is sourced from demand or supply shocks. A reverse causation arises as high inflation and its associated volatility expectedly lowers output growth because of its adverse effect on investment and the capital stock, while low inflation with the expectation of higher inflation may increase capital accumulation and growth, as physical capital becomes more attractive than monetary assets (e.g. Andreas & Hernando, 1999; Freedman & Laxton, 2009).

As alluded to above, the three variables in question are potentially mutually caused by other variables, such as the money supply and foreign reserve adjustment. Standard theory predicts that the money supply affects price and output, the strength of the effect depending, among others, on the degree of capacity utilization or unemployment (Note 5). Money's simulative impact on aggregate demand and, through it, on inflation and output is transmitted, depending on the model considered, through the interest rate, exchange rate, credit availability, and the relative price of nonmonetary assets (Mishkin, 1995).

The money supply affects the exchange rate to the extent that it generates a higher demand for traded goods that would potentially lead to nominal depreciation. The monetary approach to the balance of payments predicts this outcome if, for example, domestic money supply grows faster than its foreign counterpart. A similar causal effect stems from the induced decrease in the domestic interest rate, which, in the presence of capital mobility, would reduce net capital inflow, resulting in a lower demand for domestic currency (e.g. Frenkel & Mussa, 1985; Mishkin, 1995). The effect of monetary growth on the exchange rate is also transmitted through its impact on inflation and output growth as outlined above (Note 6).

The strength of the linkage between exchange rates and inflation and how monetary growth affects them depend on the exchange-rate regime. Under non-floating exchange rate arrangements, balance-of-payments equilibrium requires in part (as in the "managed" case) or in whole (as in the "pegged" case) reserve adjustment, suggesting a nexus between the latter and the exchange rate as well as with domestic inflation, which, given a managed/fixed exchange rate, would lead to a loss of competitiveness and progressive erosion of foreign reserves. In the face of limited access to borrowing in international financial markets, this would require nominal depreciation, or would eventually necessitate devaluation (under a fixed regime), suggestive of a causation running from inflation to a reserve loss, and from the latter to a decrease in the value of the exchange rate (Note 7). The type of exchange rate arrangement is also relevant in characterizing the link between monetary growth and inflation, which, given the level of output, positively depends on the degree of exchange rate flexibility (Fielding & Bleaney, 2000).

The discussion above highlights the expected causal relationships between and among inflation, real exchange rate and output growth, each and the relationship among them affected by mutual causal factors such as growth in the money supply and foreign reserves. Plainly, the strength and direction of their causality is an empirical question, as it would depend on a number of structural and institutional features including the degree of capacity utilization, reserve adjustment, the extent of sterilized intervention, and the exchange rate regime. Understanding the linkages and the terrain of causation among the said financial and real variables at the empirical level is important to appropriately design monetary and exchange rate policies and to enhance their effectiveness in fostering domestic price stability and external competitiveness.

2.2 Empirical Evidence

Although the literature is replete with empirical studies on the determination of each of the variables of interest in the context of structural or reduced-form models, the evidence on their temporal causality and dynamics in Africa, in general, and in Malawi, in particular, is rather thin and mixed. A review of the latter type of empirical studies in Malawi and the region is provided below, preceded by a sampling of evidence based on regressions with one or two of the other variables appearing as explanatory variables. A case in point is the empirical analysis of the equilibrium exchange rate based on a dynamic model of a small, open economy by Mathisen (2003). The results reveal that real per capita output and monetary growth are among the determinants of the equilibrium real exchange rate in Malawi.

Estimating an eclectic model of inflation, which incorporates both demand and supply factors, Ndaferankhande and Ndhlovu (2006) reported that the dynamics of inflation in Malawi was significantly influenced by the exchange rate, money supply, and real income growth, among others. According to their results, two factors have heightened the influence of the exchange rate on prices: the liberalization of the trade sector and the adoption of managed float exchange rate regime. Similarly, in their study of economic growth in Malawi, Tchereni and Sekhampu (2013) found the exchange rate to be one of its statistically significant determinants. More generally, Musila (2002) estimated an econometric model inclusive of various economic sectors for the study country. Dynamic simulation results based on parameter estimates of the long-run version of the model suggest that a sustained devaluation would lead to an increase in inflation and a decrease in real GDP growth.

Although inferences may be drawn from the regression results reviewed above, they hardly constitute direct evidence for the presence of causality among the variables under consideration. Moreover, the results based on the estimation of models using traditional econometric methods are subject to the "usual problems of invalid restrictions and specification errors" (Canetti & Greene, 1991, p. 7). This is particularly problematic when a feedback effect exists and is not recognized or accounted for in estimations.

More direct evidence, albeit partial, comes from the study by Ngalawa and Viegi (2011) who apply the method of innovation accounting in a structural VAR model for the analysis of the dynamic effects of a monetary policy shock in the country (Note 8). They report that consumer prices respond weakly to changes in M2; and, up to three years, exchange-rate changes account for most of the variation in the CPI excluding own shock. On the other hand, output fluctuations are attributed, among others, to monetary impulses and exchange rates, with varied timing of effects. More recently, Jombo et al. (2014), in their analysis of the exchange-rate pass-through using the augmented Phillips curve and VAR approaches using quarterly data find that exchange rate movements exerted a modest influence on domestic prices in Malawi. They characterized the exchange rate as a potentially important source of inflation in the country.

A Granger causality analysis by Canetti and Greene (1991) of quarterly data from 10 African countries detected causation from exchange rate to inflation in two countries both in bivariate and trivariate settings, the latter including money as an additional variable. The results indicate that neither the exchange rate nor monetary growth was found to play a dominant role in explaining innovations in the CPI in most of the sampled countries. On the other hand, Rouis et al. (1994), conducting a Granger causality test in a bivariate setting on pooled data from a sample of 22 African countries, reported inflation to have caused devaluation, but not in reverse.

Adopting a VAR and other structural variants, Odusola and Akinlo (2001) examined the link between the naira depreciation, inflation and output in Nigeria. They found exchange rate depreciation to have positively affected output in the medium and long run, but negatively in the short run. Output and the parallel exchange rate are reported to have influenced the dynamics of inflation in that country. In another study on Nigeria, Akinbobola (2012) investigates the dynamics of money supply, exchange rate and inflation using the vector error correction mechanism. The money supply and exchange rates are reported to have reduced inflationary pressure, unlike output growth, which exerted the opposite effect. The same set of variables is examined in the context of Democratic Republic of Congo by Maswana (2005) using monthly data and the Hsiao version of Granger non-causality method. The author reports the presence of feedback causality between inflation and monetary growth, unidirectional causation from monetary growth to the exchange rate, and from the latter to inflation.

It is clear from the preceding review that the evidence on the causal relationships among the three variables of interest is partial, thin and mixed, the latter partly explained by differences in sample composition, estimation method, and whether the analysis is conducted in a bivariate or multivariate setting. The latter is particularly consequential, since causality found between two variables in a bivariate setting can be spurious if both are mutually caused by another variable excluded from the regression (Hsiao, 1982). Controlling for the third variable would enable isolating the feedback effect between any given two other variables and would, thereby, minimize the chance of detecting spurious causality. To this end, and unlike most studies on the subject, the present study seeks to examine the relationships among the real exchange rate, inflation and output growth by controlling for monetary growth and reserve adjustment, both in the short-run and long-run contexts.

3. Data Overview

The relationships among the variables of interest are examined in the context of Malawi using quarterly data spanning the period, 1980q1-2011q4. The price level is represented by the consumer price index (CPI) and the money supply by M2 (money plus quasi money). Output (y) is alternatively represented by the industrial production index for which quarterly series is generally available and by real GDP for which quarterly series is interpolated using the quadratic sum method. The real exchange rate series is the real effective real exchange rate index, constructed such that a rise in its value connotes real appreciation. The real, rather than the nominal, exchange rate is used in the empirical analysis partly because the former, unlike its nominal counterpart, is an endogenous variable, subject to flexibility regardless of the exchange-rate regime. Since what matters for external competitiveness, as an outcome of an exchange rate policy action, is the value of the real exchange rate, understanding its behavior and relation with other variables would be useful in evaluating policy effectiveness.

The series on CPI, M2 and industrial output are all seasonally adjusted except in the descriptive statistics of the present section. Availability of foreign exchange is represented by the foreign exchange series in the IMF's International Financial Statistics (IFS) database. Data on industrial output for the 2008-2010 period is from Quarterly Statistical Bulletin (March 2011) of National Statistics Office of Malawi, and the annual series on real

GDP is from World Bank's World Development Indicators (Note 9). The other data for this study are from IFS.

Over the study period, the money supply, CPI, and real GDP trended upward, with slight fluctuations in contrast to the real exchange rate, level of foreign exchange and industrial output, which were subject to wider and frequent swings. The annualized rate of inflation over the same period was 20%, eight percentage points lower than that of monetary growth. The corresponding figure for foreign exchange was 24%. Industrial output and real GDP rose, respectively, at an average rate of 2.7 and 3.5% per annum, while the real effective exchange rate depreciated by less than one percent (Table 1).

Table 1. An overview of the data: annual rates of change by exchange rate regime

Variables	Aggregate Sample		Fixed/Pegged Exchange Rate		Free Float	
(% change)	Mean	SD	Mean	SD	Mean	SD
CPI (P)	20.1	16.8	15.2	8.8	26.0	21.6
Real effective exchange rate (e)	-0.61	19.2	0.14	9.4	-1.5	26.6
Money supply (M)	27.5	17.3	23.2	13.8	32.5	19.5
Foreign exchange (FX)	24.0	79.4	19.7	84.8	29.1	72.9
Industrial production (IP)	2.7	11.0	4.8	11.5	0.30	9.9
Real GDP (RGDP)	3.5	5.4	3.6	4.7	3.5	6.1

Note. SD=standard deviation. The real effective exchange rate is defined such that an increase in its value connotes real appreciation.

As mentioned, different types of exchange rate arrangements were in place during the study period: Fixed exchange rate until 1993, followed by a free-floating regime until 2008 and then a de facto fixed exchange rate "with administrative controls over current account transactions" since then (Chuka, 2012). A comparison of the behavior of these variables between the free float and other arrangements (1994-2008 versus the remaining period) reveals, as to be expected, some notable differences. Thus, the free-float period was on balance associated with weaker inflation performance (26 vs 15%), higher monetary expansion (33 vs 23%), and much smaller growth in industrial activity (0.3 vs 5%), while the growth rate of real GDP was the same in the two sub-periods. Flexibility in the nominal exchange rate resulted in real depreciation at an annual rate of 1.5%, which compares with a negligible appreciation when the exchange rate was not floating. All but foreign exchange and industrial output were subject to a greater degree of volatility under the floating regime.

A look at Figure 1 shows a co-movement in the same direction of inflation and monetary growth until 1999 or so after which the relationship between the two variables was less clear. On the other hand, the inflation rate and the rate of appreciation of the real exchange rate appear to exhibit a tendency to move in opposite directions, while a positive association seems to characterize the growth profiles of foreign exchange and industrial output series (Figure 2).

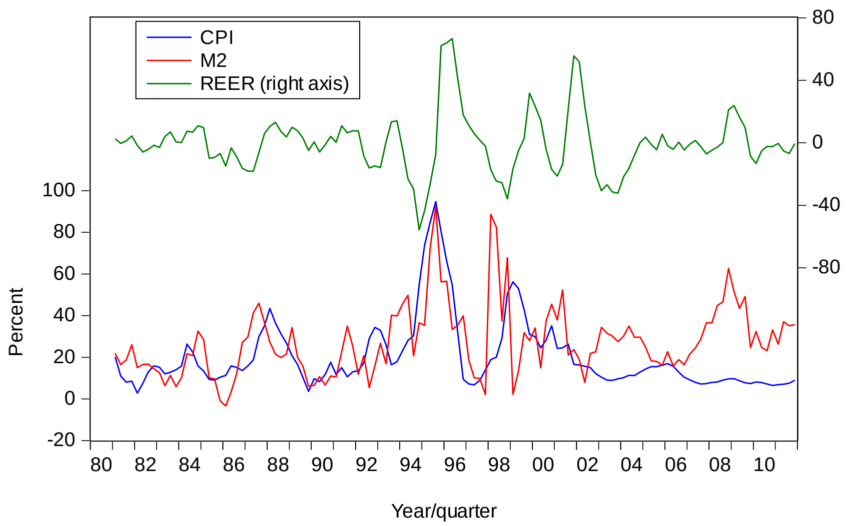

Figure 1. CPI, money supply, and real effective exchange rate annual rates of change (%)

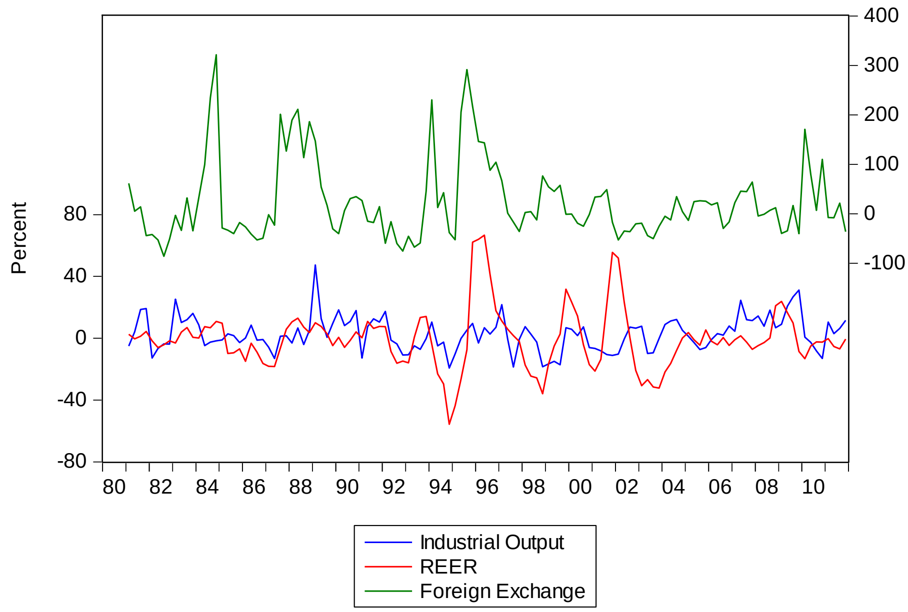

Figure 2. REER, foreign exchange, and industrial output: growth rates (%)

4. Method

The estimation method employed to investigate the causality and dynamics of the variables under consideration is the bounds testing approach to cointegration developed by Pesaran and Shin (1999) and Pesaran et al. (2001). Conducted within an autoregressive distributive lag (ARDL) framework, this methodology, unlike conventional methods of cointegration analysis (Johansen & Juselius, 1990; Johansen, 1995), can be employed with a mix of I(0), I(1) or fractionally integrated series. The procedure allows estimation in a single-equation setup by ordinary least squares (OLS) with flexible lag structure for the regressors, and it is relatively more efficient in small samples, giving it an advantage over other conventional methods.

The ARDL model is set up as an unrestricted error-correction model (ECM) where the lagged error correction term in a standard ECM is replaced by a linear combination of lagged levels of variables. The model takes the following form for the variables that are under study (see e.g. Narayan & Smyth, 2004).

$$\Delta logz_t = \alpha_{1z} + \lambda_{1z} logz_{t-1} + \lambda_{2z} logP_{t-1} + \lambda_{3z} loge_{t-1} + \lambda_{4z} logM_{t-1} + \lambda_{5z} logy_{t-1} + \lambda_{6z} logFX_{t-1} + \sum_{i=1}^{n} \beta_{iz}\,\Delta logz_{t-i} + \sum_{i=1}^{n} \gamma_{iz}\,\Delta logP_{t-i} + \sum_{i=1}^{n} \delta_{iz}\,\Delta log\Delta e_{t-i} + \sum_{i=1}^{n} \theta_{iz}\,\Delta logM_{t-i} + \sum_{i=1}^{n} \varphi_{iz}\,\Delta logy_{t-i} + \sum_{i=1}^{n} \phi_{iz}\,\Delta logFX_{t-i} + \mu_{tz} \quad (1)$$

Where z=[P,e,M,y,FX], n is the lag length, Δ is the difference operator, and μ is the error term, assumed serially uncorrelated, and "λ"s are long-run multipliers, representing long-run (cointegration) relationships.

The bounds testing procedure involves estimating equation (1) for each variable by OLS and conducting an F-test for the joint significance of the "λ"s. (Note 10) The distribution of the F-test used to test this hypothesis is non-standard and depends on the number of regressors and whether the variables are I(0) or I(1) and whether an intercept and/or a trend term are included in the model. For these different situations, Pesaran et al. (2001) provide two sets of critical values with lower and upper bounds, the former based on the assumption that all the variables are I(0), and the latter that they are I(1). A computed F-statistic exceeding the upper bound is interpreted to suggest the existence of cointegration and long-run relationship, as a value below the lower bound leads one to conclude that the variables are not cointegrated. Neither can be said if it falls between the two bounds, rendering the test inconclusive.

5. Results and Discussion

5.1 Unit Root Test

The time-series properties of the variables of the model are examined using the Augmented Dickey-Fuller (ADF) and Phillip-Perron (PP) procedures to ascertain that the order of integration does not exceed one, a requirement for the application of the bounds test procedure. The results are reported in Table 2. Both the ADF and PP statistics show that the logarithms of P, M, IP, and RGDP become stationary only after first differencing (integrated of order one), while log(e) is stationary at levels (integrated of order zero).

Table 2. Unit root test results

Variable	Series	Augmented Dickey-Fuller			Phillips-Perron		
		Lag	Stat	Prob.	Bandwidth	Stat	Prob.
logP	Level	1	-0.992	0.941	7	-0.808	0.961
	FD	0	-5.433	0.000	5	-5.573	0.000
logM	Level	5	-2.250	0.455	21	-2.01	0.592
	FD	4	-4.677	0.000	8	-13.33	0.000
Loge	Level	3	-5.109	0.000	3	-3.886	0.015
	FD	4	-6.704	0.000	9	-8.089	0.000
logFX	Level	2	-2.989	0.140	7	-4.373	0.003
	FD	1	-11.24	0.000	3	-14.59	0.000
logIP	Level	2	-1.693	0.749	9	-2.3	0.415
	FD	1	-10.73	0.000	32	-13.95	0.000
logRGDP	Level	8	-1.182	0.909	7	-2.36	0.399
	FD	8	-3.294	0.017	125	-6.410	0.000

Note. Lag length is chosen using AIC with maximum lag=8. In the level series a constant and trend are included while only a constant is included for first-difference series. Bandwidth (Newey-West automatic) using Bartlett kernel. The series logP, logM, and logIP are seasonally adjusted. FD=First difference.

5.2 Cointegration Test

Having established that the order of integration for all series does not exceed one, the bounds testing procedure was applied to test for the existence of long-run relationship by estimating equation (1) for each variable. The lag order in each of the estimations is determined by AIC. However, when serial correlation is detected at a lag thus selected, the lag length is adjusted until the hypothesis of no serial correlation is accepted, for this is a key assumption in the application of the bounds testing procedure (Pesaran et al., 2001). Once the maximum lag is selected, the general-to-specific modelling strategy is followed and highly insignificant added lags are dropped to achieve parsimony. The results of the cointegration analysis are recorded in Table 3 where four sets of the computed F-statistics for the joint significance of the lagged levels appear.

Table 3. Summary of bounds test results: F-statistic

	Whole Sample		Controlling Outliers	
Hypothesis	F-Stat	Serial Corr. Prob.	F-Stat	Serial Corr. Prob.
$F_p(P\|e, y^i, FX, M)$	4.44	0.381	3.96	0.235
$F_e(e\|P, y^i, FX, M)$	5.43	0.479	10.9	0.180
$F_M(M\|P, e, y^i, FX)$	3.74	0.556	4.31	0.286
$F_{FX}(FX\|P, e, y^i, M)$	1.35	0.455	---	---
$F_y^i(y_i\ \|P,e, FX, M)$	2.15	0.334	2.95	0.338
$F_e(e\|P, y^{ii}, FX, M)$	---	--	9.06	0.497

Note. "Whole Sample" estimates refer to regression results based on all available observation without controlling for outliers. y^i=industrial output, y^{ii}=Real GDP. The bounds test critical values used here are those generated by Narayan (2005) for n=80, which approximates our sample better than the ones in Pesaran et al. (2001) based on n=1000. At the 5% level of significance and for k=4, the lower and upper bound critical values are 3.01 and 4.216, respectively. The corresponding values at the 1% level are 4.096 and 5.512 [Case III, unrestricted intercept and no trend]. In contrast, the critical values from Pesaran et al. (2001) are: 2.86 and 4.01 (5%); 3.74 and 5.06 (1%) [Case III, unrestricted intercept and no trend].

The F-stat normalized on dependent variable, z, is denoted by $F_z(z|\ldots)$, the dots representing the explanatory variables (k), excluding the lags of z. The first set of estimates is based on the entire sample, according to which the variables in question are cointegrated at the 1% and 5% levels when the regression is normalized on the real exchange rate and price, respectively, as the computed F-statistics exceed their corresponding upper bound critical values for k=4.We fail to reject the null hypothesis of no long-run relationship in the other equations at the conventional level of significance. Controlling for outlier observations strengthens the case for the existence of a long-run relationship, with the real exchange rate as the dependent variable (Note 11). The opposite is true when the regression is normalized on P, providing no evidence of cointegration at the 5% level.

In view of the possibility of changes in the estimated coefficients of a time series regression and its implication for long-run relationship, it would be necessary to check for the stability of the long-run multipliers (Hansen, 1992). More so because the study period covers three decades during which different types of policy and structural changes have occurred in the country. We use the procedure developed by Bai and Perron (1998, 2003) to endogenously determine whether there was a structural break in the long-run relationship and when the break may have occurred by allowing the lagged level coefficients to vary across regimes, while the short-run parameters are constrained to remain unchanged, given our interest in the long-run relationship. Applying the double maximum break selection method (weighted and unweighted double maximum) for the test of the null hypothesis of no structural break (against the alternative, unknown M globally determined breaks) shows no structural break in the exchange rate equation at the 5% level of significance (Note 12). However, given the two broad types of exchange rate arrangements implemented during the study period, the intercept term and lagged level coefficients were allowed to shift by including the exchange-rate regime dummy variables additively (in the case of the intercept) and multiplicatively (with respect to the slope coefficients) to test whether the observed long-run relationship among the variables was robust to changes in the exchange rate regime. The F-statistic, $F_e(e|P, y, FX, M)$, is computed to be 4.81 under the fixed exchange rate sub-period, while the corresponding figure for the floating rate sub-sample is 9.6, significant at the five and one percent levels, respectively. The null of no long-run relationship is rejected in both cases, although at a much higher level of significance under the floating than under the fixed exchange rate regime.

5.3 Long-Run Effects

Given that a long-run relationship is observed in the regression normalized on the real exchange rate, an error-correction model of this variable is estimated. Consider first the long-run effects. Using the estimates of "λ"s in equation (1), where z is the real exchange rate, the long-run coefficients are extracted as the negative of the ratio of the respective "λ"s and λ_{1e}; i.e., $-(\lambda_{ie}/\lambda_{1e})$, yielding the estimates appearing in Table 4.

The long-run coefficient on the price level is negative but statistically insignificant, suggesting that the price level has no discernable long-run effect on the real exchange rate. This probably reflects the adjustment of the nominal exchange rate over the years, which may have countervailed the incipient effect of inflation on the real exchange rate. Likewise, the money supply emerged with a negative coefficient, significant at the 10% level (and at 5% when y is represented by real GDP), indicating that monetary expansion modestly contributed to real depreciation. Although the coefficient is only moderately significant, its sign is consistent with theory. Its estimate suggests that, all equal, a 1% increase in the money supply will result in as much as 0.3% depreciation in the real exchange rate. On the other hand, the parameters on the other two variables are signed positive and statistically significant, suggesting that foreign exchange depletion would result in real depreciation as would a decline in economic activity. A *ceteris paribus* one percent growth in the stock of foreign exchange would cause the real exchange rate to appreciate by 0.1%. The corresponding response from an equivalent growth in real GDP is roughly1%. It may be noted that representing "y" by real GDP magnified the effects of all but the price level which became even more imperceptible.

A comparison of the long-run multipliers under the two exchange rate regimes reveals no significant difference with respect to the price level and the money supply. The long-run effect of the former is statistically zero in both cases, reversal of its sign notwithstanding. The effect of the money supply appears to be larger numerically under floating but much smaller statistically. The long-run multipliers of output and foreign exchange, on the other hand, are appreciably different between the two regimes. Output influences the real exchange rate positively and significantly during the pegged arrangement, while no clear effect is observed under the other regime. The effect of foreign exchange is stronger both numerically and statistically under floating. The results suggest that the real exchange rate appreciates by 0.18% in response to a one percent increase in the stock of foreign exchange when the exchange rate is floating, which is much higher and significant than the 0.04% estimated for the other sub-period.

Table 4. Long-run relationships (implied long-run parameters): dependent variable: loge

Explanatory Variables	Aggregate Sample		Fixed Exchange Rate	Floating Exchange Rate
	Estimates with y=industrial output	Estimates with y=real GDP	Estimates with y=industrial output	
logP	-0.0543	-0.0192	-0.0254	0.0852
	(0.694)	(0.209)	(0.261)	(0.330)
logM	-0.1184	-0.2770	-0.1338	-0.2376
	(1.814)*	(2.378)**	(1.856)*	(1.276)
Logy	0.2897	1.01	0.4106	0.0065
	(2.398)**	(2.246)**	(3.349)***	(0.020)
logFX	0.0942	0.1046	0.0378	0.1763
	(3.191)***	(2.907)***	(1.727)*	(2.889)***

Note. Long-run coefficients are computed using the Bardsen (1989) method as the negative of the ratio of the estimated coefficient on the lagged variable of interest to that on the lagged dependent variable in the unrestricted ECM. Figures in parentheses are absolute values of t-statistics; and the standard errors are derived using the Delta method. The asterisks *, **, and ***, respectively, denote significance at the 10, five and one percent level.

5.4 Short-Run Dynamics

The short-run dynamics of the model, based on the estimation of equation (2), with z replaced by the real effective exchange rate, are presented as follows.

$$\mathbf{\Delta loge_t = -0.0382 \underset{(4.26)^{***}}{} + 0.2810\Delta loge_{t-1} \underset{(4.01)^{***}}{} + 0.2258\Delta logP_{t-4} \underset{(1.74)^{*}}{} + 0.1945\Delta logM_{t-3} \underset{(2.35)^{**}}{} + 0.2416\Delta logM_{t-4} \underset{(3.57)^{***}}{} + 0.7196\Delta logy_{t-1} \underset{(2.91)^{***}}{}} \quad (2)$$

$$\mathbf{-0.5257\Delta logy_{t-4} \underset{(1.92)^{*}}{} - 0.0171\Delta FXy_{t-3} \underset{(1.49)}{} - 0.2796ect_{t-1} \underset{(6.32)^{***}}{} + \text{residual (Note 13)}}$$

-0.0382	+0.2810Δloge(t-1)	+0.2258ΔlogP(t-4)	+0.1945ΔlogM(t-3)	+0.2416ΔlogM(t-4)	+0.7196Δlogy(t-1)
(4.26)***	(4.01)***	(1.74)*	(2.35)**	(3.57)***	(2.91)***
-0.5257Δlogy(t-4)	-0.0171ΔFXy(t-3)	-0.2796ect(t-1)	+ residual (Note 13)		
(1.92)*	(1.49)	(6.32)***			

Adj. R^2=0.64 F-stat=17.6*** S.E.R.=0.05 Serial Corr.:Chisq(4)=4.8, Prob.=0.31

Clearly, the real exchange rate is strongly influenced by its inertia, a one percent increase in its lagged value leading to a 0.3% rise in its current value. In the short run, price affects the real exchange rate positively with a lag. Significant at the 10% level, the coefficient estimate indicates that the rate of real appreciation will rise by roughly 2% consequent upon a 10% hike in the inflation rate, holding on other determinants. Monetary growth exerts a positive effect on the real exchange rate in the short run. The effect of foreign exchange accumulation is estimated to be negative, albeit statistically insignificant. Allowing the short-run effect of foreign exchange accumulation on the real exchange rate to shift across the two exchange rate regimes renders the effect significant under the pegged regime, at the 5% level. The negative sign could arise, for example, if increased foreign exchange availability allowed greater volume of imports that dampened the inflationary pressure, in turn, triggering a fall in the real exchange rate.

Real GDP growth seems to occasion real appreciation at first lag, with the opposite effect observed later, although at a lower level of significance. The positive coefficient on real GDP, on the other hand, could arise in the presence of concomitant demand-pull inflation or an induced increase in money demand (as the monetary approach predicts). The delayed negative effect may reflect policy responses in the form of devaluation to downturns in economic activity.

The short-run adjustment coefficient is correctly signed and highly significant, congruent with the results of the bounds test for cointegration. The parameter estimate suggests that no less than a quarter of the deviation of actual real exchange from its long-run equilibrium level is corrected in the next quarter, implying that the process of adjustment to long-run equilibrium would be completed within a year. Comparing the speed of adjustment between the two exchange rate regimes—fixed/pegged and floating regimes—shows that the adjustment coefficient is significantly negative in both cases, slightly smaller in absolute value and more significant under the floating exchange rate regime (Note 14). Nevertheless, a Wald test that the two parameter estimates are equal yields an F-stat of 0.699 (Prob.=0.41), failing to reject the null that the speed of adjustment is the same during the two exchange-rate regimes.

5.5 Granger Causality Analysis

As reported, the variables under study are cointegrated, when normalized on the real exchange rate. This suggests the presence of Granger causality between or among them at least in one direction, although the direction of causality cannot be inferred therefrom. A Granger causality analysis of the variables in question in a bivariate setting detects the terrain of causation sketched in Figure 3 (Note 15). The results suggest that there exists, at the conventional level of significance, a unidirectional causation from the real exchange rate to foreign exchange and price, from the latter to industrial production, money supply and foreign exchange, from money supply to the real exchange rate, and from real GDP to foreign exchange. A bi-directional causality characterizes the relationship between real GDP and the real exchange rate at the one percent level of significance. At the 10% level, the real exchange rate and money supply are each observed to Granger cause industrial output.

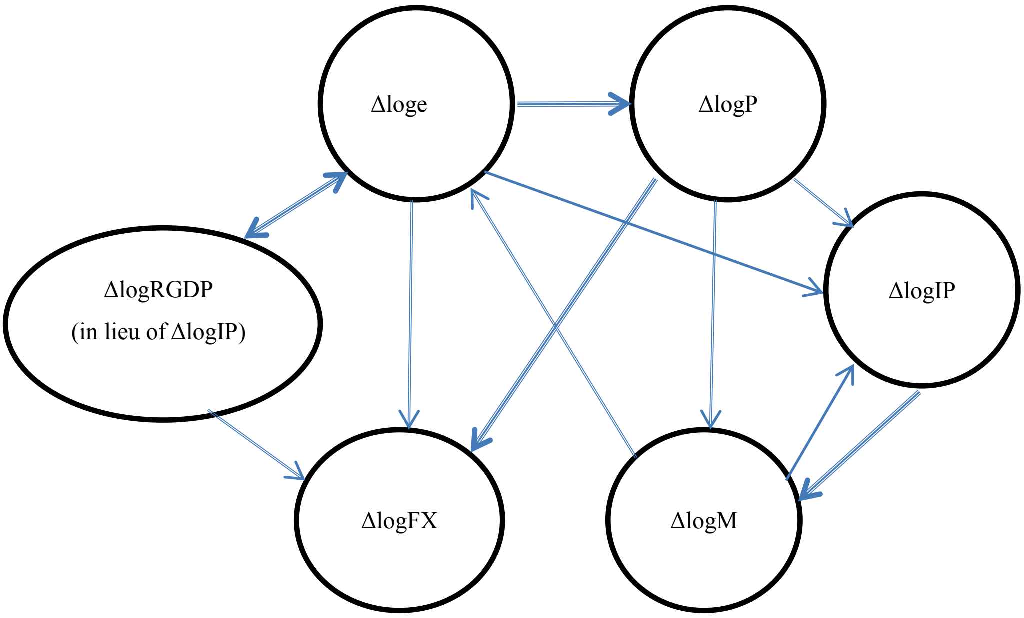

Figure 3. Bivariate granger causality

Note. Single, double, and triple arrows denote significance at the 10, 5, and 1 percent level, respectively.

As mentioned, a causality analysis in a bivariate setting could yield misleading results if the two variables are commonly caused by another factor that is excluded from the analysis. Moreover, the forgoing analysis considered short-run causality only, ignoring the implications of their long-run relationship. Therefore, the pattern of causality among the variables is examined in a multivariate setting within the error-correction mechanism, incorporating a lagged error-correction term where applicable (Note 16). The results are summarized in Table 5 and depicted in Figure 4.

The F-statistics on each explanatory variable in Table 5 tests the joint significance of the lagged terms of the respective variable to establish whether short-run causality runs from it to the corresponding response variables appearing in the first column. The results indicate that there exists a short-run Granger causality at the five percent or better from the real exchange rate to price and output. The latter two are also causally related, causation running from price to output. Foreign exchange is Granger caused both by price and money supply, while feedback causality appears to be the case between the latter and output.

It is worth noting that the unidirectional causality detected in the bivariate setting from the real exchange rate to foreign exchange accumulation, and from price to the money supply disappeared when the other variables are controlled for, weakening the case for the said causality, although neutrality cannot be concluded given the bivariate test results. The findings from the two settings also differ in terms of the strength of the causal relationships observed. A case in point is the causal effects of price, the real exchange rate and money supply on industrial output, which are now significant at a higher level. However, the pattern of causality among the three variables of interest is the same in both settings, albeit differences in significance levels. It is worth noting that no reverse causation was established from inflation to real appreciation, suggesting that the nominal exchange rate adjusted to the inflation differential as predicted by the PPP hypothesis, which, according to Mangani (2012), appears to hold for the bilateral rates of the Malawi Kwacha.

The coefficient on the lagged error-correction term is significantly negative, as previously noted. This provides evidence for the presence of long-run causality running interactively through ect_{t-1} from price, money, output and foreign exchange to the real exchange rate, although, in a multivariate setting, none of them is found to individually Granger cause it in the short run (Note 17). Although the findings are not strictly comparable owing, among others, to differences in estimation procedures and model specifications, our results on the role of the exchange rate in price adjustment are consistent with those reported by Ngalawa and Viegi (2011), Jombo, et al (2014), and Canetti and Greene (1991). The responses of output to the exchange rate and money supply reported by Ngalawa and Viegi (2013) for Malawi are implied by our Granger causality test results.

Table 5. Multivariate granger causality analysis

Dependent Variable	Causal Variables: F-Stat [Prob.]							Serial Correlation[iii]	Normality[iv]
	Lag	ΔlogP	Δloge	Δlogy	ΔlogM	ΔlogFX	ECT_{-1}		
ΔlogP	1	---	4.32	0.095	0.550	0.037	---	0.171	1.85
			[0.039]	[0.759]	[0.460]	[0.845]		[0.68]	[0.396]
Δloge	4	1.12	---	0.966[i]	1.745	1.21	-0.317	5.52	1.05
		[0.352]		[0.430]	[0.146]	[0.312]	(4.973)[ii]	[0.238]	[0.592]
Δlogy	4	3.69	4.71	---	2.85	2.19	---	6.15	1.08
		[0.008]	[0.002]		[0.028]	[0.076]		[0.186]	[0.583]
ΔlogM	3	1.72	0.583	2.81	---	0.452	---	1.79	4.78
		[0.168]	[0.627]	[0.043]		[0.717]		[0.618]	[0.092]
ΔlogFX	3	3.00	1.75	0.232	3.61	---	---	1.70	3.04
		[0.034]	[0.162]	[0.874]	[0.016]			[0.638]	[0.219]

Note.

i. With real GDP (in lieu of industrial production), the F-stat and associated probability are 2.16 and 0.079.

ii. The number in parentheses is the t-statistic, significant at the 1% level.

iii. The serial correlation test is the Breusch-Godfrey LM Chi-square stat with associated probabilities under the null that serial correlation is present at the specified lag order. The normality test column records the Jarque-Bera stat for the null of normal distribution.

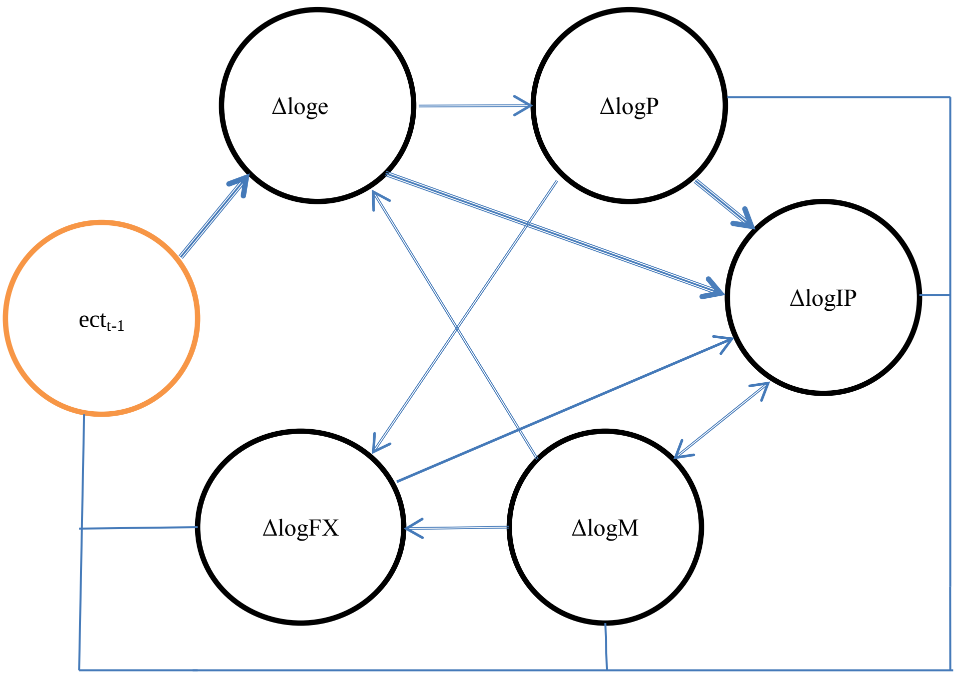

Figure 4. Multivariate granger causality

Note. Single, double, and triple arrows, respectively, denote significance at the 10, 5, and 1 percent level.

6. Summary and Conclusions

The purpose of this paper has been to explore the temporal causality and dynamics of real exchange rates, inflation, and output growth in Malawi. Controlling for monetary growth and foreign reserves accumulation, the relationships among the said variables were examined using quarterly data spanning three decades. Whether a long-run relationship existed among the variables of interest was tested using the bounds testing approach. The test results suggest that a long-run relationship among the variables exists over the study period when the regression is normalized on the real exchange rate. In the long run, the real exchange rate was found to respond significantly to the growth rates of output, the money supply, and foreign reserves, but not to inflation, although the nature and significance of some of these effects were sensitive to the exchange rate regime in place.

Analysis of the short-run dynamics reveals that the real exchange rate was influenced by output growth and inflation as well as by the other financial variables at varying levels of significance and lag structure. The short-run adjustment coefficient is correctly signed and highly significant. Its estimate suggests that the process of adjustment to long-run equilibrium would be completed within a year. And no statistically significant difference is observed in the speed of adjustment between pegged and floating exchange rate regimes.

Granger causality analysis in a multivariate setting points to causation running from the real exchange rate to inflation and from both to output growth. The latter was found most responsive, driven by all model variables. The lagged error correction term, where included, emerged significant, providing evidence for the presence of long-run causality running interactively through it from the other variables as a group to the real exchange rate. On the other hand, the money supply, as represented by M2, was not found to cause inflation, except perhaps through the real exchange rate, which is at odds with the monetarist view and indicative of the limitation of monetary policy in managing inflation, and probably reflecting the importance of factors such as food supply constraints as a determinant of inflation in the country. Although the results are not confirmed in the multivariate setting, the detection of a one-way causation from inflation to monetary growth points to the possibility that monetary policy was accommodative, validating inflation precipitated by such factors. On the other hand, the two-way causality observed between monetary and output growth is consistent with monetary policy feedback rule, indicative of also the potential real effect monetary policy can exert.

The finding that both inflation and output growth are Granger caused by the real exchange rate underscores the importance of developments in the foreign sector, such as exchange rate policy changes, foreign price shocks, and external competitiveness, for domestic price and output adjustment. This seems to point to the consequentiality of the volatility of the real exchange rate for domestic economic activity. Taken together, the results indicate the relevance of domestic economic activity, monetary policy, and foreign exchange availability for the evolution of the real exchange rate, which, in turn, is observed to have played a role in influencing domestic inflation and output growth in Malawi.

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Notes

Note 1. See table I in the appendix for a summary of domestic and international trade policy actions undertaken since the early 1980s. See also Government of Malawi (2012). Second PRSP-Growth and Development Strategy 2011-2016. Report No. 69134.

Note 2. The Pound Sterling, US dollar, the Deutschmark, the Japanese Yen, the South African Rand, the Italian lira and the Zimbabwe dollar.

Note 3. Even under a fixed exchange rate arrangement, inflation could lead to nominal devaluation, albeit with a relatively longer lag, as persistent relative domestic inflation and the resulting deterioration of the balance of payments and loss of foreign reserves would eventually force currency devaluation.

Note 4. The monetary approach to exchange rate determination postulates a direct relationship between income and exchange rate movements through the effect of the former on money demand, given relative money supplies and money demand and income abroad. Alternatively, higher income could engender a rise in the demand for foreign exchange to finance the purchase of imports and foreign assets, causing deterioration in the balance of payments and exerting a downward pressure on the value of the exchange rate as predicted in the Mundell-Fleming model. Under fixed rates, the possible effect of output growth on inflation provides an additional channel through which the former could influence the real exchange rate.

Note 5. A case for a reverse causation can be made where monetary growth is “endogenous or ‘passive’, adjusting to the level of activity and rate of inflation” (Taylor, 1990, p. 3), as hypothesized in new structuralist models that view monetary growth as a symptom of structural rigidities, such as inelastic food supply and foreign exchange constraints, emphasized as the causes of inflation in developing countries. As well, monetary policy responses (by way of money supply tightening/easing) to inflation and recession (for example, when inflation targeting is the objective of monetary policy) provide a case for a reverse causation.

Note 6. A reverse causation from the exchange rate to the money supply is expected through its impact on inflation and foreign reserves where the exchange rate is not freely floating. The exchange rate could also influence the money supply via its possible effect on the level of fiscal deficits, where international transactions are a major source of government revenue and where the deficit is monetized (see e.g.Yiheyis, 2000).

Note 7. A reverse causation from exchange rates to foreign reserves would occur as currency depreciation, to the extent that it is successful in enhancing external competitiveness, leads to a buildup of foreign reserves (e.g. Hausmann et al., 2006; Adler & Camilo, 2011).

Note 8. The variables considered in their analysis include CPI, output, exchange rates, reserve money, M2, bank lending, and lending rate.

Note 9. Missing data on this series for 2004q3-q4 and 2011q1-q4 (6 observations) are filled by forecasted values using converted real GDP and quarter dummy variables as regressors.

Note 10. When ΔlogP is the dependent variable, for example, the null hypothesis of no cointegration, i..e., H_0: $\lambda_{1P} = \lambda_{2P} = \lambda_{3P} = \lambda_{4P} = \lambda_{5P} = \lambda_{6P} = 0$ is tested against the alternative hypothesis, H_1: $\lambda_{1P} \neq \lambda_{2P} \neq \lambda_{3P} \neq \lambda_{4P} \neq \lambda_{5P} \neq \lambda_{6P} \neq 0$.

Note 11. The DFFITS option of the "Influence statistics" procedure of Eviews was used to determine outlier (influential) observations for each regression. DFFITS measures the difference in fitted values between the original regression and the regression without a given observation, divided by an estimate of the standard deviation of the fit. Binary variables equaling 1 for each of the years with outliers and zero otherwise were included in the relevant regressions, dropping those which are statistically insignificant at the 10% level.

Note 12. The maximum number of breaks was set at 5 and the test was conducted under the assumption of heterogeneous error distributions across breaks.

Note 13. Outlier dummy variables are included in the estimations, but not shown here in the interest of space. The Chi-square stat is the Breusch-Godfrey serial correlation LM residual test at lag=4 under the null of no serial correlation. S.E.R.=standard error of regression. The asterisks *, **, and *** denote significance at the 10, 5 and 1% level, respectively.

Note 14. The coefficient estimates and the corresponding t-ratios, shown in parentheses, are -0.3455(3.82) and -0.2591(5.12) under fixed and floating regimes, respectively—both significant at the 1% level.

Note 15. Details of the analysis are reported in Table II in the Appendix.

Note 16. See e.g. Narayan and Smyth (2004) for a similar approach.

Note 17. While the real exchange rate responds to the variables of the model at one or another lag in the context of short-run dynamics, the combined lagged effects associated with a given regressor are such that the Granger non-causality hypothesis could not be rejected.

Appendix

Appendix 1. Malawi economic policy actions under different policy regimes, 1964-2012

Period	Period	Domestic Policy Actions	International Trade Policy Actions
Pre-Reform Period	1964-1980	• Active government involvement in economic activities (Malawi Development Corporation (MDC) and ADMARC investments). • Provision of extension services and active research in agricultural technologies, maize seeds and other crops. • Macroeconomic stability - low and stable inflation, low and stable interest rates • Preferential lending to agricultural sector.	• Malawi–Botswana reciprocal trade agreement in 1968. • Overvalued exchange rate system fixed peg • Limited tariff protection • Non-tariff barriers to trade such as import licensing and implicit foreign exchange rationing
	1981-1986	• Periodic increases in interest rates and agricultural prices. • Restructuring of state-owned enterprises. • Liberalization of industrial output prices.	• Periodic devaluation of the Malawi Kwacha. • Increases in trade taxes and foreign exchange rationing
	1987-1994	• Liberalization of the financial sector and interest rates between 1987 and 1989 • Removal of preferential lending to agricultural sector in 1990	• Periodic devaluation of the Malawi Kwacha and eventual floatation in February 1994 • Elimination of quantitative trade restrictions and foreign exchange rationing.

Reform Period		• Liberalization of agricultural marketing services (output in 1987 and inputs in 1990 • Liberalization of the prices of some agricultural produce in 1988 • Removal of fertilizer subsidies by 1991 • Privatization of state-owned enterprises • Liberalization of entry into manufacturing in 1991	• Introduction of duty drawback system in 1988. • Introduction of surtax credit scheme in 1989 • Bilateral trade agreement with South Africa in 1991. • Reductions in tariffs leading to a maximum of 75% in 1994.
Post-Reform Period	1995-2007	• Removal of restrictions that prevented smallholder farmers from producing and marketing high value crops in 1995. • Reduction in base surtax to 20% in 1996 • Liberalization of prices for all crops except maize and introduction of a maize price band in 1996. • Privatization of state-owned enterprise since 1996. • Elimination of the maize price band in 2000 • Agricultural input support programs for smallholder farmers	• Introduction of EPZ incentives in 995. • Export levy on tobacco and sugar in 1995 and eventual removal in 1999 • Bilateral trade agreement with Zimbabwe in 1995. • Removal of import and export licensing in 1997 • Elimination of import duty on raw materials for manufacturing in 1997. • Devaluation of the Malawi Kwacha in 1998.Reduction of maximum tariff to 40%in 1996; to 35% in 1997; and to 25%in 1999. • COMESA Free Trade Area by 2000
	2008-2012	• Upward adjustment of bank rate from 13% since 2010 to 16% • Increased independence of monetary authority in operations and decisions • Fuel price adjusted upward by 30% and electricity tariffs by 63.5%	• Devaluation of the Kwacha by 49% • Freeing up of the exchange rate determined by foreign exchange bureaus • Reversal of surrender requirements on tobacco dollars

Source: Adapted/updated by authors from Chirwa and Zakeyo (2003).

Appendix 2. Bivariate granger causality tests

Null Hypothesis	Lag	F-Stat [Prob.]	Chi-sq [Prob]
Price and real exchange rate:	4		3.2 [0.518]
Real exchange rate does not Granger cause price		3.92 [0.005]	
Price does not Granger cause real exchange rate		1.95 [0.107]	
Price and money:	5		2.6 [0.628]
Money does not Granger cause price		1.58 [0.171]	
Price does not Granger cause money		3.04 [0.013]	
Price and industrial output:	3*		2.9 [0.583]
Price does not Granger industrial output		2.63 [0.054]	
Industrial output does not Granger price		1.34 [0.264]	
Price and real GDP:	9		1.4 [0.847]
Price does not Granger real GDP		1.15 [0.338]	
Real GDP does not Granger price		1.48 [0.165]	
Price and foreign exchange:	2		4.3 [0.942]
Price does not Granger foreign exchange		6.18 [0.003]	
Foreign exchange does not Granger price		0.78 [0.460]	
Real exchange rate and foreign exchange:	6		6.8 [0.144]
Real exchange rate does not Granger foreign exchange		2.56 [0.024]	
Foreign exchange does not Granger cause real exchange rate		1.31 [0.260]	
Real exchange rate and money:	5		3.32 [0.505]
Real exchange rate does not Granger money		1.06 [0.385]	
Money does not Granger cause real exchange rate		3.09 [0.012]	
Real exchange rate and industrial output:	4		6.9 [0.142]
Real exchange rate does not Granger industrial output		2.26 [0.067]	
Industrial output does not Granger cause real exchange rate		0.35 [0.846]	

Real exchange rate and real GDP:	5**		1.23 [0.873]
Real exchange rate does not Granger real GDP		3.36 [0.007]	
Real GDP does not Granger cause real exchange rate		3.75 [0.004]	
Money and industrial output:	3		3.53 [0.474]
Money does not Granger industrial output		2.29 [0.082]	
Industrial output does not Granger cause money		5.49 [0.002]	
Money and real GDP:	5		3.96 [0.412]
Money does not Granger real GDP		1.04 [0.397]	
Real GDP does not Granger cause money		1.51 [0.193]	
Money and foreign exchange:	2		1.23 [0.873]
Money does not Granger foreign exchange		1.31 [0.272]	
Foreign exchange does not Granger cause money		0.36 [0.698]	
Foreign exchange and industrial output:	2		1.19 [0.880]
Foreign exchange does not Granger industrial output		0.774 [0.464]	
Industrial output does not Granger cause foreign exchange		0.711 [0.493]	
Foreign exchange and real GDP:	9		2.51 [0.643]
Foreign exchange does not Granger real GDP		1.61 [0.122]	
Real GDP does not Granger cause foreign exchange		2.10 [0.036]	

Note. All variables are in first difference of logarithms. Lag length is chosen using AIC, except where marked *(**), in which case the lag length increased (decreased) by one to correct for serial correlation, which was detected at the AIC-determined lag order. The F-Stat and associated probabilities in the third column pertain to the null hypothesis in the first column. The last column records the LM Chi-square statistics and probability for the null that there is serial correlation at the specified lag.

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