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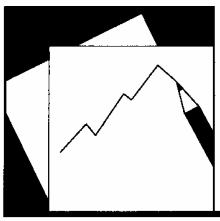

IMF Working Paper

An Empirical Investigation of the Exchange Rate Pass-Through to Inflation in Tanzania

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An Empirical Investigation of the Exchange Rate Pass-Through to Inflation in Tanzania

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Abstract

The paper examines the effect of exchange rate changes on consumer prices in Tanzania using structural vector autoregression (VAR) models. Using a data set covering the period 1990–2005, we find that the exchange rate pass-through to inflation declined in the late 1990s despite the depreciation of the currency. This could be partly attributed to the macroeconomic and structural reforms that were implemented during this period. The decline in the pass-through does not necessarily imply that exchange rate fluctuations are less significant in explaining macroeconomic fluctuations. The recent increase in the share of imports in the economy suggests that the pass-through could rise over the medium term. The findings imply that the authorities should remain vigilant in assessing the potential impact of foreign prices on the dynamics of inflation in Tanzania. In this regard, the authorities should seek to maintain low and stable inflation and continue the ongoing structural reforms designed to improve efficiency and increase competition.

JEL Classification Numbers: C32, E31, E 41, O55

Keywords: Pass-through, Exchange rate, Inflation, Structural VAR, Tanzania

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I. INTRODUCTION

Quantifying the size of the exchange rate pass-through to inflation has received considerable attention in recent theoretical and empirical studies because anecdotal evidence suggests that there was surprisingly little transmission of large exchange rate movements to prices in the 1990s (Choudhri and Hakura, 2001; Taylor, 2000). The paper examines the evolution of the exchange rate pass-through to inflation in Tanzania and shows when and by how much it has declined since the early 1990s. It also examines the factors behind the decline in the exchange rate pass-through to inflation, particularly as it occurred during a period characterized by a continued nominal depreciation. Most empirical studies use a recursive vector autoregression (VAR) framework to examine the impact of exchange rate movements on consumer prices (McCarthy, 2000). This paper uses structural vector autoregression (SVAR) models to capture the impact of exchange rate shocks on inflation. In order to ensure the robustness of the results to the econometric procedure, the paper also utilizes vector error correction (VEC) models and Granger causality tests to examine the importance of exchange rate movements.

The empirical findings indicate an incomplete exchange rate pass-through to inflation in Tanzania during the period 1990-2005. A 10 percent depreciation is associated with a 0.05 percent increase in inflation after a two-quarter lag. The pass-through to inflation during this period is persistent, implying that exchange rate movements have a small but prolonged impact on inflation. The results indicate that the pass-through to inflation has decreased, from a low degree of pass-through during the early 1990s to a complete absence of pass-through since the mid-1990s. Specifically, during the period 1995:Q4 to 2005:Q1, a 10 percent depreciation of the currency is associated with a 0.03 percent decrease in inflation compared with the period 1990:Q1 to 1995:Q3, when it was associated with a 0.17 percent increase in inflation, after a two-quarter lag. The VEC model results support these findings and indicate a small but persistent effect of exchange rate shocks on short-run inflation. They also indicate a long-run negative relationship between exchange rate depreciation and inflation. The Granger causality tests demonstrate that exchange rate movements do not "granger cause" inflation, lending further support to the empirical findings of the SVAR and the VEC approaches.

There are several possible explanations for the decline in the pass-through in Tanzania since the mid-1990s. This decline can be attributed to the change in monetary policy stance in 1995—in particular, the active intervention by the central bank to control money supply growth and the resulting downward revision of private agents' inflationary expectations. These results support the empirical findings that the degree of pass-through is higher in economies with higher inflation, as the period with the higher pass-through (from 1990 until 1995) was characterized by chronically high and volatile inflation, averaging 32 percent, while the period with the lower pass-through (the period since 1995) exhibited lower inflation, of about 9 percent. Other factors include higher productivity, increased competition

and a decrease in import tariffs following implementation of structural reforms.[2] The decline in the pass-through is also partly attributed to the decrease in the share of imported goods in the economy during 1994–2004, as the weighting of the CPI basket was revised in 1994 to reflect this decrease in imports.

The paper contributes to the discussion on factors behind the low inflation and high depreciation paradox in Tanzania by examining the pass-through over time: most studies on African countries tend to focus on estimating the size of the pass-through without considering its evolution over time (Kiptui, Ndolo, and Kaminchia, 2005; Choudhri and Hakura, 2001).[3]

The remainder of this paper is organized as follows. Section II briefly describes inflation and exchange rate developments in Tanzania. Section III summarizes recent empirical work on the exchange rate pass-through. Section IV presents the empirical model utilized to capture the relationship between inflation and the exchange rate and describes the identification strategy used to capture the impact of the shocks within the context of a SVAR model. Section V presents the main empirical results from the SVAR approach and as well as results from the Granger causality tests and VEC approach. Section VI examines the factors behind the decline in the exchange rate pass-through, and Section VII concludes with some policy recommendations.

II. Money, Exchange Rates, and Inflation in Tanzania

The evolution of macroeconomic developments in Tanzania can be divided into four periods: (i) the late 1970s to mid-1980s, characterized by stagflation and overvalued currency; (ii) the late 1980s, characterized by a sharp economic recovery, mainly due to resurfacing of underground economy as the stringent controls were relaxed; (iii) the early 1990s, characterized by a decrease in GDP growth, chronically high inflation, and gradual exchange rate liberalization; and (iv) the period from the mid-1990s, characterized by a stable macroeconomic environment with declining inflation and high growth. Monetary policy in Tanzania was subordinated to fiscal imperatives of financing large and ultimately unsustainable fiscal deficits during the 1970s and 1980s.[4] From the late 1980s, the economy rebounded as measures were taken to move toward a market-based economy. This period was marked by an easing of controls, in particular, price and trade liberalization. Despite the economic recovery, inflationary pressure remained high largely on account of monetary

[2] See for example Laflèche (1997) for literature on the impact of increased competition on retail prices. For a discussion of the impact of structural reforms on productivity and competition in Tanzania, see Treichel (2005).

[3] A more detailed survey of the literature is provided in Section III.

[4] Monetary policy was geared toward supporting the government's two overarching aims—stimulating rapid economic growth and achieving self-reliance—following the move to socialism in 1967.

financing and exchange controls.[5] Moreover, the government's waning commitment to reforms in the early 1990s—confirmed by its laxity in public finance management—resulted in large widening fiscal imbalances and soaring inflation even after the various exchange rates were unified in 1993.

The emergence of a new government in 1995 provided a fresh platform to undertake macroeconomic reforms to achieve price stability. The central bank, Bank of Tanzania (BOT), received legislative autonomy to implement its overarching objective of minimizing the level and volatility of inflation. It embarked on a monetary targeting program, whose loss function included minimizing exchange rate and output fluctuations.[6] The solid track record of policy implementation resulted in a decline in inflation to its lowest levels in over 20 years.[7] The decrease in inflation has also been associated with a decline in growth and volatility of the nominal exchange rate and broad money supply (Figures 1–2, Table 1). Inflation during the period has been largely broad-based, and until recently was closely in line with food prices, reflecting the weight of food in the CPI basket.[8] Despite the success in achieving price stability, the currency has remained weak, depreciating at an average annual rate of 6.6 percent during the period 1996–2004. The paper will analyze this apparent weak exchange rate pass-through to inflation.

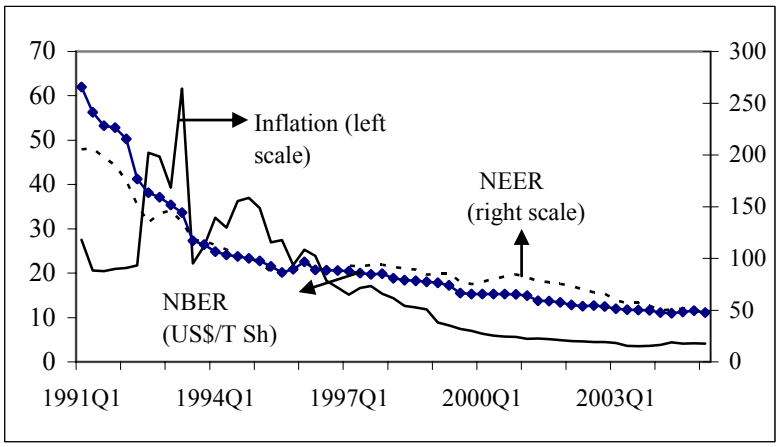
[5] Kaufmann and O'Connell (1997) note that faster unification of the exchange rates would have reduced monetary growth and inflationary pressures. Exchange rate unification was delayed as attempts were made to maintain patron-client networks through monetary financing and exchange controls.

[6] The primary mission of the BOT as stated in the Bank of Tanzania Act, 1995, is "...to formulate and implement monetary policy, directed to the economic objective of maintaining price stability, conducive to a balanced and sustainable growth of the national economy of Tanzania." In addition, the Review of Monetary Policy Implementation frequently notes that "The Bank of Tanzania continued to exercise a free floating exchange rate policy with limited interventions for liquidity management and to smoothen fluctuations in the supply and demand of foreign exchange in the market" (Bank of Tanzania Monetary Policy Statement, June 2005).

[7] The government tightened fiscal policy and, as a result, the government deficit halved to an average of 9.3 percent of GDP during 1990-97 compared to 1985-90.

[8] The weight of food items in the CPI basket was 64 percent, during the period 1990–93. It was increased to 71 percent in 1994. Since September 2004, a new basket of consumer goods and services has been utilized in the compilation of the CPI to capture the changing consumption pattern. The new CPI basket accords a lower weight to food items, 55.9 percent, and incorporates a broader range of goods.

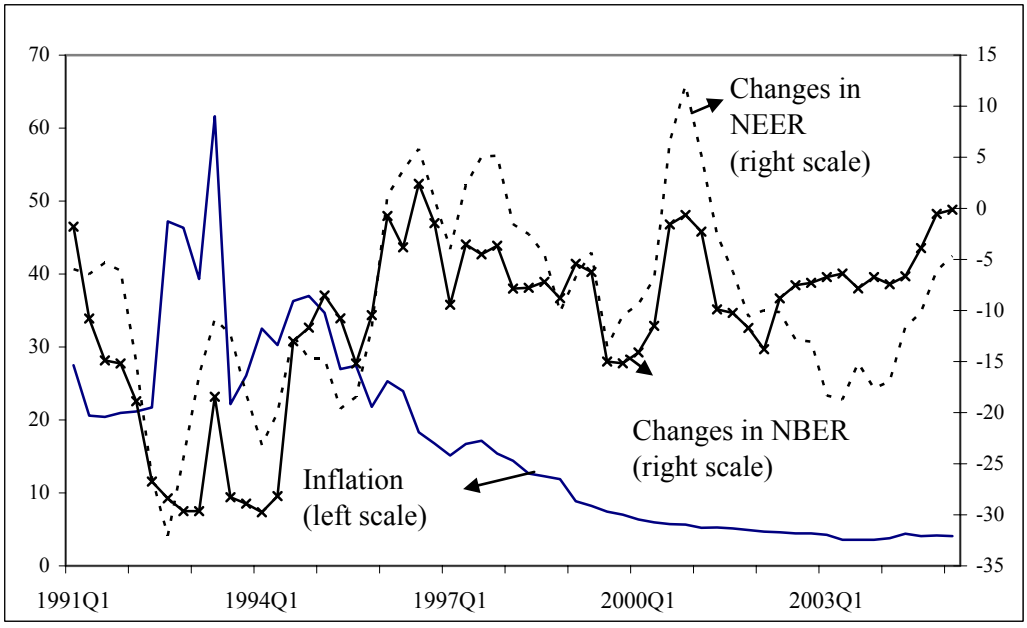
Figure 1. Nominal Bilateral Exchange Rate (NBER), Nominal Effective Exchange Rate (NEER) Indices, and Inflation Rate, 1991–2005[1]



Sources: Bank of Tanzania (BOT) and IFS.

[1] NBER is bilateral exchange rate of the Tanzania shilling (T Sh) relative to the U.S. dollar. An appreciation is reflected in an increase in the indices. Annual inflation is provided.

Figure 2. Inflation and Nominal Effective Exchange Rates, 1991–2005[1] (annual averages, in percent)



Sources: BOT, National Bureau of Statistics (NBS), IFS.

[1]An appreciation is denoted by an increase in the index.

Table 1. Average Growth and Volatility of Selected Indicators, 1991–2005[1]

	Prices	NBER	NEER	Broad Money	Reserve Money	Real GDP
Average growth (in percent)						
Full sample	16.69	20.67	46.33	-10.93	-9.21	4.10
1991 Q1 – 1995 Q3	31.59	31.08	109.66	-19.40	-15.93	1.68
1995 Q4 - 2005 Q1	9.24	15.46	14.67	-6.69	-5.85	5.31
Volatility						
Full sample	13.38	8.92	122.57	8.64	9.04	2.18
1991 Q1 – 1995 Q3	11.12	5.03	200.41	8.92	7.41	0.97
1995 Q4 - 2005 Q1	6.32	4.96	10.45	4.36	7.89	1.50

Sources: BOT, National Bureau of Statistics (NBS), IFS.

[1]Volatility is calculated as the standard deviation of the growth rates of the variables. Annual percent growth is utilized.

III. A SURVEY OF THE LITERATURE

A number of common results emerge from research papers on the pass-through of exchange rate movements. In general, these studies find that, since the 1990s, the pass-through to inflation has declined and is smaller than expected. At the aggregate level, this could be attributed to a lower proportion of imports in the CPI basket or a lower proportion of imported inputs in the production process. The degree of competitiveness of different sectors seems to be an important determinant of the ability of importers to pass-through exchange rate movements to consumers (Laflèche, 1997). Changes to the microeconomic environment also play an important role in explaining the decrease in the pass-through (Webber, 1995).[9]

As the decline in the pass-through to inflation has coincided with significant falls in the level of inflation, the papers have examined whether the degree of pass-through is related to the credibility of the monetary policy regime and the anchors of inflation expectations. From a theoretical perspective, these models are generally based on the underlying assumption that inflation expectations are anchored to low inflation in a credible monetary policy regime. Taylor (2000) was the first to demonstrate how nominal rigidity in a low-inflation environment could result in low exchange rate pass-through. Using staggered price setting, Taylor finds that the pass-through of changes in cost, including those related to exchange rate movements, decline as the expectation of persistence of cost changes decreases. Choudhri and Hakura (2001) provide a more formal model of these linkages in a new open macroeconomic framework.

[9] Webber (1995) presents a theoretical analysis to determine the sensitivity of the pass-through to the microeconomic environment, in particular, sensitivity to productivity changes, monoposonistic behavior, imperfect competition, timeframe of the firm, and tariff protection.

Recent empirical findings indicate that there is a significant relationship between the inflation environment and the degree of pass-through. Gagnon and Ihrig (2002) find that roughly a third of the variation in pass-through across countries can be attributed to differences in the inflation environment. Choudhri and Hakura (2001) find that the level of inflation dominates the volatility of inflation and the exchange rate as an explanation of cross-country differences in the pass-through. They find zero pass-through to inflation in Ethiopia and incomplete pass-through in other African countries during the period 1997–2000. However, their study did not consider Tanzania. They also obtain zero pass-through to inflation in other countries including Bahrain, Canada, Finland, Pakistan, and Singapore. Canetti and Greene (1992) find that exchange rate movements and monetary expansion affect consumer price inflation in sub-Saharan Africa (SSA). In particular, they find that exchange rates have a significant "Granger causal" impact on prices in Tanzania, Sierra Leone, and Democratic Republic of Congo. This is linked to the high inflation episodes in these economies. They find that monetary expansion "Granger causes" inflation in the Gambia and Uganda. Kiptui, Ndolo, and Kaminchia (2005) find that pass-through in Kenya during the period 1972–2002 is incomplete. An exchange rate shock leads to a sharp increase in CPI inflation; however, this dies out after four years. Exchange rate shocks account for 46 percent of the variation in inflation in the first year, peaking at 57 percent in the third year.

The econometric techniques utilized to model the pass-through to inflation can be broadly divided into four categories: single equation econometric methods, VAR models, structural macroeconometric models, and dynamic stochastic general equilibrium (DSGE) models. Most studies using single equation econometric methods estimate the pass-through with aggregated data. Some utilize the VEC approach to capture the dynamic response of prices to exchange rate movements under the assumption of cointegration.[10] Gagnon and Ihrig (2002) estimate simple relationships between exchange rate and inflation or import price movements using time series data. In a second stage, these estimates are related to the macroeconomic variables which theory suggests are important using the cross-country dimension of the data. They examine whether the decline in the size of pass-through is related to inflation stabilization by breaking the sample for each country at a point where there was a regime shift or structural change. Following the recent literature that has highlighted that the impact of exchange rate shocks could differ across sectors, several papers also look at sectoral data (Goldberg and Knetter, 1997; Campa and Goldberg, 2002; and Choudhri and Hakura, 2001). A number of papers use variants of the VAR models to analyze the effect of exogenous shocks along the pricing chain using a recursive VAR framework to identify the shocks (McCarthy, 2000).[11] Recent empirical literature has focused on the use of SVAR models to capture the impact of exchange rate disturbances on inflation.[12]

[10] However, the Johansen (1988), Johansen and Juselius and the Pesaran-Shin approaches provide an estimate of the cointegrated VAR disturbances but not an estimate of the structural disturbances or of the common stochastic trends.

[11] This is achieved by the Cholesky decomposition, which imposes restrictions on the residual variance-covariance matrix and assumes that the errors are orthogonal. However, the covariance between innovations is

(continued)

IV. THE MODELING STRATEGY

We develop a VAR model to capture the relationship between short-term movements in exchange rate and inflation. We consider a multivariate system of the economy in which $ygap_t$ is the excess aggregate demand at time t, s_t is the nominal exchange rate defined as U.S. dollars (US$) per Tanzania shilling (T Sh), p_t is domestic prices, and m_t is broad money supply.[13] m_t captures the effect of private sector decisions, in particular, the lagged reaction of private agents to a decreasing inflation rate. The Nominal Effective Exchange Rate and other categories of money supply including narrow money (M1) are also considered, but the VAR results are very weak and therefore not reported. Domestic prices are expected to increase during periods of excess demand. Therefore, the output gap is included to capture the impact of the stage of the business cycle on inflation.[14]

Economic agents' expectations tend to rely on past developments and assume that the government's policy stance is maintained. This is partly due to the government's established track record of prudent fiscal and monetary policy and the lack of data on output at the time of forecasting. Inflation developments are mainly influenced by adaptative expectations with agents for most of the period expecting the control on inflationary pressure to be maintained due to the strong record of fiscal and monetary discipline. It is assumed that the conditional expectations are equivalent to a linear projection based on lags of the endogenous variables in the VAR.

$$A(L)y_t = u \quad \text{where} \quad A(L) = \sum_{j=0}^{p} A_j L^j \tag{1}$$

---

rarely zero, thus the common component in the disturbances is wrongly attributed to the first variable in the VAR.

[12] The restrictions imposed to identify the variance covariance matrix tend to have some economic foundations, such as assumptions about delays in the reaction of particular classes of agents to disturbances originating outside their own sector. While these restrictions do not flow from any economic theory, they are easy to assess and arguably represent the data.

[13] Output gap is defined as the difference between actual output and potential output where potential output is an unobservable variable that reflects the maximum output an economy can sustain without inducing inflation. It is debatable whether low-income economies like Tanzania have reached their potential level or demonstrate unused long-run capacity; nevertheless, in the short-run, increases in demand above trend level may fuel increases in inflation.

[14] Fiscal and debt dynamics are excluded, as the model essentially attempts to capture only the impact of short-run changes in exchange rates on inflation. The impact of supply shocks is not included due to the absence of reliable proxy for international supply shocks. Oil prices are not representative of exogenous shocks because until 2000 they were controlled by the state, resulting in cushioning the effect of international price shocks on domestic energy prices.

$A(L)$ is a 4×4 matrix polynomial in the lag operator L and u_{it} is a time t serially independent innovation to the i_{th} variable. The time period t corresponds to one quarter. These innovations can be thought of as linear combinations of independently distributed economically useful shocks, e_{it}, such that

$$u_t = \beta e_t \tag{2}$$

Structural shocks in each period t are determined by expectations conditional on available information at the end of period $t-1$, ($E_{t-1}(.)$), and an error term (u_t). The one-period ahead error made in forecasting s_t is equal to u_{st}, and, since from equation (2), $u_{st} = \alpha e_{ygapt} + e_{st} + \theta_4 e_{pt} + \theta_5 e_{mt}$, these errors are caused by exchange rate shocks and other shocks—the demand shocks (exogenous aggregate demand shocks) and nominal shocks (domestic price and money supply shocks).

$$\begin{bmatrix} u_{ygapt} \\ u_{st} \\ u_{pt} \\ u_{mt} \end{bmatrix} = B \begin{bmatrix} e_{ygapt} \\ e_{st} \\ e_{pt} \\ e_{mt} \end{bmatrix} \tag{3}$$

where the B matrix is

$$= \begin{bmatrix} 1 & \theta_1 & \theta_2 & \theta_3 \\ \alpha & 1 & \theta_4 & \theta_5 \\ \beta & \gamma & 1 & \theta_6 \\ \delta & \chi & \varphi & 1 \end{bmatrix} \tag{4}$$

In order to determine the role of exchange rate movements in *causing* movements in consumer prices we need to estimate the effect of exogenous shock on the exchange rate, e_s, on consumer prices. However, as long as $\alpha \neq 0$, $\theta_4 \neq 0$ and $\theta_5 \neq 0$, the innovation to the observed variable s_t will depend on both the shock to exchange rate e_{st} and on the shocks $e_{ygapt}, e_{pt}, e_{mt}$. The paper therefore imposes restrictions to extract e_{st} from the other innovations while allowing for contemporaneous feedback effects and adjustment of parameters to these exchange rate innovations using structural decompositions. Drawing on Bernanke (1986) and Sims (1986) we utilize the SVAR approach as it imposes contemporaneous structural restrictions consistent with a priori theoretical expectations to identify the impact of the various shocks. Imposing theory-consistent restrictions on the structure of the B matrix gives economic meaning to the derived shocks.

Excess demand shocks tend to be influenced by exogenous factors, such as adverse weather conditions. The El Niño rains in 1997, for example, had a detrimental effect on inflation and aggregate industrial production through their negative effect on the transport infrastructure,

electricity generation, and food crop production. As a result, despite the prudent fiscal policy, inflation remained in double digits and the period 1996–98 was characterized by periods of negative per capita growth. We therefore model the real output gap shocks as independent to the shocks to other variables by allowing the data generation process of this variable to follow an autoregressive process AR(p) where p is the lag length assumed in estimating the VAR (equation (5)).

$$u_{ygapt} = e_{ygapt} \tag{5}$$

Shocks to the exchange rate largely reflect exogenous factors, such as unexpected surge in aid inflows and terms of trade improvements, and are assumed to be independent of other macroeconomic disturbances in the model (equation (6)).[15] Tanzania has maintained a managed float exchange rate regime, with the BOT intervening in the foreign exchange market to smoothen excessive fluctuations, since 1994 when the exchange rate was fully liberalized.[16]

$$u_{st} = e_{st} \tag{6}$$

Domestic price shocks are assumed to be associated with excess aggregate demand and exchange rate shocks. It is assumed that the innovations to money demand do not have a contemporaneous effect on inflation (equation (7)).

$$u_{pt} = \beta e_{ygapt} + \gamma e_{st} + e_{pt} \tag{7}$$

Using equations (6) and (7) we have

$$u_{pt} = \beta' u_{ygapt} + \gamma' u_{st} + e_{pt} \tag{8}$$

Money demand is still reacting to developments in inflation (Buffie and others, 2004). Chronically high inflation in the late 1980s and 1990s had a negative effect on money demand. Therefore, domestic price shocks feed through into the money supply equation capturing the inflation-induced demonetization of the late 1980s and early 1990s, which is still in the process of being reversed (equation (10)).

$$u_{mt} = \delta e_{ygapt} + \chi e_{st} + \varphi e_{pt} + e_{mt} \tag{9}$$

$$u_{mt} = \delta' u_{ygapt} + \chi' u_{st} + \varphi'(u_{pt} - \beta' u_{ygapt} - \gamma' u_{st}) + e_{mt} \tag{10}$$

Therefore, the following system of shocks is estimated:[17]

[15] The decrease in investment as a share of GDP, from its peak of 40 percent in 1990 to 26 percent in 1994, is mainly attributed to the widescale exodus of donor aid in the mid-1990s.

[16] Prior to 1993−94 , the exchange rate was fixed and characterized by frequent realignments.

[17] Structural decompositions do not necessary result in recursive systems (Bernanke, 1986).

$$\begin{bmatrix} u_{ygapt} \\ u_{st} \\ u_{pt} \\ u_{mt} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ \beta & \gamma & 1 & 0 \\ \delta & \chi & \varphi & 1 \end{bmatrix} \begin{bmatrix} e_{ygapt} \\ e_{st} \\ e_{pt} \\ e_{mt} \end{bmatrix} \quad (11)$$

V. Empirical Results

A. Data and Econometric Issues

The sample period consists of quarterly observations from 1990:Q1 to 2005:Q1. Ideally, the estimation period should not include the crawling peg period. However, this would yield an insufficient number of observations; therefore the period leading up to the flexible exchange rate regime, prior to 1993:Q4, characterized by frequent realignment, is also included.[18] The precise definitions of the variables and the sources of data are provided in Appendix I.

The output gap is calculated using the Hodrick-Prescott (HP) filter under the assumption that output fluctuates around some potential level (equation (12). The HP filter decomposes output into permanent and transitory components generating a smoothened trend of output. The generated smoothened series is the estimated potential output. As GDP data are only available on an annual basis, annual GDP was interpolated into a quarterly trend using quadratic summation.[19]

$$Y_{gapt} = (rGDP_t - rGDP_t^p) \quad (12)$$

Exchange rate movements are correlated with domestic price movements, albeit after a one-quarter lag. The peak correlation coefficients are not very large. Figure A1, in Appendix II, indicates that the cross-correlation between exchange rate and consumer price movements is negative, peaking after a one-quarter lead at -0.46. Exchange rate movements are also correlated with lagged consumer prices peaking at -0.31 and -0.37 after a one-quarter lag and a four-quarter lag, respectively (Figure A2 in Appendix II). The low size of the correlation coefficients might be due to the fact that the CPI is largely composed of food items, which tend to be sheltered from external competition.[20]

In order to estimate the SVAR, all time series are transformed to stationary series, with the exception of output gap which is a stationary series. We perform two standard unit root tests,

[18] Market exchange rates are used to capture exchange rate developments.

[19] This was transformed into logarithms before application of filtering methods.

[20] Delgado, Minot, and Tiongco, 2004.

augmented Dickey Fuller (ADF) and Phillips Perron (PP), to determine the order of integration of the series. The ADF test finds that all the variables are I(1), with the exception of output gap, and rejects the null hypothesis of nonstationarity (Table A1 in Appendix II). Although the PP test finds that money supply is also stationary, visual inspection of money supply does not support the PP findings. Therefore, drawing on ADF findings we assume that the series is an I(1) process (Table A1).[21]

A four-variable VAR is estimated with output gap, consumer prices, nominal bilateral exchange rate vis-à-vis the U.S. dollar, broad money supply (M2) all in differences, with the exception of output gap.[22] The Nominal Effective Exchange Rate and narrow money (M1) are also considered, but the VAR results are very weak and therefore not reported. Moreover, anecdotal evidence suggests that economic agents monitor the U.S. dollar more than the South African rand, Kenya shilling and Japanese yen for which trade shares are much higher. This is partly because the U.S. dollar is the medium of exchange in Tanzania. To hedge against currency fluctuations, most traders tend to utilize the U.S. dollar. Moreover, trading partner data reflect the country of production and may not accurately capture re-exports. For example, most imports listed as Japanese tend to be purchased in the United Arab Emirates, which has a fixed peg to the U.S. dollar.

We verified the statistical properties of the VAR (Table 2). The VAR is estimated with seven lags. The model is stable as the calculated roots of the characteristic polynomial are located within the unit circle. According to visual inspection, the residuals display a number of significant outliers, such that we expect significant non-normality (Figure A3 in Appendix II). To check whether the description of the data is consistent with the assumption of white noise errors, multivariate serial correlation of the residuals is calculated. The Lagrange multiplier test cannot reject the null of no autocorrelation. The Jarque-Bera test rejects the null hypothesis of normality due to excess kurtosis.[23] Table A2, in Appendix II, presents the matrix of residual correlation. Off-diagonal elements are rather close to zero, implying that no contemporaneous correlation is being ignored by the VAR.

[21] Though annual (year-on-year) inflation displays a distinct downward trend and appears to be I(1), quarterly inflation is trend stationary.

[22] Dummy variables to capture the change in exchange rate regime in 1993 and the shift in policy stance in 1995 toward prudent fiscal and monetary policy following the entrance of the third regime government were not significant.

[23] When the normality assumption is rejected, Monte Carlo tests for serial correlation should still be very accurate, though not exact.

Table 2. Results from the VAR Diagnostic Tests[1]

Multivariate tests

	1	2	3	4	5	6	7	8	9	10	11	12
LM test	17.16	21.02	19.98	12.49	7.80	16.23	18.02	14.65	12.68	14.13	13.55	8.16
	(0.38)	(0.18)	(0.22)	(0.71)	(0.95)	(0.44)	(0.32)	(0.55)	(0.70)	(0.59)	(0.63)	(0.94)
Normality JB							42.83					
							(0.00)					
Skewness							1.20					
							(0.88)					
Kurtosis							41.63					
							(0.00)					

Univariate tests

	dygap	*ds*	*dm*	*dp*
Normality JB	12.74	12.73	11.43	5.93
	(0.00)	(0.00)	(0.00)	(0.05)
Skewness	0.01	0.18	0.00	1.01
	(0.93)	(0.67)	(0.98)	(0.31)
Kurtosis	12.73	12.55	11.43	4.92
	(0.00)	(0.00)	(0.00)	(0.03)

[1]The LM test denotes the Breusch-Godfrey test. The null hypothesis is no serial autocorrelation. The null hypothesis for the Jarque-Bera tests is normally distributed errors. The table reports p-values of corresponding tests in parentheses.

The VAR results indicate that a currency appreciation is associated with a decrease in inflation rate, with a one-quarter lag. We present the estimates of parameters from the inflation equation in equation (13) with t-statistics in square brackets (see Appendix I equation (17) for the full estimated equation).

$$\pi_t = \underset{[-2.90]}{-18.5}\Delta ygap_{t-2} \underset{[-2.71]}{-0.46}\Delta s_{t-1} + \underset{[2.41]}{0.43}\pi_{t-3} + \underset{[2.48]}{0.44}\pi_{t-7} + u_{\pi t} \qquad (13)$$

B. Exchange Rate Pass-Through to Inflation

Impulse response functions and variance decompositions are utilized to assess the pass-through from exchange rate fluctuations to domestic inflation. Impulse response functions trace the effects of a shock emanating from an endogenous variable to other variables through the dynamic structure of the VAR. Variance decompositions measure the percentage of the forecast variance in inflation that can be attributed to various shocks. We first examine the size of pass-through during the entire period and then analyze how pass-through has evolved during the 1990s by dividing the sample into the periods before and after 1995:Q4. The exchange rate pass-through to inflation over *T* periods can be defined as the accumulated partial effect of a one-unit increase in nominal exchange rate in period *t* on consumer prices

in period $t + T - 1$. To examine the pass-through over the short and medium run, we present estimates of the T-period pass-through for $T = 1, 2, 4$, and 12.

Full sample estimation results

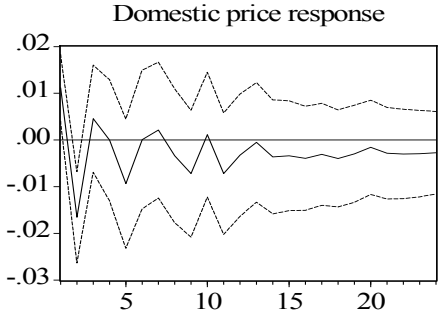
The impulse response functions indicate a low degree of exchange rate pass-through effect to inflation that dies out after a long period (Table 3, Figure 3). An exchange rate appreciation, a positive exchange rate shock, results in a decrease in inflation after a two-quarter lag, T = 2, consistent with Figure A2, in Appendix II, where the cross-correlation estimates indicate that exchange rate shocks have a noncontemporaneous effect on inflation.[24] However, the pass-through though significant is low, with a 10 percent exchange rate appreciation resulting in a 0.05 percent decrease in inflation, at T = 2 (Table 3, Figures 3 and 4). The prolonged pass-through effect largely reflects the impact of adaptative inflationary expectations. As indicated in equation (13), there is a delayed partial adjustment to past inflation.[25]

Table 3. Estimated Impulse Response Function for Inflation, 1990 Q1–2005 Q1[1]

Impulse Response Function of inflation to:				
Period	Shock:			
	Ygap	Exchange Rate	Domestic prices	Money demand
T= 1	-0.002	0.011	0.025	0.000
T = 2	0.006	-0.005	0.021	0.002
T = 4	-0.015	-0.001	0.039	-0.006
T = 12	-0.013	-0.028	0.066	0.026

[1]Period refers to a quarter. A 12-quarter horizon is considered.

Figure 3. Impulse Response to Exchange Rate Shocks, 1990–2005[1]

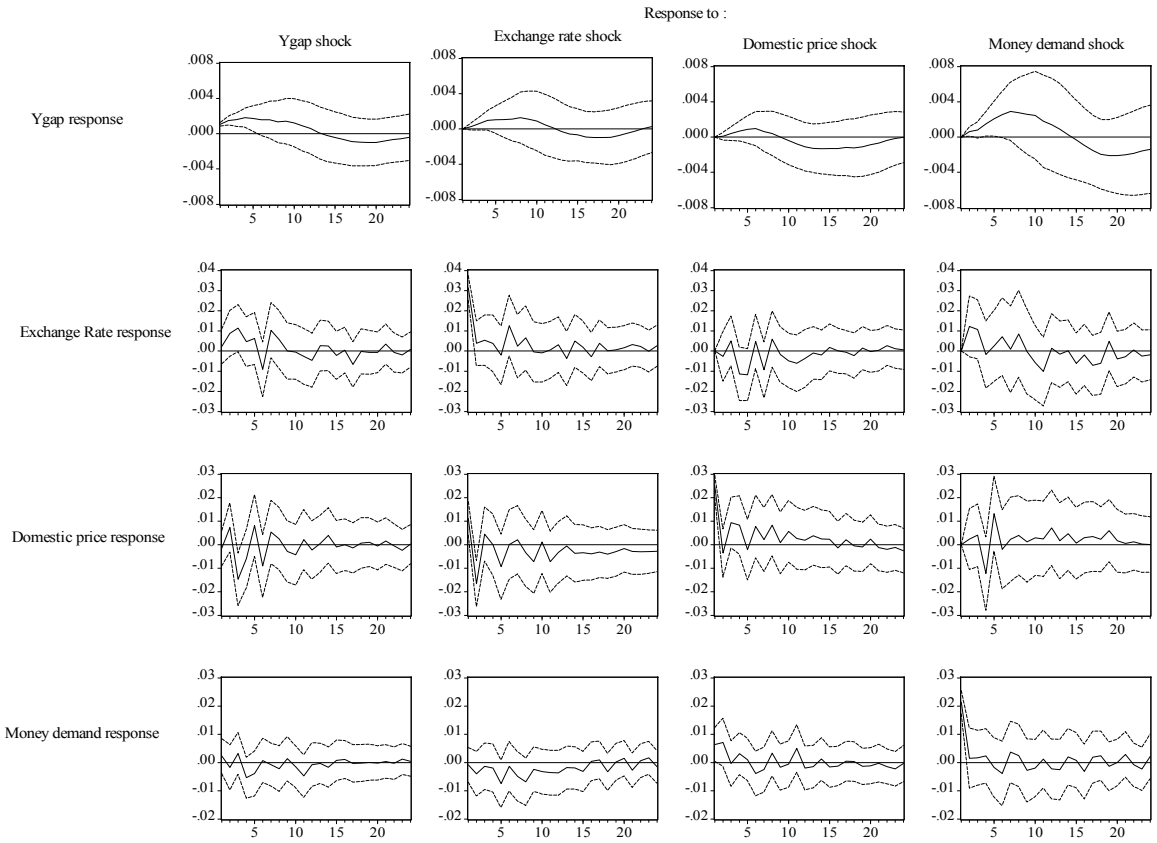


[1]Response to structural one standard deviation innovation over 100-quarter period. The dotted line reflects two standard error bands. The exchange rate shocks refer to an appreciation in the exchange rate.

[24] An increase in the exchange rate index reflects an appreciation.

[25] The response of excess demand to disturbances is hump-shaped, in line with other empirical findings.

Figure 4. Impulse Response to Exchange Rate, Domestic Price, Excess Demand, and Monetary Shocks 1990–2005[1]



[1]Response to structural one standard deviation innovation over a 24-quarter period. The dotted line reflects two standard error bands. The exchange rate shocks refer to an appreciation in the exchange rate.

The impulse response functions indicate that an appreciation is also associated with an immediate increase in inflation. This follows from the estimated system of shocks from the SVAR which obtains a significant but small contemporaneous relationship between exchange rate and inflation shocks. A 10 percent exchange rate appreciation is associated with a 0.11 percent increase in inflation (equations (14) and (15)). (See equations (18) - (21) in Appendix I for the full set of results.) Since the inflation equation (13), also includes the impact of past exchange rate innovations on inflation, the contemporaneous impact of exchange rate shocks on inflation could be driven by past exchange rate variable (s_{t-i}), that is the partial adjustment of exchange rate, in addition to contemporaneous exchange rate shock innovations.

$$u_{\Delta st} = \underset{\mathbf{(0.0)}}{0.031} e_{\Delta st} \tag{14}$$

$$u_{\pi t} = \underset{(0.50)}{-2.11} u_{\Delta ygapt} + \underset{\mathbf{(0.00)}}{0.36} u_{\Delta st} + \underset{\mathbf{(0.00)}}{0.02} e_{\Delta \pi t} \tag{15}$$

(p-values in parentheses, where significant values are in bold).

The sectoral pass-through estimations indicate an incomplete pass-through to inflation; however, the speed of pass-through differs across sectors (Table 4).[26] Sectors that tend to be more open, such as clothing and drinks, have a rapid pass-through effect with inflation decreasing immediately after an exchange appreciation. For example, a 10 percent appreciation results in a 0.07 percent decrease in clothing sector inflation and 0.02 percent decrease in drinks inflation after a one-quarter lag, T = 1. However, sectors that are more closed such as food, rent, and fuel (utility) display the conventional pass-through effect after a three-year lag. Specifically, a 10 percent appreciation is associated with a 0.12 percent decrease in food sector inflation, in T = 12. A 10 percent appreciation results in a 0.19 percent decrease in rent inflation in T = 4 and a 0.3 percent decrease in fuel sector inflation in T = 12.

Table 4. Impulse Response Function by Sector, 1990 Q1–2005 Q1[1]

Impulse Response Function of inflation to:

Period	Food	Rent	Furniture	Fuel	Recreation	Cloth	Drinks	Household	Personal care	Transport
T= 1	0.014	0.009	0.003	0.009	-0.012	-0.007	-0.002	0.001	-0.001	0.000
T = 2	0.012	0.017	-0.001	0.015	-0.027	-0.012	0.006	0.002	0.002	-0.011
T = 4	0.016	-0.019	0.000	0.009	-0.025	-0.016	-0.002	0.001	-0.005	-0.015
T = 12	-0.012	-0.073	0.002	-0.031	0.006	-0.024	-0.020	0.002	0.007	-0.066

[1]Period refers to a quarter. A 12-quarter horizon is considered.

The variance decompositions findings indicate that fluctuations in inflation are mainly driven by domestic price shocks.[27] Exchange rate shocks account for about 17 percent of inflation volatility after a one-quarter lag. The impact of exchange rate shocks rises to its peak, of

[26] Due to lack of data on the import content of the various sectors, disaggregation into tradable and nontradables sectors is not possible. Instead, the individual results for each sector in the CPI, with the exception of education sector, are presented. The sectoral classification of the CPI is as follows: food and food manufacturing (henceforth, food index), beverages and tobacco (henceforth, drinks index), clothing and footwear (henceforth, clothing index), furniture and utensils (henceforth, furniture), household operations (henceforth, household index), personal care and health (henceforth, personal care), recreation and entertainment (henceforth, recreation), transportation (henceforth, transport index), fuel, light, and water (henceforth, fuel index), and rent index. The education sector is not considered due to the absence of data in the early 1990s.

[27] Own innovations account for about 80 percent of the variance but this declines steadily to about 38 percent after five quarters.

about 36 percent, after a two-quarter lag (Figure 5 and Table 5). The accumulated response of inflation to exchange rate shocks is persistent, decreasing slowly over time.

Figure 5. Variance Decompositions

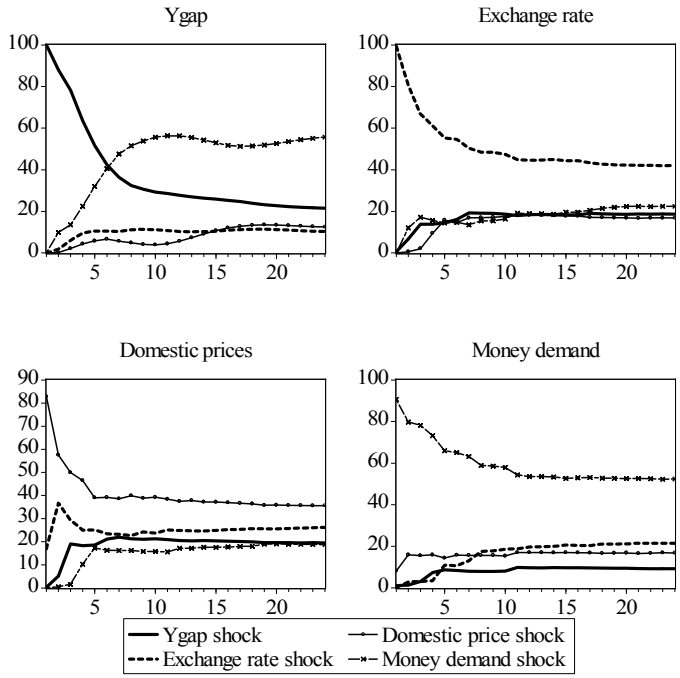


Table 5. Variance Decomposition of the Inflation Equation, 1990 Q1–2005 Q1[1]

Variance Decomposition of inflation:					
Period	S.E.	Shock:			
		Ygap	Exchange Rate	Domestic prices	Money demand
1	0.027	0.72	16.92	82.36	0.00
2	0.033	7.13	36.12	56.23	0.52
4	0.041	19.84	24.57	45.54	10.06
12	0.051	21.83	24.50	36.82	16.85

[1] S.E denotes standard error; Period refers to a quarter. A 12-quarter horizon is considered.

Sub-sample estimation results

While the extent and speed of pass-through are important, we are also interested in the way that the pass-through relationship may have changed in the past decade or so. Drawing on Gagnon and Ihrig (2002), we split the sample into two where the break point, 1995:Q4, reflects changes in the monetary policy regime. Sample 1, 1990:Q1 to 1995:Q3, captures the period characterized by passive monetary policy with high and volatile inflation and nominal exchange rate movements. Sample 2, 1995:Q4 to 2005:Q1, captures the period characterized by depreciation and declining and stable inflation. Due to data limitations on import structure

of goods in the consumer price index, the paper does not investigate empirically the impact of the changes in import structure of goods on pass-through.

We find that there has been a statistically significant decrease in the short-run elasticity of prices to exchange rate movements in the second sample, covering the period 1995:Q4–2005:Q3. Specifically, the impulse response functions indicate that a 10 percent depreciation during the period 1990:Q 1 to 1995:Q3 results in a 0.17 percent increase in inflation, with the pass-through effect rising to 0.89 percent in T = 12. This can be contrasted with the period since 1995:Q3, where a depreciation of the same magnitude is associated with a 0.03 percent decrease in inflation with the pass-through effect rising to 0.23 percent in T = 12 (Tables 6 and 7, respectively). In addition, the results indicate that the speed of pass-through decreased in the late 1990s while persistence has increased.

Table 6. Impulse Response Function of Inflation, 1990 Q1–1995 Q3[1]

Impulse Response Function of inflation to:				
Period	Shock:			
	Ygap	Exchange Rate	Domestic prices	Money demand
T = 1	0.013	0.023	0.049	0.018
T = 2	0.004	-0.017	0.010	0.010
T = 4	0.002	-0.016	0.024	0.027
T = 12	0.031	-0.087	0.031	0.088

[1]Period refers to a quarter. A 12-quarter horizon is considered.

Table 7. Impulse Response Function of Inflation, 1995 Q4–2005 Q1[1]

Impulse Response Function of inflation to:				
Period	Shock:			
	Ygap	Exchange Rate	Domestic prices	Money demand
T = 1	0.001	0.001	0.004	0.000
T = 2	0.003	0.003	0.004	0.003
T = 4	0.004	0.004	0.002	0.009
T = 12	0.021	0.023	-0.014	0.046

[1]Period refers to a quarter. A 12-quarter horizon is considered.

The sectoral developments generally support the finding of zero pass-through during the period after 1995:Q3 but generally find an incomplete pass-through during the period 1990:Q1–1995:Q3 (Tables 8 and 9). With the exception of the food and personal care sectors, all the sectors indicate an incomplete pass-through to inflation during the period 1990:Q1–1995:Q3. Most sectors indicate zero pass-through during the period 1995:Q3–2005:Q1 including the clothing sector. However, the food sector displays incomplete pass-through in T = 12.

Table 8. Impulse Response Function by Sector, 1990 Q1–1995 Q3[1]

Impulse Response Function of inflation to:										
Period	Food	Rent	Furniture	Fuel	Recreation	Cloth	Drinks	Household	Personal care	Transport
T= 1	0.016	-0.026	-0.005	0.006	-0.019	-0.011	-0.012	-0.008	0.007	0.002
T = 2	0.014	-0.018	-0.002	0.010	-0.010	0.003	0.002	-0.014	0.030	-0.033
T = 4	0.013	-0.028	-0.002	0.005	-0.024	-0.003	-0.011	-0.014	0.013	-0.017
T = 12	0.008	-0.020	-0.014	-0.008	-0.073	-0.002	-0.006	-0.011	0.030	-0.029

[1]Period refers to a quarter. A 12-quarter horizon is considered.

Table 9. Impulse Response Function by Sector, 1995 Q4–2005 Q1[1]

Impulse Response Function of inflation to:										
Period	Food	Rent	Furniture	Fuel	Recreation	Cloth	Drinks	Household	Personal care	Transport
T= 1	0.005	0.002	0.005	0.009	-0.003	0.007	-0.005	0.003	0.000	0.003
T = 2	0.006	0.001	0.009	0.008	-0.003	0.006	0.001	0.005	0.002	0.003
T = 4	-0.002	0.002	0.006	0.008	-0.007	0.004	-0.013	0.004	0.000	0.007
T = 12	-0.010	-0.001	0.003	-0.006	-0.012	0.005	-0.019	0.000	-0.004	0.009

[1]Period refers to a quarter. A 12-quarter horizon is considered.

The variance decompositions indicate that exchange rate shocks account for about half of inflation volatility during the period 1990:Q1–1995:Q3 and 20 percent of inflation variation post 1995:Q3 (Tables 10 and 11, respectively). The impact of exchange rate shocks on inflation is higher and more persistent during the period 1990:Q1–1995:Q3 than after 1995:Q3. The variance decompositions indicate that monetary shocks have a stronger impact on inflation than exchange rate shocks during the period 1995:Q3–2005:Q1 This reflects the importance of the reversal of the de-monetization that had occurred in the earlier period.

Table 10. Variance Decomposition of the Inflation Equation, 1990 Q1–1995 Q3[1]

Variance Decomposition of inflation:					
Period	S.E.	Shock:			
		Ygap	Exchange Rate	Domestic prices	Money demand
1	0.001	7.10	21.55	71.35	0.00
2	0.002	5.52	45.88	47.90	0.70
4	0.004	5.39	41.04	45.81	7.76
12	0.006	6.49	44.25	37.81	11.46

[1] S.E. denotes standard error, Period refers to a quarter. A 12-quarter horizon is considered.

Table 11. Variance Decomposition of the Inflation Equation, 1995 Q1–2005 Q1[1]

Variance Decomposition of inflation:					
Period	S.E.	Shock:			
		Ygap	Exchange Rate	Domestic prices	Money demand
1	0.001	6.56	8.17	85.27	0.00
2	0.001	12.48	12.80	55.69	19.03
4	0.003	8.77	9.34	40.83	41.06
12	0.015	11.59	12.71	17.51	58.19

[1] S.E. denotes standard error, Period refers to a quarter. A 12-quarter horizon is considered.

VI. Factors Behind the Low and Declining Exchange Rate Pass-Through

In this section, we discuss the factors behind the zero pass-through finding, that is, the finding that depreciation is not associated with an increase in inflation. We note that the macroeconomic and structural reforms adopted in the late 1990s had a positive effect on economic growth, removing monopolistic barriers to competition, increasing productivity, and reducing costs and uncertainties associated with high and volatile inflation and policy reversals. In addition, the decline in the share of imports in the economy during the period reduced the exposure of consumer prices to exchange rate movements. The decrease in the level and volatility of inflation is partly linked to active intervention by the BOT to control money supply and the downward reversion of private agents' inflationary expectations. Though the decrease in inflation has been associated with a weaker exchange rate, periods of high inflation have been associated with larger changes in the exchange rate and periods of lower inflation with smaller changes in the exchange rate (Table 1). The findings are in line with empirical evidence that exchange rate pass-through correlates with the initial inflation rate, with the degree of pass-through declining as inflation decreases (Choudhri and Hakura, 2001).

Privatization, foreign exchange, and trade and financial sector liberalization in the late 1990s had a positive effect on investor confidence, inducing both foreign and domestic investment (Treichel, 2004). Domestic investment was partly induced by greater availability of funding including foreign exchange and rationalization of tax administration. Prior to financial sector liberalization, credit was rationed and mainly directed to state-owned firms and parastatals while foreign exchange was limited and had to be obtained from the central bank (Treichel, 2004; and Bank of Tanzania, Economic Bulletin, 1995). However, the removal of interest rate controls, privatization of state-owned banks, and development of microcredit institutions provided sources of financing and foreign exchange to domestic investors. Stable macroeconomic policy, greater availability of foreign currency in the late 1990s, and increased confidence among investors about nonreversal of the government's stance toward private sector activity resulted in a surge in activity including in the nontradable sector (Mwase and Ndulu, forthcoming). The decrease in import tariffs reduced pass-through from import goods. During the period 1993–2000, the number of non-zero tariffs was reduced

from 7 to 4, and the top rate was reduced from 40 percent to 25 percent (IMF, forthcoming, and World Bank, 2004).[28]

The absence of pass-through since 1995:Q3—particularly in clothing, transport, household care, and furniture sectors—could be partly linked to the surge in production following the structural and macroeconomic reforms (Table 12).[29] The entrance of new players—including a larger number of export-import traders specializing in used goods—increased competition, inducing distributors of foreign goods to cut marginal profits and/or search for cheaper sources of goods in the face of nominal depreciation, and spurring domestic producers to increase their productivity (Mwase and Ndulu, forthcoming*)*. The pass-through of exchange rate movements to fuel inflation is slow and incomplete as the fuel sector faced administratively controlled prices during most of the period.

Since the food sector in Tanzania is largely a nontradable sector, its prices are more responsive to adverse weather conditions than exchange rate movements (Delgado, Minot, and Tiongco, 2004). The finding of zero pass-through to food inflation in the early 1990s is largely driven by the rebound in production in the early 1990s. Adverse weather conditions, particularly during the El Niño, resulted in an increase in food prices and food imports. As a result, the food sector indicates an incomplete pass-through during the period 1995:Q3–2005:Q1.

Table 12. Sectoral Decomposition of Real GDP Growth, 1986–2004[1]

	1986 - 89	1990 - 95	1996-2004
GDP	4.0	2.7	5.05
Sectoral Components of GDP			
Agriculture	2.9	3.6	4.02
Industry	6.8	1.5	8.12
Mining	0.5	11.8	15.47
Manufacturing	3.2	0.7	6.27
Electricity and water	8.7	4.4	4.93
Construction	19.2	0.3	9.38
Services	4.8	2.3	4.98
Trade, hotels and restaurants	1.8	2.2	5.98
Financial and business services	5.6	2.5	4.39
Public adminstration and other services	12.0	1.2	3.40

Source: Economic Survey of Tanzania, 2005.

[28] The net impact of the decrease in tariffs, particularly after 1995, could be smaller due to the widespread tax exemptions and tax evasions in the early 1990s (IMF, 1996).

[29] See for example Clerides (2005) for literature on impact of used goods on prices.

The decline in the pass-through to inflation is partly linked to the decrease in the share of imports in the economy particularly as the consumer goods component of total imports decreased substantially from 1994. This was partly reflected in the rise in the weight of food items from 64 percent, during the period 1990–93, to 71 percent in 1994, when the CPI basket was revised to reflect the decrease in aggregate imports as a share of GDP. The early 1990s were characterized by high and rising imports, from 37.5 percent of GDP in 1990 to 47.8 percent in 1993, reflecting the effect of trade liberalization. The ensuing period was characterized by a decrease in imports as a share of GDP at an annual average rate of 13.5 percent, reaching 26.6 percent in 1997. This was induced by the sharp reduction in donor aid in the mid-1990s and increased uncertainty about the government's policy stance during most of this period (Mwase and Ndulu, forthcoming). Import growth as a share of GDP throughout most of the ensuing period remained low and did not recover to previous levels, partly on account of the closure of defunct state-owned firms (Mwase and Ndulu, forthcoming).

The decline in the estimated exchange rate pass-through does not necessarily imply that exchange rate fluctuations are less important in explaining macroeconomic fluctuations in Tanzania. Since September 2004, a new basket of consumer goods and services has been utilized in the compilation of the CPI to capture the changing consumption pattern. The new CPI basket accords a lower weight to food items, 55.9 percent, and incorporates a broader range of goods.[30] Macroeconomic forecasts suggest that imports are expected to increase as a share of GDP, reflecting accelerating economic growth, government subsidies for fertilizers, and higher oil prices. Moreover, the surge in the share of imports in the economy in the late 1990s has raised concerns about the pass-through to domestic prices particularly as oil prices, since 2001, no longer face state controls.

VII. Conclusion and Policy Recommendations

The paper finds an incomplete and decreasing exchange rate pass-through to inflation in Tanzania, consistent with findings on other countries. Our empirical results indicate a low, significant and persistent pass-through throughout the period 1990:Q1 to 2005:Q1 and zero pass-through during the period 1995:Q3 to 2005:Q1. The nonconventional response of inflation to exchange rate movements—in particular, a decrease in inflation despite exchange rate depreciation—could be attributed to the effect of macroeconomic and structural reforms. We argue that the findings reflect the impact of increased competition, higher productivity, and tighter monetary policy in the late 1990s anchored by lower inflation expectations. The decrease in the pass-through is partly attributed to the macroeconomic and structural reforms. The results are mainly driven by the deflationary effects of expansion in clothing, furniture production, and the household products sectors, predicated on liberalization. The decline in inflation is partly attributed to the opening up of sectors previously sheltered from

[30] For example, video cassettes and cellular telephone calling cards are currently included.

competition such as furniture production. We also find that sectors facing competition from the used goods market, such as the clothing sector, experienced downward inflationary pressure.

This study has obvious limitations. First, the CPI index is adjusted infrequently and does not fully reflect actual prices. Since an increasing share of these new consumer goods tends to be imports—for example, cellular phones—and the choice of consumer goods and weights are changed infrequently, the actual CPI could be much higher. Second, the structure of imports could change. A rise in the share of imports in the consumer goods basket or imported inputs of goods in the CPI would result in an increase in pass-through. Third, changes in economic agents' expectations about future inflationary developments could induce inflationary pressure. Since April 2002, when for the first time the Tanzania shilling depreciated to above T sh 1,000 per U.S. dollar, the public have become increasingly concerned about the impact of a weaker currency on oil prices and other imports. The findings imply that the authorities should remain vigilant in assessing the potential impact of foreign prices on the dynamics of inflation in Tanzania. In this regard, the authorities should seek to maintain low and stable inflation and continue the ongoing structural reforms designed to improve efficiency and increase competition.

DATA SOURCES AND ESTIMATION

Definition of variables

LCPI	Consumer price index
LNBER	Nominal bilateral exchange rate
LNEER	Nominal effective exchange rate
YGAP	Real GDP gap generated from Hodrick - Prescott filter
LM2	Broad money supply
LM0	Reserve money

All the variables are in natural logarithms. Data on inflation rate is obtained from National Bureau of Statistics (NBS) and International Financial Statistics (IFS). Nominal exchange rate and GDP data is obtained from IFS and BOT. Broad money supply and reserve money is obtained from the BOT. All the data are seasonally adjusted. Tanzania macroeconomic data display strong seasonality. The base year for consumer price and exchange rate indices is 1994 Q4.

The NEER is calculated using trade weighted exchange rate of major trading partner countries.

Estimates of the SVAR coefficients

Estimation of the inflation equation in the VAR (equation **Error! Reference source not found.**):

$$\pi_t = c + \sum_{i=1}^{7} a_{ygap,i}\Delta ygap_{t-i} + \sum_{i=1}^{7} a_{s,i}\Delta s_{t-i} + \sum_{i=1}^{7} a_{p,i}\pi_{t-i,} + \sum_{i=1}^{7} a_{m,i}\Delta m_{t-i} + u_{\pi t} \qquad (16)$$

yielded the following estimated parameters (equation (17)). The t-statistics are provided in parentheses.

$$\pi_t = -0.0 + 7.2\Delta ygap_{t-1} - 18.5\Delta ygap_{t-2} + 11.1\Delta ygap_{t-3} + 5.9\Delta ygap_{t-4} - 0.6\Delta ygap_{t-5} - 10.6\Delta ygap_{t-6} + 6.3\partial ygap_{t-7}$$

(-1.39) (1.70 **(-2.90)** (1.63) (0.80) (-0.08) (-1.52) (1.45)

$$-0.5\partial s_{t-1} + 0.0\Delta s_{t-2} + 0.1\Delta s_{t-3} + 0.1\Delta s_{t-4} - 0.1\Delta s_{t-5} + 0.2\Delta s_{t-6} - 0.0\Delta s_{t-7}$$

(-2.7) (0.03) (0.54) (0.56) (-0.51) (1.25) (-0.34)

$$-0.2\pi_{t-1} + 0.2\pi_{t-2} + 0.4\pi_{t-3} - 0.2\pi_{t-4} - 0.2\pi_{t-5} + 0.0\pi_{t-6} + 0.4\pi_{t-7}$$

(-0.82) (0.89) **(2.41)** (-0.99) (-1.30) (0.27) **(2.48)**

$$+0.1\Delta m_{t-1} + 0.3\Delta m_{t-2} - 0.1\Delta m_{t-3} + 0.2\Delta m_{t-4} + 0.0\Delta m_{t-5} + 0.4\Delta m_{t-6} - 0.2\Delta m_{t-7} + u_{\pi t}$$

(0.37) (1.12) (-0.44) (0.81) (0.01) (1.85) (-0.88) (17)

Imposition of the identification restrictions resulted in the following shocks

$$u_{\Delta ygapt} = 0.001 e_{\Delta ygapt} \quad (18)$$
(0.0)

$$u_{\Delta st} = 0.031 e_{\Delta st} \quad (19)$$
(0.0)

$$u_{\pi t} = -2.1 u_{\Delta ygapt} + 0.356 u_{\Delta st} + 0.025 e_{\pi t} \quad (20)$$
(0.5) **(0.00)** **(0.0)**

$$u_{\Delta mt} = 2.7 u_{\Delta ygapt} - 0.1 u_{\Delta st} + 0.3 u_{\pi t} + 0.021 e_{\Delta mt} \quad (21)$$
(0.31) (0.24) **(0.0)** **(0.0)**

Test for over identifying restrictions
LR test p = 0.59

ROBUSTNESS TESTS

Estimates from Granger causality tests

Granger causality tests reject causality from exchange rate to inflation, lending support to the findings of low exchange rate pass-through to inflation (Table A1).[30] The results indicate that output gap 'granger causes' inflation while money supply does not have a *causal* effect on inflation. These findings suggest that decline in inflation is linked to structural factors.[31]

Table A1. Results from the VAR Pairwise Granger Causality Tests, 1990 Q1–2005 Q1[1]

	Variable to be excluded									
Dependent variable	Domestic prices		Exchange rate		Output gap		Money supply		All	
Domestic prices			9.88	(0.20)	14.31	**(0.05)**	6.85	(0.44)	51.41	**(0.00)**
Exchange rate	16.26	**(0.02)**			12.36	(0.09)	11.17	(0.13)	49.59	**(0.00)**
Output gap	9.20	(0.24)	8.27	(0.31)			22.35	**(0.00)**	39.60	**(0.01)**
Money supply	7.65	(0.36)	8.73	(0.27)	3.17	(0.87)			20.19	(0.51)

[1]Numbers are test statistics of block exogeneity Wald –type causality tests from the estimated VAR, taking into account all 7 lags of the respective variables. The null hypothesis is "no granger causality". The p-values are provided in parentheses. 'All' refers to exclusion of all the endogenous variables from the VECM, other than the lags of the dependent variable. Significant test statistics (at the 5 percent level are in bold). P-values are χ^2 .

Estimates from VEC approach

Using the VEC approach, the estimate of the long-run pass-through effect from nominal appreciation to domestic prices is significant; however, it is positive (22).[32] This captures the overall downward trend in inflation despite exchange rate depreciation observed in Figure 1. The decrease in inflation reflects the change in policy stance, in particular, tightening of fiscal and monetary policy, and trade liberalization which has removed supply bottlenecks. It is evident that money and output have a stronger impact on prices than the exchange rate. Robustness checks using VECM models of the long-run relationship between exchange rate

[30] Following Granger (1969): *X* granger causes *Y* if and only if Y_t is predicted better by using the past history of *X* , together with the past history of *X* itself, rather than by using just the past history of *Y*. For further discussion of the concept of Granger causality, see Pierce and Haugh (1977).

[31] The null of no granger causality running from money supply to the output gap is firmly rejected. This can be interpreted as a traditional demand side argument, where increase in money supply increases real balances and causes demand to exceed supply. The results from sub-sample estimation and diagnostic tests are not reported.

[32] The VECM models capture dynamic response of inflation to exchange rate movements under the assumption of cointegration. They do not provide an estimate of the structural disturbances or of the common stochastic trends. Following the Granger theorem, an error-correction specification is utilized since the series of variables are cointegrated. There is a single cointegrating relation with inflation, money, exchange rate and output. Diagnostic results are not reported here.

and inflation support the variance decomposition findings that exchange rate movements have low impact on inflation (Table A2).

$$p_t = 17.5 + 3.023m_t + 1.434s_t - 5.166y_t \qquad (22)$$
$$\textbf{(8.29)} \quad \textbf{(3.95)} \quad \textbf{(9.47)}$$

The short-run dynamics suggest that the speed of adjustment of inflation to its long-run equilibrium has a half life of about 4 quarters. The coefficient on the lagged error correction term for inflation is -0.125. This means that if inflation exceeds its long run equilibrium by 1 percentage point, for example because of a temporary exchange rate shock, 12.5 percent of this deviation is adjusted for every quarter, so it takes about 8 years for inflation to adjust to its long-run equilibrium. This suggests that shocks to inflation are persistent.

Table A2. Estimated Long-Run Cointegration Equation, 1990 Q1–2005 Q1[1]

	Exchange rate	Real GDP	Money supply	Sum of coefficients
Coefficient	1.433864	5.166375	3.02335	9.623589
Standard error	**(0.36)**	**(0.55)**	**(0.36)**	

[1]Normalization on inflation variable.

Figure A1. Cross Correlation Between Exchange Rate and Consumer Prices (Lead)

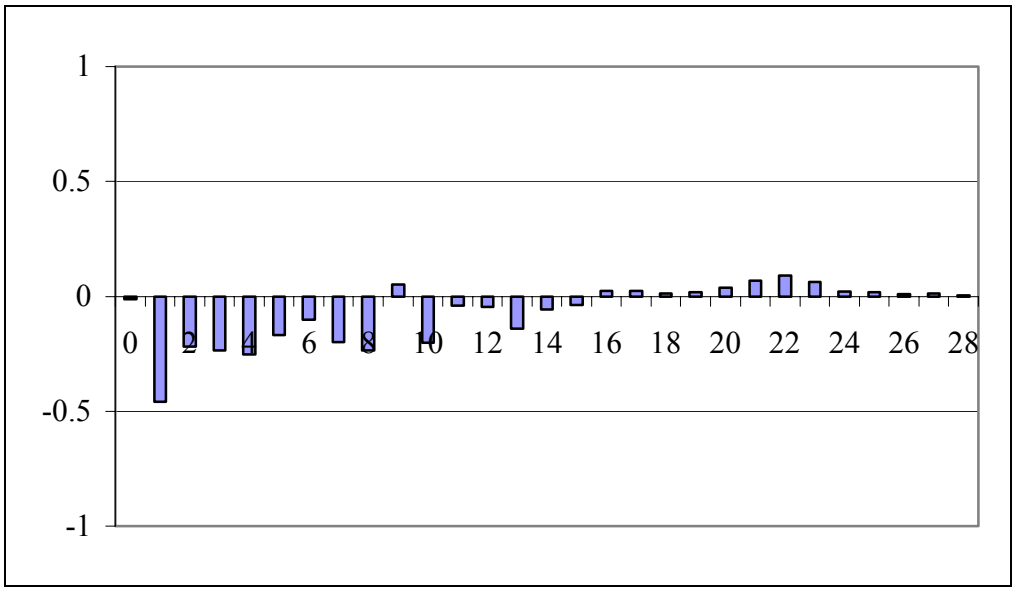


Figure A2. Cross Correlation Between Exchange Rate and Consumer Prices (Lag)

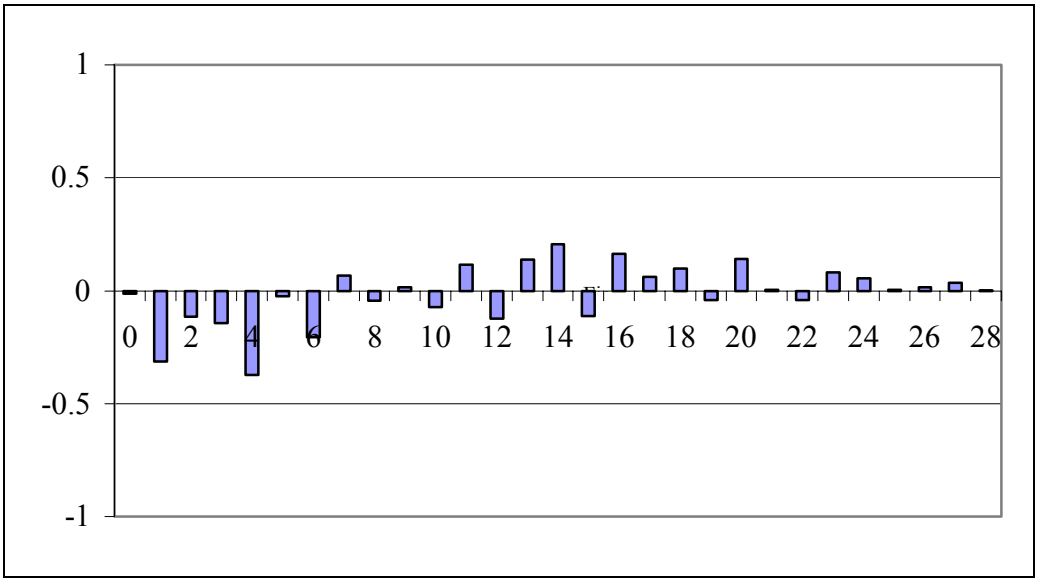


Figure A3. VAR Residuals

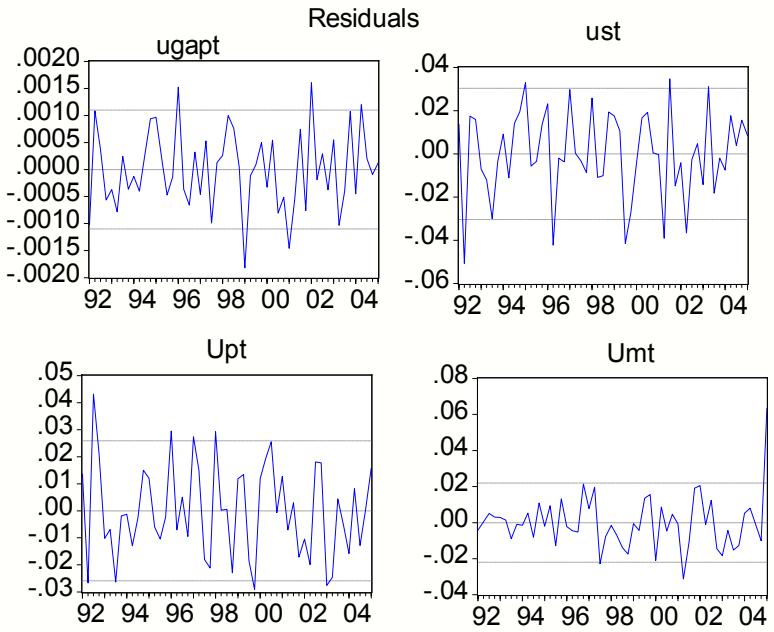


Table A3. Results from the Unit Root Tests[1]

	Levels		First Differences	
Time series	ADF	PP	ADF	PP
Domestic prices	-0.28	3.3	-5.99	-5.1
	(0.58)	(0.99)	(0.00)***	(0.00)***
Exchange rate	-0.86	-2.27	-6.18	-4.64
	(0.95)	(0.18)	(0.00)***	(0.00)***
Output gap	-3.86	-2.15		
	(0.00)***	(0.03)**		
Money supply	2.45	-3.61	-6.39	-6.43
	(0.99)	(0.04)**	(0.00)***	(0.00)***

[1]*, **, and *** denotes significance at 10 percent, 5 percent, and 1 percent, respectively. P-values are in parentheses. ADF denotes Dickey Fuller tests and PP refers to Phillips Perron tests.

Table A4. Results from VAR Residual Correlations

	Ygap	*dp*	*dπ*	*dm*
Ygap	1	0.1	-0.1	0.1
dp	0.1	1	0.4	0.0
dπ	-0.1	0.4	1	0.2
dm	0.1	0.0	0.2	1

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