Exchange Rate Volatility and Currency Substitution in South Africa- A Portfolio Balance Approach

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Abstract:

This article interrogates the question of whether currency depreciation and inflation volatility in South Africa resulted in currency substitution away from the South African Rand(ZAR) to the United States of America Dollar(USD). The research used the Portfolio Balance Model in its analysis and tested for unit roots and hence cointegration to establish if there was a long-term relationship between South African Capital Account (SAKO), nominal interest rate and exchange rate over the period 1980 to 2018. The econometric results show that higher interest rate differential in favour of South Africa resulted in the improvement of the South African Capital Account and this indicated the presence of currency substitution for the study period. The study also found a deterioration of the capital account with a rise in the inflation rate. Ultimately the study concluded that the chief determinants of capital account and hence currency substitution are interest rate and inflation and not exchange rate.

Keywords: Cointegration, Currency Substitution, Inflation Volatility

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INTRODUCTION/BACKGROUND OF THE STUDY

Calvo and Vegh (1992) regard currency substitution (CS) as the use of different currencies as medium of exchange in an economy. On the other end of the spectrum, McKinnon (1985) solves the "semantic problem" by introducing the idea of direct and indirect currency substitution. Direct currency substitution refers to the use of two or more currencies as means of payments within the same commodity space. Indirect currency substitution, on the other hand, means that investors switch between non-monetary financial assets, which is akin to capital mobility or capital flight. Apart from possibly causing inflation volatility exchange rate shocks may lead to currency substitution in the economy (Akinlo, 2008).

Agenor and Khan (1992), El-Erian (1988) and Fasano-Filho (1986) view currency substitution as a situation where foreign money substitutes domestic money in its three traditional roles. Domestic money plays three traditional roles, which are medium of exchange, unit of account and a store-of-value. The store-of-value substitutability is regarded as the key theoretical issue in this research. In this store-of-value function, currencies are dominated by interest-bearing assets as well as real assets. Khan and Ramirez-Rojas (1986) see currency substitution as taking various forms from increase in foreign currency deposits in the domestic financial system, deposits held abroad by domestic residents and foreign currency circulating within the borders of a country.

The problem with foreign money substituting local money is that it becomes problematic when it comes to implementing monetary or fiscal policy. Currency substitution can be partial or complete. Complete CS occurs when the economy is fully using foreign currency as a medium of exchange as in the case of Zimbabwe since the fall of the Zimbabwe dollar in 2008 and partial currency substitution occurs when only a fraction of the foreign currency is used. Currency substitution may also be in form of domestic agents preferring to hold domestic bonds or foreign bonds or a mix of the two as a way of storing value.

A study by Adom (2006) found the presence of currency substitution in South Africa using a modified version of Darrat et al. (1996) model which detected CS using the instability of the domestic money demand. The model runs the regression of real money demand on a vector of variables including the exchange rate changes. If a parameter on the exchange rate change is negative, then this signals presence of CS. In the case of South Africa, Adom (2006) found a parameter of '– *0.0205', which* was significant. The problem with this modified version of the Darrat et al. (1996) model is that it ignores the foreign money demand in its specification. The foreign money demand helps to capture the elasticity of substitution between local and foreign money in a robust way. The other method available to ascertain the existence of CS is the use of simple bi-variate correlation between the ratio of real domestic balances to real foreign balances and the domestic interest rate as well as the foreign interest rate. If CS exists then a negative and positive relationship exists between domestic and foreign interest rate and the money balances ratio respectively. It is better, then for a researcher to triangulate the results from the money demand instability approach with those from the real money balances ratio approach.

The challenge with higher degree of currency substitution is that it frustrates the efforts of financial authorities to measure the demand for national currency and this makes it harder to pursue robust monetary policies (Imrohoroğlu, 1994). In addition, currency substitution creates interdependence between nation states and this scenario may precipitates a financial crisis through the contagion effect (Akinlo, 2008). The other thing about currency substitution, especially adopting the US dollar, creates dominance that leads some people to view the current monetary system as a primary bulwark for U.S. hegemony (D'Arista, 2001). This research intends to measure the extent to which exchange rate volatility, as a result of, low pass-through, would affect currency substitution. This will be useful to policy designers to craft policies that minimise local currency substitution that has the potential to create disequilibria on the money market.

Research aim and objectives

The aim of the research is to investigate the presence of currency substitution as a result of exchange rate volatility in South Africa.

The specific objectives are:

1. To measure the degree currency substitution in South Africa as a result of exchange rate volatility
2. To ascertain the degree of currency substitutability with regards to holding bonds rather than cash

3. To capture the degree of direct and indirect currency substitution and their determinants

Research Questions

The main research question to be addressed in this research is to what extend do economic agents in South Africa substitute local currency for foreign currency following the exchange rate volatility. This broad question can be answered by addressing the following sub-questions:

1. What are the trends in the exchange rate as well as currency substitution in South Africa?
2. To what extend has the exchange rate volatility caused currency substitution in South Africa?

Hypothesis of the study

There is increasing and significant currency substitution as a result of the exchange rate volatility in South Africa.

Significance of the study

The research brings with it a different paradigm in respect of modelling currency substitution. In detecting the presence of currency substitution this study shall consider both the role played by domestic money demand as well as the foreign money demand to fully capture any presence of currency substitution in the economy. The model will be designed to capture direct and indirect currency substitution through interest rate differentials between South Africa and its major trading partner, the United States of America (USA). Other research efforts such as that by Adom (2006) ignored the foreign money demand in his modelling of currency substitution and thus failed to capture elasticity of substitution between the two currencies in the face of currency volatility.

Previous researches on South Africa have not exhaustively researched on the role of exchange rate volatility on Currency Substitution and this means there is more to be discovered regarding how agents prefer to hold foreign currencies and bonds ahead of local currency. Currency substitution and its financial and economic implications is an important reality in an environment characterised by exchange rate volatility and as such should be part of the exchange rate changes analysis. This research will incorporate the CS analysis for the case of South Africa. The few studies done elsewhere on CS and exchange rate volatility left out variables that were theoretically relevant for the analysis. The variables left out in previous researches included foreign interest rate, a measure of domestic inflation and indeed, exchange rate volatility. These control variables are crucial in this study as determinants of currency substitution.

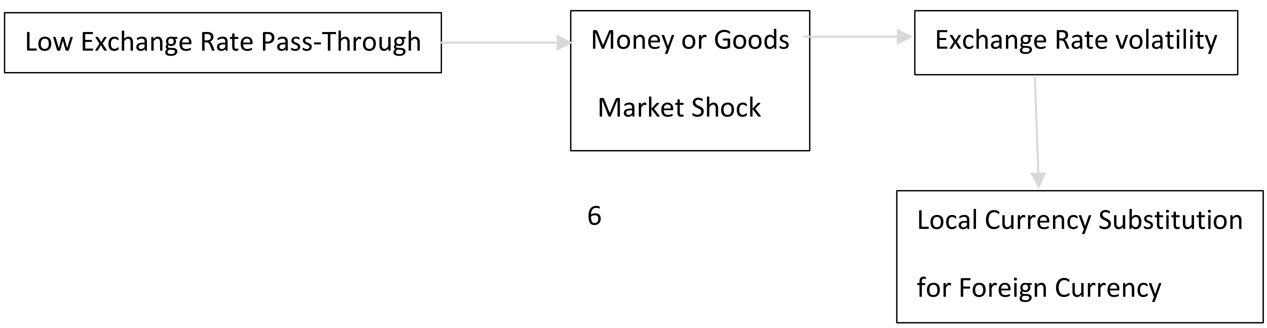
The other contribution this research brings is the estimation models. This paper shall employ multiple approach to estimation techniques such as the use of the Autoregressive Distributed Lag Model (ARDL) to capture both the short-term and long-term ERPT coefficients. This study shall also use the Bayesian Vector Autoregressive (BVAR) methodology as well as Vector Error Correction (VECM) for the purposes of capturing impulse response functions among the study variables. Existing models would be adopted and adapted by including more variables such as output gap that explain changes in domestic prices robustly. The approach would be to include as many variables as is possible and then employ model reduction technique to do away with redundant variables. Przystupa and Wróbel (2014) adapted the standard VAR and VECM models to estimate the impact of exchange rate changes on a number of important macroeconomic variables that included import prices and currency substitution by including the output gap as well as financial gaps in their specifications.

LITERATURE REVIEW

Exchange Rate Pass-through and Currency Substitution

Full or partial use of the foreign currency is an economy means that economic agents prefer to hold foreign currency instead of the local currency. This is caused by the volatility of the exchange rate between a country and its trading partners (Yinusa and Akinlo, 2016). There has been a number of studies on exchange rate pass-through to domestic prices but there haven't been many studies looking into what effect exchange rate change has on currency substitution. The channel through which currency substitution occurs is shown in Fig 3 below.

Fig 1



Source: *Authors's own construction*

Fig 1 shows that when there is a low exchange rate pass-through to prices then in the event of a shock in any macroeconomic variables such as a shock that reduces the supply of foreign goods, a very large home depreciation, as was pointed out earlier is required in order to raise the price of foreign goods enough to reduce home demand sufficiently (Devereux and Engel, 2002). This leads to some people preferring to hold more of the currency that is persistently appreciating as its value is not eroded quickly over time and this is in keeping with the well-known Gresham's Law where *bad* money chases away *good* money. Similarly, an expansionary monetary policy such as increase in money supply would require a big change (depreciation in this case) in the exchange rate for prices to rise so that money demand starts to increase until there is equilibrium on the money market; this unfortunately may trigger the onset of inflation.

Currency substitution has a number of implications for the stability of the local currency. Some of the drawbacks of currency substitution include loss of independence of the exchange rate policy, difficulty in measuring the level of the demand for national currency and as a result makes it difficult to achieve money supply targets. The currency substitution literature has shown that, if the currencies of two countries are close substitutes to money-demanders, then the central banks of these countries cannot follow independent monetary policies even under flexible exchange rates (Melvin, 1985).

Currency substitution creates interdependence between nation states and a nation cannot determine its own monetary policy under a floating exchange rate (D'Arista, 2001). In the end currency substitution may precipitates a financial crisis. An increase in foreign currency deposits held in domestic banks may increase the vulnerability of the banking system through the "balance sheet effect" (Agenor, 2004). Canzoneri and Rogers (1990) argue that multiple currencies imply valuation and currency conversion costs, which impede trade between regions.

Evidence on Currency Substitution

Structural Imperfections and exchange rate volatitilty

Firstly, when there is exchange rate volatility there is an emergence of structural imperfections such as the informal sector for foreign exchange. This informal sector does not pay tax and in the end Government may try to minimise its loss through inflation. Cavalcanti and Villamil (2003) explained that currency substitution and structural imperfections results in asymmetric welfare cost function and therefore welfare loss. Secondly, if CS is incomplete, then the economy ends up with multiple currencies for transactions. This scenario implies increasing valuation and currency conversion costs, which impedes trade between regions.

Exchange rate volatility diminishes the trust people have on the local currency and in the end economic agents would feel better off holding foreign currency that seems to be more stable. This substitution of local currency for the perceived stable currency has economic and financial implications for the country. Monetary policy outcomes and the financial system development are undermined as a result. A study by Yinusa and Akinlo (2016) revealed that there was currency substitution in the domestic banking system in Nigeria. The existence of currency substitution in Nigeria has a number of implications for the stability of the local currency, the Naira. As a result of currency substitution, Nigeria has moderately dollarised the economy. This finding confirms the Portfolio Balance Approach by (Miles, 1978) that says agents would want to hold both local and foreign money. In the event of local currency volatility they would perform a portfolio shift where they now prefer to have more of the foreign currency than local.

Theoretical Framework (Basic Model of ERPT)

This section explains the building blocks of the models that this study will use. In particular, the section deals with how the estimation model for determining the ERPT to prices as well as the model for currency substitution.

Analytic Framework for Currency Substitution

The Portfolio Balance Theory

The starting point to deriving the money demand function used to analyse the currency substitution is to consider the Portfolio Balance Approach (PBA) in which agents derive utility from holding local and foreign bonds as well as domestic and foreign money balances. we also assume perfect interest rate arbitrage on the market. The model we follow is that by Miles (1978) in which money balances (domestic and foreign) enter the CES production function to explain money services. The agent's problem is to:

$$\max\left(\frac{MS}{P_d}\right) = \left[\emptyset_1\left(\frac{M}{P}\right)^{-\rho} + \emptyset_2\left(\frac{M^*}{P^*}\right)^{-\rho}\right]^{-\frac{1}{\rho}} \tag{1}$$

subject to the budget constraint (cash-in-advance approach is assumed)

$$\frac{M_0}{P_d} = \frac{M}{P}(1+i) + \frac{M^*}{P^*}(1+i^*) \qquad (2)$$

MS = money service (proxied by total money holdings, M and M^* are domestic and foreign money balances, M_0 is desired level of money services fixed at the previous stage of the portfolio money services maximisation problem. P_d is domestic prices of consumer goods and P^* is foreign price. Maximising the production function subject to the constraint gives us the first order conditions:

$$\frac{\partial MS}{\partial M_d} = \lambda(1+i) \qquad (3)$$

$$\frac{\partial MS}{\partial M_f} = \lambda(1+i^*) \qquad (4)$$

$$M_0 = M_d(1+i) + eM_f(1+i^*) \text{ (in nominal terms)} \qquad (5)$$

After taking partial derivatives with respect to M_d (domestic money holding) and M_f (foreign money holding) and noticing that λ is the Lagrange Multiplier we get:

$$\frac{\phi_1}{\phi_2}\left(\frac{M_d}{M_f}\right)^{-(1+\rho)} = \frac{1+i_d}{1+i^*} \qquad (6)$$

After taking logarithms of both sides (to base e ≈ 2.7183) we get:

$$ln\left(\frac{M_d}{eM_f}\right) = \frac{1}{1+\rho}\ln\left(\frac{\phi_1}{\phi_2}\right) + \frac{1}{1+\rho}ln\left(\frac{1+i_f}{1+i_d}\right) + \varepsilon \qquad (7)$$

Where $\sigma = 1/(1 + \rho)$ is the elasticity of substitution between domestic and foreign currency. Multiple variants of the original model by Miles have been developed and used by researchers such as Bordo and Choudhri (1982) who included other variables like income (GDP) and exchange rate. Having derived the money demand function one can then adopt and modify it to suit the question under scrutiny.

Models that have been developed by most of the renowned economists have helped to analyse exchange rate pass through with some degree of accuracy but still needed polishing and a lot of augmenting in order to be more accurate. Modern day economic enquiry demands that we work with up-to-date models that are more realistic in the spirit of positivism and being more pragmatic in our approach to scientific enquiry.

A few observations have been made during sampling of past research work by other economists. A model by Ogbonna (2015) to estimate currency substitution lacked a number of variables that are crucial. The variables missing in the money demand function include output gap, foreign interest rate and foreign inflation rate all of which are considered to be traditional determinants of currency substitution.

The pioneer of the money demand model that is used to estimate currency substitution was that by Miles (1978). While it paved the way for modern models it had some shortcomings. One of the shortcomings was that the model itself was incorrectly specified and as such required some modification. Bordo and Choudhri (1982) used a much more improved model but could have included the quality of money as well as the exchange rate itself which happens to be the main determinant of money demand by locals. Melvin (1985) used a log-linear model in which there was a flawed assumption that domestic and foreign interest rates are always positive as the research considered logarithms of such variables.

Research Methodology

This section deals with the research philosophy that guides the research methodology. It also deals with the models that study shall use as well as description and nature of the variables to be used including data sources. This research departs from existing studies by using an eclectic econometric approach that includes the Phillips Curve (PC) framework to analyse the relationship between exchange rate and inflation. A Generalised Methods of Moments (GMM) model will be applied to a linearised Constant Elasticity of Substitution (CES) function in analysing ERPT to import, consumer and producer prices. VAR and VECM estimation shall be employed in order to study the effect of shocks on variables through impulse response functions. The study's main thrust, though, is to analyse the effect of the exchange rate changes to import prices in South Africa.

Definition of variables

Below are variables that are going to be used in the estimation of Currency Substitution and other various statistical analysis.

1. P^{imp} = Import Prices (Border Import Price Index)

2. *xchange* = Exchange Rate (with the USA) = Number of local units per USD

3. *SAKA* =South African Capital Account

4. *USAKA* =USA Capital Account

5. *sai* = South African interest rates (Six-months Treasury Bill rates for South Africa)

6. *usai* = Foreign interest rate (Six-months Treasury Bill rates for the USA)

7. infl = inflation rate (South African)

Some missing quarterly data would be obtained by transforming annual data into quarterly data using cubic spline and rebase as an index with 2010 =100.

Model Specification

Exchange rate volatility and currency substitution

This study makes use of open economy money demand function which basically is a modified model derived by Miles (1978) and shown in equation (22). Functionally the model to be used is :

$$kasa = f(sai, usai, exchange, infl) \qquad (8)$$

Expected regression parameter signs:

$\frac{\partial kasa}{\partial sai} > 0$, (as local interest rate increases capital account increases as well)

$\frac{\partial kasa}{\partial usai} < 0$, (foreign interest differential is attractive capital will flow away from South Africa)

$\frac{\partial kasa}{\partial exchange} < 0$, (exchange rate increase (depreciation) results in people liquidating their rand-denominated assets in favour of dollar-denominated ones. [1]

$\frac{\partial kasa}{\partial infl} < 0$, (the higher the inflation rate the more will interest rate fall leading to fall in capital account.)

The actual specification equation for estimation is the modified model used by Giovannini and Chazen (1992) is :

$$kasa_t = \theta_0 + \theta_1 i_t + \theta_2 i^*{}_t + \theta_3 (i^*{}_t + s_t^e) + \varepsilon_t{}^2 \quad (9)$$

Data Sources

Most of the variables to be used in this study will be sourced from the International Financial Statistics (IFS) as well as from the Word Bank Database including verification with South African sources such as the Reserve Bank of South Africa (RBSA) and Statistics South Africa.

1. CPI & Inflation Rate (Domestic) to be sourced from IFS (index 2010 = 100) and Statistics South Africa (SSA)
2. Bilateral Exchange Rate (with the USA): IFS database and defined as national currency per USD, period average as well as the Reserve Bank of South Africa (RBSA)
3. Domestic and Foreign Capital Account: IFS and World Bank Dataset
4. Local and foreign interest rates (these are six-months Treasury Bill rates) from the IFS
5. The study shall use quarterly data from 1980q1 to 2019q2.

Estimation Techniques

The contribution of the study mentioned the use of an eclectic approach to estimation of ERPT and one of these methodologies involves the use of GMM approach to capture the exchange rate pass-through to Import, Consumer and Producer prices, BVAR and the VECM.

[1] The relationship between interest rate and exchange rate is not conclusive and hence is non-monotonic (Hnatkovska, Lahiri and Vegh, 2008)

[2] The term $i^*{}_t + e_t^e$ was first suggested in the money demand function by Branson and Henderson (1985) and it stands for a return on foreign bonds expressed in local currency. If it rises, then the demand for foreign bonds increases at the expense of its portfolio substitutes such as money balances.

The case for GMM model

In order to capture the impact of the exchange rate changes on import, consumer prices as well as producer prices we make use of the Generalised Methods of Moments (GMM) estimation instead of the OLS approach. The GMM approach takes into consideration the dynamics that may be present in the model and at the same time addresses the problem of endogeneity in the estimation model. Though GMM is not a proper solution to endogeneity problem it offers a class of estimators that are suited enough to mitigate biases due to endogeneity issues. GMM is preferred to other methods such as the Maximum Likelihood approach since the data generating function is not known. The estimators of the GMM approach are consistent, asymptotically normal and more efficient in the class of all estimators where extra information about data generation procedure is not given.

The Sargan-Hansen J-test for GMM validity

The GMM is valid to use when it meets certain criteria. One of the conditions is that the data be generated by a weakly stationary ergodic stochastic process. This means that the following should be fulfilled:

$$m(\theta_0) \equiv E[g(Y_t, \theta_0)] = 0 \qquad (10)$$

Where E denotes expectation, and Y_t is a generic observation, θ_0 is a parameter to be estimated and $m(\theta_0)$ is its moment. For GMM to work well the term $m(\theta_0)$ should differ from zero for $\theta \neq \theta_0$.

The empirical counterpart of equation 37 above is $\hat{m}(\theta) \equiv E[g(Y_t, \theta)]$ (11)

The GMM estimator θ_0 is the solution to the minimisation of $\hat{m}(\theta)$ with respect to θ and is empirically given by

$$\hat{\theta} = \arg\min_{\theta \in \emptyset} \left(\frac{1}{T}\sum_{t=1}^{T} g(Y_t, \theta)\right)^T \hat{W} \left(\frac{1}{T}\sum_{t=1}^{T} g(Y_t, \theta)\right) \qquad (12)$$

With $\hat{W}$ being the weighted positive-semi definite matrix the null hypothesis is:

H_0: $m(\theta_0) = 0$ (ie model is "valid") against

H1: $m(\theta_0) \neq 0$, $\forall \theta \in \emptyset$. the test statistic is the J statistic that is asymptotically a chi-square distribution with k -1 degrees of freedom. The J-statistic is:

$$J = T.\left(\frac{1}{T}\sum_{t=1}^{T} g(Y_t, \theta)\right)^T \hat{W} \left(\frac{1}{T}\sum_{t=1}^{T} g(Y_t, \theta)\right) \xrightarrow{d} \chi^2_{k-l} \qquad (13)$$

Where k is the number of moment conditions (dimension of vector g), and l is the number of estimated parameters (dimension of vector θ). However, in most cases we use the probability value and in this case if the p-value is greater than 5% we fail to reject the H_0 and then conclude that the GMM estimators are consistent, efficient and asymptotically unbiased.

The case for Bayesian Vector Auto-Regressive (BVAR) and the Vector Error Correction (VECM) model

Variables normally show some level of dependency on their past values. It is this dependency of variables on their lagged values that warrants the use of a Bayesian Vector Autoregressive (BVAR) model. The VAR of the Bayesian type is essential in capturing the econometric dynamics among the variables and to study the association among variables through the decomposition of their variances (VD) as well as looking into the responses of variables to innovations that are introduced in the system through Impulse Response Functions (IRF). The BVAR is better than the traditional VAR in the sense that it is more effective than the no-Bayesian model when analysing short periods.

The other reason why a BVAR will be used is that model allows for analysis further along the pricing chain (to producer and consumer prices) than can be done in their single equation model. Choudhri and Hakura (2015) used similar techniques as in this study to examine pass-through to import, producer, and consumer prices in the non-US G7 countries. Furthermore, the BVAR is good when we consider the New Keynesian Phillips curves (NKPC) in which the additional lags of inflation capture the inflation persistence. This is the backward-looking phenomenon that is captured by a BVAR.

The case for the Vector Error Correction Model (VECM) model

Having established the unit-root statuses of the variables it is important to also capture the short-term and the long term-term relationships that exist among the variables. This is done through the use of the VECM.

This study uses the Vector Autoregressive (VAR) and Vector Error Correction Model (VECM) to capture the dynamic relationship between the dependent and the independent variables over time as well as capturing the degree and speed of exchange rate pass-through to import prices.

In terms of the variables this research will, in addition to the usual output gap, bring on an important variable called the financial gap as an extra control factor to explain exchange rate pass-through. This variable is informed by the fact that any large difference between the actual and the expected financial resource has implications for the cost of production and hence the consumer prices. For examining the effect of exchange rate pass-through to import and export prices the study shall make use of the CES model. Since the CES itself is difficult to make use of in regressions, we shall use the 2nd degree Taylor Expansion to obtain a corresponding linear model. In the spirit of the (Choudhri and Hakura, 2015) this study shall estimate a simple regression model as well as a VAR model in order to understand the dynamics among variables over a period of time.

Descriptive Statistics

A good medical doctor checks vital signs such as temperature, pulse rate and other basic signs before treatment is given to the patient. Likewise, in statistical and regression analysis, the study needs to work with data whose basic characteristics are known such as normality, mean versus median, standard deviation and extreme values such as maximum and minimum. Working with data that is highly skewed and not normally distributed may result in spurious inferences. Furthermore, the relevance of normality is for the fulfilment of the central limit theory (Kirkwood and Steme,2003). The available normality tests are the Jarque-Bera, Anderson-Darling and the Kolmorogov-Smirnov tests. Each is suitable for use under certain circumstances. The most commonly used test is the Jarque-Bera test and is given below:

$$JB = n\left[\frac{S^2}{6} + \frac{(K-3)^2}{24}\right]$$

Where n = sample size, S is the coefficient of skewness and K is the kurtosis term. The null hypothesis is H_0 : S = 0 and K = 3 The null is rejected if the JB is greater than the critical value of the Chi-square with 2 degrees of freedom.

Stationarity Tests (ADF, PP and KPSS)

Stationarity of variables is crucial in obtaining non-spurious statistical results. A variable is stationary when it exhibits a constant variance and mean over time. All variables (excluding dummies) are to be tested for stationarity to establish order of integration using the Augmented Dickey-Fuller (ADF) and the Phillips-Peron (PP) tests where sample is large enough. The Phillips-Peron test, though asymptotically more efficient, tends to work better in the presence of heteroscedasticity and autocorrelation. Generally, the PP test is more robust in situations where there is deviation from the *gentleman's* set of properties before testing for unit root.

Before testing for stationarity we establish the optimal number of lags to be used using the lag-length criteria determined by Akaike Information Criteria (AIC) or Schwartz Bayesian Criterion (SBC).

If an AR of order 1 is given by $y_t = \alpha y_{t-1} + \varepsilon_t$ or $\Delta y_t = \rho y_{t-1} + \varepsilon_t$ where $\rho = \alpha - 1$ in which case the series is declared non-stationary if $\rho = 0$ or $\alpha = 1$. The general ADF unit-root testing model is given by:

$$\Delta y_t = \varphi_0 + \pi y_{t-1} + \varphi_2 t + \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + \epsilon_t \quad \dots \qquad (14)$$

Where φ_0 is a drift value, and φ_2 is the trend-coefficient. One can test for stationarity in which the drift and trend occur or one in which none occur or in which one of the two occurs. The null hypothesis in this case is that $\Delta y_t \sim I(0)$ meaning the first difference of the series is stationary. The presence of unit root is rejected if the absolute ADF statistic is greater than the Mackinnon (1991) critical values. Because of the shortcomings of the ADF in the presence of autocorrelation Phillips and Perron (1988) developed a modified test from the ADF known as PP test and has the same distribution as the ADF test statistic and hence the same critical ADF values can be used.

Kwiatkowski et al. (1992) also developed a Kwiatkowski, Phillips, Schmidt and Shin (KPSS) test that is based on the notion of stationarity of a time series around deterministic trend. The following equations are used in the KPSS test:

$$y_t = \beta' D_t + \omega_t + u_t \dots \qquad (15)$$

$$\omega_t = \omega_{t-1} + \varepsilon_t \dots \qquad (16)$$

$$\varepsilon_t \sim WN(0, \sigma^2_\varepsilon)$$

Where D_t contains deterministic components (constant or constant plus time trend). The departure from the ADF and the PP tests is that $u_t \sim I(0)$ but may be heteroschedastic and ω_t is a random walk (RW) model with a normal distribution with zero mean and variance σ^2_ω.The null hypothesis for a KPSS test is that the random walk has a zero variance ($H_0 : \sigma^2_\varepsilon = 0$) The KPSS test statistic is given by:

$$KPSS = T^{-2} \sum_{t=1}^{T} \frac{\hat{s}_t^2}{\tilde{\lambda}_t^2} \dots \qquad (17)$$

Where $\hat{s}_t = \sum_{j=1}^{T} \hat{u}_{tj}$ and $\tilde{\lambda}_t^2$ is the consistent estimator of the variance of u_t.

The KPSS critical values are found from simulated asymptotic distributions (Kwiatkowski *et al.*, 1992). We reject H_0 is the KPSS test statistic is greater than the 100(1-α)% level of significance for the simulated critical value.

Cointegration tests

It is natural that in the event of finding the variables being cointegrated we would want to test if they have a long-term association in terms of direction of movement. We have to test if the variables are cointegrated so that we can, in the end, estimate a model that explains the short-term and the long-term relationships and also get the speed of adjustment towards the long-term equilibrium. Cointegration relationships will be tested using the celebrated Johansen Procedure using the trace and the maximum eigenvalue statistics.

Additional Post Regression Estimations

1. VAR and VECM stability tests
2. Cholesky Decomposition carried out to identify shocks
3. Impulse Response Functions of PPI and CPI inflation to orthogonal shocks of exchange rate appreciation and import price inflation to provide likely effects of these variables on domestic inflation
4. Variance Decomposition of PPI and CPI inflation to help determine importance of external shocks for domestic inflation

Statistical Analysis

This section deals with the major regression analysis, unit root testing as well as cointegration tests.

Regression Analysis

Dependent Variable = South African (SA) Capital Account (SAKA)

Exogenous Variable	**OLS coeff**	p_Value	**2-SLS coeff**	p-Value	**GMM coeff**	p-Value
Inflation (infl)	-0.057900	0.3343	-0.057900	0.3343	-0.011463	0.8546
xrate	-0.132212	0.0001***	-0.132212	0.0001***	-0.121069	0.0000***
Interest Rate_SA (sai)	-0.057885	0.3790	-0.057885	0.3790	-0.087258	0.1584
Interest_Rate_USA						

(usai)	-0.165122	0.0447**	-0.165122	0.0447**	-0.084799	0.3124
SAKA_lag1	0.349274	0.0259**	0.349274	0.0259**	0.407658	0.0068***
SAKA_lag2	0.063851	0.6344	0.063851	0.6344	0.060466	0.6058
USAKA	-0.000459	0.1389	-0.000459	0.1389	-0.000741	0.1133
USAKA_lag1	-2.91E-05	0.8690	-2.91E-05	0.8690	-8.97E-05	0.5370
USAKA_lag2	-7.26E-05	0.6853	-7.26E-05	0.6853	-9.10E-05	0.4013
Constant	4.485631	0.0000***	4.485631	0.0000***	4.051920	0.0000***

* significant at 10% level of significance
** significant at 5% level of significance
*** significant at 1% level of significance
Prob (F-statistic) = 0.0000 for all regressions implying the models were appropriate.
Durbin Watson Statistic = 2.02 for the regressions
Adjusted R-squared = 0.75 (on average)

Test for Serial Correlation in residual terms (Post Regression Diagnostics)

H_0: No autocorrelation in residuals	Regressions			Decision Rule H_0 is upheld and we conclude absence of serial correlation and confirming the DW statistic.
Statistic	OLS	2SLS	GMM	
nR^2 Probability value	2.271 0.3212	2.271 0.3212	Not applicable	

Interpretation of the regression results:

The South African Rand/United States of America (USA) Dollar exchange rate was found to be negatively related to the South African Capital Account. The impact of the exchange rate on the capital account was even more significant using the 2-SLS and the GMM techniques. This relationship does not sound intuitively correct and one would expect a positive relationship. In this case currency substitution is proxied by capital flight or reduced capital account and this constitutes direct currency substitution.

An indirect currency substitution is seen through the impact of South African interest rate as well as the USA interest rate on the SA capital account (SAKA). An increase in the South African interest rate attracts Foreign Direct Investment (FDI) and this improves its capital account. This is on the assumption that there is a positive interest rate differential between SA and the USA. The regression results have shown that an increase in the USA interest rate would cause a reduction in the SA capital account and this, again, is evidence of currency substitution. The impact of interest rates on currency substitution, though, is not significant.

Results show that there is a significant short-term persistence of the previous capital account position on the current one but the same cannot be said in the long-run. The long run persistence is captured through the coefficient of the second lag of SAKA. The inflation rate has the expected sign on currency substitution with all the models though it is not a significant factor.

UNIT ROOT TESTING

Variable	**ADF (in levels) (H_0: unit root)**	**ADF (1ST difference)**	**PP (in levels) (H_0: unit root)**	**PP (1st Difference)**	**KPSS (in levels) (H_0: stationary)**	**KPSS (1st Difference)**	**Decision Rule**
CPI(*cpi*)	3.198 (1.0000)	-4.667 (0.0004)	2.696 (1.0000)	-4.958 (0.0001)	0.915 5% crit: 0.463	0.512 5%: crit 0.463	*cpisa*~ I(1)
Exchange rate Change (*xratech*)	-6.471 (0.0000)	-	-5.387 (0.0000)	-	0.070 5% crit: 0.463	-	*xratech*~ I(0)
Exchange Rate (*xrate*)	-0.380 (0.9084)	-10.016 (0.0000)	-0.162 (0.9390)	-10.039 (0.0000)	1.382 5% crit: 0.463	0.087 5% crit: 0.463	*xrate*~ I(1)
Import Price (*imp*)	0.8399 (0.9944)	-8.252 (0.0000)	1.174 (0.9979)	-7.471 (0.0000)	1.474 5% crit: 0.463	0.305 5% crit: 0.463	*imp*~ I(1)
SA Interest rate (*sai*)	-2.61 (0.0914)	-5.911 (0.0000)	-2.413 (0.1399)	-4.684 (0.0001)	0.975 5% crit: 0.463	0.138 5% crit: 0.463	*sai*~ I(1)
USA Interest rate (*usai*)	-3.435 (0.0112)	-	-2.210 (0.2035)	-8.755 (0.0000)	1.265 5% crit: 0.463	0.118 5% crit:0.463	*usai*~ I(1) (by Majority)
Inflation (π)	-1.641 (0.4592)	-6.571 (0.0000)	-1.700 (0.4289)	-9.855 (0.0000)	1.181 5% crit: 0.463	0.073 5% crit: 0.463	π~ I(1)
Capital account (*saka*)	-12.290 (0.0000)	-	-12.290 (0.0000)	-	0.320 5% crit: 0.463	-	*saka*~ I(1)

Johansen Cointegration Test

Unrestricted Cointegration Rank Test (TRACE)			
Hypothesised No. of CE(s)	Trace Ststistic	5% Critical value	Probability Value
None*	88.5198	69.8189	0.0008
At most 1*	50.4144	47.8561	0.0282
At most 2	19.2778	29.7971	0.4731
At most 3	7.4511	15.4947	0.5258
At most 4	0.0627	3.8415	0.8022

Trace statistic indicates 2 cointegrating equations at 5% level of significance. * denotes rejection of H_0 at the 0.05 level.

The Johansen Cointegration Tests concludes that there are two cointegrating equations. However, only one leading cointegrating relationship will be considered even though we have two.

VAR Lag Order Selection Criteria
Endogenous variables: SAKA INFL SAI XRATE USAI
Exogenous variables: C

Sample: 1980Q1 2019Q2
Included observations: 152

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-2125.997	NA	1035148.	28.03944	28.13891	28.07985
1	-1235.948	1709.832	11.79918	16.65721	17.25403	16.89966
2	-1148.007	163.1539	5.159915	15.82904	16.92321*	16.27353*
3	-1113.997	60.85993*	4.595210*	15.71049*	17.30200	16.35702
4	-1097.211	28.93448	5.145212	15.81856	17.90742	16.66713

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

The lag selection criteria shows that the analysis should use three (3) lags as optimal.

Vector Error Correction Model (VECM) : Target variable = **SAKA**

Cointegrating Equation	**coefficient**	**t-statistic**	**conclusion on significance**
SAKA(-1)	1.000 (Normalised)		
Infl(-1)	0.4825	2.0961	significant
sai(-1)	-1.1699	-5.1033	significant
usai(-1)	1.4401	4.0214	significant
Xrate	0.0401	0.1122	not significant
C	-0.0381		
Short-Term Impacts & ECM	**coefficient**	**t-statistic**	**conclusion on significance**
ECM (-1)	-0.8735	-5.0399	significant
ΔSAKA(-1)	-0.0723	-0.0467	not significant
Δinfl(-1)	0.3265	0.3917	not significant
Δsai(-1)	2.7170	1.4324	not significant
Δusai(-1)	-0.1182	-0.0591	not significant
Δxrate(-1)	-0.6698	-0.3175	not significant
C	0.2667	0.2637	not significant
Durbin Watson Statistic on average = 2.000			

The Error Correction Coefficient (ECM) of -0.8735 shows a system that quickly recovers from any past disequilibria at a rate of about 87 percent. This shows a vibrant and an economy that is alive and responds to macroeconomic variables; which is important for business. Increase in inflation reduces exports that ultimately reduces output in the primary effect after an inflation shock. During the secondary effect, there will be a fall in real money demand and hence interest rate that makes South Africa unattractive as an investment destination. Foreign Direct Investment (FDI) falls leading to a fall in the capital account as shown in the long-term relationship of the ECM. Similarly, an increase in the South African interest rate leads to an increase in the capital account and the long-run ECM shows that. The cointegrating relationship also shows that when the exchange rate increases (depreciation/devaluation) the capital account would rise through a secondary effect of a currency shock –

$\downarrow R \rightarrow \uparrow X \rightarrow \uparrow TE \rightarrow \uparrow Y; \uparrow Y \rightarrow \uparrow M^D/p \rightarrow \uparrow i \rightarrow \downarrow I \rightarrow \ldots \downarrow Y$

↑ capital account

Where R = rand strength, X = exports, TE = Total expenditure, Y = output, MD/p = real money demand, i = interest rate, I = investment.

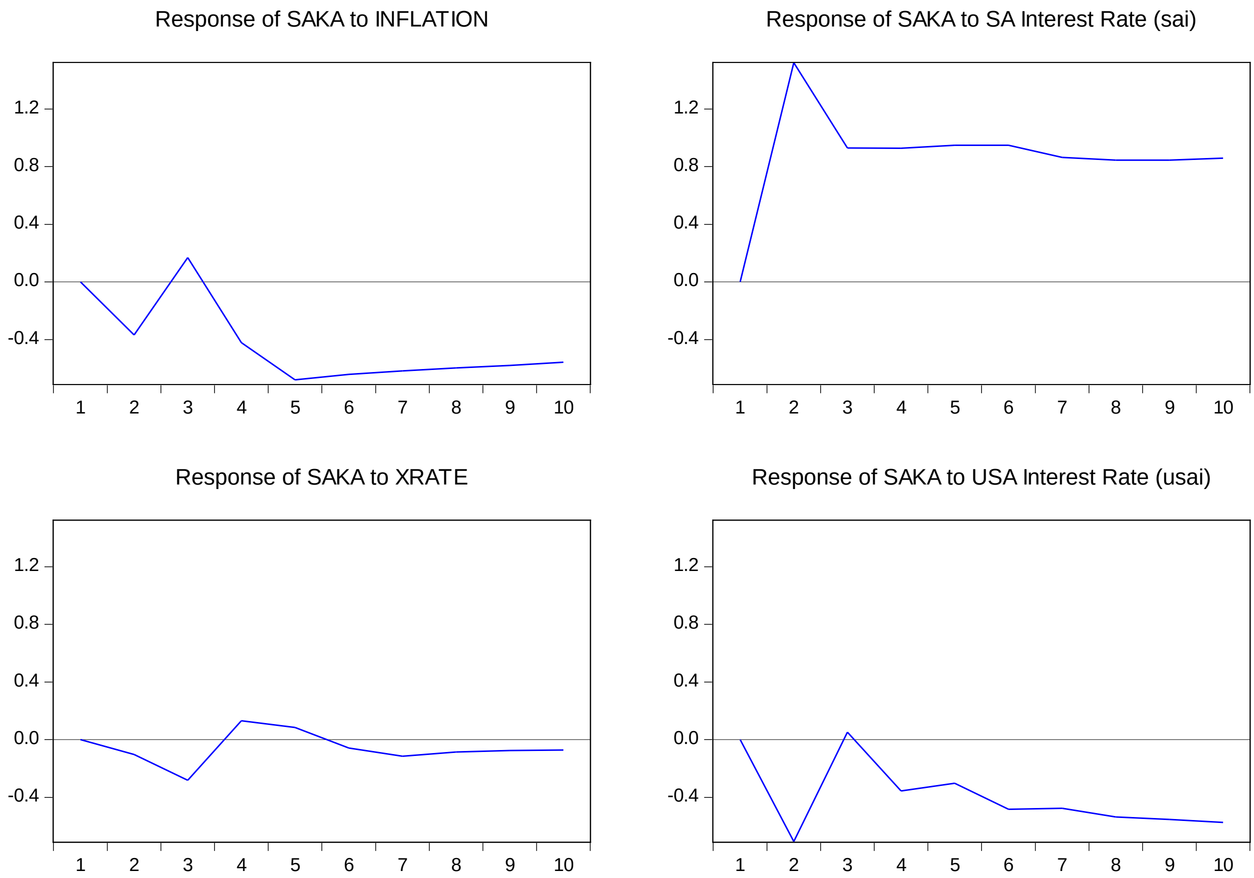
VEC Residual Serial Correlation LM Tests

Sample: 1980Q1 2019Q2
Included observations: 152; Null Hypothesis: No serial
Correlation at lag g.

Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	91.38799	25	0.0000	3.929570	(25, 469.6)	0.0000
2	61.44223	25	0.0001	2.558869	(25, 469.6)	0.0001
3	27.30687	25	0.3407	1.097004	(25, 469.6)	0.3410
4	70.21349	25	0.0000	2.951557	(25, 469.6)	0.0000

The test for serial correlation in the residual terms is a bit worrying but then we should bear in mind that we were likely to get these results since lagged variables are naturally correlated with current values.

Impulse Response Functions



The response functions shown show that a monetary policy that shocks inflation ultimately transmits a negative shock on the capital account. I shock in the interest rate produces a persistent positive change in the capital account. Shocking exchange rate produces no significant shift in the capital account in South Africa especially in the long run. The last table implies that a positive interest rate differential in favour of South Africa's trading partner, USA, causes an outflow in the FDI and this illustrates currency substitution in the country.

Variance Decomposition Table

Period	S.E.	KASA	INFL	sai	XRATE	usai
1	11.62637	100.0000	0.000000	0.000000	0.000000	0.000000
2	11.78147	97.86950	0.097219	1.665005	0.007521	0.360756
3	11.85400	97.20288	0.116260	2.258872	0.063697	0.358296
4	11.94193	96.41495	0.238877	2.830123	0.074649	0.441401
5	12.09853	95.51126	0.547390	3.371149	0.077700	0.492497
6	12.21336	94.55808	0.813374	3.910778	0.078559	0.639212
7	12.32663	93.75707	1.049920	4.329831	0.085941	0.777236
8	12.44311	92.99234	1.260215	4.709651	0.089145	0.948648
9	12.56118	92.25932	1.449400	5.074450	0.091148	1.125682
10	12.67582	91.53821	1.616613	5.441207	0.092718	1.311249

Cholesky Ordering: KASA INFL sai XRATE usai

The Variance Decomposition table reveals that most of the variation in the South African capital account emanates from the South African interest rate followed by inflation. This means that interest rate is the chief determinant of the capital account in South Africa. The exchange rate, once again, is not the chief determinant of currency substitution in South Africa.

Conclusion & Policy recommendations

The Error Correction Model shows that both inflation and interest rate are the key determinants of currency substitution and not exchange rate. The exchange rate coefficient has the expected sign and it does cause currency substitution but then it is not significant. The results also showed that inflation causes an increase in currency substitution. The Error Correction Model showed that a positive interest rate differential helps improve the South African capital account thereby arresting a negative currency substitution. The response functions show that a monetary policy that shocks inflation ultimately transmits a negative shock on the capital account. A shock in the interest rate produces a persistent positive change in the capital account. The shock to exchange rate produces no significant shift in the capital account in South Africa. The last table implies that a positive interest rate differential in favour of South Africa's trading partner, USA, causes an outflow in the FDI and this illustrates currency substitution in the country.

A policy that stabilises the rand would be good to arrest currency substitution. A volatile currency leaves economic agents with a lot of uncertainty regarding their investment. However, the monetary authorities should be more cautious with the interest rate and inflation for these are the chief causes of currency substitution in South Africa. The interest rate should be such that it is pegged at a level that rewards investors and make them see South Africa as a favourable destination for their funds. The monetary authorities are encouraged to maintain the current inflation-targeting policy as the research has shown that higher inflation triggers capital flight and hence currency substitution.

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