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THE IMPACT OF REAL EXCHANGE RATE CHANGES ON SOUTH AFRICAN AGRICULTURAL EXPORTS: AN ERROR CORRECTION MODEL APPROACH

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This study evaluates the long run and short run effects of real exchange rate changes on South African agricultural exports using an Error Correction Model (ECM). The results suggest that there is a unidirectional causal flow from exchange rate to agricultural exports. Moreover, appreciation of the Rand will be detrimental to agricultural exports.

1. INTRODUCTION

In his seminal paper, "The Exchange Rate and U.S. Agriculture", Schuh (1974), argued that an over-valued exchange rate was detrimental to US agricultural exports. Since then, a series of studies followed that have evaluated the effects of exchange rate on exports, more specifically on agricultural exports (Batten and Belongia, 1986; Belongia and King, 1983; Chambers and Just, 1979; Grigsby and Arnade, 1986; Orden, 1986; Pick and Vollrath, 1994; Schwartz, 1986; Saunders and Biswas & Mohaptra, 1999). All these studies concluded that appreciation of the real exchange rate would reduce the volume of agricultural exports. Though the hypotheses originally put forward by Schuh have been criticised widely, however it should be acknowledged that his research initiated a series of follow up research on this specific topic.

This paper investigates the short and long run relationship between real exchange rate and agricultural exports in the case South Africa, using an Error Correction model (ECM). The cointegration-ECM approach allows for the estimation of both the long run and steady state condition. South Africa makes an interesting case, particularly because the exchange rate has been depreciating against many major currencies since the 1980's.

The paper is organised as follows: The next section contains a brief discussion of the implications of exchange rates on exports. A historical prospective of the exchange rate regime of South Africa is provided in section 3. In section 4, a discussion of the theoretical model and the pre-test of the data series for the presence of the order of integration. The actual estimation procedure is

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discussed in section 5. Section 6 describes the data source. In section 7, are the empirical results and the implications of the results are in section 8. Section 9 is the summary and the conclusion.

2. EXCHANGE RATE AND EXPORTS

Theoretically, in a floating exchange regime, markets set the foreign exchange rate of a currency. Exchange rate affects exports and imports through changes in their relative prices, i.e. appreciation of the Rand will increase the foreign price of South African exports, thus making South African exports more expensive for importers. Alternatively, a depreciation of the Rand will lead to an increase in demand for South African exports. Mathematically, this can be expressed as follows: let P_d be the domestic price of South African agricultural exports and let E_r be the exchange rate of the Rand, expressed as the price of foreign currency in terms of Rand. Demand for South African exports, X_{DSAE} , in its simplest form can be expressed as:

$$X_{DSAE} = F \left(\frac{P_d}{E_r} \right) \quad (1)$$

If

$$E_r \uparrow,$$

that is the Rand depreciates, then ratio

$$\left(\frac{P_d}{E_r} \right)$$

decreases. Hence, theoretically it is expected that

$$X_{DSAE}$$

will increase. In mathematical language, this implies that

$$\frac{\partial X_{DSA}}{\partial \left(\frac{P_r}{E_D} \right)} > 0.$$

Alternatively if $E_{r\downarrow}$, the Rand appreciates making it more expensive for foreign buyers to buy South African exports. And if

$$\frac{\partial X_{\text{DSA}}}{\partial \left(\frac{P_r}{E_D} \right)} > 0$$

it implies that depreciation encourages exports. In summary depreciations encourages whereas appreciation discourages exports.

3. EXCHANGE RATES AND AGRICULTURAL EXPORTS: THE SOUTH AFRICAN CASE

Since World War II, the South African exchange rate has been characterised by three regimes, namely a fixed exchange rate for the period 1947-71, a pegged rate from 1971-1978, and finally from 1979 onwards a managed floating regime. The post-1979 exchange regime was initially aimed at protecting the gold mining industry. Since the late 1980s, the South African Rand has been depreciating continuously. Between February and March 1996, the Rand was devalued by 30%. In 1995, the Rand was quoted above R3.50 per US dollar. In, it was above R7.0 per US dollar on an average. The value of agricultural exports rose from R372.5 million in 1965 to R13394.1 million in 1998. The share of agricultural exports has been fluctuating widely. It constituted 26% of total exports in 1970, then decreased to 6.5% during the droughts period of the early 1980s, only to bounce back again to 10.54% in 1994. These trends imply that a weaker exchange rate lead to an increase in South African agricultural exports (IDC, 1998).

4. METHODOLOGY

4.1 Cointegration and error-correction model

The application of times series methods in the analysis of price relationships to agricultural sector problems has become quite common. Recognising that the non-stationary nature of data series frequently renders traditional empirical analyses of exports and exchange rates suspect, i.e. possibly spurious in the sense of Granger and Newbold (1974), agricultural economists have increasingly used the statistical concept of integration and cointegration. Conceptually, a simple functional form with no *a priori* requirements on stationary properties of the real exports (REXP) and real exchange rate (REXCH), establishes a conventional regression equation with exports as a

function of the exchange rate:

$$REXP_t = \alpha_0 + a_1 REXCH_t + \varepsilon_t \quad (2)$$

Equation 2 posits an equilibrium problem between the change in exchange rate and the value of exports. The lack of instantaneous adjustment from exchange rate to exports gives rise to a temporal state of disequilibria, because the effects of an exchange rate change may take more than one period of time (quarter, year etc) to influence exports. Thus, a dynamic relationship between exchange rate and exports is formulated in terms of an adjustment process of the market agent towards a steady state of equilibrium solution. To overcome the restrictive nature of equation 2, an autoregressive structure is introduced. Expanding equation 2 to a general distributed lag specification [ADL(n,m)] yields the following:

$$REXP_t = b_0 + \sum_{i=1}^n b_i REXCH_{t-i} + \sum_{j=1}^m d_j REXP_{t-j} + \xi_t \quad (3)$$

Equation 3 is the basis for a wide variety of commonly used equations in dynamic models with various economic interpretations. It gives rise to an error correction model (ECM). Assuming that REXP and REXCH rate have the appropriate properties to formulate an ECM (discussed later) and following Hendry, Pagan and Sargan (1984), the ECM representation of Exports demand is expressed as

$$\Delta REXP_t = \alpha_0 + \alpha_1 ECT_{t-1} + \beta(L) \Delta REXCH_{t-1} + \gamma(L) \Delta REXP_{t-2} + \xi_t \quad (4)$$

where

$$ECT_{t-1} = REXP_{t-1} - a_0 - a_1 REXCH_{t-1} \quad (5)$$

Similarly,

$$\Delta REXCH_t = \alpha_0 + \alpha_1 ECT_{t-1} + \beta(L) \Delta REXP_{t-1} + \gamma(L) \Delta REXCH_{t-2} + \zeta_t \quad (6)$$

where

$$ECT_{t-1} = REXCH_{t-1} - a_0 - a_1 REXP_{t-1} \quad (7)$$

If the two series are found to be cointegrated of order one, then their relationships can be represented by an error correction model (ECM). The ECM corrects for the disequilibria that arise in the inter-temporal adjustment process between the cointegrated variables. The error correction representation (equations 4 and 6) captures the short run dynamics of the variables in the cointegrated system. The cointegration relationship between the two series represents the long run equilibrium relationship. The ECM illustrates the short run dynamics that restores the equilibrium relationships represented by the cointegrating vectors in the event of asymmetric shocks.

Before estimating equation 4, there is a series of steps involved, with respect to non-stationary problem. If the individual series are non-stationary, then the existence of a stationary error term implies co-movement between agricultural exports and the exchange rate. Evaluation of short and long run dynamics are the basis of stationary properties of both the series. If the series are stationary, the long run properties can be easily evaluated by restricting the sum of the slope parameters to unity in equation 3. If the series are non-stationary the long run, behaviour of exports can be represented by an ECM mechanism such as equation 4 and 6. Accordingly, the equilibrium relationship between real exports (REXP) and real exchange rate (REXCH) can be described by a cointegration process of the variables when the individual series are integrated of order one, i.e., $I(1)$ and a linear combination of the two series, REXP and REXCH, is integrated of order zero, i.e., $I(0)$. If the two series are cointegrated, then, as Engle and Granger (1987) have shown that there exists an error correction model (ECM) representation of the cointegrating relationship. The cointegration-ECM approach allows for estimation of both long run, steady state equilibrium conditions implied by the theory, as well as short run dynamic adjustments based on the non-stationary properties of the data.

5. UNIT ROOT TEST AND COINTEGRATION

Conventionally, the cointegration-ECM estimation involves the following series of testing procedures in several steps. First, the series are tested for its stationary properties. A series

$$\{Y_t\}$$

is stationary, i.e., is integrated of order zero $I(0)$, if it has a time invariant mean

μ and variance σ^2 , another series

$$\{X_t\}$$

is integrated of order “d” $I(d)$ if

$$\Delta^d X_t$$

is $I(0)$. If two series are both non-stationary, then they can be linearly combined to produce a single series that is integrated of order $I(d-b)$. The two series are then said to be integrated of order (d, b) , (Engle and Granger, 1987). Thus, if

$$\{X_t\}$$

and

$$\{X_t\}$$

are each integrated of order one, but their combination

$$Y_t = \alpha + \beta X_t + \varphi_t$$

generates a residual series

$$\varphi_t$$

which is integrated of order zero, $I(0)$, i.e., the residual series is stationary, then

$$\{Y_t\}$$

and

$$\{X_t\}$$

are said to be cointegrated of order $(1,1)$. It is necessary when conducting a cointegration analysis that variables under examination are integrated of the same order and be non-stationary.

Following the standard convention, the first step is to pre-test each series for their order of integration. The two tests used in this paper are the Augmented Dickey-Fuller test of Dickey and Fuller (1981) and the test of Philips-Perron (1988). [There are also other test such as the KPSS test of Kwaitkwosi, Phillips, Schmidt, and Shin (1992) and Park-Ouliaris-Choi (1988)]. Both the ADF and Philips-Perron tests test the null hypothesis that the series has a unit root (that is the series is non-stationary) against the alternative that it has not. Unit root tests, such as the Dickey-Fuller and Philips-Perron, suffer from low power in that they fail to reject the null hypothesis of a unit root test. The KPSS test in contrast, tests the null hypothesis that a series is trend stationary or level stationary against the alternative that the series has a unit root with a drift. Kwaitkwosi, Philips, Schmidt and Shin (1992) argued for the use of the KPSS test as complement to the standard test for unit roots (such as the ADF and Philip-Perron tests) testing in certain conditions, i.e. when the series appear to be stationary, the series appear to have a unit root and for series whose status are unclear. As stated previously, these tests identify whether the series are stationary or whether the series need differentiation to induce stationarity.

If both series REXP and REXCH are found to be integrated of the same order, the cointegrating relationships are subsequently investigated using Johansen's cointegration test or Engle-Granger's (1987) bivariate cointegration test. The Engle-Granger test is based on the residuals of the hypothesised equilibrium relationships (such as in equation 2). In this case, the residuals test involves the estimation of the cointegration regression equation 2, and performing unit root tests on the estimated residuals

$$\hat{\epsilon}_t$$

The null hypothesis of no cointegration is tested similarly to the hypothesis of the unit root test described above. Engel-Granger recommended the ADF test for this purpose. The ADF test statistics are derived from the residuals based on the following equation

$$\Delta \hat{\epsilon}_t = -\hat{\rho} \hat{\epsilon}_t + \sum_{i=1}^s \hat{\alpha}_i \Delta \hat{\epsilon}_{t-i} + \xi_t$$

If computed ADF values are larger than the critical values, then the null hypothesis of no cointegration is rejected. For a complete discussion of issues involving in testing the order of integration of time series data, as well as the theoretical and empirical application of cointegration techniques, the reader is advised to read Campbell and Perron (1991), Bannerjee *et al* (1993) and Rao (1994). In this paper, the ADF testing sequence suggested by Dolado *et al*

(1990) is closely followed. The tests of cointegration must be preceded by the test of the order of integration of the variables amongst which cointegration relationships are hypothesised to exist. If the series are found to be cointegrated, then an error correction model estimation is appropriate.

6. DATA

Quarterly data for the period 1991:Q1 to 1999:Q2, for exports value (EXP) were provided by the Department of Trade and Industry, while the real exchange rate (REXCH) was obtained from the Reserve Bank of South Africa. The real exchange rate is an index with base year 1995. Exports are deflated by an export price index.

7. EMPIRICAL RESULTS

7.1 Unit root and cointegration test results

The steps described above were subsequently followed to test for the different properties. Bierens (1990) suggested that an initial lag truncation parameter value of 5. However in this study " $T^{1/4}$ " is used in the estimation where " T " is the total number of observations. Table 1 below reports the ADF and Philip-Perron Test results. In Table 1, the numbers in parenthesis are the orders of integration that were found to be significant.

Table 1: Augmented Dickey-Fuller and Philip-Perron test results

Variable	With Trend		Without Trend	
	ADF	PP	ADF	PP
REXP	-1.3819(4)	-3.9195(3)	-0.4209(4)	-0.26718(3)
REXCH	-3.1754(4)	-2.6866(3)	-1.6308(4)*	-1.717959(3)
$\Delta(REXP)$	-2.3001(4)*	-11.4396(3)*	-1.6691(4)*	-10.3747(3)*
$\Delta(REXCH)$	-2.5967(4)*	-5.6775(3)*	-2.6905(4)*	-5.85044(3)*

** Indicates rejection at the 5% level of significance.*

For each of the series, REXP and REXCH, testing of the autocorrelation and partial correlation functions of the residuals for the final lag chosen, indicated that the residuals are white noise. Breusch-Godfrey tests for serial correlation in the regression residuals and LaGrange Multiplier tests for ARCH type error processes supported these conclusions. A test value of greater than the critical value supports the existence of a unit root. The test results in table 1 below support the presence of unit roots for both series, REXP and REXCH.

The ADF test results for cointegration are reported in table 2 below. The computed values are above the critical values in all the cases. The null hypothesis of no cointegration is rejected. For the Johansen-Juselius test, a VAR specification with a linear trend in levels of the series with a constant term in the cointegration vector is chosen. Cointegration is said to exist if the values of computed statistics are significantly different from zero. The Johansen-Juselius test yields an eigen value statistic of 13.618 with critical value of 12.25, which is statistical significant at 5%. The results of table 1 and 2 suggest that an ECM model can be estimated.

Table 2: Engle-Granger test for bivariate cointegrating vectors

Variable	Constant	REXP	REXCH	ADF
REXP	-1478991		6.36936	-2.490650*
REXCH	93.65142	0.000384		-2.815084

* Rejects the unit root hypothesis at 1% level of significance.

7.2 Estimated results of the ECM

The ECM was estimated using the Engel and Granger methodology. Thus, the hypothesis tested above was that there exists a cointegrating relationship between the two series REXP and REXCH, which reflects what Baillie and Bollerslev (1989) call the "... joint determinants or fundamentals of the system". What is examined below is how exports (REXP) respond to deviations from equilibrium relationships with changes in the real exchange rate (REXCH) and how REXCH responds to deviation from equilibrium relationships with REXP.

The estimated ECM results are reported below in Tables 3 and 4, in column 2 are the coefficients and in column 3 are the t-statistics. The estimated ECM in table 3 was tested for mis-specification using Ramsey's Reset test. The computed F-statistics of $F(2,33) = 0.7475$, with a p-value of 0.595, which suggests that possible endogeneity of exports and exchange rate leads to consistent OLS estimates. The ECM terms are residuals from the regression equation of table 2. The lag length used is 2, the same as that used in the Johansen and Engle-Granger cointegration tests. Breusch-Pagan-LaGrange multiplier statistics were calculated, but not reported. They fail to reject the hypothesis of no autocorrelation for all of the models. Also, the DW suggests that the residuals are non-autocorrelated.

The results from the Table 4 indicate that real agricultural exports do not have an impact on real exchange rate in short run. This is in contrast with the results from Table 3, which indicate that changes in real exchange rates do have an impact on real agricultural exports (since the error correction term is significantly different from zero and also has the proper sign). From results in Tables 3 and 4, it can be concluded that a unidirectional causal flow exists from real exchange rate to agricultural exports. This is similar to the conclusions of Grigsby and Arnade (1986), as well as Schwartz (1986).

Table 3: Estimated ECM results with agricultural exports as the dependent variable

$\Delta(REXP)$	Coefficient	t-statistics
Const.	14999868	0.189927
ECT_{t-1}	-0.445130	-1.8500**
$\Delta(REXP(-1))$	-0.097519	-0.9789
$\Delta(REXP(-2))$	-0.409710	-2.2450*
$\Delta(REXCH(-1))$	10166294	0.37153
$\Delta(REXCH(-2))$	23525836	0.85570
D.W	2.0719	
Adjusted R ²	0.5313	

Table 4: Estimated ECM results with agricultural exports as the dependent variable

$\Delta(REXCH)$	Coefficient	t-statistics
Const.	0.706395	1.1520
ECT_{t-1}	-0.141931	-1.2191
$\Delta(REXP(-1))$	-0.000029	-1.7093***
$\Delta(REXP(-2))$	-0.000007	-0.5957
$\Delta(REXCH(-1))$	-0.031035	-0.8849
$\Delta(REXCH(-2))$	-0.006752	-0.3136
D.W	1.9916	
Adjusted R ²	0.1196	

$\Delta(REXP)$, $\Delta(REXCH)$ are change in real value of exports and real exchange rate, respectively.

8. POLICY IMPLICATION OF THE RESULTS

From the estimated results, an import policy conclusion can be drawn. First, due to the unidirectional causal flow from exchange rate to agricultural exports, the monetary authorities should consider the short run effects of monetary policy on South African agricultural exports. It implies that if the Reserve Bank of South Africa uses a contractionary monetary policy to strengthen the Rand against other currencies, as was recently proposed (in order to lower the inflation rate by increasing interest rates), definitely it will affect South African agricultural exports negatively. The empirical results suggest that a monetary policy geared towards appreciating the Rand will be detrimental to South African agricultural exports in the short-run, as it will decrease agricultural exports. This result further support the arguments put forward Chambers and Just (1979) who empirically evaluated the linkages of the monetary sector and the US agriculture.

9. SUMMARY AND CONCLUSION

The empirical findings establish the short-run relationship between real agricultural exports and the real exchange rate, which confirms strong linkages between the macro sector and the South African agricultural sector. This linkage is a unidirectional causal flow from the exchange rate to agricultural exports. This study also provides important information about the relationship between real exchange rate and the South African agricultural sector, i.e. that there exists a long-run relationship between the real exchange rate and the South African agricultural sector.

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