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Estimation of the Equilibrium Real Exchange Rate for South Africa

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Estimation of the Equilibrium Real Exchange Rate for South Africa[1]

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Abstract

Based on the Johansen cointegration estimation methodology, much of the long-run behavior of the real effective exchange rate of South Africa can be explained by real interest rate differentials, GDP per capita (both relative to trading partners), real commodity prices, trade openness, the fiscal balance, and the extent of net foreign assets. On the basis of these fundamentals, the real exchange rate in early 2002 was found to be significantly more depreciated with respect to the estimated equilibrium level. The half-life of the deviation of the real exchange rate from the estimated equilibrium one was found to be somewhat more than two years.

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I. Introduction

In the first quarter of 2002, the real effective exchange rate of the South African rand was 25 percent weaker than its value in the same period of the previous year and 45 percent more depreciated than its average 1995 level. A depreciation of this magnitude raises the question as to what extent it can be considered an equilibrium phenomenon (that is, consistent with persistent movements in economic variables that regularly affect the real exchange rate) rather than a temporary deviation from equilibrium. The depreciation also raises the question of how long it would take for any temporary deviation to dissipate. In this paper, we address these questions by estimating an equilibrium path for South Africa's real effective exchange rate over the period from 1970 to the first quarter of 2002.

The outline of the remainder of this paper is as follows. After reviewing the existing literature, the paper briefly describes the dynamics of the real exchange rate and its determinants. Subsequently it investigates the presence of a long-run cointegrating relationship between the real exchange rate and certain explanatory variables, and estimates the speed at which the real exchange rate converges toward its equilibrium level. It then derives measures for the equilibrium real exchange rate and, correspondingly, the gap between the actual and the equilibrium levels.

II. Brief Review of the Literature

There is a considerable body of literature on the estimation of the equilibrium real exchange rate, some of which has been surveyed in MacDonald (1995) and Rogoff (1996). This literature indicates that purchasing power parity (PPP) is not an appropriate model for the determination of equilibrium exchange rates because of the slow mean reversion of real exchange rates to a constant level (which is the long run equilibrium implied by the PPP assumption). This has resulted in a shift away from PPP based measures of the equilibrium exchange rate to ones which focus on the link between the real exchange rate and various so-called real determinants, such as productivity and net foreign assets (see MacDonald and Stein (1999) and Hinkle and Montiel (1999)). Most of this recent work uses cointegration techniques to identify persistent patterns of co-movements among variables.

The main explanatory variables identified in the literature for developing countries includes commodity price movements (or terms of trade), productivity and real interest rates differentials vis-à-vis trading-partner countries, measures of openness of the trade and exchange system, the size of the fiscal balance, and the extent of net foreign assets.[2] The rationale for most variables is based on a simple neoclassical theoretical framework that assumes the prices of tradable goods are equalized across countries and investigates how changes in the real exchange rate arise mainly from relative movements in the price of nontradables across

[2] Other variables often include the investment-to-GDP ratio, and the net capital inflows-to-GDP ratio.

countries. Relaxing the assumption of price equalization should provide richer insights into the transmission mechanisms (as in the presence of imperfect substitutable traded goods across countries, the real exchange rate would also be affected through the relative price of traded goods), but leads to broadly similar conclusions (see MacDonald and Ricci (2002)). In either case, the chosen variables explain why the real exchange rate can be expected to vary over time and provide a rationale for deviations from PPP.

The classic example of an equilibrium deviation from PPP is the Balassa-Samuelson effect (see Balassa (1964) and Samuelson (1964)). If a country experiences an increase in the productivity of the tradable sector (relative to its trading partners), its real exchange rate would tend to appreciate. For given prices of tradables, such stronger productivity would induce higher wages in the tradable sector; if wages are equalized across sectors, this would be reflected into higher prices of nontradables, and, hence, an increase in the consumer price index relative to trading partners.[3]

An increase in the world price of the commodities that a country exports would also tend to appreciate the real exchange rate. Such an increase would induce higher wages and a higher price of nontradables (see Cashin, Cespedes, and Sahay (2002)). An increase in commodity prices could also induce—more generally—a positive wealth effect, which would raise domestic demand and, hence, the price of nontradables (see Diaz-Alejandro (1982)). In principle, these effects should be captured more comprehensively by the terms of trade, as their numerator encompasses all exports—as opposed to only commodity based exports—and their denominator reflects the price of the country-specific imports, as opposed to a generic industrial country export deflator. In practice, few studies find a significant effect of the terms of trade (see, however, Goldfajn and Valdes (1999)), while many researchers find commodity prices to be strongly cointegrated with the real exchange rate of commodity exporters.[4] One rationale for the findings is provided by the relative accuracy of the measurement of commodity prices, as opposed to the arbitrariness involved in the construction of country-specific export and import deflators. Another rationale relates to how frequently commodity price data are made available which may allow financial markets to tailor their financial decisions about the currencies of commodity exporters to the prices of these commodities.

The real interest rate differential could represent several factors—aggregate demand, productivity, and persistent monetary policy—all pointing to a positive relationship with the real exchange rate. First, an increase in absorption relative to savings would put upward pressure on the real interest rate in an economy with less than perfect capital mobility. At the same time, the demand for both tradable and nontradable goods would increase, inducing an increase in the price of nontradables, which, in turn, would result in an appreciation of the real exchange rate. Second, real interest rate differentials may also reflect productivity differentials: to the extent

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[3] For recent empirical evidence on the Balassa-Samuelson effect, see MacDonald and Ricci (2001 and 2002).

[4] See Chen and Rogoff (2002), MacDonald (2002), and Cashin, Cespedes, and Sahay (2002).

that the measure employed to proxy for the Balassa-Samuelson effect is not perfect, the real interest rate differential may help capture this empirically; also, if the productivity of capital raises with respect to trading partners, capital will flow to the home country, thereby inducing an appreciation of the real exchange rate.[5] Third, a tightening of monetary policy would raise real interest rates—an outcome that would need to be associated with an expectation of currency depreciation, given the interest parity condition. Hence, the nominal exchange rate would appreciate beyond its long-run value, so as to allow the expected depreciation to occur once the monetary policy shock had disappeared (the "overshooting" effect described in Dornbusch (1976)). In the presence of price rigidities, the real exchange rate could also be appreciated relative to its long-run value (see Obstfeld and Rogoff (1996) for a formal derivation in the new open macroeconomic setup). This last effect could be persistent if the monetary shock—that is, the rise in real interest rates—is persistent: in this sense, the cointegration analysis would capture this effect as part of the "long-run" relation.[6]

An improvement in the fiscal balance will have an ambiguous effect on the real exchange rate. On the one hand, depreciation would tend to occur because the improved fiscal balance would normally induce a less-than-proportional reduction in private saving, so that total domestic demand would decrease while overall savings would increase.[7] As part of the decline in spending falls on nontradable goods, their prices would drop, bringing about a depreciation of the real exchange rate. The effect is likely to be stronger if the fiscal improvement comes from a reduction in government consumption, as opposed to an increase in taxes, to the extent that government consumption falls more intensively on nontradable goods than private spending (in which case, the depreciation would be reinforced in the presence of imperfectly substitutable traded goods).[8] In principle, the fiscal effect should simply be part of the main aggregate demand effect described above; whether the interest rate fully captures both effects is an empirical question. On the other hand, a further effect would operate on the relative price of traded goods in a model which features stock-flow consistency (such as the portfolio balance

[5] However, the repayment of the net foreign liabilities accumulated would eventually require a depreciation of the real exchange rate to achieve current account surpluses.

[6] This does not contradict the fact that in the steady state of the economy (the long run, as commonly conceived), the Dornbusch model would not predict an effect of monetary policy on the real exchange rate simply because, by definition, the monetary shock would have vanished in the steady state.

[7] Assuming that Ricardian equivalence does not hold, for example because of uncertainty about the duration of the improvement in the fiscal balance.

[8] See De Gregorio, Giovannini and Wolf (1994) for a theoretical and empirical analysis of the impact of government spending on the real exchange rate. The effect of a reduction of government spending, as opposed to the effect of an increase in taxes, may be stronger also if the larger multiplier effect of the former is not neutralized by the optimal saving choices of consumers.

model). In such a model the current account surplus generated by the initial real depreciation would have to be annihilated in the long run by a real appreciation which ensures a sufficient trade deficit to offset the positive net foreign assets.

A more open trade regime is likely to be associated with a more depreciated real exchange rate. Trade restrictions increase the domestic price of tradable goods, thereby raising the overall price level and the real exchange rate (see Goldfajn and Valdes (1999)). In the present study, openness is proxied by the ratio of exports plus imports to GDP. Such a measure is widely used, even though it is an imperfect substitute reflecting also a multiplicity of other factors than trade and exchange restrictions. In the context of the present paper, these drawbacks are likely to have a limited impact. In fact, the endogeneity of the openness ratio to the real exchange rate is corrected automatically by the econometric methodology employed. The ratio would also reflect the effect of trade sanctions during the apartheid period, which is likely to induce a similar effect on the domestic price of the tradable goods and, hence, on the real exchange rate.

The size of net foreign assets is likely to be associated with a more appreciated exchange rate in the long run. Higher net foreign assets induce larger expenditure on domestic goods, thus raising the price of non-tradables, and appreciating the real exchange rate. An alternative mechanism is based on the absence of price equalization of tradables: a country that reaches a higher level of net foreign assets can afford to finance a worse current account balance and can therefore sustain a loss in competitiveness associated with a more appreciated real exchange rate. For a theoretical discussion and empirical evidence, see Lane and Milesi-Ferretti (2000). [9]

In terms of previous work on South Africa, see Aron, Elbadawi, and Kahn (2000) who provide an estimation of the equilibrium real effective exchange rate for the country over the period 1970–1995. They use a single equation approach to identify a long run relation on the basis of the following explanatory variables: terms of trade, the price of gold, tariffs, capital flows, official reserves, and government consumption. The paper also offers an interesting historical background.

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[9] The rapid reduction of the Central Bank's forward book since 1998 has often been indicated as contributing to the depreciation of the rand. As the reduction is associated with an improvement in the net foreign asset position, such claim could appear incompatible with the theoretical prior outlined in this section. However, as shown in Section IV, the negative pressure on the exchange rate from an increase in the net foreign asset position is likely to be temporary, while the long run effect is likely to be positive, as theoretically predicted.

III. DATA AND METHODOLOGY

The real effective exchange rate and the main variables employed in the empirical analysis are plotted over the 1970–2001 period in Figure 1 and Figure 2, respectively.[10] Some interesting patterns are worth highlighting, particularly for the recent period:

- the significant real depreciation of the rand since 1995, which accelerated in 2001;
- the increase in real interest rates in the 1990s, partly associated with tight monetary policy;
- the persistent decline in real GDP per capita with respect to trading partner countries, throughout the sample period;[11]
- the steady decline in real prices for South Africa main commodity exports since the beginning of the 1980s;
- the decline in openness during the 1980s—in part owing to trade sanctions—and the opening up of the economy since the end of the apartheid;
- the strengthening of fiscal performance, as measured by the fiscal balance, in the post-apartheid period; and
- the recent improvement in the net foreign asset position, owing in great part to the reduction of the forward book.

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[10] The variable definitions and sources are presented in Appendix I. The variables in Figure 1 and 2 are not in logarithmic terms.

[11] As often in estimation of equilibrium exchange rates, we employ real GDP per capita with respect to trading partner countries as a proxy for the Balassa-Samuelson effect. The very peculiar nature of labor market dynamics in South Africa before and after the end of the apartheid prevents a meaningful use of labor productivity data.

Figure 1. South Africa: The Real Effective Exchange Rate,

1970Q1–2002Q1 (Index, 1995=100)

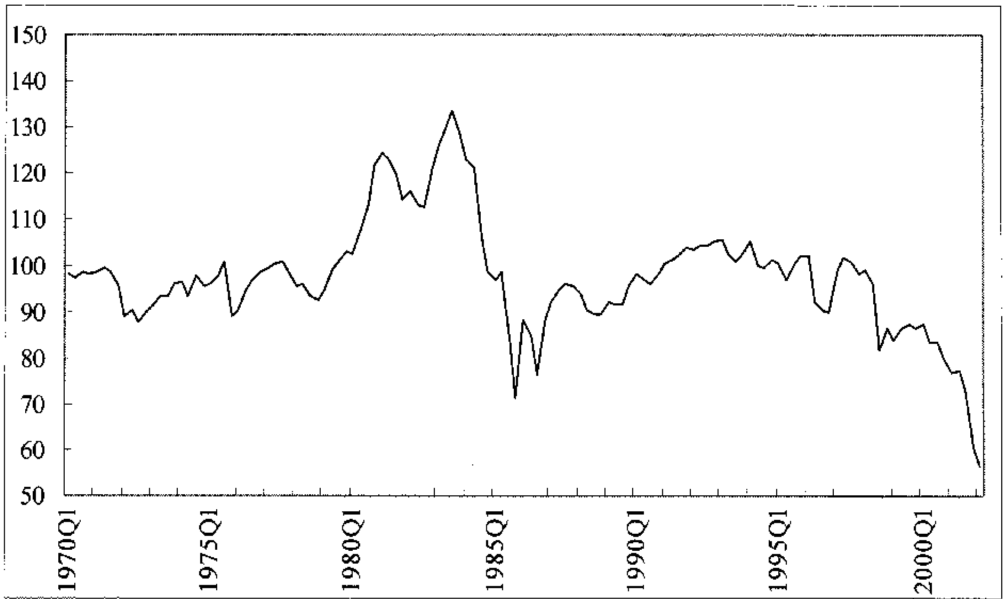
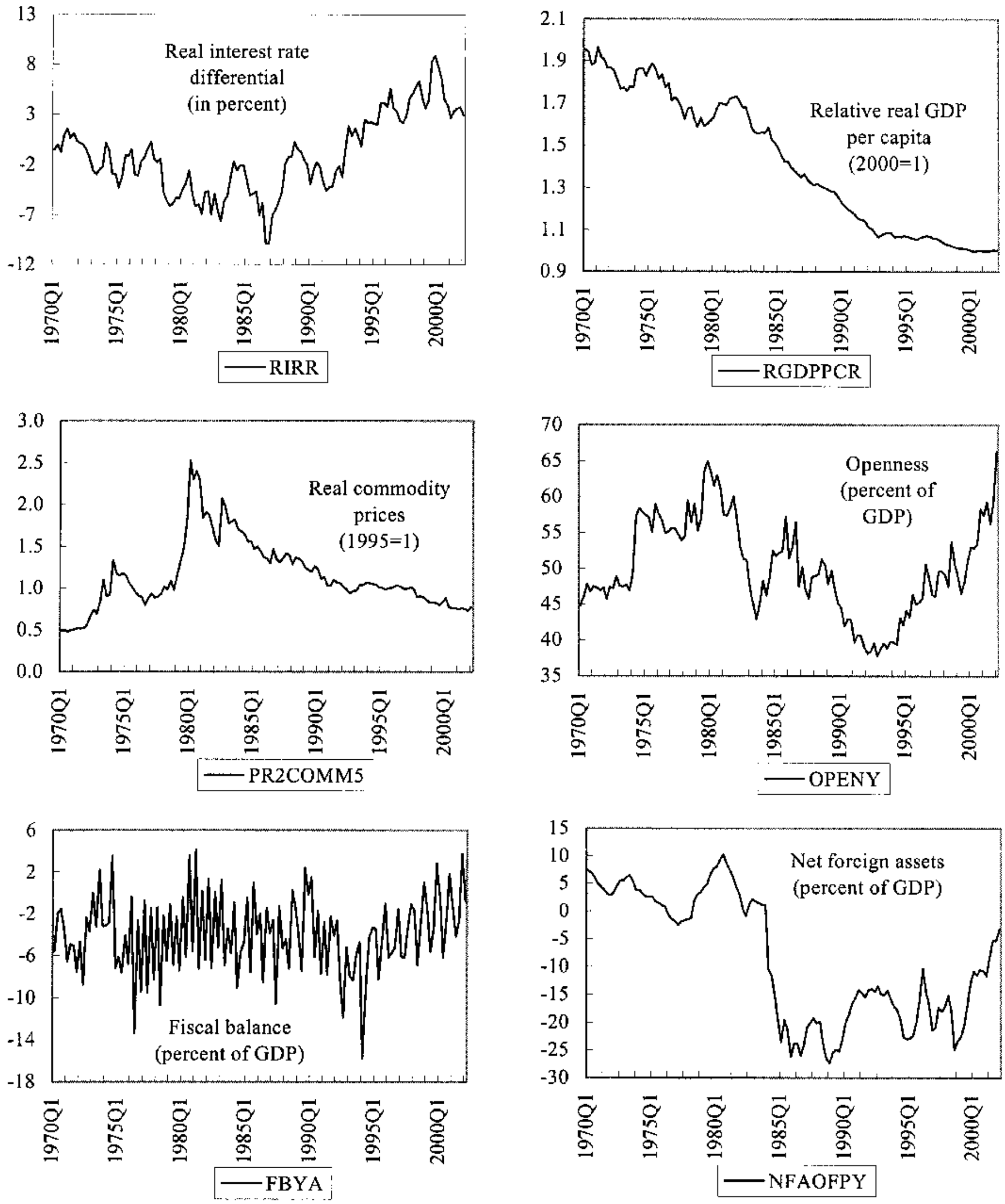


Figure 2. South Africa: Determinants of the Real Effective Exchange Rate, 1970-2002Q1



Sources: South African Reserve Bank; Statistics South Africa; and staff estimates.

A. The Econometric Methodology

In order to investigate the existence of a long-run, cointegrating, relationship between the real effective exchange rate and the variables discussed above, our study employs the Johansen (1995) maximum likelihood estimator, which corrects for autocorrelation and endogeneity parametrically using a vector error-correction mechanism (VECM) specification.[12]

The Johansen methodology can be described as follows. Define a vector:

$$\mathbf{x}_t = [lreers, rirr, lrgdppcr, lpr2comm5, openy, fbya, nfaopfy]',$$

and assume the vector has a VAR representation of the form:

$$\mathbf{x}_t = \eta + \sum_{i=1}^{p} \Pi_i \mathbf{x}_{t-i} + \varepsilon_t,$$

where η is a (nx1) vector of deterministic variables, ε is a (nx1) vector of white noise disturbances, with mean zero and covariance matrix Ξ, and Π_i is a (nxn) matrix of coefficients. The above expression may be reparameterised into the so-called vector error correction mechanism (VECM) as:

$$\Delta\mathbf{x}_t = \eta + \sum_{i=1}^{p-1} \Phi_i \Delta\mathbf{x}_{t-i} + \Pi\mathbf{x}_{t-1} + \varepsilon_t$$

where Δ denotes the first difference operator, Φ_i is a (nxn) coefficient matrix (equal to $-\sum_{j=i+1}^{p} \Pi_j$), Π is a (nxn) matrix (equal to $\sum_{i=1}^{p} \Pi_i - I$) whose rank determines the number of cointegrating vectors. The presence of cointegration is indicated by the rank of Π:

- If Π is of either full rank, n, or zero rank, Π=0, no cointegration exists amongst the elements in long-run relationship (in these instances it would be appropriate to estimate the model in, respectively, levels or first differences).

- If, Π is of reduced rank, r (where r<n), then there exist (nxr) matrices α and β such that Π=αβ', where β is the matrix whose columns are the linearly independent cointegrating vectors, and the α matrix is interpreted as the adjustment matrix, indicating the speed with which the system responds to last period's deviations from the cointegrating relationships.

The existence of cointegration amongst the variables contained in $\mathbf{x}_t$ can be determined by two tests proposed by Johansen. The trace test statistic (TR) for the hypothesis that there are at most **r** distinct cointegrating vectors is as follows:

$$TR = T \sum_{i=r+1}^{N} \ln(1 - \hat{\lambda}_i),$$

---

[12] There are alternative ways of addressing serial correlation and endogeneity in a cointegrating framework, such as Phillips and Hansen (1990).

where $\hat{\lambda}_{r+1},.....,\hat{\lambda}_N$ are the N-r smallest squared canonical correlations between $\mathbf{x}_{t-k}$ and $\Delta\mathbf{x}_t$ series (where all of the variables entering $\mathbf{x}_t$ are assumed to be I(1)), corrected for the effect of the lagged differences of the $\mathbf{x}_t$ process (for details of how to extract the λ's, see Johansen (1988); and Johansen and Juselius (1990)).

The likelihood ratio (LR) statistic, for testing at most r cointegrating vectors against r+1 is defined as:

$$LR = T\ln(1-\hat{\lambda}_{r+1})$$

Johansen (1995) shows that the TR and LR statistics have non-standard distributions under the null hypothesis. He does, however, provide approximate critical values for the statistics generated using Monte Carlo methods, and these are the critical values used in this paper.

One of the key advantages of the Johansen methodology in the current application is that the estimated coefficient – the β vector – can be used to prove a measure of the equilibrium real exchange rate and therefore a quantification of the gap between the prevailing real exchange rate and its equilibrium level. The methodology also derives estimates of the speed at which the real exchange rates converges to the equilibrium level.

IV. Econometric Results and Their Robustness

The first column of Table 1 shows the estimation of the VECM employing the following variables: the real effective exchange rate in log terms (LREERS), real interest rate relative to trading partners (RIRR), logarithm of the real GDP per capita relative to trading partners (LRGDPPCR), real commodity prices—choosing the more general one, based on 5 commodities and deflated by the industrial countries export deflator—(LPR2COMM5), openness (OPENY, i.e. the average ratio to GDP of exports and imports), the ratio of fiscal balance to GDP (FBYA), and the ratio to GDP of net foreign assets of the banking system (NFAOFPY).[13] The specification includes four lags for the changes in each variable and centered seasonal dummies: such a structure is quite common when employing quarterly data (as discussed below, the lag structure is supported by appropriate tests).

[13] The role of different commodity prices and other variables is also investigated. The net foreign asset variable relates to commercial banks as well to the monetary authorities, and includes the forward book of the latter. Note that whether the net foreign assets of the banking system are able capture the long run behavior of the net foreign assets of the economy is an empirical issue (quarterly data were not available for the variable at the economy-wide level).

The second column of Table 1 presents results for the VECM estimated using the same variables as in the previous specifications, with the addition of dummies that control for the presence of outliers, so as to eliminate the effect of those outliers on the estimates.[14]

Both specification pass a number of tests. The cointegration tests indicate the presence of one cointegrating vector using a 1 percent significance level (see Table 1, column 1 and 2).[15] We have used the 1 per cent significance level, rather than the usual 5 per cent level, to address potential small sample bias in our estimates. The coefficients of the cointegrating vector are plausible, significant, and of the correct sign. All of the variables prove to be nonstationary (I(1)) when using the Johansen test (see Table 2, panel A), which (unlike standard stationarity tests) takes into account the cointegration space. Implicitly, this test indicates that the presence of cointegration is not driven by stationarity of any single variable. Hence the cointegration analysis is both appropriate (as variables are nonstationary) and meaningful (as not driven by stationarity of one variable). Furthermore, the exclusion test suggests that none of the variables—with the exception of LRGDPPCR—can be excluded from the long-run relationship (Table 2, panel B) at the 5 percent significance level. However, we retain LRGDPPCR in the specification, as the hypothesis of exclusion is borderline accepted in this specification and is often rejected in other specifications.

In Table 3 we present normality tests for this specification and these indicate that the hypothesis that the residuals have a normal distribution (panel A) is rejected due to excess kurtosis. Paruolo (1997) has demonstrated that in instances where normality is rejected for this reason, rather than skewness, the Johansen results are not affected.[16] Table 3 also indicates that all four lags are necessary in our VECM specification (the test in the first column of Panel B rejects the hypotheses that each of the four lag is jointly insignificant across equations). The lag structure appears to be correct: if a fifth lag is introduced, the test accepts the hypothesis that the additional lag is jointly insignificant across equations (Table 3, Panel B, second column). The diagnostic tests presented in Table 2 and 3 generally carry through all specifications in Table 1.

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[14] The four dummies introduced take the value of 1 for 1984 Q1, 1985 Q4, 1986 Q1, 1994 Q1, respectively. In these cases, residuals from the VECM estimated in column 1 had a size in excess of three times the standard deviation.

[15] The trace-statistic test suggest there may be two cointegrating vectors at the 5 percent significance level.

[16] In some of the specifications that we run the hypothesis of normality is accepted.

Table 1. Selected Results of the VECM

Regression number	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Number of cointegrating vectors:							
Trace Statistic							
5%	2	1	1	1	1	1	1
1%	1	1	1	1	1	1	1
Max Eigenvalue Statistic							
5%	1	1	1	1	1	1	1
1%	1	1	1	1	1	1	1
Estimates of the cointegrating relationship with the real exchange rate							
LREERS(-1)	1	1	1	1	1	1	1
RIRR(-1)	-0.03	-0.03	-0.04	-0.03	-0.04	-0.03	-0.04
	[-6.96]	[-7.03]	[-5.58]	[-6.67]	[-5.71]	[-6.66]	[-5.98]
LRGDPPCR(-1)	-0.14	-0.13	0.05	-0.09	0.08	-0.13	0.01
	[-1.88]	[-1.75]	[0.43]	[-1.16]	[0.71]	[-1.62]	[0.06]
OPENY(-1)	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	[5.97]	[5.87]	[3.70]	[5.67]	[3.99]	[5.90]	[4.64]
FBYA(-1)	0.02	0.02	0.01	0.02	0.01	0.02	0.01
	[4.31]	[5.60]	[1.95]	[5.02]	[1.45]	[4.90]	[1.64]
NFAOFPY(-1)	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
	[-5.09]	[-4.50]	[-3.24]	[5.24]	[-3.99]	[-5.37]	[-4.44]
LPR2COMM5(-1)	-0.46	-0.45					
	[-12.17]	[-11.75]					
LPRCOMM5(-1)			-0.48				
			[-8.51]				
LPR2COMM3(-1)				-0.46			
				[11.23]			
LPRCOMM3(-1)					-0.49		
					[-8.74]		
LPR2GOLD(-1)						-0.42	
						[-11.19]	
LPRGOLD(-1)							-0.43
							[-9.28]
C	-4.96	-4.95	-5.06	-4.98	-5.13	-4.45	-4.56
	[-57.41]	[-56.66]	[-35.92]	[-53.65]	[-36.53]	[-46.89]	[-37.11]
Estimates of the short term impact of net foreign assets on the real exchange rate (DLREERS)							
D(NFAOFPY(-1))	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
	[-2.62]	[-2.35]	[-2.64]	[2.19]	[-2.47]	[-2.19]	[-2.46]
Estimates of the speed of adjustment of the real exchange rate							
CointEq1	-0.08	-0.07	-0.10	-0.05	-0.09	-0.04	-0.09
	[-0.91]	[-0.92]	[-1.92]	[-0.61]	[-1.66]	[-0.58]	[-1.61]
Half lifetime of the deviation from equilibrium exchange rate in years	2.1	2.4	1.6	3.4	1.8	4.2	1.8

Note: *t*-statistics in square brackets.

Table 2. Johansen Test for Stationarity and Exclusion Test 1/
(Chi-squared test statistics)

	A. Johansen test for stationarity 2/		B. Exclusion test 3/	
	Regression (1)	Regression (2)	Regression (1)	Regression (2)
CHISQ	14.07	14.07	3.84	3.84
LREERS	47.10	58.10	29.65	31.47
RIRR	52.49	63.13	28.18	34.40
LRGDPPCR	38.87	47.21	3.18	3.15
LPR2COMM5	57.71	71.36	31.79	38.29
OPENY	48.05	58.43	13.91	15.74
FBYA	44.42	55.23	12.20	21.04
NFAOFPY	49.94	57.92	9.90	8.55
C			27.75	29.16

1/ Significance level at 5 %.
2/ Ho: variable is stationary (if corresponding statistic is smaller than CHISQ).
3/ Ho: variable can be excluded (if corresponding statistic is smaller than CHISQ).

In order to assess the robustness of the results, several exercises have been performed. First, the main specification is also run with different measures of commodity prices, as this variable is found to be the most important variable explaining the long run behavior of the real exchange rate both in this study and in other studies related to countries similar to South Africa.[17] As shown in Table 1 (columns 3-7) the results are broadly similar. Second, sequentially dropping variables does not have major impacts on the other coefficients, apart from the case of variables that are already weak (such as LRGDPPCR).[18] Third, labor productivity in the manufacturing sector (as a ratio of trading partners labor productivity) does not perform as well as relative real GDP percapita as a proxy for the Balassa-Samuelson effect. In fact, if labor productivity is entered instead of LRGDPPCR, its coefficient is insignificant. This could be due to the large fluctuations in employment in South Africa, which alter the link between labor productivity and total factor productivity.

[17] The commodity price variable has the most stable and robust coefficient when alternative specifications are tried: even in a VECM with just the real exchange rate and commodity prices, the coefficient of the latter is -0.67, very close to the one presented in Table 1.

[18] These results are availabe from the authors upon request.

Table 3. VEC Tests
(Chi-squared test statistics)

Panel A. VEC Test for Skewness, Kurtosis, and Normality, of residuals. 1/ 2/

	degr. freedom	Regression (1) Probability	Regression (2) Probability
Skewness	7	0.14	0.52
Kurtosis	7	0.00	0.00
Normality	14	0.00	0.00

Panel B. VEC Lag Exclusion Wald Test 3/ 4/

	Regression (1) Joint	Regression (1) Joint	Regression (2) Joint	Regression (2) Joint
DLag1	137.2	128.8	131.9	120.1
	[0.00]	[0.00]	[0.00]	[0.00]
DLag2	70.9	67.6	71.9	66.1
	[0.02]	[0.04]	[0.02]	[0.05]
DLag3	122.2	122.3	113.3	114.7
	[0.00]	[0.00]	[0.00]	[0.00]
DLag4	82.4	87.7	80.9	80.5
	[0.00]	[0.00]	[0.00]	[0.00]
DLag5		47.6		49.8
		[0.53]		[0.44]
degr. freedom	49	49	49	49

1/ Ho: residuals have no Skewness, no-Kurtosis, and are Normal, respectively, if probability value is larger than chosen significance level.

2/ Skewness and Kurtosis is based on joint Chi-square test;
Normality is based on joint Jarque-Bera test;
Orthogonalization is based on Cholesky (Lutkepohl).

3/ Ho: Lag's coefficients are jointly non-significantly different from 0 (i.e. can be excluded) if probability value is larger than chosen significance level.

4/ Numbers in [ ] are probability values.

A. The Long-Run Relationship

Table 1 shows evidence of cointegration between the real exchange rate and the explanatory variables. Accordingly, the long-run relationship between the real exchange rate and these variables can be identified as follows:

- An increase in the real interest rate relative to trading-partner countries of 1 percentage point is associated with an appreciation of the real effective exchange rate of around 3 percent.
- An increase in real GDP per capita relative to trading-partner countries of 1 percent is associated with an appreciation of the real effective exchange rate of 0.1-0.2 percent.[19]
- An increase in real commodity prices of 1 percent is associated with an appreciation of the real effective exchange rate of around 0.5 percent.
- An increase in openness of 1 percentage point of GDP is associated with a depreciation of the real effective exchange rate of about 1 percent.
- An improvement in the fiscal balance of 1 percentage point of GDP is associated with a depreciation of the real effective exchange rate of around 2 percent.
- An increase in net foreign assets of 1 percentage point of GDP is associated with an appreciation of the real effective exchange rate of around 1 percent.

B. The Short-Run Relationship

Short-run effects are generally found to be insignificant across the various specification (and therefore not reported), with the exception of one. As shown in Table 1 by the coefficient of D(NFAOFPY(-1)), as increase in net foreign assets of the banking system is likely to depreciate the real exchange rate in the short-run (i.e. one quarter). This effect is likely to be due to the temporary impact of changes in reserves on the nominal exchange rate. Hence, an improvement in the net foreign asset position (like the one arising from the reduction of the forward book in recent years) is likely to have induce a temporary depreciation of the exchange rate, but in the long run it is likely to be associated with an appreciation of the equilibrium real exchange rate.

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[19] The coefficient of the proxy for Balassa Samuelson effect appears rather low. However, such coefficient is biased downwards by the high correlation between such a proxy and the net foreign asset variable. In a specification without NFAOFPY, most coefficients remain unchanged while the coefficient of LRGDPPCR raises—in absolute value—to about 0.4, which is closer to the theoretical prediction for the Balassa-Samuelson effect (i.e. the share of non-tradables in GDP).

V. Equilibrium Real Exchange Rate

The long-run relationship summarized above permits the calculation of an estimate of the equilibrium real exchange rate. Ideally, this measure can be defined as the level of the real exchange rate that is consistent in the long run with the equilibrium values of the explanatory variables. It can therefore be obtained by evaluating the cointegrating relationship at these equilibrium levels.

As evident from Figure 2, however, the explanatory variables can exhibit a substantial degree of "noise" or fluctuations. One way of neutralizing the impact of the temporary fluctuations in these variables on the evaluation of the equilibrium real exchange rate is the application of smoothing techniques to eliminate short run fluctuations in explanatory variables, so as to derive a proxy for the long run equilibrium values of these variables. Figure 3 shows an example of the equilibrium real exchange rate derived in this manner and compares the outcome with the actual real effective exchange rate.[20]

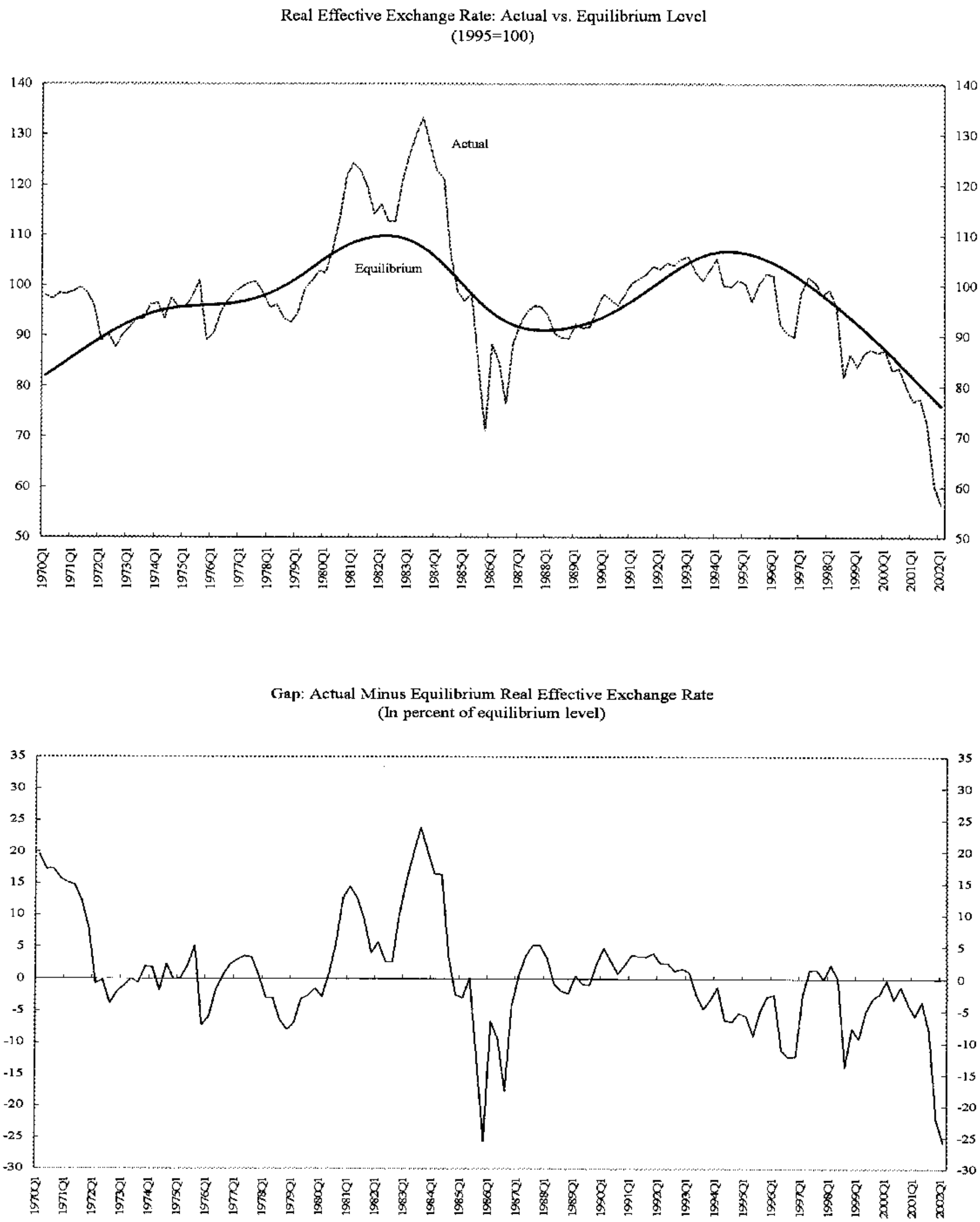
According to Figure 3, the actual rate appears to have been close to its estimated equilibrium level in the first half of the 1990s, but it subsequently depreciated by much more than the equilibrium rate, that is, about 44 percent versus 28 percent, respectively. The decline of the equilibrium level over this period arose from conflicting factors. On the one hand, the decline in commodity prices, the increase in openness, the improvement in the fiscal balance, and the slower productivity growth relative to trading partners accounted for a depreciation of the equilibrium real exchange rate in the order of 13 percent, 15 percent, 12 percent, and 1 percent, respectively. On the other hand, the increase in net foreign assets and in real interest rate differential partly offset these forces by contributing to an appreciation in the order of 7 and 5 percent, respectively.

A. The Gap Between the Real Exchange Rate and Its Equilibrium Level

At any point in time, the real exchange rate is likely to differ from the equilibrium level either because a change in the explanatory variables alters the equilibrium level or because temporary factors (such as financial market pressure on the rand) move the real exchange rate away from it.

[20] Choosing the degree of smoothing is admittedly arbitrary. The equilibrium real exchange rate in Figure 2 is derived by applying to the explanatory variables a Hodrick-Prescott filter with a smoothing factor of 1,600, which is what Hodrick and Prescott suggested for quarterly data. A larger (smaller) factor would generate a smoother (less smooth) equilibrium real exchange rate path. It should be noted that the Hodrick-Prescott filter tend to perform poorly at both ends of the series.

Figure 3. Actual and Equilibrium Real Effective Exchange Rate, 1970-2001.



One of the aims of the study is to quantify this gap in the first quarter of 2002, when the rand was recoverying from the large depreciation that occurred in late 2001. When the equilibrium values of the explanatory variables are smoothed, as in Figure 3, the gap is found to be in the order of 26 percent. Alternatively, one can evaluate the deviation of the real effective exchange rate from a notional equilibrium level, based on a set of economic priors for the equilibrium values of the explanatory variables. Accordingly, a gap of 24 percent would result from the following plausible values for the exogenous variables:

- a real interest rate differential of about 250 basis points, that is, roughly the level of the yield spreads in 2001;
- a relative real GDP per capita equal to the actual level in the first quarter of 2002 (given that the variable exhibits a clear and relatively smooth trend, its actual value can be considered as a good proxy for its equilibrium value at each point in time);
- a level of real commodity prices equal to the average for the period 1995-2001 (such a choice appears appropriate in light of the quick rebound of commodity prices in 2002);
- a degree of openness equal to the average for the period 1995-2001 (close to 50 percent of GDP);
- a fiscal deficit of about 2 percent of GDP, which corresponds roughly both to the average level since 1998 and to the authorities' target; and
- a net foreign assets position relative to GDP equal to the actual level in the first quarter of 2002.

As the large fluctuations in commodity prices (evident from Figure 2) are found to contribute heavily to movements in the real exchange rate, it is interesting to evaluate the gap for the first quarter of 2002 at the levels of commodity prices prevailing in 1995 or at the beginning of 2002, while keeping the other variables unchanged at the values indicated above. In the former case, the gap would amount to 28 percent, while in the latter case the gap would correspond to only 19 percent.

B. Speed of Adjustment

When a gap between the real exchange rate and its equilibrium level arises, the real exchange rate will tend to converge to its equilibrium level. Depending on the cause of the gap, the adjustment requires that the real exchange rate either moves progressively toward a new equilibrium level, or returns from its temporary deviation to the original equilibrium value. The estimates derived in this study (see Table 1) suggest that, on average, about 8 percent of the gap is eliminated every quarter, implying that in the absence of further shocks about half of the gap would be closed within two to two-and-one-half years. However, large deviations, such as those experienced in 2001 and 2002, could take less time to absorb, as suggested by the recent literature on non-linear exchange rate models (see Sarno and Taylor, 2002).

VI. CONCLUSIONS

Drawing on existing literature, this study estimates a long-run equilibrium real exchange rate path for South Africa. The main explanatory variables were found to be commodity price movements, productivity and real interest rates differentials vis-à-vis trading-partner countries, measures of openness, the size of the fiscal balance, and net foreign assets position. The analysis suggests that in the first half of the 1990s the real exchange rate was close to its equilibrium level and that about two-thirds of its subsequent depreciation until early 2002 can be accounted for by movements in the explanatory variables. In the first quarter of 2002, the average value of the rand (R11.5 per U.S. dollar) appeared to be about 25 percent more depreciated than the level (R8.8 per U.S. dollar for the first quarter of 2002) consistent with the estimated equilibrium of the real exchange rate. Different ways of distinguishing between permanent and temporary movements in the explanatory variables provide similar results.

These calculations may, however, overestimate the equilibrium exchange rate to the extent that they do not account for structural factors, such as high unemployment and the HIV/AIDS pandemic; taking these into account could generate a smaller gap than that estimated.

If the real exchange rate deviates from its equilibrium level owing to temporary factors, it can be expected to revert to equilibrium fairly quickly, in absence of further shocks. The study suggests that about half of the gap is normally eliminated within two to two-and-one-half years. However, large deviations are likely to be absorbed at a faster pace.[21]

The paper also shows that the rapid reduction of the forward book in recent years may have driven only a temporary negative pressure on the exchange rate. In the long run, such an improvement in the net foreign asset position is likely to be associated with an appreciation of the equilibrium real exchange rate.

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[21] After overshooting at the end of 2001, the real exchange rate regained value of the course of 2002 and the first quarter of 2003. From the first quarter of 2002 to the beginning of March 2003, the real exchange rate appreciated by nearly 40 percent, reflecting a nominal effective appreciation of about 28 percent and an inflation differential vis-à-vis trading partners of about 10 percent. The large appreciation of the real exchange rate was more than enough to close the gap that prevailed in the first quarter of 2002. At the same time, however, the strengthening of commodity prices may have induced an appreciation of the equilibrium real exchange rate. Assuming the commodity prices were to persist at the high levels prevailing at the beginning of March 2003 (say US$350 per ounce for gold, US$650 per ounce for platinum, and US$26 per tonne for coal), the dollar value of the rand consistent with the estimated equilibrium real exchange rate (and therefore with a zero gap) would be calculated at R7.8 per US dollar for early March 2003.

Variables: Definitions and Source

The dataset consists of quarterly data from 1970 to the first quarter of 2002 for South Africa and the four major trading partners.

- **LREERS: Real effective exchange rate.** In logarithmic terms. Source: South African Reserve Bank (SARB).

- **RIRR: Real interest rate relative to trading partners.** Nominal interest rate on 10 year bond, minus inflation in past four quarters. Foreign variable calculated as the weighted average of four major trading partners, based on the SARB weights for the real effective exchange rate: Germany (proxy for European Union, 47 percent), United States (20 percent), United Kingdom (20 percent), and Japan (13 percent). Sources: SARB and International Monetary Fund, *International Financial Statistics* (*IFS*).

- **LRGDPPCR: Real GDP per capita relative to trading partners.** In logarithmic terms. Normalized for each country to 1 in 2000. Foreign variable calculated as above. Sources: SARB; *IFS;* and World Bank.

- **LPR2COMM5 and other indicators: Real commodity prices.** In logarithmic terms. Six different indicators of commodity prices were constructed, based on three choices of aggregating the main commodities exported by South Africa and two ways of deflating them. The former encompassed weighted averages of the five, three, or single most exported commodity(ies)—excluding diamonds, for which a price series is not available. The latter relate to the price deflator for developed countries exports or to the US CPI level. The combination generates respectively: LPR2COMM5, LPR2COMM3, LPR2GOLD, LPRCOMM5, LPRCOMM3, and LPRGOLD. Sources: Cashin, Cespedes, and Sahay (2002); DataStream; and *IFS*.

Main commodities exported and relative weights

Commodity	Weight	Weight (5)	Weight (3)	Weight (gold)
Gold	0.604	0.710	0.903	1
Coal	0.151	0.177	0	0
Iron	0.033	0.039	0.049	0
Copper	0.032	0.038	0.048	0
Platinum	0.031	0.036	0	0

- **OPENY: Openness**. Ratio of exports and imports to GDP. Sources: SARB, *IFS*.

- **FBYA: Fiscal balance**. Ratio of the annualized fiscal balance to GDP. Sources: SARB and *IFS*.

- **NFAOFPY: Net foreign assets including the forward book**. Ratio of the end of period net foreign assets of the banking system (monetary authorities and commercial banks) to GDP. The numerator includes the open forward position, as a liability, from the first quarter of 1984 onwards, when data becomes available. Sources: *IFS*; SARB; and authors' calculations.

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