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"THE SUSTAINABILITY OF INDIA'S CURRENT ACCOUNT"

(1950-2003): EVIDENCE FROM PARAMETRIC AND NON-PARAMETRIC UNIT ROOT AND COINTEGRATION TESTS

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The Sustainability of India's current account (1950-2003): Evidence from parametric and non-parametric unit root and cointegration tests

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Abstract

This study conducts an investigation into the sustainability of the Indian current account over the study period 1950-2003. It is argued that a necessary condition for current account sustainability is that exports and imports are cointegrated. After testing for unit roots that allow for a structural break, we employ parametric tests for cointegration: based on Johansen (1995) and Saikonnen and Lütkepohl (2000) as well as the nonparametric procedure proposed by Breitung (2002) and Breitung and Taylor (2003) that does not assume linearity. By employing these procedures recursively, two distinct regimes are identified characterised by whether or not imports and exports are cointegrated. The regime of non-cointegration runs until the late 1990s and the second regime of cointegration is present after that. This latter regime coincides with the liberalisation of the Indian economy.

Keywords: India, current account, sustainability, cointegration, nonparametric cointegration, rolling and recursive *p*-values.

JEL: C5, F1, F4

1. Introduction

In recent years many researchers have expressed great concern at the current account deficits exhibited by less developed countries (LDCs).[1] A variety of factors have been advanced in explaining these imbalances. With respect to the 1980s and 1990s where large increases in LDC current account imbalances were observed, the main reasons have included the dramatic fall in commodity prices, the global recessions of 1981-82 and 1991-93, which caused a contraction in world trade and increased protectionism in the developed world against LDC exports. In recent years, the Indian economy has become more open, especially since 1991, and it is now more integrated with the world economy, with an expanding export sector. Against this background, the purpose of this paper is to assess whether Indian current account deficits are sustainable in the long run. For this purpose, parametric and non-parametric unit root and cointegration tests are applied to annual Indian data over the study period 1950-2003. Additionally, we seek to empirically assess the initial (and ongoing) impact of India's process of economic liberalisation on the current account.

There are several points of research interest related to this study. First, a sustainable current account is consistent with the sustainability of external debts. Given that a policy of curtailing imports as a means of reducing current account deficits has been regarded as unacceptable by LDCs on the grounds of stifling growth and development objectives, LDCs have typically opted to fund widening current account balances through further borrowing but this has led to unacceptably high debt-service to exports ratios. The current account deficits have therefore contributed towards LDC debt and a potential downward spiral of negative basic transfer (loss of foreign exchange and a net outflow of capital), which have contributed to dwindling foreign reserves and stalled development prospects. However, a sustainable current account might indicate there is no incentive for the country to default on its external debts. In the case of developed countries, temporary current account deficits are not necessarily 'bad' as they reflect the reallocation of capital to countries where capital is more productive. However persistent deficits in the case of both

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[1] See, for example, Todaro and Smith (2003).

developed countries and LDCs are more serious. They may lead to increased domestic interest rates to attract foreign capital and, in addition to this, the accumulation of external debt owing to persistent deficits. This would imply increasing interest payments that impose an excess burden on future generations.

A second key reason for carrying out this research is that this is the first study that conducts a formal cointegration analysis of Indian current account sustainability using a range of unit root and cointegration tests. Potential problems with respect to investigating Indian current account sustainability using standard Johansen cointegration tests are twofold: on the one hand they assume linearity and on the other hand, the issue of structural breaks is not addressed. This paper utilises a non-parametric cointegration test (Breitung 2002) that allows us to relax the restrictive linearity assumption. We also employ a recently developed parametric cointegration test (Saikkonen and Lutkepohl 2000a, b, c) (S&L) which is asymptotically superior to one proposed by Johansen (1995). Third, the sustainability of the current account is consistent with intertemporal models of current account deficits, and hence supports its validity (see Husted 1992). The modern intertemporal model of current account determination uses consumption smoothing behaviour to predict that the current account acts as a buffer to smooth consumption in the face of shocks. This implies that exports and imports should be cointegrated with a coefficient of unity. Fourth, as argued below, the majority of the existing literature has focussed on OECD countries. This study contributes to the current account sustainability debate in LDCs for which there is a far more limited number of studies. Lastly, this study reinforces the results of previous studies that highlight the limited role that exports played prior to the 1991 liberalisation for the Indian economy (see Sharma and Panagiotidis 2005 who find evidence against the export-lead growth hypothesis for India).

The paper is set out as follows. Section 2 discusses the relevant literature. The third section describes the data and methodology. The fourth section discusses the results. We find evidence that suggests that exports and imports are cointegrated. However, the restrictions that satisfy sustainability are only satisfied in eight cases. The final section concludes.

2. Literature

Recent studies of LDCs include Coakley and Kulasi (1997) who find that the trade balance is stationary and therefore sustainable for India but not Korea and Taiwan and Chortareas et al (2004) who document support for external debt sustainability in a number of Latin American countries. Early studies that investigate the stationarity of the current account deficit have mainly examined OECD countries and include, *inter alia*, Trehan and Walsh (1991) and Wickens and Uctum (1993) who look at the US, Otto (1992) who looks at the US and Canada, Liu and Tanner (1996) who examine the G7 countries, and Gundlach and Sinn (1992) who examine a larger sample of twenty three countries. These studies generally find that current accounts are non-stationary for several major industrialised countries. Finally, using US data for 1967-89, Husted (1992) finds that the US imports and exports are cointegrated, though with an increase in the equilibrium deficit since 1983.

More recently, Wu (2000) and Wu *et al.* (2001) confirm sustainability of OECD current account deficits using panel data unit root and cointegration tests. Similarly, Coakley *et al.* (1999) look at the case of LDCs using panel data unit root tests. However, these studies are not country-specific in the sense that they focus on the group estimates of the long-run relationship between exports and imports without detailed consideration of which members from within the panel are responsible for non-rejection or rejection of the sustainability hypothesis. This issue is emphasized by the panel data study of Holmes (2006) who finds that sustainability is more likely to hold for the non-Euro rather than the Euro based economies.

2.1 India’s case

Previous research on India’s current account balance is most often carried out within the wider context of capital flows, exchange rate adjustments and India’s debt position (see Acharyya 1994, Singh 2002, Go and Mitra 1998, Shah and Patnaik 2005, and Anoruo and Ramchander 1998). Research on the evolution of, and adjustment patterns for, India’s current account is limited and most research tends to focus on capital flows, volatility issues and the role of capital controls and national debt (in relation to India's high fiscal deficit). The sustainability of India’s current account has rarely been addressed systematically in the literature, and possible co-integrating relationships are not examined in a parametric or nonparametric framework. Shah and Patnaik (2005) touch upon some issues related to the sustainability of current account deficits, but mainly concern themselves with an examination of institutional factors, policy rules and the effects of capital flows. Razmi (2005) tests the validity of the balance of payments constrained growth (BPCG) model for the case of India, using the Johansen framework and finds support for the BPCG model over the long run only.

In its early industrialisation period (1950s to the 1970s), India had a low savings rate ranging between 9.8% and 17.2% (*RBI: Handbook of Statistics on the Indian Economy* 2004). Indian economic planners were well aware of the opportunity to use current account deficits and net capital inflows to supplement domestic savings and to increase the levels of investment within the economy, so as to attain higher levels of growth. However, persistent large-scale trade deficits can be burdensome because of the associated transfer of wealth to the rest of the world and the burden imposed on future generations. In the context of low levels of savings, low levels of foreign direct investments and capital flows, and low levels of investment in the domestic economy, high current account deficits can often be viewed as a regrettable necessity in order to augment investment and growth. In the past, low export levels, pegged exchange rates and low trade to GDP ratios have also contributed to a significant stock of external debt. Such thinking is reflected in the following (Mohan 1996:49):

> The sustainability of […] economic growth would require continuing high growth in exports. … If exports manage to increase to these levels, it would become feasible for India to sustain a wider current account deficit which is required for the non-inflationary absorption of external capital inflows. It is suggested that a sustainable level of current account deficit would increase from the current level of 1.5 per cent of GDP to 2.5 per cent in 2000-01 and 3 per cent in 2005-06. It would then be possible for the net capital inflow to rise from the current level of about $7 billion to $8 billion to about $17 billion to $20 billion by 2000-01 and about $25 billion to $30 billion by 2005-06.

These figures were exceeded by 2003-04 (Shah and Patnaik 2005: 5-6). Exports reached $118 billion (or 18% of GDP) and net capital inflows reached $20.5 billion). In spite of this, current account deficit did not rise further (as envisaged in Mohan 1996), but India instead achieved a current account *surplus* of 1.7% of GDP in 2003-04. India's policy planners have favoured current account deficits, as elaborated in the X Plan (Planning Commission of India 2002: 100):

> During the Ninth Plan period, India's balance of payments position remained mostly comfortable [1997-2002]. The current account deficit narrowed down and on the average was 0.8 per cent of gross domestic product (GDP), less than one half of the 2.1 per cent envisaged in the plan.

India's trade performance was for a long time characterized by a low trade to GDP ratio and a highly repressed capital account. However, this situation coexisted with strong institutions and well-developed legal and accounting norms, a history of private equity ownership and trading and an absence of default. India's policy reform and trade reforms have aimed to augment domestic GDP growth by attracting FDI and portfolio flows, even though some capital controls remain. Shah and Patnaik (2005) argue that even though microeconomic benefits have been realized from the presence of FDI and the entry of foreign investors, a sustainable macroeconomic framework for India's current account deficit and for augmenting domestic investment by making use of inward capital flows is not yet in place.

3. Data and Methodology

This study employs annual Indian data for imports, exports and the current account over the study period 1950-2003. All data are expressed as a percentage of GDP. The required data for imports and exports expenditure, net interest payments on debt and GDP are obtained from *International Financial Statistics* and the Reserve Bank of India. This is the longest period permitted by data availability. The data are presented in Figure 1.

3.1 Unit Root Test with Structural Break

Unit root testing is a key part of our investigation in terms of current account stationarity as well as the time-series properties of exports and imports. If there is a shift in the time series, it should be taken into account in testing for a unit root because the ADF test may be distorted if the shift is simply ignored. Saikkonen and Lutkepohl (2002) and Lanne et al (2002) have proposed the following model:

$$y_t = \mu_0 + f_t(\theta)'\gamma + u_t$$

where θ and γ are unknown parameters or parameter vectors and the errors u_t are generated by an AR(p) process. The shift function, $f_t(\theta)'\gamma$, could be (*i*) a simple shift dummy variable with shift data T_b, (ii) based on the exponential distribution function which allows for nonlinear gradual shift to a new level starting at time T_b and (iii) a rational function in the lag operator applied to a shift dummy. Saikkonen and Lutkepohl (2002) and Lanne et al (2002) have proposed unit root tests based on estimating the deterministic term by the generalised least squares (GLS) procedure and subtracting it from the original series. Thereafter an ADF-type test is performed on the adjusted series. If the break date is unknown, the authors recommend choosing a reasonably large AR order in the first step (based on simulation results) and then picking up the break data that minimises the generalised sum of squares errors of the model in first differences.

3.2 Specifying the Cointegrating Rank

Three methodologies are used to test for cointegration between exports and imports; the trace test developed by Johansen (1995), the two-step procedure proposed by (Saikkonen and Lutkepohl 2000a, b, c) and the nonparametric test for cointegration proposed by Breitung (2002).

In Johansen's (1995) notation, we write a p-dimensional Vector Error Correction Model (VECM) as:

$$\Delta y_t = \Pi^* \begin{bmatrix} y_{t-1} \\ 1 \end{bmatrix} + \sum_{j=1}^{p-1} \Gamma_j \Delta y_{t-j} + u_t$$

where $\Pi^* = \left[\Pi : \nu_0^*\right]$ is $(K \times (K+1))$. The intercept can be absorbed into the cointegrating relations; thus $\Pi^* = \alpha\beta^{*\prime}$ has rank r. The trace test is of the form:

$$LR(r_0) = -T \sum_{j=r_0+1}^{K} \log(1-\lambda_j)$$

where the λ_j are the eigenvalues obtained by applying reduced rank regression techniques.

In Saikkonen and Lutkepohl (2000a, b, c), two-step procedures are considered in which the mean term is estimated in a first step by a feasible GLS procedure. Substituting the estimator for μ_0 in the equation below, one could apply an LR-type test based on a reduced rank regression. The resulting test statistic has an asymptotic distribution that is different from the one obtained for the intercept version. In fact asymptotically the power of the test is superior to the one obtained from Johansen (1995) (Saikonnen and Lutkepohl 1999).

$$\Delta y_t = \Pi(y_{t-1} - \mu_0) + \sum_{j=1}^{p-1} \Gamma_j \Delta y_{t-j} + u_t$$

The Johansen (1995) and the Saikonnen and Lutkepohl (2000) procedures, like many others, require estimation of various structural and nuisance parameters. For example, a vector autoregressive (VAR) lag order must be specified and the lag parameters. To get around this problem we employ the recently developed nonparametric test for cointegration due to Breitung (2002) and Breitung and Taylor (2003). No lag structure or deterministic terms need to be estimated.

The latter has a number of advantages: Firstly, the short-run component does not affect the asymptotic null distribution of the test statistic and as a result the test is robust against deviations from the usual assumption of linear short-run dynamics. Secondly, the outcome does not depend on the lag length and the inclusion of a trend or a constant. By employing this we investigate the possibility of non-linear relationship between the two variables.

3. Results

We consider four unit root tests: (i) the Augmented Dickey Fuller (ADF), (ii) the Phillips-Perron (PP), (iii) the Breitung (2002) and Breitung and Taylor (2003) and (iv) one proposed by Saikkonen and Lutkepohl (2002) and Lanne et al (2002) (unit root test with structural break). The first two are well known in the literature. Breitung (2002) and Breitung and Taylor (2003) propose a nonparametric unit root test which is robust to structural breaks.

Saikkonen and Lutkepohl (2002) and Lanne et al (2002) have proposed a test for processes with level shift. A shift dummy was used in this study based on the residuals analysis. The break data is chosen based on simulation results and the AR order on the relevant information criteria. The unit root tests for each series are presented in Tables 1 and 2. There is evidence that both exports and imports are integrated of order one i.e. they are *I(1)*. All tests suggest that the first differences of the series are stationary. A break in 1958 was found for both imports and exports. This was caused by the severe and increasing trade deficit, severely depleted foreign exchange reserves, an overvalued rupee and high inflation that characterised the entire 1950s.

We also test the current account, defined as the difference between exports and imports (expressed as a percentage of GDP) for a unit root employing the group of tests outlined above and we also use the test procedure suggested by Zivot and Andrews (1992). The results are presented in Tables 3, 4a and 4b and in Figures 2 and 3. Zivot and Andrews reject non-stationarity (and do not reject sustainability) at the 1% significance level whereas all the others do so at the 5% significance level (ADF, PP and Unit Root with Structural Break). Estimating recursively an DF type of regression (Figure 3) reveals that the null that $c(2)=0$ is rejected after 1965. In a rolling window framework (rolling estimates with a 42 observations window), the null that $c(2)=0$ is rejected all the time (see Figure 4). However, the Breitung test produces a simulated p-value of 0.068 and rejects non-stationarity at the 10% level. Zivot and Andrews (1992) and Saikkonen and Lutkepohl (2002) produce different break dates, as one might expect, since they make different assumptions (see also the Bai and Perron (1998) test for multiple unknown structural breaks in the Appendix).[2]

Having established that both exports and imports contain a unit root we can proceed to investigate the existence of a cointegrating relationship. Moreover, by employing rolling and recursive cointegration we reveal whether and how the relationship between imports and exports has evolved over time.

[2] With regard to the behaviour of C(1) in Figure 3, this is consistent with a current account that is reverting towards a decreasing mean value across the study period. This can be seen in the context of the earlier quote by Mohan (1996) who suggests that the size of sustainable current account deficit would increase to -3% by 2006.

Table 5 presents the results using all the available data. At the 5% significance level all three tests reject the null hypothesis of no cointegration. This provides evidence favouring the non-rejection of the hypothesis that the Indian current account is sustainable (the necessary condition). A similar conclusion for all three tests makes the latter statement even stronger. The (1,-1) restriction on β was accepted using a Wald test (see Table 6).

However, this is only part of the story. Over the study period India had different policy and exchange rate regimes among other factors that could alter the relationship between the exports and imports. At this point we would attempt to answer two questions: (i) would this result change if we employ an expanding window or would a researcher reach the same result if she was to employ the same methodology as existed a couple of years ago? (ii) would there be any difference if one was to employ a rolling window? If the cointegrating relationship has changed, then this approach can provide insights into structural change (see Hansen and Johansen 1999). Both expanding and rolling windows are employed.

Figures 5 and 6 provide the answer to both these questions. For each of the three tests, we provide the *p*-values for the null hypothesis of $r=0$, or no cointegration between exports and imports. Figure 5 provides the *p*-values from an expanding window (starting from 1950 to 1980 and adding one observation at a time). The null hypothesis of no-cointegration is rejected after 2001 in the Johansen framework, after 1995 in the S&L and after 1999 in the Breitung nonparametric test framework. Figure 6 presents the *p*-values using a rolling window of 41 observations (starting from 1950 to 1990, and dropping and adding one observation at a time). The null of no cointegration is rejected in 1997, 2000 and 2003 when employing the Johansen test, in 1995 and after 1999 with S&L test and never with the Breitung nonparametric test.

4. Conclusions

This study conducts an investigation into the sustainability of the Indian current account over the study period 1950-2003. It is argued that a necessary condition for current account sustainability is that exports and imports are cointegrated. We employ a range of parametric and nonparametric tests for cointegration that does not assume linearity and nonlinearity. There is evidence in favour of a sustainable current account that emerges in the late 1990s. This roughly in the time period that follows the 1991 liberalisation of the Indian economy. However, we also find evidence against the necessary condition of sustainability (cointegration) for the period prior to the late 1990s. This is consistent with the findings from other studies that point towards the relatively low importance of exports with respect to the Indian economy (see the discussion in Sharma and Panagiotidis 2005).

References

Acharyya, R. (1994) Liberalized Exchange Rate Management System and Devaluation in India: Trade Balance Effect, *Journal of Economic Integration,* **9** (4), 534-42.

Anoruo, E. and S. Ramchander (1998) Current Account and Budget Deficit: Evidence from India, *The Indian Economic Journal,* **45,** 66–80.

Bai J. and Perron P, (1998) Estimating and Testing Linear Models with Multiple Structural Changes, *Econometrica*, 66(1), 47-78,

Breitung, J. (2002) Nonparametric tests for unit roots and cointegration, *Journal of Econometrics*, **108**, 343-363.

Breitung, J. and Taylor, A.M.R. (2003), Corrigendum to "Nonparametric tests for unit roots and cointegration", *Journal of Econometrics*, **117**, 401-404.

Chortareas, G., Kapetanios, G. and Uctum M. (2004) An Investigation of Current Account Solvency in Latin America using non linear nonstationarity tests, *Studies in Nonlinear Dynamics and Econometrics*, 8(1), 1-17.

Coakley, J., and Hasan, F., and Smith, R. (1999) Saving, Investment and Capital Mobility in LDCs, *Review of International Economics*, 7, 4, 632-40.

Coakley, J., and Kulasi, F. (1997) The Cointegration of Long Span Saving and Investment, *Economics Letters*, 54, 1-6.

Go, D. S and P. Mitra (1998) Trade Liberalization, Fiscal Adjustment and Exchange Rate Policy in India, *World Bank Policy Research Working Paper* WPS 2020.

Gundlach, E., and Sinn, S. (1992), Unit Root Tests of the Current Account: Implications for International Capital Mobility, *Applied Economics*, June, 617-20.

Hansen, H. and Johansen, S. (1999), “Some tests for parameter constancy in cointegrated VAR-models”, *Econometrics Journal*, 2, 306-333.

Holmes, M.J. (2006), How Sustainable are OECD Current Account Balances in the Long-run?, *Manchester School*, 74, 626-43.

Husted, S. (1992), The Emerging US Current Account Deficit in the 1980s: A Cointegration Analysis, *Review of Economics and Statistics*, 74, 159-66.

Johansen, S. (1995) *Likelihood-Based Inference in Cointegrated Vector Autoregressive Models*, Oxford University Press, Oxford.

Lanne, M., Lütkepohl, H. and Saikkonen, P. (2002). Comparison of unit root tests for time series with level shifts, *Journal of Time Series Analysis*, 23, 667 – 685.

Liu, P., and Tanner, E. (1996), "International Intertemporal Solvency in Industrialised Countries: Evidence and Implications", *Southern Economic Journal*, 62, 3, 739-49.

Lütkepohl, H. and Kratzig, M. (2004), *Applied Time Series Econometrics*, Cambridge University Press.

Mohan, R. (1996), *The India Infrastructure Report (Expert Group on the Commercialisation of Infrastructure Projects)*, Committee Report: Ministry of Finance, Government of India.

Otto, G. (1992), "Testing a Present-Value Model of the Current Account: Evidence from US and Canadian Time Series", *Journal of International Money and Finance*, October, 414-30.

Planning Commission of India. (2002), 10th *Five Year Plan (2002-2007)*, Planning Commission: Yojana Bhawan, New Delhi.

Razmi, A. (2005). 'Balance of payments constrained growth model: The case of India', *University of Massachusetts (Amherst) Working Paper* No. 2005-05.

Reserve Bank of India. (2004), *Handbook of Statistics on the Indian Economy*, New Delhi: RBI.

Saikkonen, P. and Lütkepohl, H. (1999) Local power of likelihood ratio tests for the cointegrating rank of a VAR process, *Econometric Theory*, 15, 50-78.

Saikkonen, P. and Lütkepohl, H. (2000a) Testing for the cointegrating rank of a VAR process with an intercept, *Econometric Theory* 16: 373-406.

Saikkonen, P. and Lütkepohl, H. (2000b) Testing for the cointegrating rank of a VAR process with structural shifts, *Journal of Business & Economic Statistics* 18: 451-464.

Saikkonen, P. and Lütkepohl, H. (2000c) Trend adjustment prior to testing for the cointegrating rank of a vector autoregressive process, *Journal of Time Series Analysis* 21: 435-456.

Saikkonen, P. and Lütkepohl, H. (2002) Testing for a unit root in a time series with a level shift at unknown time, *Econometric Theory* 18:313-348.

Shah, A. and I. Patnaik (2005) 'India's experience with capital flows: The Elusive quest for a sustainable current account deficit', National Bureau of Economic Research, *NBER Working Paper* 11387.

Sharma, A. and Panagiotidis, T. (2005), An analysis if exports and growth in India: Some Empirical Evidence, *Review of Development Economics*, 9 (2), 232-248.

Singh, T. (2002). ‘India's Trade Balance: The Role of Income and Exchange Rates’, *Journal of Policy Modeling 24 (5): 437-52.*

Todaro, M., and Smith, S. (2003), *Economic Development*, 8th Edition, Addison-Wesley.

Trehan, B. and Walsh, C. (1991), "Testing Intertemporal Budget Constraints: Theory and Applications to US Federal Budget Deficits and Current Account Deficits", *Journal of Money, Credit and Banking*, May, 423-41.

Wickens, M., and Uctum, M. (1993), "The Sustainability of Current Account Deficits: A Test of the US Intertemporal Budget Constraint", *Journal of Economic Dynamics and Control*, May, 423-41.

Wu, J-L (2000), "Mean Reversion of the Current Account: Evidence from the Panel Data Unit Root Test", *Economics Letters*, 66, 215-22.

Wu, J-L, Chen S-L, and Lee, H-Y (2001), "Are Current Account Deficits Sustainable? Evidence from Panel Cointegration", *Economics Letters*, 72, 219-24.

Zivot, E. and Andrews, D. W.K. (1992), Further Evidence on the Great Crash, the Oil-Price Shock, and the Unit-Root Hypothesis, *Journal of Business & Economic Statistics*, **10(3)**, 251–270.

Figure 1 Imports and Exports and Current Account as % of GDP

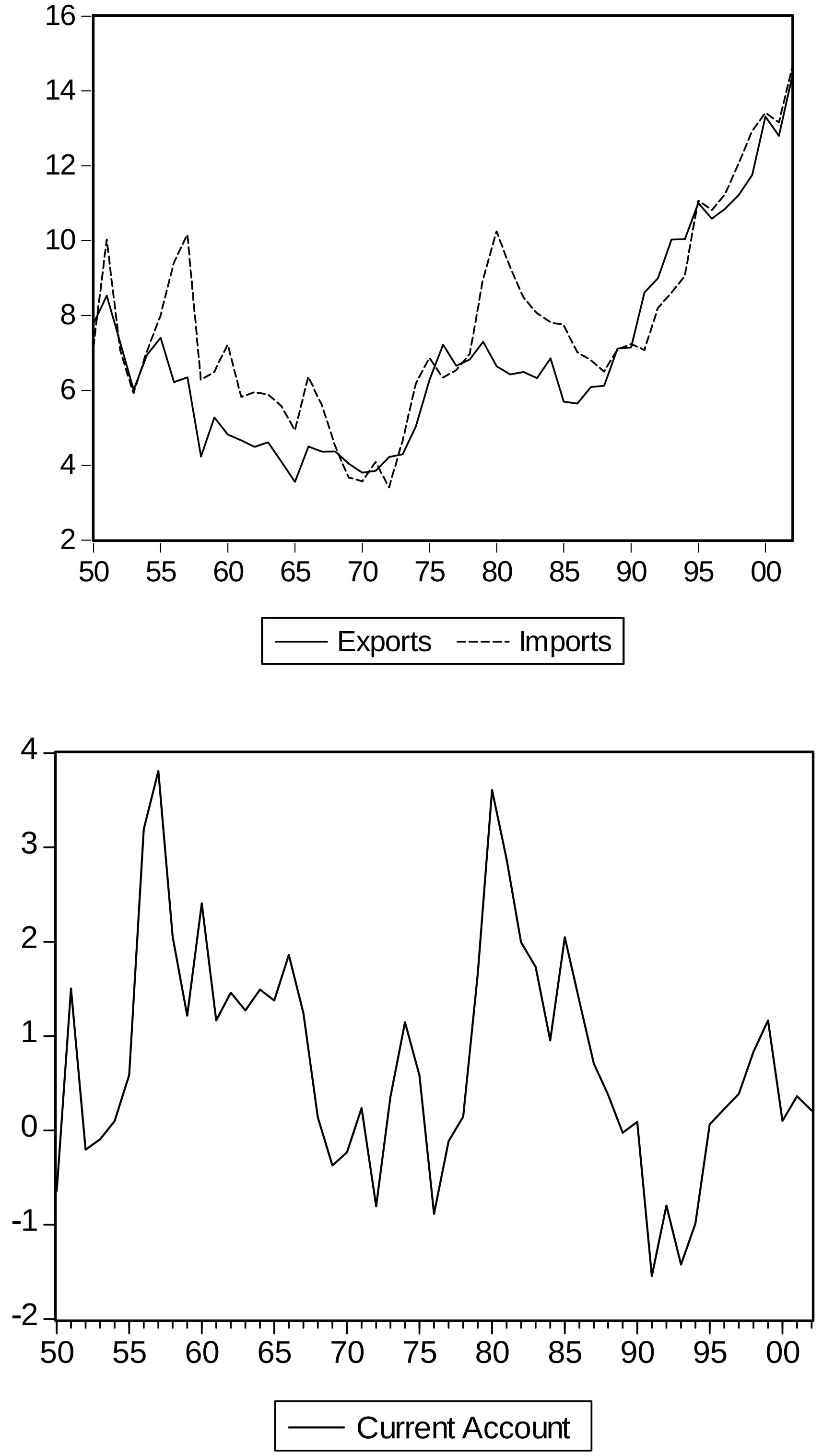


Figure 2: Zivot and Andrews Unit Root Test for the Indian Current Account

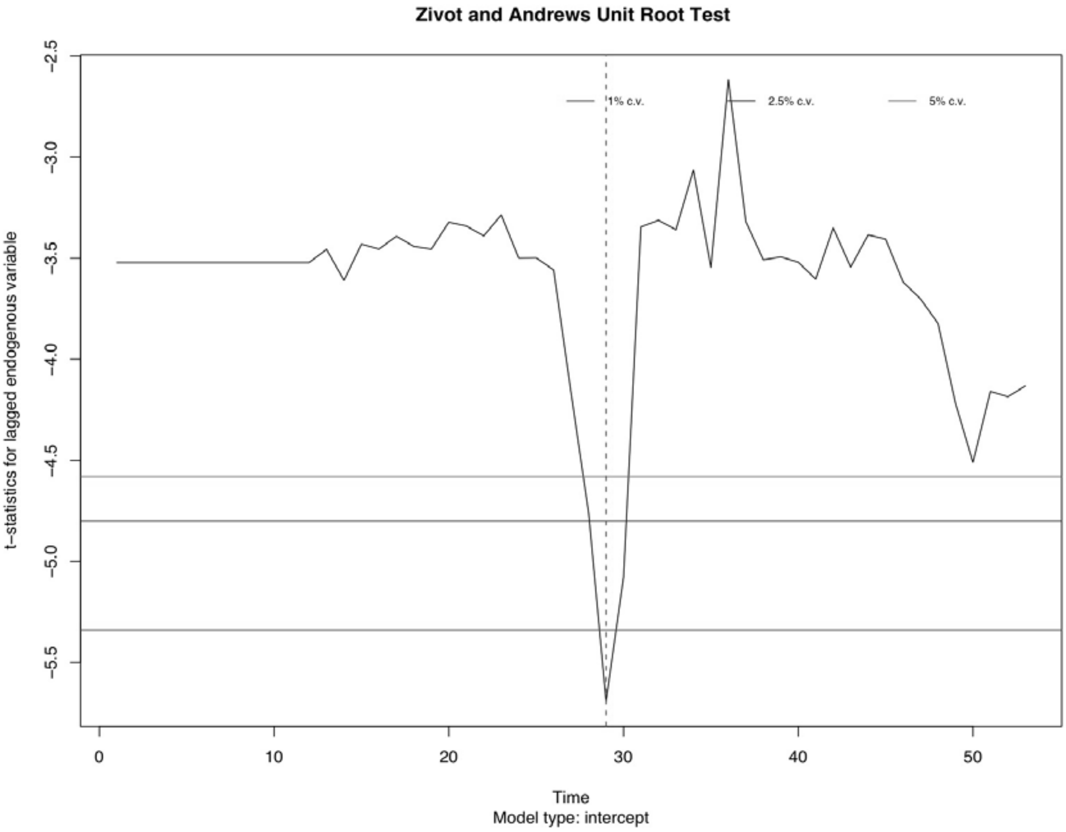


Figure 3: Recursive Estimates of DF regression: $\Delta y_t = c(1) + c(2) y_{t-1}$

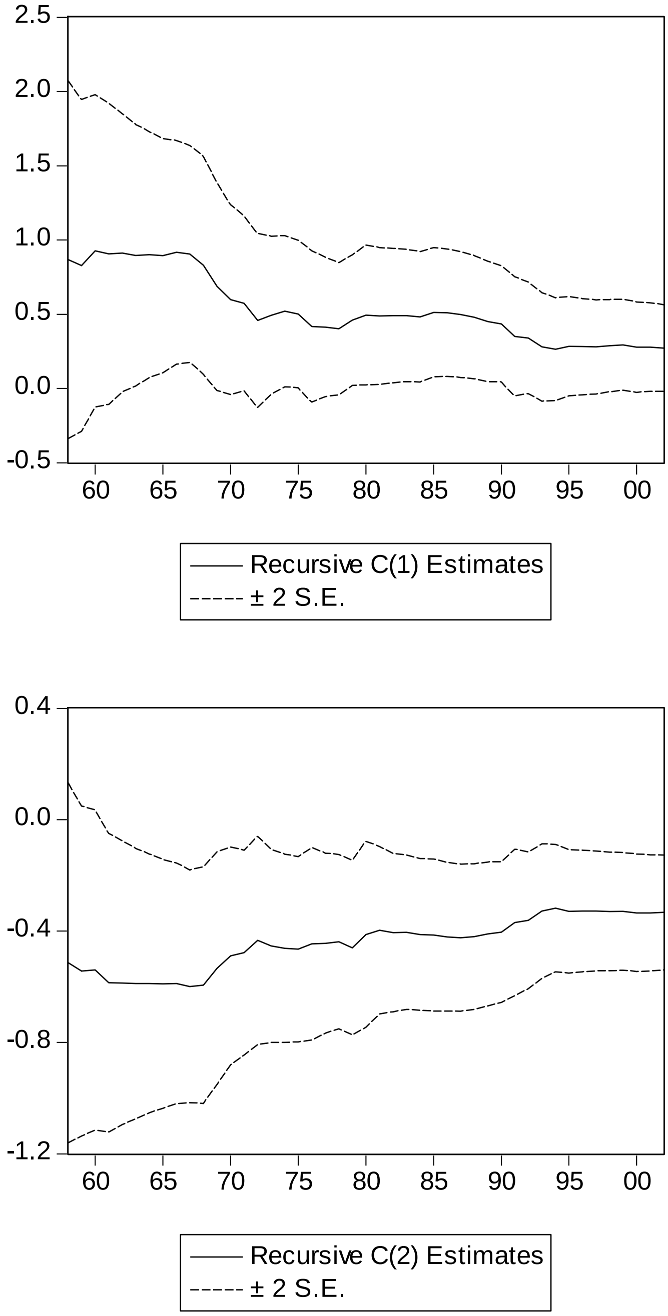
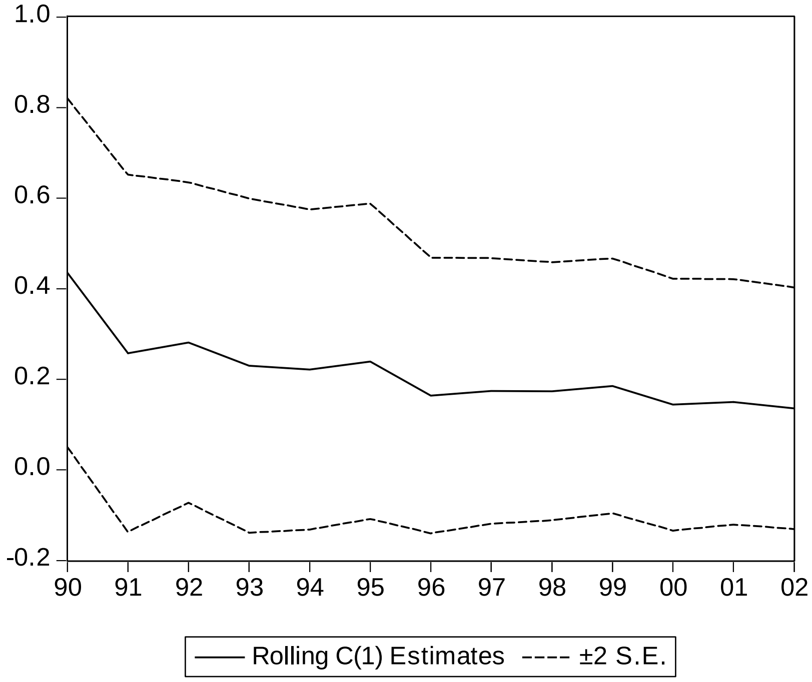


Figure 4: Rolling Estimates of DF regression: $\Delta y_t = c(1) + c(2)y_{t-1}$
(window of 41 observations)



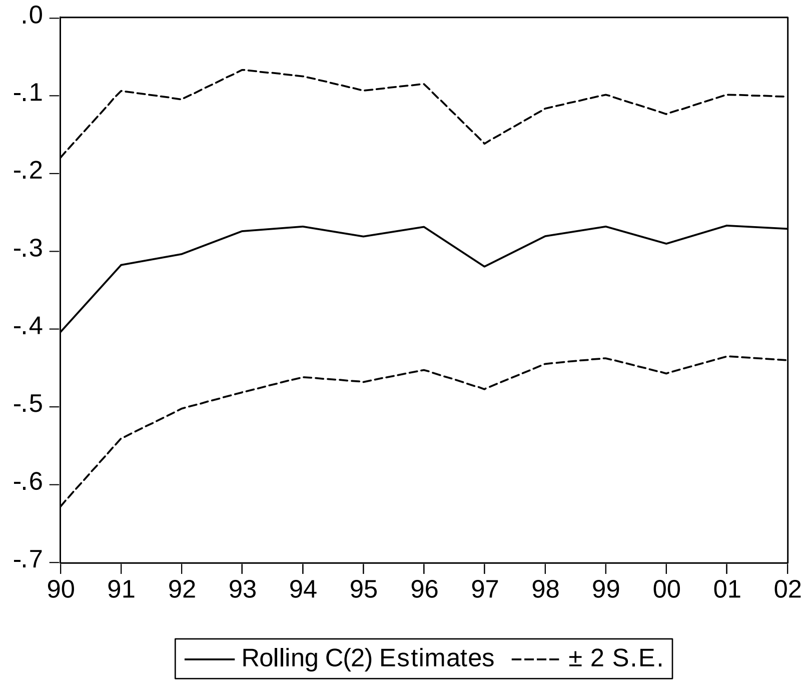


Figure 5: p-values from three cointegration tests (expanding window)

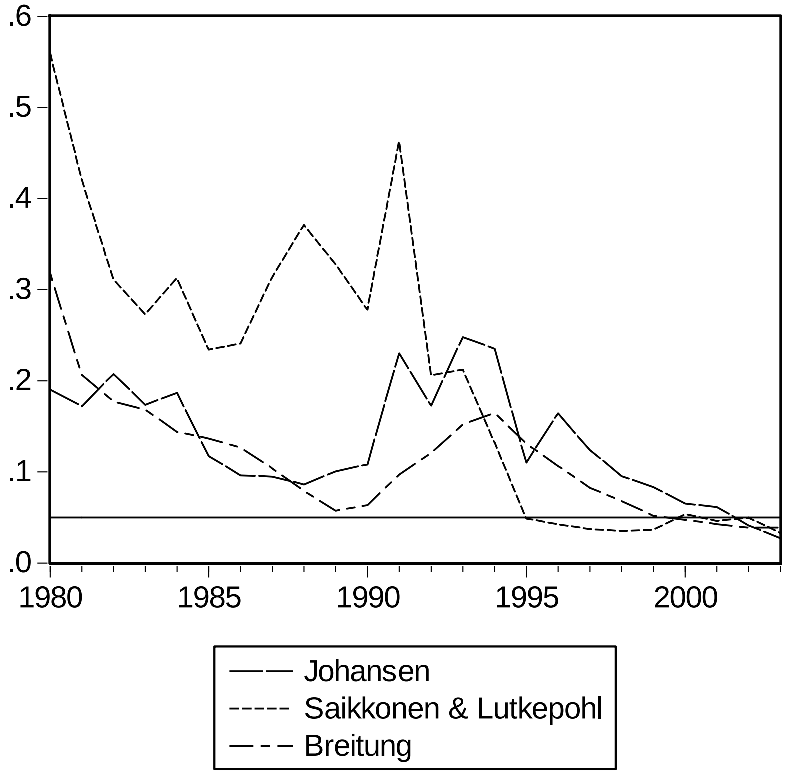


Figure 6: p-values from three cointegration tests (rolling window of 41 observations)

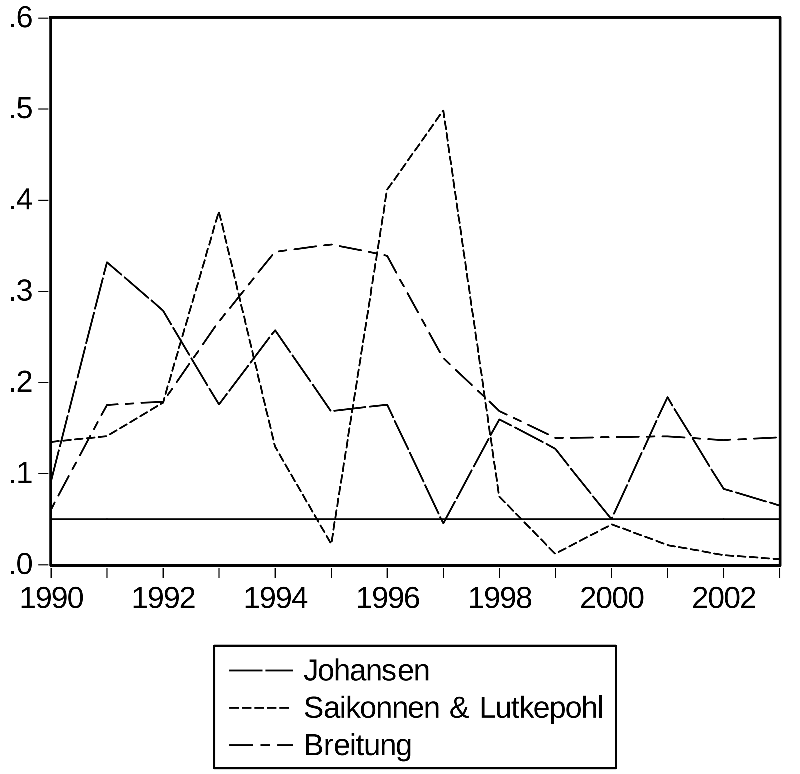


Table 1: Unit Root tests

		Levels		**1st Differences**	
		t-Statistic	**p-value***	**t-Statistic**	**p-value***
Exports	ADF	0.951	0.996	-4.125	0.002
	PP	1.185	0.998	-7.760	0.000
	Breitung	0.058	0.610	0.001	0.005
Imports	ADF	-0.496	0.884	-7.502	0.000
	PP	-0.499	0.883	-7.485	0.000
	Breitung	0.044	0.500	0.005	0.000

Note: *MacKinnon (1996) one-sided p-values. ADF is the Augmented Dickey-Fuller test statistic, PP is the Phillips-Perron test statistic, CV Critical Values, ADF Lag Length: (Decision based on Schwartz Info Criterion, MINLAG=0 MAXLAG=11), PP Bandwidth selection based on Newey-West, Breitung test is the nonparametric unit root test suggested by Breitung (2002) (5% C.V. 0.01004), The p-value of the test is simulated on the basis of a Gaussian AR(p) model for $z(t)$-$z(t$-1), in batches of k replications (1000 in this case). The errors are drawn from the normal distribution with zero mean and variances the squared OLS residuals (wild bootstrapping).

Table 2: Unit Root tests with Structural Breaks for the Levels

	Test statistic	Break Date
Exports	1.888	1958
Imports	0.057	1958
Critical Values	1%	5%
Lanne et al. 2002	-3.48	-2.88

Note: Unit Root test with structural break is the unit root tests suggested by Saikonen and Lutkepohl (2002) and Lanne et al (2002).

Table 3: Unit Root tests on the Indian Current Account

		t-Statistic	p-value*
Current Account	ADF	-3.228	0.024
	PP	-3.228	0.024
	Breitung	0.01128	0.0680

See Notes in Table 1. Figure 3 presents recursive ADF estimates and Figure 4 rolling ones.

Table 4a: Unit Root tests with Structural Breaks for the Current Account

	Test statistic	Break Date
Current Account	-3.2377	1956
Critical Values	1%	5%
Lanne et al. 2002	-3.48	-2.88

Note: Unit Root test with structural break is the unit root tests suggested by Saikonen and Lutkepohl (2002) and Lanne et al (2002).

Table 4b: Zivot and Andrews unit root test on Current Account

		Critical values		
	test statistic	1%	5%	10%
intercept only	-5.6921	-5.34	-4.8	-4.58
intercept and trend	-5.6666	-5.57	-5.08	-4.82

Note: Break point at 1978 (see Figure 2)

Table 5: Tests for Cointegration

	r	LR	p-value	95%
Johansen	0	21.95	0.0272	20.16
	1	1.56	0.8527	9.14
Saikkonen and Lütkepohl	0	16.86	0.0325	15.76
	1	0.48	0.9257	6.79
Breitung	0	347.78	0.0387	329.9
	1	16.98	0.5793	95.6

The *p*-values for the Breitung are simulated (1000 simulations of Gaussian random walks). The *p*-values for $r=0$ correspond to the last points in Figure 5.

Table 6: VECM results

$$\begin{bmatrix} d(imports) \\ d(exports) \end{bmatrix} = \begin{bmatrix} -0.491 * \\ -0.168 * \end{bmatrix} \begin{bmatrix} 1.00 * & -1.049 * \end{bmatrix} \begin{bmatrix} Imports_{t-1} \\ Exports_{t-1} \end{bmatrix} + \begin{bmatrix} 0.361 * \\ 0.201 * \end{bmatrix} [Constant] + \begin{bmatrix} u_{1t} \\ u_{2t} \end{bmatrix}$$

* denotes significance at the 1% S.L. *t*-statisitc of -1.049 is -10.25 and standard deviation is 0.102

Testing restriction to the cointegrating vector (1,-1)

WALD TEST FOR BETA RESTRICTIONS

test statistic: 0.2299

p-value: 0.6316

TECHNICAL APPENDIX:

ZIVOT AND ANDREWS

Zivot and Andrews (1992) extend the Dickey and Fuller (DF) procedure to allow for the simultaneous estimation of possible breakpoints for the intercept and slope of the trend model. Their method addresses possible problems which arise when choosing structural breakpoints by simple visual examination of the plots of the time series. Such issues arise because plots of drifting unit root processes can often be very similar to processes that are stationary about a trend with a break. Zivot and Avdrews' (1992) test is based upon the recursive estimation of a test regression, where the test statistic is defined as the minimum t-statistic of the coefficient of the lagged endogenous variable. The null hypothesis of the ZA test is that the time series is *integrated* (i.e. has a unit root) and no exogenous structural break. The unit-root null hypothesis is rejected if the test-statistic is more negative than the critical value. If this is the case the time series are considered trend stationary about a deterministic trend with a single breakpoint.

BREITUNG (2002) UNIT ROOT AND COINTEGRATION

Breitung's unit roots and cointegration test employ a variance ratio as the test statistic. As noted this approach can eliminate the problem of the specification of the short run dynamics and the estimation of nuisance parameters. If $\{y_t\}_1^T$ denotes an observable process that can be decomposed as $y_t = \delta' d_t + x_t$, where $\delta' d_t$ is the deterministic part (d_t=1 or $[1,t]'$), and x_t is the stochastic part. If we do not assume the deterministic part, then y_t is consistent with x_t. The null hypothesis is that x_t is $I(1)$, if $T \to \infty$, $T^{-1/2} x_{[aT]} \Rightarrow \sigma W(a)$, where σ>0 represents the constant (long-run variance), and $W(a)$ denotes a Brownian motion, [ ] is the integer part. The expression of x_t makes possible the application of a general data generating process. Asymptotically, to construct a consistent estimate which does not require the specification in short run dynamics and an estimate of σ, Breitung has proposed the following test statistic

$$\hat{\rho} = \frac{T^{-4}\sum_{t=1}^{T}\hat{U}_t^2}{T^{-2}\sum_{t=1}^{T}\hat{u}_t^2}$$

where $\hat{u}_t$ is the OLS residuals that $\hat{u}_t = y_t - \hat{\delta}' d_t$, and $\hat{U}_t$ is the partial sum process that $\hat{U}_t = \hat{u}_1 + ... + \hat{u}_t$. If y_t is $I(0)$, the test statistic $\hat{\rho}_T$ converges to 0. Breitung shows that the variance ratio test has favourable small sample properties using Monte Carlo simulations.

We could proceed and test for cointegration by the generalisation of the nonparametric unit roots test on the assumption that the process can be decomposed into a q-dimensional vector of stochastic trend components ξ_t and a $(n\text{-}q)$-dimensional vector of transitory components of v_t where n is the number of variables. Asymptotically, ξ_t and vt is $T^{-1/2}\xi_{[aT]} \Rightarrow W_q(a)$ and $T^{-2}\sum_{t=1}^{T} v_t v_t' = o_p(1)$, respectively, where $W_q(a)$ denotes a q-dimensional Brownian motion with unit covariance matrix. The dimension of ξ_t is related to the cointegration rank. In addition, it assumes that the variance of ξ_t diverges with a faster rate than v_t instead if assuming the stationarity of v_t. From the assumption, the transitory component denoting the cointegration relationship can be generated by any process.

To test the number of cointegrating vectors, Breitung (2002) has proposed the following problem about the n x n matrix A_t, B_t.

$$\left|\lambda_j B_T - A_T\right| = 0$$

where $A_T = \sum_{t=1}^{T}\hat{u}_t\hat{u}'_t$, $B_T = \sum_{t=1}^{T}\hat{U}_t\hat{U}'_t$, and $\hat{U}_t = \sum_{j=1}^{t}\hat{u}_t$ represent the n-dimensional partial sum concerning $\hat{u}_t$. The problem is equivalent to solving the eigenvalue of $R_T = A_T B_T^{-1}$. The solution of equation (3) is $\lambda_j = (\eta_j' A_T \eta_j)/(\eta_j' B_T \eta_j)$ where η_j is the eigenvalue of λ_j. If the vectors of the stochastic trends are less than q, $T^2\lambda_j$ diverges to infinity. In that case, since stochastic trends are linked with each other, a cointegrating vector exists. Hence, the test statistic is the following.

$$\Lambda_q = T^2\sum_{j=1}^{q}\lambda_j \ ,$$

where $\lambda_1 \le \lambda_2 \le ... \le \lambda_n$ is the ordered eigenvalues of R_T. The idea of cointegration rank behind the approach is similar to Johansen's idea. The statistic tests whether a q-dimensional stochastic component is rejected at the significance level.

APPENDIX: BAI AND PERRON (1998) APPROACH FOR MULTIPLE STRUCTURAL BREAKS (Estimated using R 2.4.1 and the package **strucchange**.)

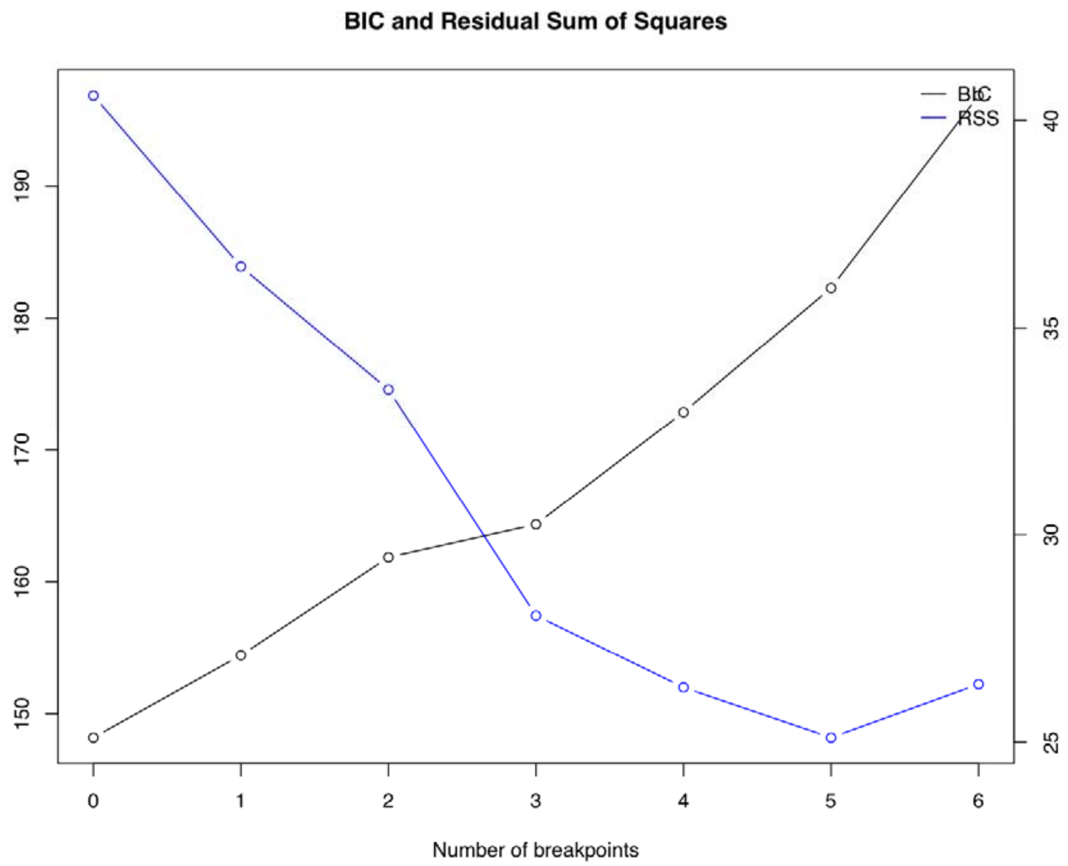
Bai and Perron (1998) based multiple structural breaks correspond to:

m = 1	1965
m = 2	1977 1984
m = 3	1966 1977 1984
m = 4	1956 1966 1977 1984
m = 5	1956 1966 1977 1984 1993
m = 6	1956 1963 1970 1977 1984 1993

Fit:

m	0	1	2	3	4	5	6
RSS	40.60	36.48	33.51	28.06	26.32	25.11	26.39
BIC	148.19	154.43	161.84	164.33	172.86	182.27	196.83

Figure 5: *m*-structural breaks on CA without trend (Bai and Perron)



For dating multiple structural breaks using Bai and Perron's (BP) approach, for the series CA without a trend, we can see clearly strong evidence in favour of m=0 or m=5. We follow BP and employ two possible criteria for dating structural breaks, BIC or RSS. If we minimise BIC, for CA with or without trend, m=0. If we minimise RSS, for CA with or without trend, m=5. Interestingly (and consistent with the Lanne et al 2002 and the ZA test) we pick up breakpoints for 1956 and 1977 (1978 in ZA) with the BP approach also. Given the small number of observations and limited data we have, our alternative approach employing BP confirms that for the case of a 2-partition function call (identical to the case for a single structural break i.e. m = 1), for CA without a time trend, our break date is 1965. It is interesting to note that for the case where we model CA without a trend and date multiple structural breaks, the procedure always seems to pick up year (m=1) = 1965 or 1966, which is very close to or indeed identical to the year of India's major currency devaluation (in 1966).