SUSTAINABILITY AND ASYMMETRIC ADJUSTMENT: SOME NEW EVIDENCE CONCERNING THE BEHAVIOUR OF THE US CURRENT ACCOUNT

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Abstract

This study conducts an investigation into the extent of sustainable and asymmetric adjustment of the US current account over the study period 1960Q4-2003Q2. It is argued that a necessary condition for current account sustainability is that exports and imports are cointegrated. We find evidence in favour of cointegration through the application of the Breitung (2002) and Breitung and Taylor (2003) nonparametric cointegration test procedure, that does not assume linear short dynamics, on the one hand, and the standard Johansen methodology on the other. Employing a recursive Johansen technique, two distinct regimes are identified according to whether or not imports and exports are cointegrated. Further analysis of the asymmetric short-run dynamics reveals that adjustment towards long-run equilibrium is primarily driven by US exports responding to current account deficits.

Keywords: US Current Account, Sustainability, Cointegration, nonparametric cointegration, recursive trace test statistic, recursive betas, asymmetric error correction.

JEL: C5, F1, F4

1. Introduction

In recent years, much concern has been expressed at the size of the US current account deficit in relation to US GDP. This has led many observers to consider whether or not such a deficit is sustainable with the potential to increase without bounds unless checked by government action or developments with respect to foreign exchange markets.[1] Evidence supporting long-run sustainability in the case of OECD current accounts is, at best, mixed (see, *inter alia*, Trehan and Walsh (1991), Gundlach and Sinn (1992), Otto (1992), Wickens and Uctum (1993), Liu and Tanner (1996), Wu (2000) and Wu *et al*. (2001)]. The methodologies employed in many of these studies have been largely based on standard cointegrating methods (Engle-Granger 1987, Johansen, 1988, 1991), which assume the *linear* adjustment in the short-run dynamics which gives rise to a potential misspecification problem. In this paper, we argue that cointegration between exports and imports is a necessary condition for current account sustainability. Non-cointegration, on the other hand, implies an unsustainable current account with the potential to increase without bounds and may provide certain countries with the incentive to default on their international debts.

In this study, we address two issues regarding the sustainability of the US current account. The first issue is to assess whether the US current account has transgressed regimes of sustainability and non-sustainability over time. Taylor (2002) employs annual current account data for a sample of fifteen countries over the study period 1870 to the present. While current account deficits are found to be stationary over this period, it is acknowledged that in some periods, it is conceivable that unsustainable current account were being run on account of disruption through crisis, real adjustments and default. More recently, Raybaudi *et al*. (2004) employ quarterly U.S. data over the period 1970-2002 and use a Markov regime-switching ADF model to indicate that the US current account was unsustainable during the periods 1983-7 and 1993-2002. It also estimated that the expected times that the US current account would remain in sustainable and unsustainable regimes is 21 and 29 quarters respectively. In this paper, we address the issue sustainable and unsustainable regimes for the US current account by conducting the Trace test for cointegration between imports and exports using the Johansen procedure. However, the Trace test is based on an expanding data window so we can identify periods where cointegration is confirmed and rejected. In addition to this, we also use and expanding window to test for long-run homogeneity between imports and exports.

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[1] See, for example, Financial Times, "US current account deficit $1.5bn a day", June 19/20 2004, which reflects on the behaviour of the dollar, overseas demand for US assets and fiscal discipline.

The second issue that we address is whether or not there is an asymmetric adjustment towards sustainability. We adopt a novel approach in our investigation. The long-run relationship between exports and imports is examined, but we allow for an asymmetric adjustment in the data generation process. There is little economic motivation, beyond model simplification, for viewing the behaviour of economic variables as necessarily governed by linear dynamics. Despite or because of their inherent simplicity, theoretical models of macroeconomic behaviour have traditionally posed empirical difficulties that arguably emanate from a failure to recognize asymmetric adjustment. This paper offers the first formal investigation of asymmetries with respect the adjustment of US exports and imports towards long-run equilibrium.

Recent econometric literature provides considerable evidence of asymmetries in key economic variables.[2] In the context of this study, the response of exports and imports to positive or negative deviations of the current account balance from equilibrium could lead to differing speeds of adjustment. For example, current account deficits and surpluses may be associated with exchange rate depreciations or appreciations and therefore relative price effects with respect to imports and exports. Indeed, the demand for exports and imports may react differently to macroeconomic fundamentals. Leonard and Stockman (2002) consider the general issue of non-linear relationships between the current account, exchange rates and cross-country ratios of GDP. At a more specific theoretical level, Stockman (2000) considers the impact of

[2] For example, Ramsey and Rothman (1996) and Verbrugge (1998) identify asymmetries in inflation and attribute them to downward price rigidities. Cover (1992), Rhee and Rich (1995), Karras (1996) and Madsen and Yang (1998) provide more general empirical evidence that corroborates the implications of price adjustment models where prices are primarily sticky in a downward direction. Studies by van Dijk and Franses (2000), Enders and Granger (1998), Enders and Siklos (1999) find evidence of asymmetries in nominal interest rates while Coakley and Fuertes (2002) consider real interest rates. Also, Enders and Dibooglu (2001) identify asymmetries in real exchange adjustment towards purchasing power parity (PPP).

exchange rate shocks on the current account. Chortareas *et al*. (2004) find evidence of Latin American external debt sustainability when they allow for non-linear adjustment. Herwartz (2003), using bilateral models of US imports and exports growth, finds empirical support for a nonlinear relationship with respect to exchange rate uncertainty. In addition, this relationship lacks homogeneity across countries and differs according to whether imports or exports are being considered. Baum *et al*. (2004) and Cook (2000) finds further empirical evidence of asymmetric adjustment with respect to OECD exports and imports.

By employing the nonparametric cointegration test proposed by Breitung (2002), we are able to depart from the usual assumption of linear short-run dynamics and argue that the speed of adjustment towards long-run equilibrium depends crucially on whether deviations from equilibrium are positive or negative. The more widely known Johansen procedure, like many other standard methods, requires the estimation of various structural and nuisance parameters (i.e. lag structure, deterministic term). To get around this problem, Bierens (1997) proposes a nonparametric cointegration procedure as a methodology that allows for a non-linear process where no lag structure or deterministic term need be estimated. In this paper, we employ the Breitung (2002) nonparametric methodology that does not require a weight function as employed in Bierens (1997) and, in addition, the Breitung approach does not require lag specification and the error correction term.

The structure of the paper is as follows. The following section discusses the methodology. A simple model that explains the long-run relationship between exports and imports is presented. It is shown that cointegration between exports and imports is a necessary condition for the sustainability of the current account balance. The third section discusses the data and results. We employ quarterly US data over the period

1960Q4-2003Q2. Evidence in favour of cointegration is derived from both the Breitung and Johansen procedure. Analysis of the error correction mechanism suggests that mean reversion only occurs with respect to positive deviations from long-run equilibrium. The final section concludes.

2. Theoretical Framework

Husted (1992) provides a simple framework that implies a long-run relationship between exports and imports. In the case of a small open economy, an optimising representative individual, who is able to borrow and lend in international financial markets at a given world rate of interest, faces the following current-period budget constraint,

$$C_0 = Y_0 + B_0 - I_0 - (1 + r_0)B_{-1} \tag{1}$$

where C_0, Y_0, B_0 and I_0 refer to current consumption, income, borrowing and investment, r_0 is the one-period current world interest rate which is assumed to be stationary with an unconditional mean *r* and $(1 + r)B_{-1}$ is the initial debt size. Equation (1) should hold in every time period and can therefore be solved forwards to derive

$$B_0 = \sum_{t=1}^{\infty} \psi_t (X - MM)_t + \lim_{n \to \infty} \psi_n B_n \tag{2}$$

where $Y_t - C_t - I_t = (X - MM)_t$ is the trade balance (exports expenditure minus imports expenditure) and ψ_t is the discount factor defined as the product of the first *t* values of $\lambda_0 = 1/(1 + r_0)$. This is the intertemporal budget constraint (IBC) where the present value of future trade surpluses is equal to the amount a country borrows or lends in international financial markets. This model can be used to derive a testable equation. Let

$$Z_t + (1+r)B_{t-1} = X_t + B_t \tag{3}$$

where $Z_t = MM_t + (r_t - r)B_{t-1}$. Solving forwards yields

$$MM_t + r_t B_{t-1} = X_t + \sum_{j=0}^{\infty} \lambda^{j-1}\left[\Delta X_{t+j} - \Delta Z_{t+j}\right] + \lim_{j\to\infty} \lambda^{t+j} B_{t+j} \tag{4}$$

where $\lambda = (1/(1+r))$ and $MM_t + r_t B_{t-1}$ represents expenditure on imports plus interest payments on net foreign debt. Assume that expenditure on exports and imports are both non-stationary processes,

$$X_t = a_1 + X_{t-1} + e_{1t} \tag{5}$$

$$Z_t = a_2 + Z_{t-1} + e_{2t} \tag{6}$$

Substitute (5) and (6) into (4) and rearrange,

$$X_t = \alpha + (MM_t + r_t B_{t-1}) - \lim_{j\to\infty} \lambda^{t+j} B_{t+j} + \mu_t \tag{7}$$

where $\alpha = \left[(1+r^2)/r\right](a_2 - a_1)$ and $\mu_t = \sum \lambda^{j-1}(e_{2t} - e_{1t})$. Finally, we can write

$$X_t = \alpha + \beta M_t + \mu_t \tag{8}$$

where $M_t = MM_t + r_t B_{t-1}$ and it is assumed that $\lim_{j\to\infty} \lambda^{t+j} B_{t+j} = 0$.

The sustainability of the current account concerns the validity of existing and future exports and imports. The current account balance is said to be unsustainable if exports and imports will lead to the violation of the intertemporal budget constraint. In this case, there may be a need for the government to change policy and engage in corrective action. If the current account balance is stationary, the implication is that with unchanged policies, the current account balance will not grow without limit where the discounted deficit will converge asymptotically to zero. Stationarity of the current account is therefore sufficient for sustainability. Alternatively, it might be suggested that the necessary and sufficient conditions for sustainability may be weaker, namely that exports and imports are cointegrated, with the cointegrating vector $(-1,\beta)$ where $\beta \le 1$. However, if $\beta < 1$ the current account is non-stationary and can grow unbounded giving governments the incentive to default on ever-growing international debts. We therefore take the view in this study that the cointegration of exports and imports *and* a cointegrating vector of $(-1,1)$ are probably both necessary conditions for *strong sustainability* in this framework. Clearly, there are parallels with the debate over budget sustainability where Trehan and Walsh (1988, 1991) consider the relationship between stationarity and sustainability of the budget deficit while Hakkio and Rush (1991) consider cointegration between revenues and expenditures. A further interesting reflection is offered by Quintos (1995) who, in the context of the budget deficit, reflects on the bubble term and argues that sustainability may still be present even if revenues are taxes are cointegrated with a non-unity long-run coefficient. Applying this logic to the current account deficit might enable us to define *weak sustainability* as being present when exports an imports are cointegrated with a non-unity long-run coefficient.

3. Methodology

The unit root and cointegration tests advocated by Breitung 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. Suppose $\{y_t\}_1^T$ 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 $T \to \infty$ and $T^{-1/2} x_{[aT]} \Rightarrow \sigma W(a)$, where σ>0 represents the constant (long-run variance), and $W(a)$ denotes a Brownian motion, and

[ ] is the integer part. The expression of x_t makes possible the application of a general data generating process. Breitung has proposed the following test statistic that asymptotically, is a consistent estimate that does not require the specification in short run dynamics and an estimate of σ.

$$\tilde{\rho} = \frac{T^{-4}\sum_{t=1}^{T}\hat{U}_t^2}{T^{-2}\sum_{t=1}^{T}\hat{u}_t^2} \qquad (9)$$

where $\hat{u}_t$ is the OLS residuals derived from $\hat{u}_t = y_t - \hat{\delta}' d_t$, 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 $\tilde{\rho}_T$ 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-q)-dimensional vector of transitory components of v_t where n is the number of variables. Asymptotically, ξ_t and v_t 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 is assumed 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, any process can generate the transitory component denoting the cointegration relationship.

To test the number of cointegrating vectors, Breitung proposes the following specification concerning the n x n matrices A_t and B_t,

$$\left|\lambda_j B_T - A_T\right| = 0 \qquad (10)$$

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 $\hat{u}_t$. This problem is equivalent to solving the eigenvalue of $R_T = A_T B_T^{-1}$. The solution of equation (1) 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.

$$\Lambda_q = T^2 \sum_{j=1}^{q} \lambda_j \tag{11}$$

where $\lambda_1 \leq \lambda_2 \leq ... \leq \lambda_n$ 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.

The literature on non-linearities in the behaviour of error correction models is now rich (see, for example, Granger and Lee, 1989; Granger and Teräsvirta, 1993; Escribano and Granger, 1998; Escribano and Pfann, 1998; and Escribano and Aparicio, 1999). In this study, we employ a flexible model that allows us to examine the asymmetric effects of positive and negative deviations from equilibrium (sign effects). Granger and Lee (1989) partition the error correction term into its positive and negative components, and feed them back into the short-run dynamic equations (non-linear asymmetric model). On the one hand, the alternative short-run specification employed in our study signifies a departure from the linear error correction model that is assumed in the Johansen methodology, while on the other hand, it allows us to gauge if the responses of US exports and imports to the current account imbalances are symmetric.

4. Data and Results

This study employs seasonally adjusted quarterly data on *X* and *M*, expressed as a percentage of nominal GDP, for the study period 1960Q4-2003Q2 inclusive (see Figure 1)[3]. Table 1 reports ADF, PP and Breitung unit root tests applied to *X*, *M* and the current account balance. All the unit root tests are unable to reject non-stationarity for each series. However, there is strong evidence that all series are first difference stationary.

Tables 2A and 2B report the cointegration tests based on the Johansen and Breitung procedures. The latter allow us to depart from the assumption of linear adjustment in the short-run and rejects the null of zero rank at the 5.4% significance level. The Johansen procedure offers stronger evidence in favour of cointegration between imports and exports where the null of zero rank is rejected at the 0.1% significance level. The long-run relationship between exports and imports is calculated as $X_t = 1.982 + 0.626 M_t + c$ where a unity restriction placed on β is rejected at the 5% significance level. Nonetheless, the low p-value attached to the null of non-cointegration is indicative of weak form sustainability at best.

Figure 2 presents values of the recursive Trace test divided by the corresponding critical value. Using an expanding window, we calculate the trace test adding one observation at a time. We then divide the trace test with the critical value (obtained from MacKinnon *et al*. 1999). If this is above one, the null of non-cointegration is rejected and if it is below one, the null is accepted. From the results presented in Figure 2, we can identify four key periods comprising the mid 1970's to the mid 1980's and late 1990's to 2003 where we are able to accept cointegration, and

[3] Data related to the current account balance including data on income payments and receipts are obtained from the Bureau of Economic Analysis, U.S. Department of Commerce. Website

mid 1960s to mid 1970s and mid 1980's to the end of the 1990's where cointegration is rejected.

As with the study by Raybaudi *et al*. (2004), we find the extent of current account sustainability has varied cyclically over the study period though the regimes of sustainable and unsustainable current accounts are found to be longer in our case. We also have evidence of an unsustainable current account during the period 1993-99 which might be attributable to high US growth relative to its trading partners. However, we find that the despite the large current account deficit experienced in more recent years, the necessary condition for sustainability is nonetheless satisfied. Raybaudi *et al*. (2004) find the period 1983-87 is also associated with an unsustainable current account and this might be associated with a strong US dollar. Our findings indicate that the period 1985 onwards is where the regime of an unsustainable current account deficit actually begins.

A necessary and sufficient condition for sustainability is cointegration between imports and exports accompanied by $\beta = 1$. Figure 3 reports recursive values for $-\beta$ which are generated through an expanding window. The evidence here suggests that $-\beta > -1$ throughout virtually the entire study period. The exception occurs during 1971-75 where the upper +2 standard error boundary breaches $\beta = -1$ thereby indicating the possibility of strong sustainability during the early to mid 1970s. However, the period 1971-75 is characterised by non-cointegration according to the recursive trace test.

Table 3 presents the linear and asymmetric error correction models (denoted ECM and AECM respectively) for the short-run adjustment of exports towards long-run equilibrium while Table 4 tests for non-linearity of the residuals of these two

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http://www.bea.doc.gov/bea/di1.htm. GDP data are obtained from the Federal Reserve via models.[4] Figure 4 plots the symmetric and the asymmetric error correction components. The coefficient on the positive error correction term in the AECM is found to be significantly different from zero whereas the coefficient on the negative error correction term is relatively smaller and insignificant. With an estimated coefficient of –0.054, the half-life of a positive deviation from long-run equilibrium is computed as 12.486 quarters. This suggests that that any evidence of (weak) sustainability with respect to the US current account is in terms of export adjustment that follows a deficit-based deviation from equilibrium rather than surplus.[5] This result is consistent with a scenario whereby a current account deficit is associated with a depreciation of the exchange rate that stimulates exports. However, there is no such mechanism present when we consider the case of a current account surplus. The symmetric model incorporates equal and opposite responses to both positive and negative deviations from long-run equilibrium. With no explicit distinction between positive and negative deviations form long run equilibrium, the error correction coefficient is insignificant at the 5% significance level.

We can check the robustness of our results through assessing whether or not there is evidence of any remaining non-linearities with respect to the corresponding residuals from each estimated model. Many tests have been proposed in the literature for detecting non-linearity. Instead of using a single statistical test, four different tests are considered for the purposes of this paper: McLeod and Li (1983), Engle LM

http://www.hussmanfunds.com/html/datapage.htm.

[4] These results pertain to exports only. In the case of imports, the coefficients on the error correction terms were insignificant in both models.

[5] We have also considered the non-linear error correction model suggested by Escribano and Granger (1998) and Escribano and Aparicio (1999) who use a cubic error correction term (non-linear polynomial model). Teräsvirta (1998) pointed out that non-linear models with quadratic and cubic error correction terms, are first-order approximations to smooth transition regressions (STR; see e.g. Granger and Teräsvirta, 1993), where the transition mechanism is driven by the disequilibrium error. However, this model failed to provide us with an improvement compared with the linear model. This is also supported by the Tsay test which is powerful in detecting TAR processes and does not reject the linearity hypothesis (see Table 4).

(1982), Brock et al (1996) (BDS hereafter) and Tsay (1986). All these tests share the principle that once any (linear or non-linear) structure is removed from the data, any remaining structure should be due to a (unknown) non-linear data generating mechanism. All the procedures embody the null hypothesis that the series under consideration is an *i.i.d.* process.

The McLeod and Li test looks at the autocorrelation function of the squares of the pre-whitened data and tests whether corr (e_t^2, e_{t-k}^2) is non-zero for some k and can be considered as an LM statistic against ARCH effects (see Granger and Terasvirta, 1993; Patterson and Ashley 2000). The test suggested by Engle (1982) is an LM test, which should have considerable power against GARCH alternatives (see Granger and Terasvirta 1993; Bollerslev, 1986). The Tsay (1986) test explicitly looks for quadratic serial dependence in the data and has proven to be powerful against threshold (TAR) process. The BDS test is a nonparametric test for serial independence based on the correlation integral of the scalar series, $\{e_t\}$ (see Brock, Hsieh and LeBaron 1991 and Granger and Terasvirta 1993). The BDS test statistic is a general linearity test and the alternative to linearity can be considered to be a stochastic non-linear model (Granger and Terasvirta 1993).[6]

We begin by examining the residuals of the ECM for any remaining non-linearity. Firstly, the Engle test accepts the randomness hypothesis for the residuals of the ECM model (all p-values >0.05) implying that GARCH effects are not present. McLeod-Li rejects ARCH type of structure in the residuals and Tsay threshold effects. The BDS test statistic provides strong evidence that important nonlinearities exist in the residuals of the ECM model. Therefore, we could argue that the linear ECM can not capture the dynamics of the series. The same tests for randomness were carried out using the residuals of the AECM. The *p*-values across the tests are higher in all cases. There is no evidence of (G)ARCH type of effects (see both the McLeod-Li and the Engle test). Furthermore, the BDS accepts the *iid* null (only two out of nine *p*-values are less than 0.05). Therefore we can argue that the AECM specification can capture the dynamics of the series and suggests that there is an asymmetric adjustment in the US current account. This conclusion is based on both the results of the Breitung nonparametric test which accepts cointegration and from the BDS test statistic that rejects the linear ECM model and favours the asymmetric one. Further model selection criteria indicate that the AECM is favoured over the ECM where the former (adjusted R^2 and AIC, see Table 3).

5. Conclusion

This study conducts an investigation into the asymmetric behaviour of the US current account over the study period 1960Q4-2003Q2. It is argued that a necessary condition for current account sustainability is that exports and imports are cointegrated. We find the evidence in favour of cointegration both from Breitung's nonparametric cointegration test procedure, which does not assume linear short-run dynamics and the Johansen methodology. Employing a recursive trace test we have identified distinct periods where the US current account did not satisfy the necessary condition for sustainability (mid 1960s to mid 1970s and mid 1980s to the end of the 1990s) and distinct periods where the necessary condition is satisfied (mid 1970s to mid 1980s and late 1990s onwards). However, we only find in favour of weak sustainability. We are unable to confirm strong sustainability of the current account throughout the study period because exports and imports are cointegrated with a long-run coefficient of less

[6] The reader is also referred to the detailed discussion of these tests in Barnett et al (1997) and

than unity. In this respect, our results suggest that the concerns expressed by commentators over the size of the recent deficit are justified even though the most recent years witness cointegration between exports and imports. An analysis of the asymmetric short-run dynamics reveals that adjustment towards long-run equilibrium based on weak sustainability is primarily driven by US exports responding to current account deficits. Clearly, the mechanisms through which sustainability can be achieved are complex and this would merit a fruitful avenue for future research.

Patterson and Ashley (2000).

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Figure 1: US Imports, Exports and Current Account Balance

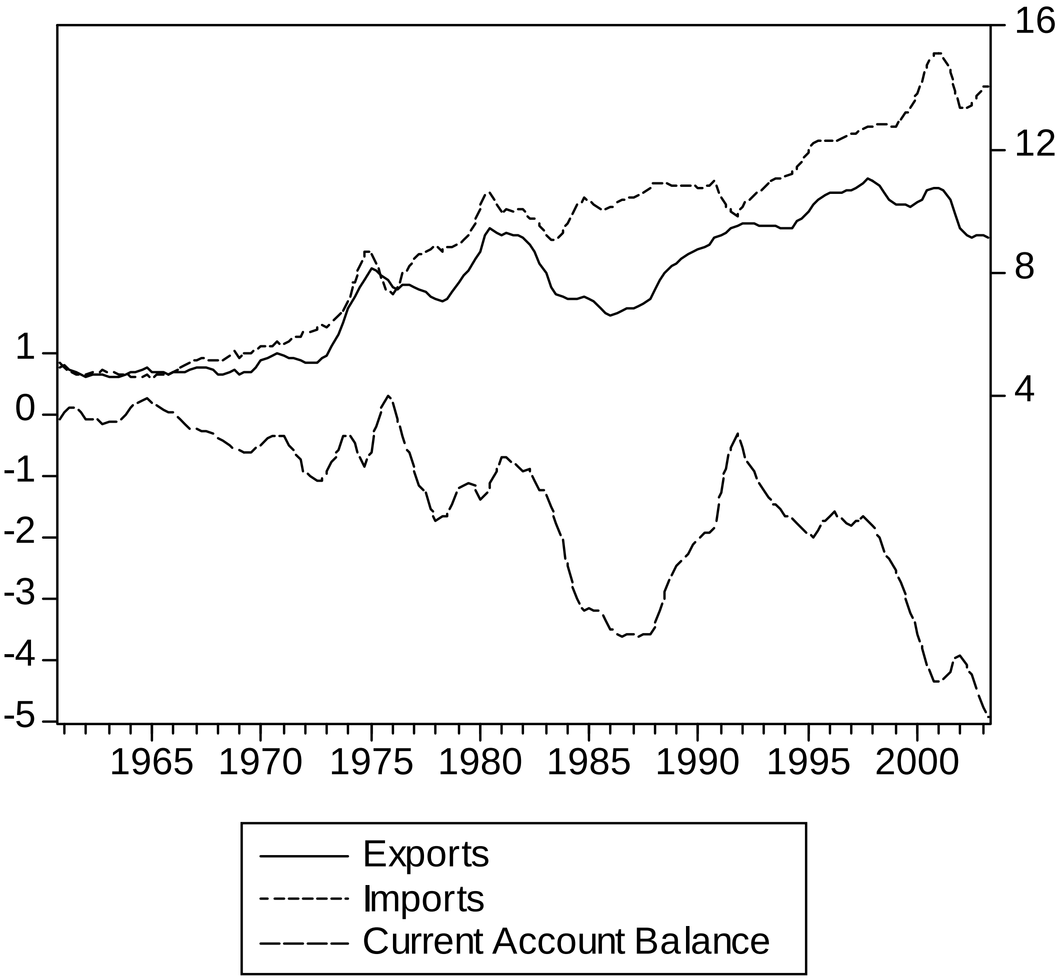

Figure 2: Recursive Trace Test / CV
Critical Values from MacKinnon-Haug-Michelis (1999)

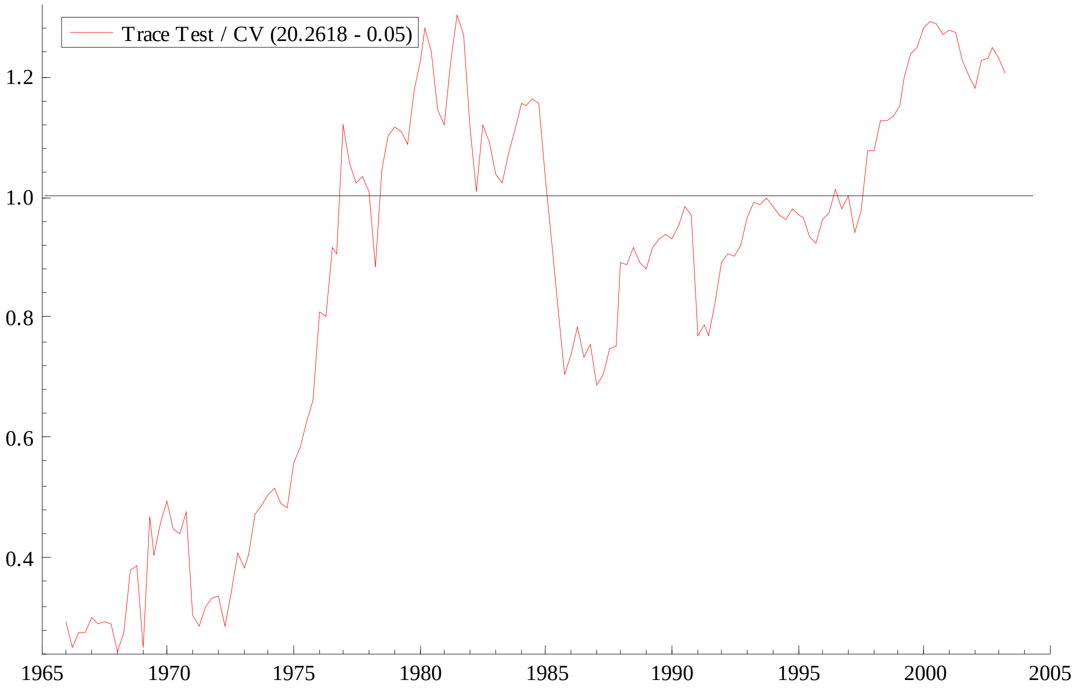

Figure 3: Recursive Breitung Nonparametric Cointegration Test (10%)

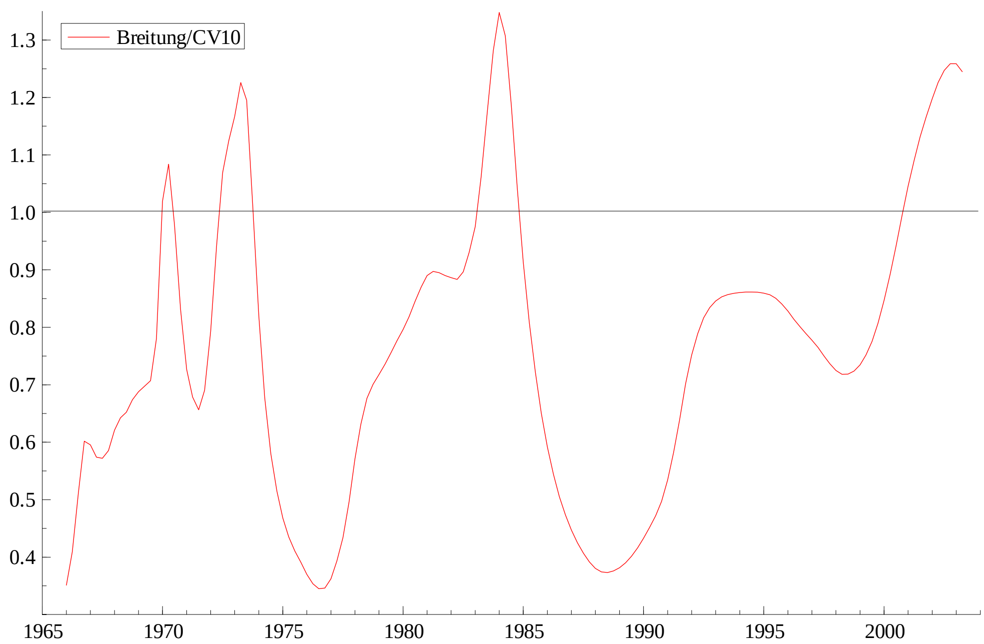

Figure 4: Recursive Breitung Nonparametric Cointegration Test (5%)

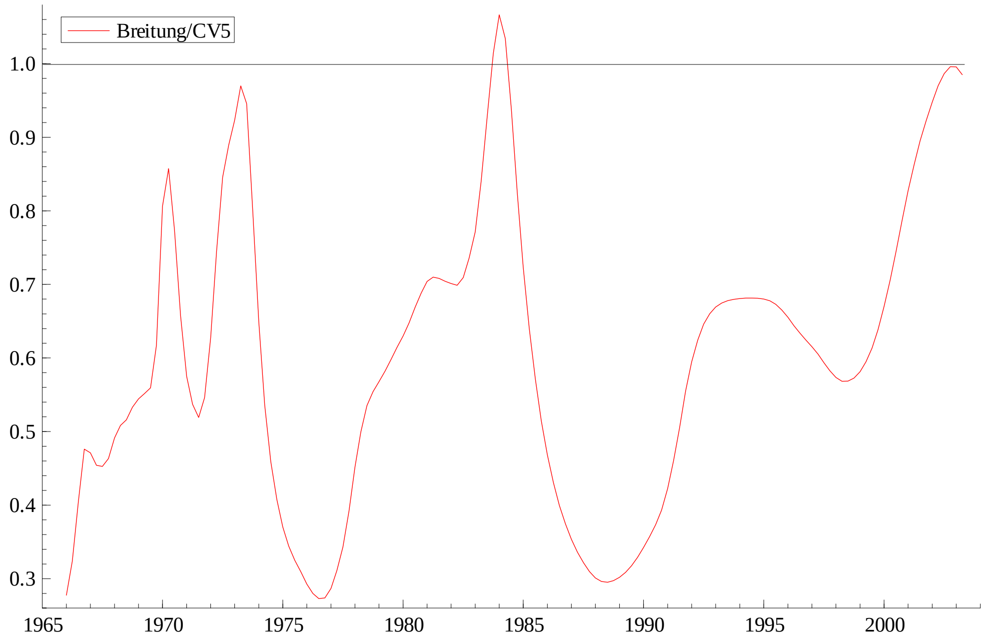

Figure 6

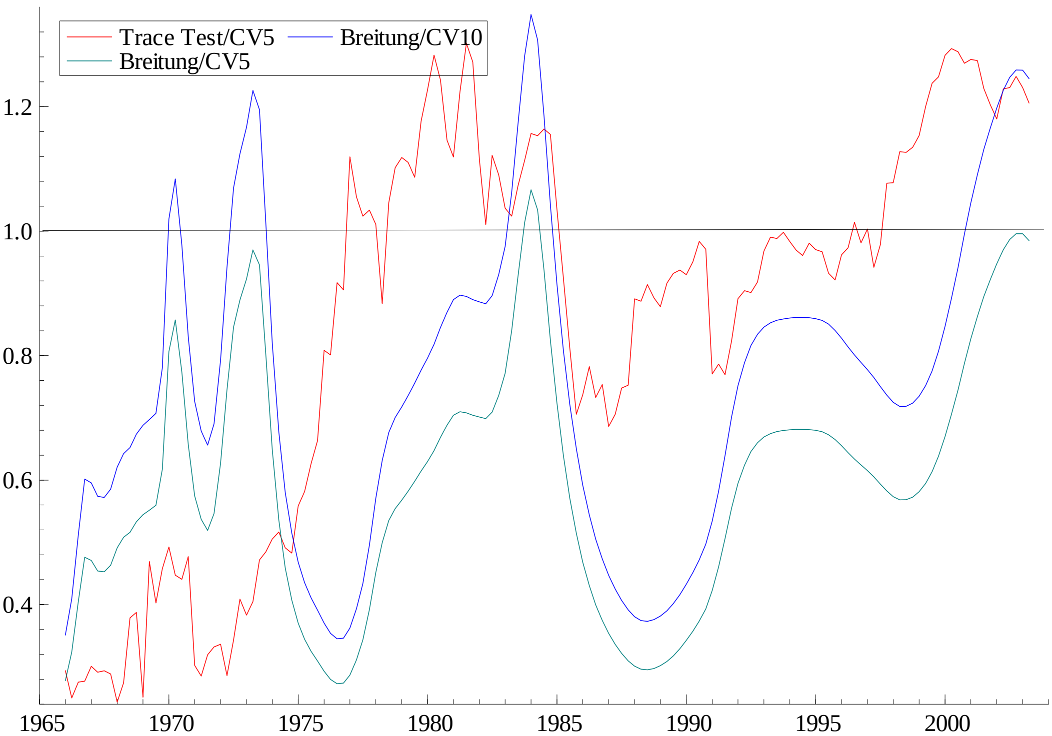

Figure 6: Recursive Beta Coefficients

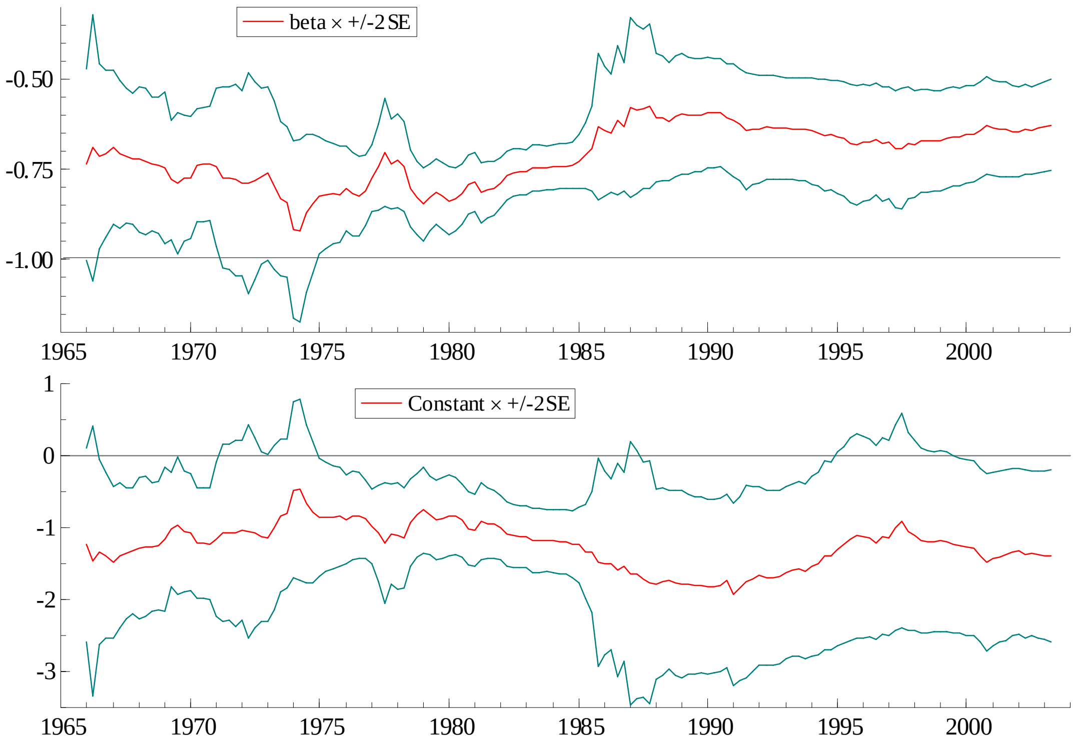

Figure 4: Error Correction Components

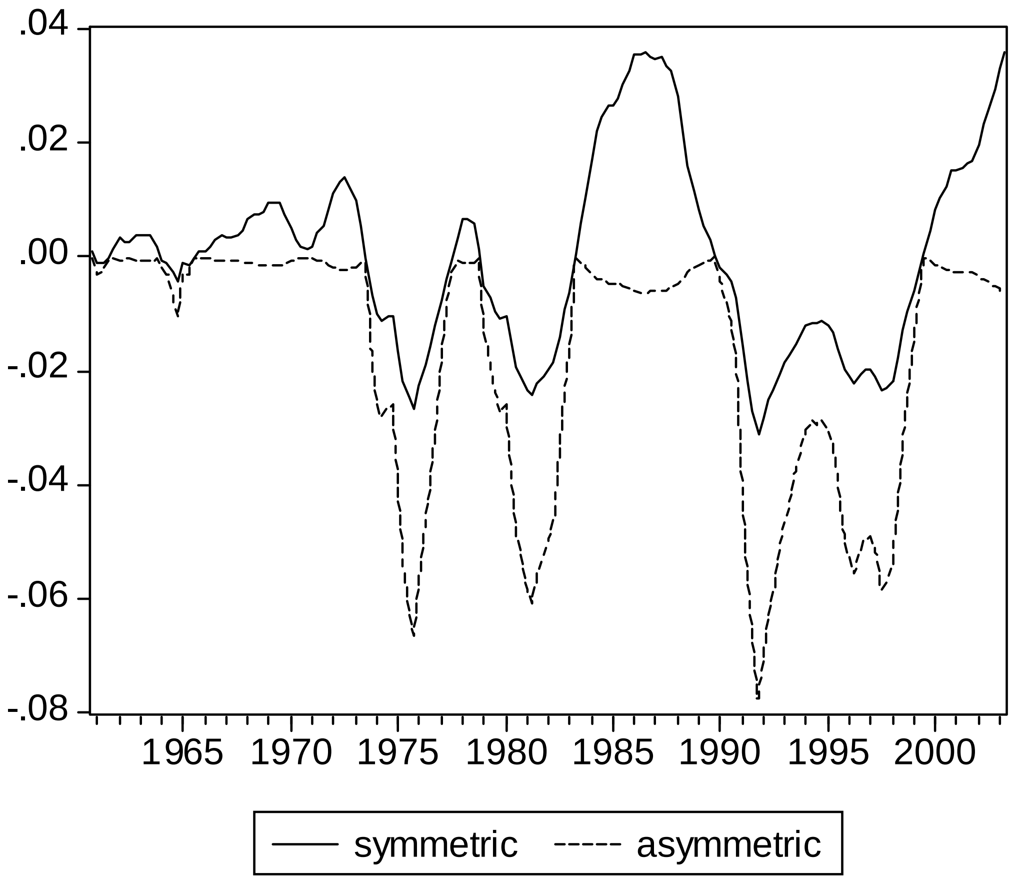

Table 1. Unit Root Tests

		Levels		First Differences	
		t-Statistic	Prob.*	t-Statistic	Prob.*
X	ADF	-1.6092	0.4757	-4.7566	0.0001
	PP	-1.2671	0.6443	-4.9590	0.0000
	Breitung	0.0853	0.6000	0.0019	0.0000
MM	ADF	-0.2179	0.9325	-8.7291	0.0000
	PP	-0.2260	0.9314	-4.4990	0.0003
	Breitung	0.0953	1.0000	0.0007	0.0000
CAB	ADF	-1.2091	0.6701	-3.4459	0.0108
	PP	-0.4010	0.9051	-4.1856	0.0009
	Breitung	0.0615	0.5000	0.0025	0.0000

Notes for Table 1. ADF: Augmented Dickey-Fuller, PP: Phillips-Perron. C.V.: 1% level -3.49917, 5% level, -2.89155, 10% level, -2.58285. * MacKinnon (1996) one-sided p-values. ADF Lag Length: (Decision based on Schwartz Info Criterion, MINLAG=0 MAXLAG=11), PP Bandwidth selection based on Newey-West. Breitung is the Breitung's (2002) nonparametric approach to test for unit roots. The prob value is based on 10 simulations.

Table 2A. Johansen Maximum Likelihood Cointegration Test

H0:rank<=	Trace Test	[Prob]
0	24.14	0.001
1	5.16	0.266

Table 2B. Breitung Test

H0: rank <=	Breitung Test	10%CV	5% CV	simulated p-value
0	324.93	261	329.9	0.0539
1	10.49	67.89	95.6	0.983

Notes for Tables 2A and 2B. With respect to Johansen estimation, the results are for the Trace test using the Restricted Constant model with a maximum of 4 lags. Prob from MacKinnon et al (1999). Breitung test is the nonparametric cointegration test suggested by Breitung (2002). The simulated *p*-values are based on 10000 replications of Gaussian random walks

Table 3. Error Correction Modelling

	ECM	AECM
	1	2
Dependent Variable	ΔX_t	ΔX_t
Regressors		
	0.012	0.030
Constant	(1.44)	(2.171)
	-0.022	
μ_{t-1}	(1.860)	
		-0.054
μ_{t-1}^{+}		(2.340)
		0.004
μ_{t-1}^{-}		(0.846)
lags of ΔX	yes	yes
lags of ΔM	yes	yes
Sample Size	166	166
Adjusted R^2	0.624	0.627
AIC	-1.688	-1.693
S.E. of regression	0.102	0.101

Notes for Table 3. Two types of error correction model. ECM is the linear error correction model. AECM is the asymmetric error correction model where an explicit distinction is made between positive and negative deviations from long-run equilibrium.

Table 4: Tests for Non-linearity

	1 - ECM			2 - AECM		
	BOOTSTRAP	ASYMPTOTIC		BOOTSTRAP	ASYMPTOTIC	
MCLEOD-LI TEST						
USING UP TO LAG 20	0.649	0.757		0.802	0.886	
USING UP TO LAG 24	0.603	0.725		0.697	0.823	
ENGLE TEST						
USING UP TO LAG 1	0.071	0.080		0.259	0.270	
USING UP TO LAG 2	0.105	0.096		0.271	0.284	
USING UP TO LAG 3	0.171	0.191		0.405	0.444	
USING UP TO LAG 4	0.227	0.253		0.455	0.506	
TSAY TEST	0.730	0.752		0.791	0.811	
BDS						
Dimension	EPS=0.50	EPS=1.00	EPS=2.00	EPS=0.50	EPS=1.00	EPS=2.00
	BOOTSTRAP					
2	0.213	0.101	0.074	0.719	0.118	0.150
3	0.077	0.021	0.028	0.377	0.038	0.071
4	0.249	0.022	0.047	0.376	0.039	0.108
	ASYMPTOTIC					
2	0.178	0.073	0.041	0.822	0.090	0.118
3	0.016	0.004	0.010	0.425	0.011	0.045
4	0.169	0.003	0.021	0.398	0.012	0.073

Note: The BDS test statistic tests the null hypothesis that a series is *i.i.d.* against the alternative of realisation from an unspecified non-linear process. *m* is the embedding dimension and ε equals $0.5\sigma_u$, $1.0\sigma_u$ and $2.0\sigma_u$, respectively, where σ_u is the standard deviation of the residuals. Given that the choices of *m* and ε are crucial for the power of the test, we report the results for different plausible values of *m* and ε as suggested by Brock, Hsieh and LeBaron (1991). Only *p*-values are reported.