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Mark J. Holmes

Waikato University, New Zealand

Theodore Panagiotidis

University of Macedonia, Greece

and

The Rimini Centre for Economic Analysis, Italy

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

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The Rimini Centre for Economic Analysis

Legal address: Via Angherà, 22 – Head office: Via Patara, 3 - 47900 Rimini (RN) – Italy

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COINTEGRATION AND ASYMMETRIC ADJUSTMENT: SOME NEW EVIDENCE
CONCERNING THE BEHAVIOUR OF THE US CURRENT ACCOUNT¹

Mark J. Holmes
Department of Economics,
Waikato University Management
School, New Zealand
holmesmj@mngt.waikato.ac.nz

Theodore Panagiotidis
Department of Economics,
University of Macedonia,
Thessaloniki, Greece
tpanag@uom.gr

Abstract

This study conducts an investigation into the extent of cointegration between imports and exports and asymmetries in the adjustment of the US current account over the study period 1960Q4-2007Q2. We find evidence in favour of cointegration through the application of the standard Johansen methodology. Employing the Trace test procedure recursively, two distinct regimes are identified according to whether or not imports and exports are cointegrated. We also consider the Breitung (2002) and Breitung and Taylor (2003) nonparametric cointegration test procedures that do not assume linear short-run dynamics. 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, structural changes, nonparametric cointegration, recursive Trace test statistic, recursive betas, asymmetric error correction.

JEL: C5, F1, F4

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1. INTRODUCTION

The behaviour of the current account is used as an indicator of macroeconomic stability where concern has been expressed at the size of the US deficit. For many analysts, the behaviour of the current account is used to reflect on the accumulation and sustainability of external debt as well as an indicator of potential exchange rate realignment. While Bohn (2007) argues that a stationary current account balance is sufficient but not necessary for the sustainability of external debts, the time-series properties of the current account and the long-run relationship between imports and exports are nonetheless informative. In the face of short-run turbulence, governments have an interest in knowing whether or not, and in what way, a current account deficit is likely to correct towards a more acceptable and stable level. In a growing literature, recent studies such as Freund (2000), Leonard and Stockman (2002), Taylor (2002) and Clarida et al. (2006) have highlighted the role that non-linearities might play in US current account adjustment. These studies have pointed out that the dynamics of adjustment have changed, often dramatically, over recent decades.

In this paper, we offer new insights regarding the adjustment of the US current account. First, we conduct a range of cointegration tests between imports and exports that allow for non-linear adjustment and structural breaks. We build on the existing literature by considering whether or not the current account has in fact transgressed regimes of cointegration and non-cointegration between exports and imports over time. Indeed, if such behaviour characterises the current account, can we then identify those periods when cointegration is present? We address this question using a recursively-based Trace test. Second, we consider whether or not there is an asymmetric adjustment in the short-run data generation process towards a long-run equilibrium relationship. Papers such as Freund (2000) and Clarida et al. (2006) consider non-linearities in the form of threshold effects, but are the dynamics of current account adjustment dependent on the sign of deviations from long-run equilibrium? Using a flexible model that allows us to examine the asymmetric effects of positive and negative deviations from equilibrium, this paper offers the first formal investigation of asymmetries with respect to the adjustment of US exports and imports towards long-run equilibrium.

The structure of the paper is as follows. The following section discusses the relevant literature. The third section presents the methodology, data and results. We employ quarterly US data over the period 1960Q4-2007Q2 and find evidence in favour of cointegration between exports and imports that is time-dependant. Our 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. LITERATURE AND METHODOLOGY

Early studies of the time series behaviour of OECD current accounts include Trehan and Walsh (1991), Otto (1992), Wickens and Uctum (1993), Liu and Tanner (1996), Wu (2000), Wu et al. (2001) and Taylor (2002). These investigations use a range of standard cointegrating methods (Engle and Granger 1987, Johansen 1995) or panel data methods applied to exports, imports and current account data. If exports and imports are related according to $Exports = a + \beta * Imports + c$, satisfaction of the intertemporal budget constraint and strong sustainability is viewed as consistent with cointegration between exports and imports accompanied by $\beta = 1$, while weak sustainability is regarded as being characterised by $0 < \beta < 1$ but with cointegration (see also Quintos 1995). While early evidence in favour of current account stationarity or cointegration between imports and exports is mixed, the methods used in these studies assume *linear* adjustment in the short-run dynamics which can give rise to a potential misspecification problem.

More recently, researchers have focussed on this issue by considering the possibility that current account behaviour is in fact governed by non-linearities. The early influential papers focussed on the nature of current account adjustments include Milesi-Ferretti and Razin (1998), Freund (2000) and Mann (2002). Milesi-Ferretti and Razin (1998) analyse reductions in current account deficits and exchange rate depreciations in low- and middle-income countries. They find that domestic factors, such as low reserves, and external factors, such as unfavourable terms of trade and high interest rates, trigger current account reversals and currency crises. Freund (2000) analyses current account adjustment among industrialised countries and finds that current account reversal begins when the current account deficit is about five percent of GDP and that such reversals are largely a function of the business cycle. On the other hand, Mann (2002) considers the adjustment process as the US moves towards a smaller current account deficit. It is argued that a relatively fast speed of adjustment will occur if global investors curtail their holdings of US assets and a declining dollar exchange rate equilibrates imports and exports. This can be contrasted with structural and policy changes such as a tighter fiscal policy or increased domestic saving which are likely to be associated with a smoother adjustment of the current account.

A further group of studies give specific focus to import and/or export behaviour. While the asymmetric adjustment of US imports and exports is highlighted by studies such as Herwartz (2003) and Chinn (2005), theoretical considerations are given more focus in studies that include Chen and Devereux (1994) who demonstrate an asymmetry between the effects of temporary import

and export price shocks on the current account insofar as income and substitution effects work so that increases in export prices improve the current account while the effects of a temporary import price fall are ambiguous. This asymmetry is found to hold for US and UK data. In a different approach, Goldberg and Tille (2006) consider the role of exchange rate pass through in explaining asymmetric effects of a depreciating dollar on flows between the US and its trading partners.

The investigation of non-linearities in current account behaviour has been based on a variety of econometric models. For example, Raybaudi et al. (2004) employ quarterly U.S. data over the period 1970-2002 and use a Markov regime-switching Augmented Dickey Fuller (ADF) model. The switch between regimes is governed by a probabilistic function where they find that the US current account was in fact non-stationary during sub-periods comprising the 1980s, 1990s and 2000s. The theme of switching in and out of sustainable regimes is also highlighted by Davig (2005) who employs a Markov-switching model of discounted debt in an analysis of fiscal policy. This builds on the theme explored by Davig (2004) that substantial rather than small changes in government policy are likely to be associated with regime-switching and have non-linear effects. In a further contribution, Clarida et al. (2006) model the dynamics of current account adjustment towards long-run equilibrium to depend on whether or not the deficit to output ratio has breached some threshold. This type of non-linearity is captured using Smooth Transition Autoregressive (STAR) modelling through which they find evidence of threshold effects.

In this study, we address non-linearities in current account adjustment in a number of ways. We conduct the Trace test for cointegration between imports and exports using the Johansen procedure. This is done recursively based on an expanding data window that allows us to identify periods where cointegration between exports and imports is accepted or rejected. We also consider an approach advocated by Johansen et al (2000) and examine the effects of structural breaks in the cointegration results, as well as nonparametric cointegration testing proposed by Breitung (2002) and Breitung and Taylor (2003). This latter procedure enables us to depart from the usual assumption of linear short-run dynamics and allows for the speed of adjustment towards long-run equilibrium to depend 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 structures, deterministic terms). To address this problem, the Breitung (2002) methodology is based on a nonparametric cointegration procedure that allows for a non-linear process where a lag structure or deterministic term need not be estimated. In addition to this, there are a number of advantages over the Bierens (1997) nonparametric procedure.

We also consider whether the response of exports and imports to positive or negative deviations of the current account balance from equilibrium leads to differing speeds of adjustment. Rather than assume a linear framework where the sensitivity of the current account is the same irrespective of the sign of the shock, we provide an alternative perspective on current account adjustment that has not been explored in the existing literature. With regard to the short-run dynamics, the literature on non-linearities in the behaviour of error correction models is now extensive (see, for example, Granger and Lee, 1989; Granger and Teräsvirta, 1993; Escribano and Granger, 1998; Escribano and Pfann, 1998; and Escribano and Aparicio, 1999). 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). 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 and allows us to gauge whether or not the responses of US exports and imports to the current account imbalances are symmetric.

3. DATA AND RESULTS

3.1 DATA

This study employs seasonally adjusted quarterly data on exports (X) and imports (M). We follow Clarida et al. (2006) and express X and M as a percentage of net output (defined as GDP minus government fixed expenditure and gross fixed capital formation). Our study period covers 1960Q4-2007Q2 inclusive (see Figure 1).² The scatterplot of imports and exports with a nonparametric fit (nearest neighbour) is the first indication of an asymmetric relationship where X levels off and does not increase more than 10% whereas M continues to do so (see Figure 2). Table 1 reports DF-GLS,³ Breitung and Saikonen and Lutkepohl (2002) unit root tests applied to X , M and the current account balance (CAB). In addition to this, we also apply KPSS stationarity tests. All the unit root (stationarity) tests are unable (able) to reject non-stationarity (stationarity) for each series. This conclusion applies in the case of the Saikonen and Lutkepohl (2002) unit root test that allows for a structural break. There is strong evidence that all series are first difference stationary. These findings may be compared with Ben-David and Papell (1997) who reject a non-trend-break non-stationary null for US import- and

² 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 <http://www.bea.gov/>. GDP data are obtained from the Federal Reserve via <http://www.hussmanfunds.com/html/datapage.htm>.

³ Since the DF-GLS unit root test is regarded as more powerful than the ADF and PP tests, the latter tests are not reported here (see also Ng and Perron 2001).

export-output ratios. In contrast, we find that endogenously-determined structural breaks from around the late 1970s to 1980, which in our case coincide with the effects of Tokyo round aimed at removing non-tariff barriers, does not affect our conclusion of non-stationarity.

Figure 1: US Imports, Exports and Current Account Balance

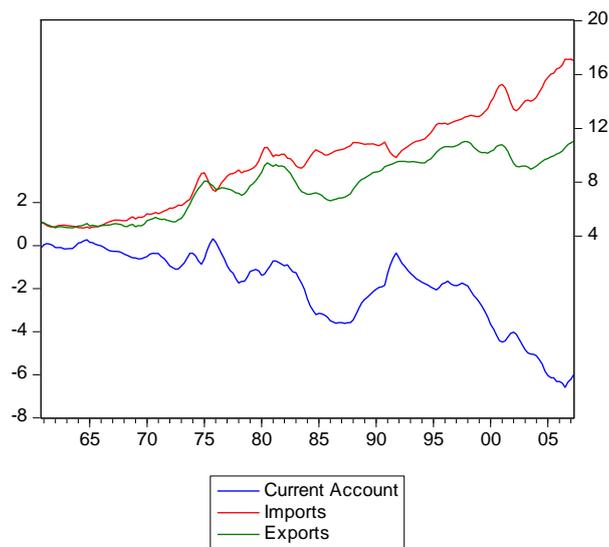


Figure 2: Scatter of Imports and Exports with a nonparametric (nearest neighbour) fit

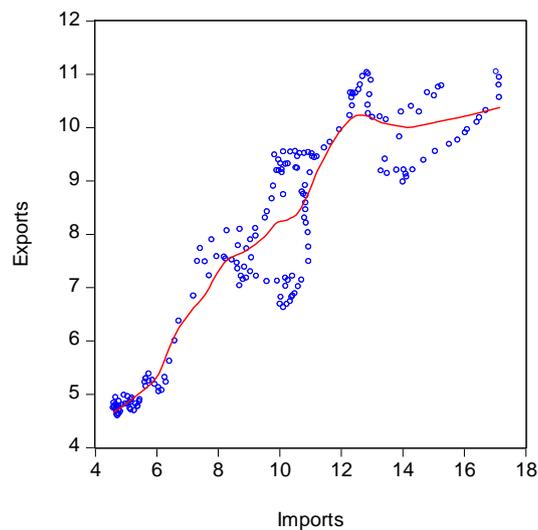


Table 1. Unit Root Tests

		Levels		First Differences	
		t-Statistic	Break	t-Statistic	Break
<i>X</i>	DF-GLS	-0.207		-4.941	
	KPSS	1.684		0.040	
	Breitung	0.085		0.001	
		(0.87)		(0.00)	
	UR with SB	-1.535	1965 Q1	-3.532	1980 Q4
<i>M</i>	DF-GLS	2.100		-3.473	
	KPSS	1.882		0.142	
	Breitung	0.094		0.002	
		(0.96)		(0.00)	
	UR with SB	0.319	1978 Q2	-2.560	1980 Q3
<i>CAB</i>	DF-GLS	-0.586		-2.352	
	KPSS	1.393		0.151	
	Breitung	0.068		0.003	
		(0.51)		(0.01)	
	UR with SB	-1.455	1977 Q1	-2.366	1991 Q1

Notes for Table 1. Critical values for the DF-GLS test (Elliott et al. 1996) are -2.57 and -1.94 at the 1 and 5% significance level respectively. Breitung is Breitung's (2002) nonparametric approach to test for unit roots. The *p*-value is given in parentheses and is based on 100 simulations where the errors are drawn from the normal distribution with zero mean and variances squared OLS residuals (wild bootstrapping). Unit Root test with a structural break (UR with SB) is the unit root tests suggested by Saikkonen and Lutkepohl (2002) and Lanne et al. (2002). The used break is provided next to the test statistic. The critical values: -3.48 and -2.88 at the 1 and 5% significance levels respectively.

3.2 LONG-RUN RELATIONSHIP

Tables 2 and 3 report the cointegration tests based on the procedures advocated by Johansen (1995), Johansen et al. (2000) taking into account structural breaks and Breitung (2002). The Johansen procedure offers evidence in favour of cointegration between *M* and *X* where the null of zero rank is rejected at the 2.7%

significance level. The long-run relationship between exports and imports is calculated as $X_t = 3.48 + 0.544M_t + c$ where a unity restriction placed on the long-run slope β is rejected at the 5% significance level. Once structural breaks of 1978Q2 and 1965Q1 are taken into account (see also Table 1), the p -values for the null of zero rank are computed as 2% and 5.8% respectively. These results may be contrasted with those obtained from the Breitung test (with and without break dates) which seems not to reject the non-cointegration null throughout.

Table 2. Johansen (1995) and Johansen et al. (2000) Maximum Likelihood Cointegration Test (with and without break)

H0:rank<=	Statistic	[p-value]	Statistic	[p-value]	Statistic	[p-value]
0	21.94	0.0273	26.96	0.0204	23.74	0.0584
1	8.07	0.0814	7.30	0.3428	8.92	0.1388

Structural Break	None	1978 Q2	1965 Q1
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Table 3. Breitung Test

H0: rank <=	Breitung Test	Breitung Test (excluding the 1965 Q1 obs.)	Breitung Test (excluding the 1978 Q2 obs.)	10%CV	5% CV
0	171.01	168.92	169.72	261	329.9
1	10.54	10.53	10.55	67.89	95.6

Simulation Results:

S = simulated test statistic

Case: No drift $r = 0$ Prob[S > 171.01] = 0.28160

Case: No drift $r = 1$ Prob[S > 10.54] = 0.98010

Actual size at 10% significance level:

Case: No drift $r = 0$ Prob[S > 261.00] = 0.10020

Case: No drift $r = 1$ Prob[S > 67.89] = 0.10170

Actual size at 5% significance level:

Case: No drift $r = 0$ Prob[S > 329.90] = 0.05030

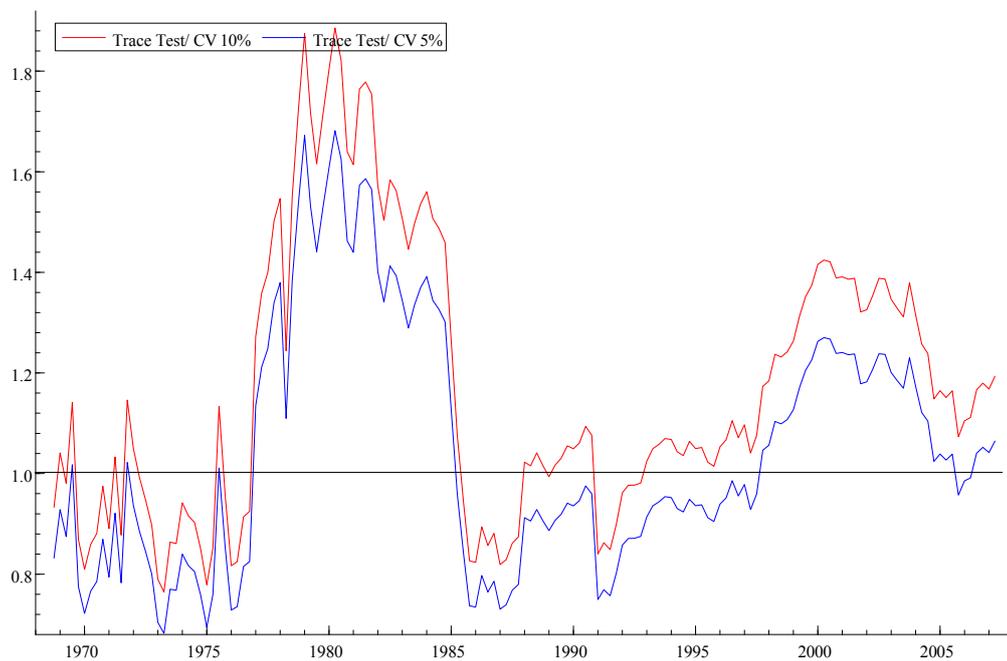
Case: No drift $r = 1$ Prob[S > 95.60] = 0.05470

Based on 10000 replications of Gaussian random walks with length $n = 187$.

Notes for Tables 2 and 3. The results from Johansen estimation are for the Trace test using the Restricted Constant model with a maximum of 6 lags. The lag length was chosen based Schwarz and Hannan-Quinn criterion with p -values based on Doornik (1998). The Breitung test is the nonparametric cointegration test suggested by Breitung (2002). The simulated p -values are based on 10000 replications of Gaussian random walks. In the case of the Trace test with a structural break, p -values are drawn from Johansen et al. (2000).

We now consider how the relationship between X and M has evolved over time. Figure 3 presents the time path values of the recursive Trace test statistic. Using an expanding window, we calculate the Trace test adding one observation at a time (see Hansen and Johansen 1999) and then dividing the Trace statistic by its 5 or 10% critical value (obtained from Doornik 1998). For a given time period, if this calculation is above one then the null of non-cointegration is rejected. If it is below one, the null is accepted. The same is also done for the Breitung test (see Figure 4). In each figure, the last point of the time path corresponds to the full sample estimates reported in Tables 2 and 3. Both tests are compared in Figure 5 where the direction of movement in the recursive Trace test is confirmed by the recursive Breitung test. The nonparametric test is smoother and rejects cointegration more often than the Johansen procedure does. Using Figure 3, we can identify four key periods: the mid 1970's to the mid 1980's and late 1990's to 2003 where we are able to reject non-cointegration between X and M ; and the mid 1960s to mid 1970s and mid 1980's to the end of the 1990's where we are unable to reject non-cointegration.

Figure 3: Recursive Trace Test



Notes. The Trace statistics are divided by 5 and 10% critical values taken from Doornik (1998).

Figure 4: Recursive Breitung Nonparametric Cointegration Test (5% and 10%)

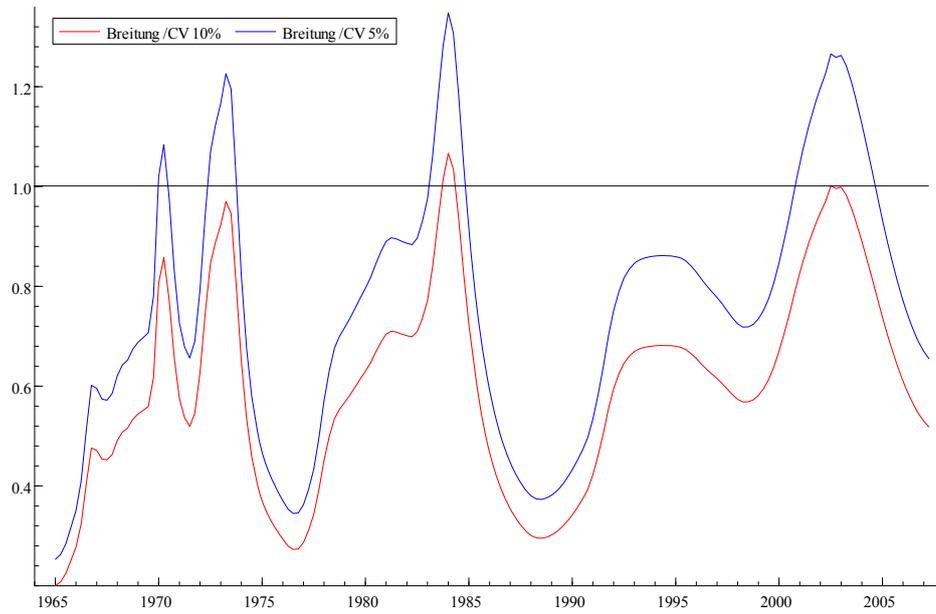
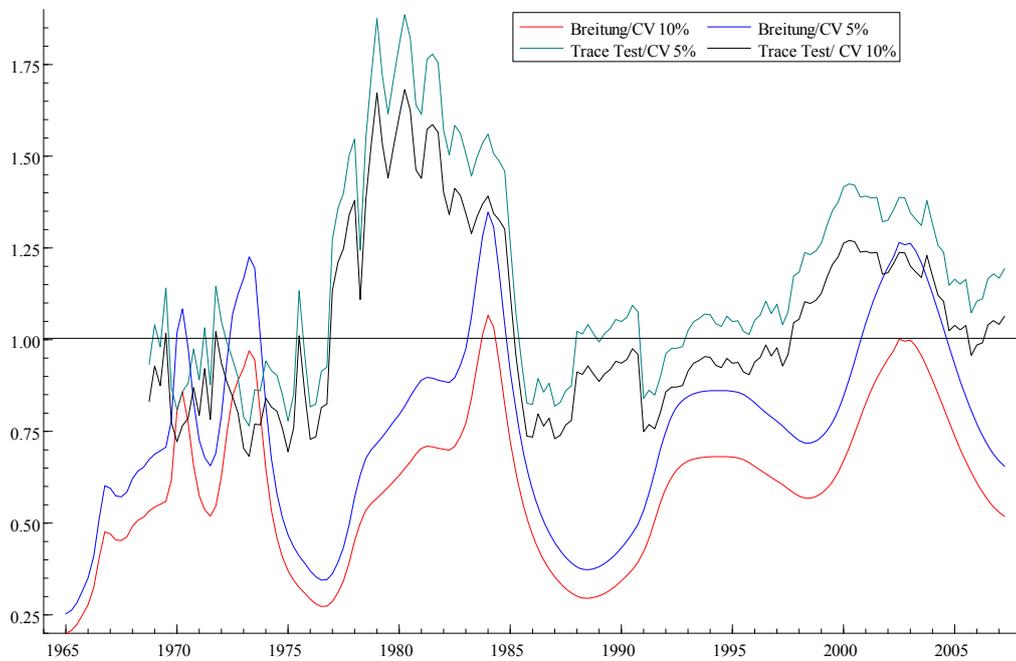


Figure 5: Comparison of tests



Our results are consistent with Raybaudi et al. (2004) who find that current account stationarity has varied cyclically over the study period, though we find that regimes of cointegration and non-cointegration between X and M are longer in our case. For example, Raybaudi et al. (2004) find evidence of a non-stationary current account during the period 1993-99. We have evidence of non-cointegration over this same period. This finding might be attributable to high US growth relative to its trading partners. Raybaudi et al. (2004) find that the period 1983-87 is also associated with a non-stationary 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 non-cointegration between exports and imports actually begins. Although studies such as Krugman (1985) have documented the depreciating US dollar in the wake of a larger current account deficit, our analysis suggests that this was not sufficient to facilitate a regime of cointegration and perhaps a much larger depreciation would have been required to improve the current account (see also Obstfeld and Rogoff (2005)).

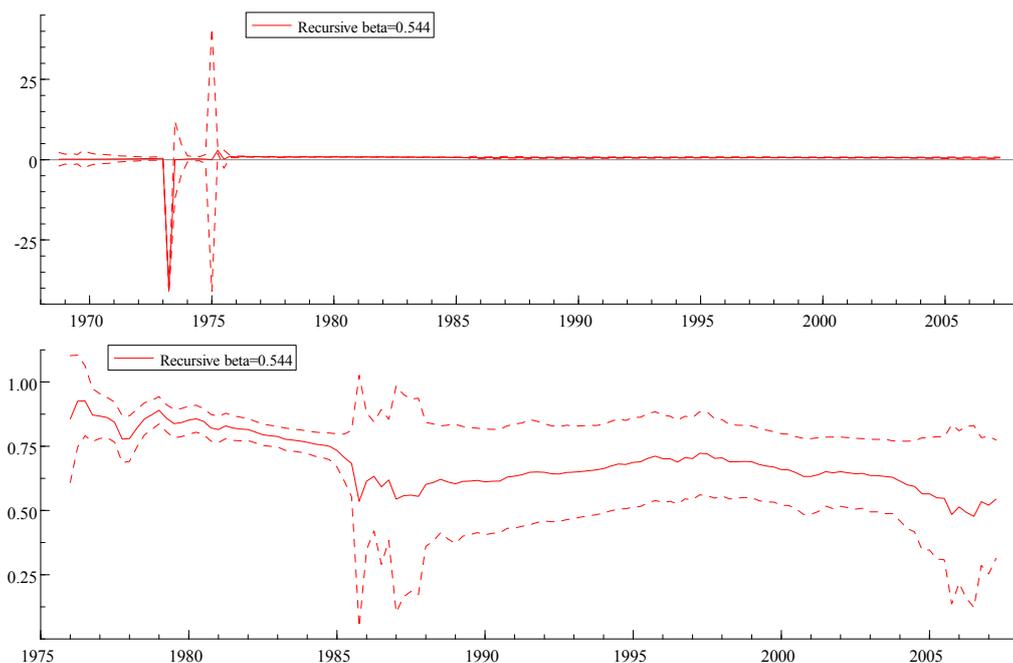
A summary of the results by decade is reported in Table 4. While non-cointegration can be rejected in the majority of cases (109 quarters out of a total of 155) for the entire study period, there is an increased prevalence of cointegration between X and M in the most recent decades. Indeed, it is the more recent years that are associated with historically large current account deficits. This result can be seen as consistent with the threshold-type effects researched by Clarida et al. (2006) and others. Studies such as Gourinchas and Rey (2005) have argued that the US has always faced a weakened external constraint on account of being able to borrow on favorable terms and earn a significant premium on its provision of global liquidity. Our analysis suggests that this ability may have weakened where recent historically large current account deficits accompany increased likelihood of cointegration between exports and imports.

Table 4. Characteristics of the decades

	Number of Quarters > 1	
Number of Quarters < 1	Cointegration	
No cointegration	Cointegration	
46 (30%)	109 (70%)	
	Number of Quarters < 1	Number of Quarters > 1
	No cointegration	Cointegration
1968-69	3 (60%)	2 (40%)
1970-79	24 (60%)	16 (40%)
1980-89	11(27.5%)	29 (72.5%)
1990-99	8 (20%)	32 (80%)
2000-07	0 (0%)	30 (100%)

A necessary and sufficient condition for a stationary current account is cointegration between imports and exports accompanied by $\beta = 1$. But to what extent is this satisfied by the data? To answer this, we recursively estimate the slope coefficient of the long-run solution (see Hansen and Johansen 1999). Figure 6 reports the recursive values for $-\beta$ together with their standard errors that 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.

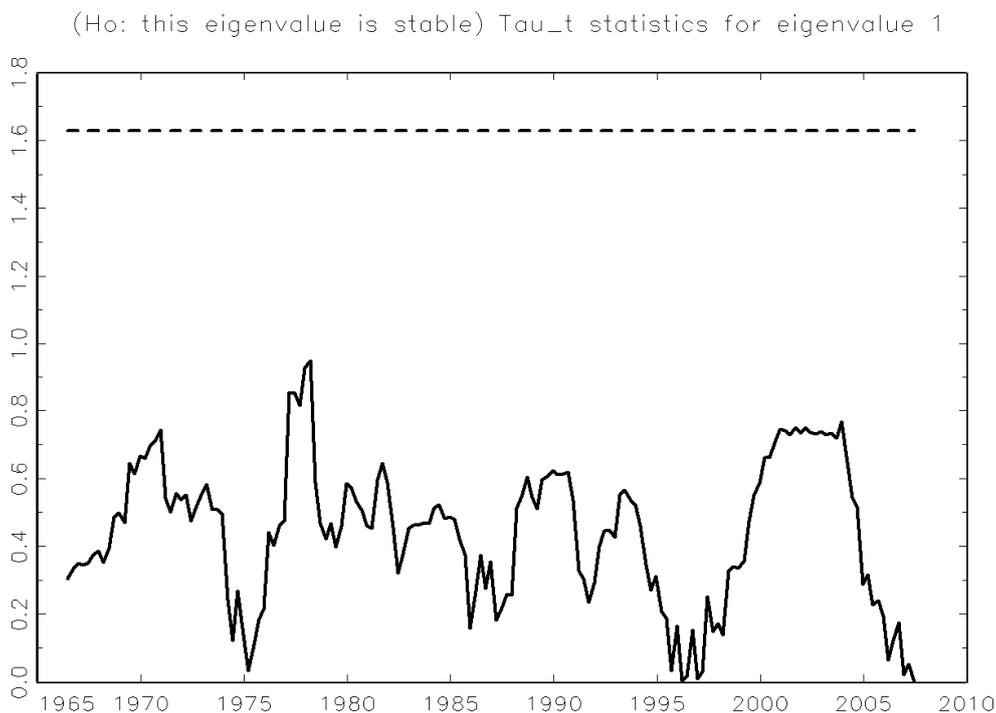
Figure 6: Recursive Beta Coefficient



Finally, the stability of the long-run relationship between X and M is also examined. Hansen and Johansen (1999) advocate the use of recursive eigenvalues to test the stability of the long-run relationship. The suggested a tau_t $T(\xi_i^{(\tau)})$ statistic compares the i^{th} eigenvalue obtained from the full sample to the one estimated from the first τ observations only (for more discussion on this, see

Hansen and Johansen 1999, and Lutkepohl and Kratzig, 2004). Stability is rejected if the difference between the eigenvalues based on the subsamples and the full sample gets too large. As a result, if $T(\xi_i^{(r)})$ exceeds the critical value (1.6), the stability of the model is rejected. Figure 7 indicates that none of the calculated tau_t statistics are above the critical value. As a result stability with regard to the long-run relationship of X and M cannot be rejected.

Figure 7: Test for the stability of all recursive eigenvalues



3.3 SHORT-TERM DYNAMICS

We now assess the nature of the dynamics towards long-run equilibrium between X and M . Table 5 presents the linear and asymmetric error correction models (denoted as ECM and AECM respectively) for the short-run adjustment of exports, Table 6 tests for non-linearity of the residuals in these two models,⁴ and Figure 8 plots the symmetric and the asymmetric error correction components. The coefficient on the positive error correction term in the AECM is found to be

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

significantly different from zero whereas the coefficient on the negative error correction term is relatively smaller and insignificant.⁵ With an estimated coefficient of -0.054 , the half-life of a positive deviation from long-run equilibrium is approximated as 12.486 quarters.⁶ This suggests that any evidence of cointegration with respect to US exports and imports is in terms of export adjustment that follows a deficit-based deviation from equilibrium rather than surplus.⁷ The F test for the equality of the positive and negative component has a p -value of 0.1 suggesting marginal statistical significance (Table 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. Given that exports are expressed as a percentage of net income rather than GDP, it can be argued that this is consistent with a J-curve effect being present. This is because during a deficit period, X may rise but not on account of an increase in one of the components of GDP such as investment. 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 from long run equilibrium, the error correction coefficient is insignificant at the 5% significance level.

⁵ AECM : $\Delta X_t = 0.030 - 0.054 \mu_{t-1}^+ + 0.004 \mu_{t-1}^- + \text{lags of } \Delta X_t + \text{lags of } \Delta M_t$.
(2.171) (2.34) (0.846)

⁶ Approximated as $\ln 0.5 / \ln(1-0.054)$.

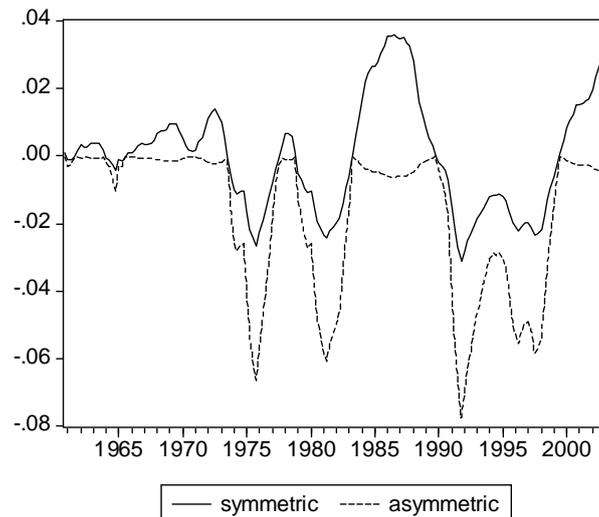
⁷ We also considered the non-linear error correction model suggested by Escribano and Granger (1998) and Escribano and Aparicio (1999) who use a cubic error correction term (non-linear polynomial model) (see also Enders and Siklos 2001). Teräsvirta (1998) pointed out that non-linear models with quadratic and cubic error correction terms, are first-order approximations to smooth transition regressions (seefor example, 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 6).

Table 5. Error Correction Modelling

	ECM	AECM
Dependent Variable	ΔX_t	ΔX_t
Regressors		
Constant	0.012 (1.44)	0.030 (2.171)
μ_{t-1}	-0.022 (1.860)	
μ_{t-1}^+		-0.054 (2.340)
μ_{t-1}^-		0.004 (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
<i>F</i> (1, 157) test of equal effects from μ_{t-1}^+ and μ_{t-1}^- <i>p</i> -value 0.10		

Notes for Table 5. Two types of error correction model are estimated. 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. T-statistics are given in parentheses.

Figure 8: Error Correction Components



Finally, we may consider some diagnostics concerning the overall quality of the chosen AECM. We can check the robustness of our results by assessing whether or not there is evidence of any remaining non-linearities in 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) for an ARCH alternative, Engle LM (1982) for GARCH, Brock et al. (1996) (BDS hereafter) for a general linearity test, and Tsay (1986) for Threshold effects. 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.⁸

Table 6: Tests for Non-linearity

	1 - ECM			2 - AECM		
	BOOTSTRAPASYMPTOTIC			BOOTSTRAPASYMPTOTIC		
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 m	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 (EPS) 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.

⁸ The reader is also referred to the detailed discussion of these tests in Barnett et al (1997) and Patterson and Ashley (2000).

We begin by examining the residuals of the ECM for any remaining non-linearity. 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. The McLeod-Li tests reject ARCH-type structures in the residuals and the Tsay tests reject 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 cannot 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 tests). Furthermore, the BDS tests accept the *i.i.d.* 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 based on the adjusted R^2 and AIC indicate that the AECM is favoured over the ECM.

4. CONCLUSIONS

This study conducts an investigation into the behaviour of the US current account through an examination of cointegration between imports and exports and asymmetries in the short-run dynamics of adjustment. Using data for a study period covering four decades, we find evidence in favour of cointegration. The relationship is stable and holds when structural breaks are taken into account as well. By employing a recursive Trace test, we have identified distinct periods where US exports and imports were not cointegrated (mid 1960s to mid 1970s and mid 1980s to the end of the 1990s) and distinct periods where they were (mid 1970s to mid 1980s and late 1990s onwards). For the most recent years, there is evidence of cointegration between exports and imports despite the historically high levels of current account deficit. This is consistent with so-called threshold effects in current account adjustment. Further analysis of the asymmetric short-run dynamics reveals that adjustment towards long-run equilibrium between exports and imports is primarily driven by US exports responding to current account deficits. Clearly, the mechanisms through which imports, exports and current account adjustment can be achieved are complex and this would merit a fruitful avenue for future research.

REFERENCES

- Barnet, W.A., Gallant, A.R., Hinich, M.J., Jungeilges, J.A., Caplan, D.T. and M.J. Jensen (1997). "A Single-blind Controlled Competition Amongst Tests for Nonlinearity and Chaos." *Journal of Econometrics* 82, 157-192.
- Ben-David, D. and D. Papell, (1997). "International Trade and Structural Change." *Journal of International Economics* 43, 513-523.
- Bierens, H.J. (1997). "Nonparametric Cointegration Analysis." *Journal of Econometrics* 77, 379-404.
- Bohn, H. (2007). "Are Stationary and Cointegration Restrictions Really Necessary for the Temporal Budget Constraint?" *Journal of Monetary Economics* 54, 1837-1847.
- Breitung, J. (2002). "Nonparametric Tests for Unit Roots and Cointegration." *Journal of Econometrics* 108, 343-363.
- Breitung, J. and A.M.R. Taylor, (2003). Corrigendum to "Nonparametric Tests for Unit roots and Cointegration." *Journal of Econometrics* 117, 401-404.
- Brock, W.A., Dechert, W., and J. Scheinkman (1996). "A Test for Independence Based on the Correlation Dimension." *Econometrics Reviews* 15, 197-235.
- Chen, L-L and J. Devereux (1994). "Export Prices and the Current Account: An Asymmetry." *Economics Letters* 44, 415-420.
- Chinn, M. (2005). "Doomed to Deficits? Aggregate U.S. Trade Flows Re-examined." *Review of World Economics/Weltwirtschaftliches Archiv* 141, 460-485.
- Clarida, R.H., Goretta, M. and M.P. Taylor (2006). "Are there Thresholds of Current Account Adjustment in the G7?" NBER working paper 12193.
- Davig, T. (2005). "Periodically Expanding Discounted Debt: a Threat to Fiscal Policy Sustainability?" *Journal of Applied Econometrics* 20, 829-840.
- Davig, T. (2004). "Regime switching Debt and Taxation." *Journal of Monetary Economics* 51, 837-859.

- Doornik, J.A. (1998). "Approximations to the Asymptotic Distribution of Cointegration Tests." *Journal of Economic Surveys* 12, 573-593.
- Elliott, G., Rothenberg, T.J. and J.H. Stock (1996). "Efficient Tests for an Autoregressive Unit Root." *Econometrica* 64, 813-836.
- Engle, R. F. and C. W. J. Granger, (1987). "Co-integration and Error Correction: Representation, Estimation, and Testing." *Econometrica* 55, 251-276.
- Enders, W. and P. L. Siklos (2001). "Cointegration and Threshold Adjustment." *Journal of Business and Economics Statistics*, 19, 2, 166-176.
- Engle, R.F. (1982). "Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of United Kingdom Inflation." *Econometrica* 50, 987-1007.
- Escribano, A. and C.W.J. Granger (1998). "Investigating the Relationship between Gold and Silver Prices." *Journal of Forecasting* 17, 81-107.
- Escribano, A. and F. Aparicio (1999). "Cointegration: Linearity, Nonlinearity, Outliers and Structural Breaks." In Dahiya, S.B. (ed.), *The Current State of Economic Science*, Spellbound Publications, Vol 1, 383-407.
- Escribano, A. and G.A. Pfann (1998). "Nonlinear Error Correction, Asymmetric Adjustment and Cointegration." *Economic Modelling* 15, 197-216.
- Freund, C.L. (2000). "Current Account Adjustment in Industrialized Countries." Board of Governors of the Federal Reserve System. International Finance Discussion Papers 692.
- Goldberg, L. and C. Tille (2006). "The International Role of the Dollar and Trade Balance Adjustment." National Bureau of Economic Research, Working Paper: 12495.
- Gourinchas, P-O and H. Rey (2005). "From World Banker to World Venture Capitalist, US external adjustment and the Exorbitant Privilege." NBER Conference on G7 Current Account Imbalances: Sustainability and Adjustment.

- Granger, C.W.J. and T.H. Lee (1989). "Investigation of Production, Sales and Inventory relationships using multicointegration and non-symmetric error correction models." *Journal of Applied Econometrics* 4, S145-S159.
- Granger, C.W.J. and T. Teräsvirta (1993). *Modelling Nonlinear Economic Relationships*, Oxford University Press, Oxford.
- Hansen, H. and S. Johansen (1999). "Some Tests for Parameter Constancy in Cointegrated VAR-models." *Econometrics Journal* 2, 306-333.
- Herwartz, H. (2003). "On the (Nonlinear) Relationship between Exchange Rate Uncertainty and Trade - An Investigation of US Trade Figures in the Group of Seven." *Review of World Economics/Weltwirtschaftliches Archiv* 139, 650-682.
- Johansen, S. (1995). *Likelihood-Based Inference in Cointegrated Vector Autoregressive Models*, Oxford University Press, Oxford.
- Johansen, S., Mosconi, R. and B. Nielsen (2000). "Cointegration Analysis in the Presence of Structural Breaks in the Deterministic Trend." *Econometric Journal* 3, 216-249.
- Krugman, P. R. (1985). "Is the Strong Dollar Sustainable?" Proceedings, Federal Reserve Bank of Kansas City, 103-155.
- Lanne, M., Lutkepohl, H. and P. Saikkonen (2002). Comparison of Unit Root Tests for Time Series with Level Shifts, *Journal of Time Series Analysis* 23, 667-685.
- Leonard, G. and A.C. Stockman (2002). "Current Accounts and Exchange Rates: A New Look at the Evidence." *Review of International Economics* 10, 483-496.
- Liu, P. and E. Tanner (1996). "International Intertemporal Solvency in Industrialised Countries: Evidence and Implications." *Southern Economic Journal* 62, 739-749.
- Lutkepohl, H. and M. Kratzig (2004). *Applied Time Series Econometrics*, Cambridge University Press

- Mann, C.L. (2002). "Perspectives on the US current Account Deficit and Sustainability." *Journal of Economic Perspectives* 16, 131-152.
- McLeod, A.I. and W.K. Li. (1983). "Diagnostic Checking ARMA Time Series Models Using Squared-Residual Autocorrelations." *Journal of Time Series Analysis* 4, 269-273.
- Milesi-Ferretti, G.M. and A. Razin (1998). "Current Account Reversals and Currency Crises: Empirical Regularities." NBER Working Paper 6620.
- Ng, S. and P. Perron (2001). "Lag Length Selection and the Construction of Unit Root Tests with Good Size and Power, *Econometrica* 69, 1519-1554.
- Obstfeld, M. and K. Rogoff (2005). "The Unsustainable U.S. Current Account Position Revisited." Proceedings, Federal Reserve Bank of San Francisco.
- 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* 11, 414-430.
- Patterson, D.M. and R.A. Ashley (2000). *A Nonlinear Time Series Workshop*, Kluwer Academic, London.
- Quintos, C. (1995). "Sustainability of the Deficit Process with Structural Shifts." *Journal of Business and Economic Statistics* 13, 409-417.
- Raybaudi, M., Sola, M. and F. Spagnolo (2004). "Red signals: Current Account Deficits and Sustainability." *Economics Letters* 84, 217-223.
- Saikkonen, P. and H. Lutkepohl (2002). "Testing for a Unit Root in a Time series with a Level Shift at Unknown Time." *Econometric Theory* 18, 313-348.
- Taylor, A. (2002). "A Century of Current Account Dynamics." *Journal of International Money and Finance* 21, 725-748.
- Teräsvirta, T. (1998). Comment on Ericsson, N. R., Hendry, D. F. and K. M. Prestwich, "The Demand for Broad Money in the United Kingdom, 1878-1993." *Scandinavian Journal of Economics* 100, 325-338.

- Trehan, B., and C. Walsh, (1991). "Testing Intertemporal Budget Constraints: Theory and Applications to US Federal Budget and Current Account Deficits." *Journal of Money Credit and Banking* 23, 206-223.
- Tsay, R.S. (1986). "Nonlinearity Tests for Time Series." *Biometrika* 73, 461-466.
- Wickens, M. and M. Uctum (1993). "The Sustainability of Current Account Deficits: A Test of the US Intertemporal Budget Constraint." *Journal of Economic Dynamics and Control* 17, 423-441.
- Wu, J-L. (2000). "Mean Reversion of the Current Account: Evidence from the Panel Data Unit Root Test." *Economics Letters* 66, 215-222.
- Wu, J-L, Chen, S-L. and H-Y. Lee (2001). "Are Current Account Deficits Sustainable? Evidence from Panel Cointegration." *Economics Letters* 72, 219-224.

TECHNICAL APPENDIX

BREITUNG NONPARAMETRIC TEST FOR COINTEGRATION

Breitung's unit root and cointegration test employs a variance ratio as the test statistic. As noted, this approach can eliminate problems in terms of specifying the short run dynamics and the estimating 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 $T \rightarrow \infty$, $T^{-1/2} x_{[aT]} \Rightarrow \sigma W(a)$, where $\sigma > 0$ 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 $\hat{U}_t = \hat{u}_1 + \dots + \hat{u}_t$. 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 $(n-q)$ -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 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 has proposed the following problem about the $n \times n$ matrix A_T, B_T .

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

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 $\hat{U}_t = \sum_{j=1}^t \hat{u}_j$ 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 eigenvector 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 $\lambda_1 \leq \lambda_2 \leq \dots \leq \lambda_n$ 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.

UNIT ROOT TEST WITH STRUCTURAL BREAK

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:

$$y_t = \mu_0 + \mu_1 t + f_t(\theta)' \gamma + u_t$$

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 generalised least squares (GLS) procedure and subtracting it from the original series. Then an ADF-type test is performed on the adjusted series. If the break date is unknown, the authors recommend (based on simulation results) choosing a reasonably large AR order in the first step and then picking up the break data that minimises the generalised sum of squares errors of the model in first differences.



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