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Testing for Non-linearity in the Balancing Item of Balance of Payments Accounts: The Case of 20 Industrial Countries

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ABSTRACT

The non-linearity of financial and economic time series is becoming a fundamental issue both at the theoretical and empirical level. This applies equally to balance of payments statistics such as balancing item (net errors and omissions), which is a residual variable needed to ensure that all debit and credit entries in the balance of payments statement sum to zero. This univariate variable is only one of a number of accounting balances that can be established in economic statistics that are used in assessing the accuracy of the balance of payments statistics. Except for Tang et al (forthcoming), the existing works which have studied the balancing item either disregard the presence of non-linearity or assume at the outset that the non-linearity takes a particular form. An AR(p) model is employed in the present paper to remove any linear structure from the balancing item series. Applying a battery of non-linearity tests, the assumption of linearity is tested for 20 industrial countries' balancing item. In general, the statistical tests reveal the presence of non-linear dependencies in the balancing item series for 16 out of the 20 industrial countries. An implication is that the non-linear dynamics of these balancing item series should be incorporated in the modelling and forecasting exercises for a majority of the countries.

1. INTRODUCTION

BROADLY SPEAKING, both the empirical and theoretical literatures show that linearity is widely assumed in the modelling and analysis of economic and financial time series. Specifically, researchers and policymakers have formulated fiscal and monetary policies based on the results of a linear modelling framework. With the advancement in statistical analysis, the assumption of linearity in financial and macroeconomic time series has been challenged in recent decades as many theoretical models are highly non-linear (Patterson and Ashley 2000, p.1). As highlighted by Potter (1999, p.506), 'Successful non-linear time series modelling would improve forecasts and produce a richer notion of business cycle dynamics than linear time series models allow. For this to happen two conditions are necessary. First, economic time series must contain non-linearities. Second, we need reliable statistical methods to summarise and understand these non-linearities suitable for time series of the typical macroeconomic length'.

Nevertheless, it is important to explain the rationale for testing non-linearity in time series data. According to Patterson and Ashley (2000, p.28), there are three reasons why the presence of non-linearity in time series data may cause problems in data analysis. First, certain estimates may be poorly behaved if a non-linear process is ignored. Second, a linear model fitted to the data may leave out important dependencies. Finally a non-linear process that is also white noise may be forecastable.[2] On top of that, Mills (1991, p.217) observed that 'An important aspect of non-linear modelling is detecting whether the time series do, in fact, contain important non-linearities and hence the development of testing procedures is paramount'.

Over the last two decades, testing for non-linearity in financial and economic time series has become an active research area. For example, Hinich and Patterson (1985) examined the presence of non-linearity in 15 common stocks and found that daily stock returns are generated by a non-linear process. Panagiotidis (2005) applied five statistical tests viz. BDS, McLeod-Li, Engle LM, Tsay, and bicovariance tests, to the residuals of the random walk model for three different indices from the Athens Stock Exchange. The study found that the residuals series are not independent and identically distributed (*iid*), suggesting that some kind of hidden structure exists in the data. In the context of foreign exchange markets, Liew *et al* (2003) tested the linearity of real exchange rates for 11 Asian economies and the empirical results confirm the presence of non-linearity for most of the Asian currencies. Using the bicorrelation test, Lim *et al* (2003) also uncovered hidden non-linear structures in the data generating process of the ASEAN-4 exchange rates returns series viz. Indonesia, the Philippines, Singapore, and Thailand.

Non-linearity in macro time series had been tested even in the 1980s (see, for example, Ashley and Patterson, 1989; Brock and Sayers, 1988). More recently, Ashley and Patterson (2000) tested the linearity assumption for real US GNP. The study found persuasive evidence that the generating mechanism for this series is non-linear in nature. Based on the results of a battery of non-linearity tests, Panagiotidis and Pelloni (2003) found conclusive evidence of non-linearity in time series for German labour markets, but not for the UK, in which most variables corroborate the assumption of linearity. A recommendation is that the presence of asymmetries, both in an aggregate and disaggregated level, should be taken into account by policymakers because failure to do so will produce unreliable employment forecasts and will affect the efficiency of employment related policies, especially for the case of Germany (see Panagiotidis and Pelloni, 2003, p. 285).

For the case of the UK, a simple AR model is adequate since the study was not able to find evidence of nonlinearity. Applying the same testing methodology, Panagiotidis and Pelloni (2007) tested the presence of non-linear serial dependence in the US and Canadian labour markets. For the US, linearity is confirmed for aggregate unemployment, but non-linearity was found for aggregate employment. In addition, the linearity assumption was rejected for sectoral level data. However, the findings for Canada are not clear-cut. The study found an unspecified non-linear component for the Canadian unemployment rate and in the sectoral shares data. Meanwhile the empirical results, which are based on a multivariate framework, allow them to conclude the existence of important asymmetries, for which a linear VAR cannot capture the dynamics of employment reallocation.

Thus, this study contributes to the empirical literature by testing the non-linear dynamics of balance of the payments account balancing item for a range of industrial countries via five non-linearity tests. This is an extension of work by Tang *et al* (forthcoming) which examined the non-linearity and sustainability of Japan's balancing item time series. By and large, empirical evidence is necessary to conclude whether a time series variable is linear or non-linear. According to Mills (1991, pp.217-218), 'It is important to emphasise that examining plots of the data will typically be of little use: many time series generated by non-linear, possibly chaotic, processes are usually indistinguishable from random series. Such departures from linearity will, therefore, not be established by simple "eyeballing" of the data, or even by using standard statistical tests of randomness'.

The balancing item is generally defined as the difference between total recorded credit transactions and total recorded debit transactions on the balance of payments account per time period (Brooks and Fausten 1998, p.31). In other words, the net balance of errors (transactions recorded incorrectly) and omissions (transactions not recorded at all) constitute the balancing item (Fausten and Brooks 1996, p.1303). This is linked to the double entry bookkeeping principle, which is applied to balance of payments accounts framework that the total recorded credit is equal to the total recorded debit. In practice, balance of payments accounts are constrained by the 'adding up' problem where total recorded debit is not equal to total credit. Consequently a value, the so-called balancing item, is added to validate this accounting principle. In addition, the balancing item reflects the net effects of differences in coverage, timing, and valuation as well as errors and omissions which occur in compiling both the current and capital accounts of the balance of payments statistics.

A survey of recent literature shows that the balancing item on balance of payments accounts is becoming a popular topic in international economics, given its profound implications. First, the size of the balancing item indicates the reliability of balance of payments statistics, while its sign suggests the direction of the 'errors and omissions' for total recorded debit or credit transactions, in general. For instance, a positive balancing item value does suggest a systematic over-reporting of debit transactions, or under-reporting of credit transactions, and vice versa. Second, as advocated by Tang (2007) (also see Tang *et al*, forthcoming) there is an implication for testing whether the balancing item is sustainable. Generally, while large balancing items are assumed to have an important role in the propagation of economic mismanagement, a small value does not necessarily mean that only small errors and omissions have occurred, given that large positive and negative errors may be offsetting. In this situation, rather than focusing on the size of the balancing item, a preferable approach is to examine whether or not the balancing item is sustainable. It will be sustainable if the continuation of large errors and omissions (positive or negative) do not entail a need for 'drastic' adjustment in the balance of payments recording system or a policy shift because of 'inappropriate' policies, given unreliable balance of payments statistics in the long run.

Numerous studies have estimated statistical descriptions of the balancing item and also the effects of its potential determinants. In 1971, Duffy and Renton modelled the UK balancing item as a function of the principal components extracted from the probable major sources of error in the balance of payments accounts (exports and re-exports of goods, imports of goods, net total invisibles, net private investments abroad and in the UK, the net change in external sterling liabilities, miscellaneous capital and the overall monetary balance) and from the likely determinants of unidentified monetary flows (spot exchange rate and interest differential). The lagged first difference of the balancing item was also considered as independent variable.

More recently, Fausten and Brooks (1996), Tombazos (2003), and Fausten and Pickett (2004) have provided insights into studying the balancing item for Australia's balance of payments accounts, using various econometrics methodologies. Fausten and Brooks (1996) examined the temporal evolution of Australia's balancing item, identifying structural breaks that are plausible *a priori*. They also explored alternative data-driven and structural approaches to the diagnosis of the errors and omissions in the statistical record. Tombazos (2003) revisited their study by using the recently revised balancing item data. Fausten and Pickett (2004) found robust evidence of structural instability in the balancing item; and financial sector transactions increasingly constitute the major source of misreporting of balance of payments outcomes. In addition, Tang and Hooy (2007) estimated the asymmetric and time varying volatility of Australia's balancing items.

In recent work, Tang (2005, 2006a and 2006b) has examined the economic factors which potentially explain the balancing item for Japan's balance of payments accounts. Overall, those studies show that Japan's balancing item is essentially due to 'timing errors' i.e. the errors are predominantly one of timing differences in data reported by the different sources used to estimate the credit and debit sides of a transaction (empirically, the current balancing item is explained statistically by its past values). On the other hand, Tang (2007) has examined the sustainability of the balancing item using unit root tests with a structural break. Results show that the balancing item for the G7 countries are sustainable (stationary in levels). Similarly, Tang and Lau (2007) applied a battery of univariate and panel unit root tests (linear framework) to examine the sustainability of the balancing item for 13 Asian countries. The results from the series-specific panel unit root test consistently illustrate that the balancing item for five of the countries (Singapore, Bangladesh, Indonesia, Korea, and Malaysia) is on a sustainable path. A recent study by Tang *et al* (forthcoming) documented that Japan's balancing item is sustainable, as suggested by the non-linear unit root test proposed by Kapetanios *et al* (2003), in which the non-linear nature of the series confirmed the Luukkonen *et al* (1988) linearity test.

It is worth noting that all the above studies, except Tang et al (forthcoming), were carried out under the assumption of linearity for the balancing item series; hence a linear modelling specification was employed. If this assumption is not true, then the results reported by these studies should be interpreted with caution. Motivated by this concern, it is imperative to determine the presence of nonlinearity so as to avoid any specification error, and to offer further valuable insight to subsequent modelling and forecasting of the balancing item series, which would be of great interest to policymakers and researchers. The next section discusses the data and the methods used. The following section reports and discusses the empirical results from a battery of non-linearity tests. The study has concludes in Section 4.

2. Data and methods

Data

The quarterly balancing item (net errors and omissions) data for industrial countries are collected from the *International Financial Statistics* of the International Monetary Fund (*dX*time, site licence 2094A). Only 20 industrial countries are included in this study because of data unavailability for a long sample span. They are New Zealand (1980.1-2005.1), the US (1973.2-2005.2), the UK (1970.1-2005.2), Norway (1975.1-2005.2), Portugal (1975.1-2005.3), Iceland (1976.1-2005.1), Sweden (1975.1-2005.1), Greece (1976.1-2004.4), Finland (1975.1-2005.2), Ireland (1981.1-2005.2), Canada (1975.1-2005.3), Australia (1959.2-2005.2), Denmark (1981.1-2004.4), Japan (1977.1-2005.1), Netherlands (1976.1-2005.2), Germany (1971.1-2005.3), Austria (1970.1-2005.2), Italy (1970.1-2005.2), France (1975.1-2005.2), and Spain (1975.1-2005.3).

The summary statistics are illustrated in Table 1. Interestingly, the balancing item is found to be normally distributed only for the case of Japan. These time series are then plotted and illustrated in Figure 1. A casual inspection suggests there is some stochastic element to the series: they appear to be reasonably stationary over the sample period. Table 2 presents the augmented Dicker-Fuller (ADF) and Phillips-Perron (PP) unit root tests of the series. Both tests suggest stationarity (I(0)) for all balancing item series except for Iceland. For Norway and Spain, PP test rejects the null hypothesis of a unit root while ADF fails to do so. As advocated by Tang (2007) the stationarity of balancing items indicates their sustainability.

Methods

A battery of statistical tests is considered to test whether the generating mechanism of a time series is or is not linear. This study applies five statistical tests for two reasons. First, most of the existing non-linearity tests have differing power against different classes of non-linear processes and none dominates all others, as shown in various Monte Carlo simulations (see, for example, Ashley *et al*, 1986; Ashley and Patterson, 1989; Lee *et al*, 1993; Brock *et al*, 1991, 1996; Barnett *et al*, 1997; Patterson and Ashley, 2000). Second, the five tests can be carried out easily with the Non-linear Toolkit provided by Patterson and Ashley (2000). This package has been widely employed by Panagiotidis (2002, 2005), Panagiotidis and Pelloni (2003, 2007), and Ashley and Patterson (2006).[3] Nevertheless, it is worth highlighting that the major objective of this study is to ascertain whether non-linearity exists in the full sample of the balancing item series, but not to determine the precise nature of the non-linearity.

The five tests included in the toolkit are the McLeod-Li test (McLeod and Li, 1983), the bicorrelation test (Hinich, 1996), the Tsay test (Tsay, 1986), the Engle LM test (Engle, 1982), and the BDS test (Brock et al 1996). The technical details of these tests are available from Panagiotidis (2002, p.2-4). All the tests work under the null hypothesis that the series under consideration is an *iid* process. The McLeod and Li test examines whether correlation (e_t^2, e_{t-k}^2) is non-zero for some k against ARCH (Autoregressive Conditional Heteroskedasticity) effects, but the Engle LM test has power against GARCH (Generalised ARCH) alternatives. On the other hand, the Tsay test explicitly tests for quadratic serial dependence in the data and has proved to be powerful against a TAR (Threshold Autoregressive) process. The Hinich bicovariance test assumes that $\{e_t\}$ is a realisation from a third-order stationary stochastic process and tests for serial independence using the sample bicovariances of the data. The BDS test is a nonparametric test for serial independence based on the correlation integral of the scalar series $\{e_t\}$, and the alternative to linearity can be considered to be a stochastic non-linear model (Granger and Terasvirta, 1993). However, the BDS test can sometimes confuse different types of non-linear structure and has limited power in detecting neglected asymmetries in conditional variance models (see Brooks and Heravi, 1999; Brooks and Henry, 2000).

Figure 1. Plots of the Balancing Item of the Balance of Payments Accounts for 20 Industrial Countries

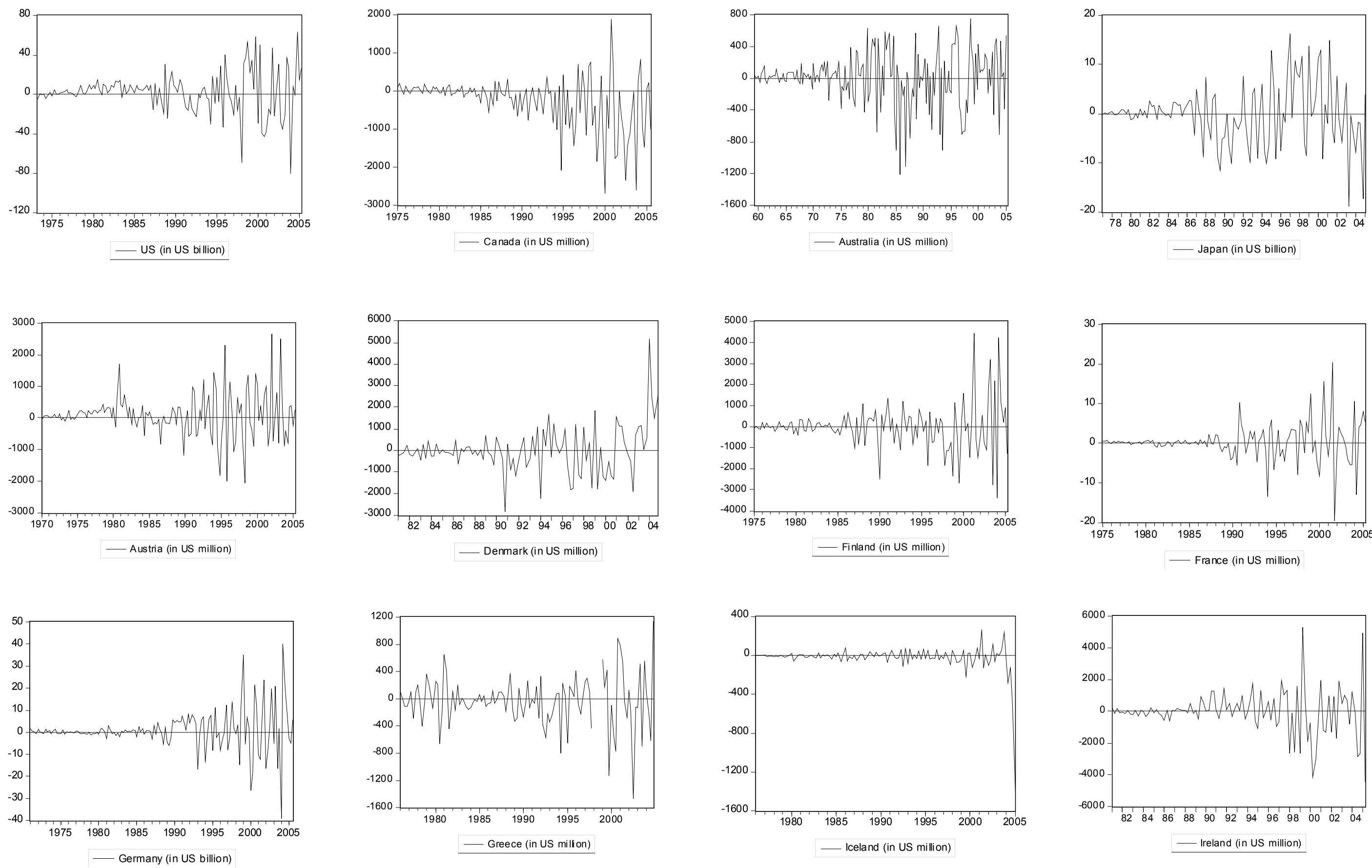

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Figure 1: *cont...*

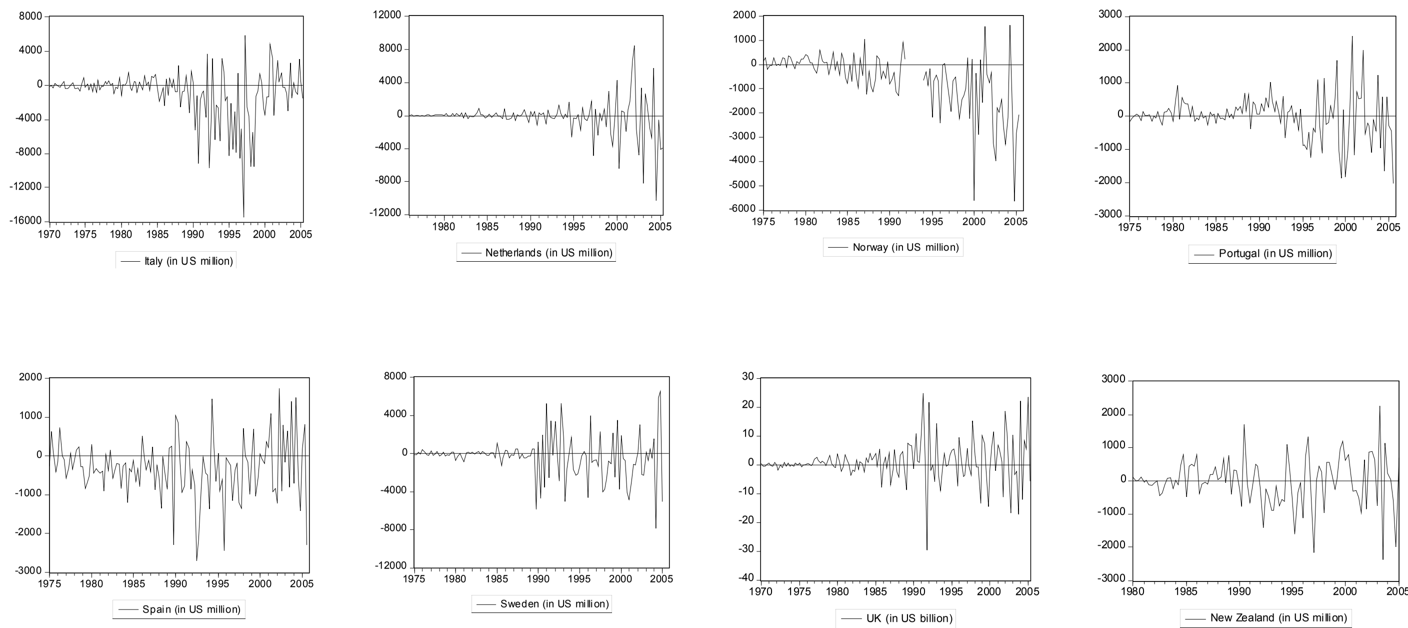

Table 1: Summary statistics on the balancing item for 20 industrial countries (millions of U.S. dollars)

	US	*Canada*	*Australia*	*Japan*	*Austria*	*Denmark*	*Finland*
Mean	2873.3	-218.0	7.6	-119.8	83.7	10.6	-22.4
Median	3500	-56.0	31.5	0.0	52.5	-84.0	-11.5
Maximum	63660	6932.0	758.0	16230	2682.0	5174.0	4429.0
Minimum	-80530	-6658.0	-1212.0	-18880	-2055.0	-2826.0	-3385.0
Std. Dev.	21569.9	2173.7	331.1	6156.5	687.7	1085.3	1062.4
Skewness	-0.3	0.0	-0.7	0.0	0.5	1.0	0.7
Kurtosis	5.6	5.2	4.4	3.9	6.3	7.7	8.0
Jarque-Bera	37.9	40.6	32.1	3.8	68.0	102.4	138.0
Probability	0.0	0.0	0.0	0.15	0.0	0.0	0.0
Sum	373530	-42508.0	1393.0	-13540	11882.0	1021.0	-2728.0
Observations	130	195	180	113	142	96	122

	France	*Germany*	*Greece*	*Iceland*	*Ireland*	*Italy*	*N'lands*
Mean	0.3	896.5	-33.2	-24.9	-27.2	-976.8	-463.2
Median	0.2	280	-33.0	-7.0	23.5	-303.5	-23.0
Maximum	20.5	40180	1130.0	262.0	5283.0	5850.0	10814.0
Minimum	-19.6	-39230	-1472.0	-1413.0	-4468.0	-15473.0	-10281.0
Std. Dev.	4.7	9005.7	366.3	150.1	1400.3	2953.9	2774.1
Skewness	0.1	0.3	-0.4	-7.0	0.1	-1.8	-0.1
Kurtosis	9.1	9.4	5.7	64.6	6.9	7.9	6.4
Jarque-Bera	188.4	236.0	36.3	19457.7	62.4	217.6	73.9
Probability	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sum	36.4	124620	-3717.0	-2918.0	-2664.0	-138706.0	-71334.0
Observations	122	139	112	117	98	142	154

	Norway	*Portugal*	*Spain*	*Sweden*	*UK*	*New Zealand*
Mean	-620.5	10.9	-314.2	-353.6	1078.4	-10.3
Median	-306.0	33.0	-316.0	-185.0	320	0.0
Maximum	1633.0	2425.0	1729.0	6542.0	24930	2258.0
Minimum	-5634.0	-2009.0	-2698.0	-7894.0	-29670	-2372.0
Std. Dev.	1203.8	656.5	749.9	2186.1	7051.9	734.8
Skewness	-1.7	-0.1	-0.2	-0.1	0.1	-0.4
Kurtosis	7.2	5.7	4.5	5.2	7.2	4.6
Jarque-Bera	138.4	36.5	12.1	25.2	105.5	13.3
Probability	0.0	0.0	0.0	0.0	0.0	0.0
Sum	-70740	1343.0	-38642.0	-42789	153130	-1039.0
Observations	114	123	123	121	142	101

Table 2: Unit root tests

	ADF(q)	*PP(q)*
US	-4.955(6)***	-11.11(4)***
Canada	-3.07(12)***	-14.85(5)***
Australia	-6.12(5)***	-12.93(7)***
Japan	-3.374(3)***	-10.36(7)***
Austria	-4.10894)***	-12.7(4)***
Denmark	-2.189(5)**	-8.29(4)***
Finland	-13.86(0)***	-14.2(4)***
France	-4.35(12)***	-12.77(1)***
Germany	-2.73(12)***	-14.0(12)***
Greece	-2.448(9)**	-10.12(3)***
Iceland	-0.967(6)	-0.1998(5)
Ireland	-11.75(0)***	-11.73(2)***
Italy	-1.747(5)*	-11.39(8)***
Netherlands	-2.736(9)***	-14.29(8)***
Norway	2.239(11)	-7.22(7)***
Portugal	-6.289(1)***	-11.0(5)***
Spain	-1.135(11)	-10.68(8)***
Sweden	-13.39(0)***	-13.21(6)***
UK	-2.43 (11)**	-14.48(8)***
New Zealand	-10.77(0)***	-10.76(4)***

Note: No constant and trend for ADF test. ***, **, and * denotes rejection of the null hypothesis at 1%, 5% and 10% level of significance, respectively.

Given that the null hypothesis is *iid*, linear dependence has to be filtered out from the data, so that any rejection of the null hypothesis is due to the presence of non-linear dependence. Technically speaking, removing linear dependence via an AR(p) model is a straightforward procedure: one only need to choose the lag length p, and the model with the minimum Schwartz Criterion (SC) is chosen. It is worth noting that SC is known to be consistent for AR(p) order determination under the null hypothesis of a linear generating mechanism, compared to alternative choices such as Akaike Information Criterion (AIC) (Panagiotidis and Pelloni, 2003, p.277). In this study, values of p from zero to ten are considered for an AR(p) model. The 'best' AR(p) models for each balancing item series of the 20 industrial countries are not reported here but available from the author upon request. Since the sample size ranged between 96 and 195, it is appropriate to estimate the test statistics using the bootstrapping approach rather than relying on asymptotic theory.

For the bootstrap results, 1000 new samples are independently drawn from the empirical distribution of the pre-whitened data. Each new sample is then used to calculate a value for the test statistic under the null hypothesis of serial independence. The obtained fraction of the 1000 test statistics, which exceeds the sample value of the test statistic from the original data, is then reported as the significance level at which the null hypothesis can be rejected (Patterson and Ashley (2000). Nevertheless, this study does not document the methodology of the five statistical tests because it is available in, for example, Patterson and Ashley (2000), Ashley and Patterson (2006), or Panagiotidis (2002). To reiterate, the five tests were carried out using the Non-linear Toolkit (version 4.52).

3. Results

The results of the 'bootstrapped' significance levels are reported in Table 3. The interpretation is straightforward: evidence of non-linearity can be drawn based on the decision rule that the *p*-value of less than 0.05 is obtained. Almost all bootstrapped *p*-values from the first four tests (McLeod-Li, bicovariance, Engle, and Tsay) are less than 0.05 for Canada, France, Germany, the UK, and the US, indicating that the source of rejection for the null hypothesis of *iid* is due to the presence of nonlinearity in the data generating process, since linear dependence has been filtered out. However, results from the Tsay test suggest the adequacy of the linear model for Australia, Austria, Denmark, Finland, Greece, Japan, Netherlands, Norway, and New Zealand.

According to Panagiotidis and Pelloni (2003, p.285): 'In cases where linearity was found to be a plausible assumption, simple AR models, which means linear models could be used for forecasting purposes'. This is not the case for Australia and Austria, as suggested by the McLeod-Li, bicovariance, and Engle tests. On the other hand, the null hypothesis of linearity is accepted by the results of both bicovariance and Tsay tests for Greece, but not the McLeod-Li and Engle tests. For Spain, Italy, and Sweden, in contrast, linearity is supported based on the results of McLeod-Li, and Engle tests, whereas the bicovariance, and Tsay test findings indicate non-linearity. Generally, all four tests provide empirical evidence of linearity in the balancing item series, at which the bootstrapped *p*-values are greater than 0.05, for Denmark, Finland, Netherlands, and Norway. This inconsistency is in line with Ashley and Patterson (2000, p.30), that excluding the BDS test, the other tests are quite inconsistent in their power across the various alternatives considered.

In addition, it is also explained by the fact that the tests have different power against different nonlinear alternatives. Bear in mind that the objective of using a battery of nonlinearity tests is to minimise the probability of missing something and thus drawing the wrong conclusion. For instance, the Engle test would suggest nonlinearity enters through the variance (multiplicative nonlinearity), which can be modelled by GARCH-type models. The bicorrelation test can only capture additive nonlinearity. The BDS test is very general, hence does not give much information for nonlinear model identification.

Table 3: Tests for Non-Linear Serial Dependence: Balancing Item (bootstrapped p-values)

	Austria	*Australia*	*Canada*	*Denmark*	*Finland*	*France*	*Greece*	*Iceland*	*Ireland*	*Italy*
McLeod-Li test										
Using up to lag 20	0.006	0.000	0.016	0.883	0.374	0.007	0.003	0.082	0.182	0.941
Using up to lag 24	0.015	0.000	0.013	0.786	0.242	0.015	0.011	0.095	0.275	0.950
Bicovariance test										
Using up to lag [.]	0.042 [7]	0.001 [8]	0.025 [8]	0.179 [6]	0.274 [6]	0.004 [6]	0.123 [6]	0.007 [6]	0.000 [6]	0.003 [7]
Engle test										
Using up to lag 1	0.000	0.002	0.506	0.792	0.847	0.006	0.000	0.672	0.309	0.706
Using up to lag 2	0.000	0.000	0.013	0.369	0.662	0.009	0.001	0.020	0.075	0.675
Using up to lag 3	0.001	0.000	0.029	0.559	0.843	0.014	0.001	0.033	0.159	0.523
Using up to lag 4	0.002	0.001	0.026	0.696	0.927	0.011	0.001	0.046	0.028	0.521
Using up to lag 8	0.020	0.001	0.032	0.694	0.683	0.040	0.001	0.079	0.071	0.894
Using up to lag 10	0.032	0.003	0.046	0.828	0.719	0.015	0.000	0.115	0.152	0.959
Tsay test	0.093	0.332	0.032	0.077	0.592	0.048	0.190	0.000	0.030	0.002

	Germany	*Japan*	*N'lands*	*Norway*	*N Zealand*	*Portugal*	*Spain*	*Sweden*	*UK*	*US*
McLeod-Li test										
Using up to lag 20	0.000	0.000	0.690	0.304	0.121	0.505	0.751	0.794	0.005	0.000
Using up to lag 24	0.000	0.001	0.637	0.256	0.209	0.535	0.734	0.887	0.005	0.000
Bicovariance test										
Using up to lag [.]	0.000 [7]	0.063 [6]	0.538 [7]	0.984 [6]	0.004 [6]	0.049 [6]	0.086 [6]	0.007 [6]	0.003 [7]	0.013 [7]
Engle test										
Using up to lag 1	0.005	0.585	0.883	0.280	0.060	0.004	0.221	0.871	0.016	0.104
Using up to lag 2	0.007	0.850	0.980	0.535	0.011	0.016	0.230	0.607	0.000	0.058
Using up to lag 3	0.010	0.481	0.999	0.709	0.030	0.031	0.179	0.799	0.000	0.001
Using up to lag 4	0.011	0.622	0.975	0.861	0.046	0.054	0.280	0.747	0.001	0.001
Using up to lag 8	0.030	0.003	0.968	0.650	0.074	0.140	0.670	0.708	0.005	0.004
Using up to lag 10	0.036	0.010	0.676	0.766	0.056	0.246	0.769	0.733	0.008	0.006
Tsay test	0.000	0.753	*0.527*	0.941	0.093	0.014	0.015	0.034	0.000	0.035

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BDS TEST	*Austria*			*Australia*			*Canada*		
Dimension	EPS=0.5	EPS= 1.0	EPS= 2.0	EPS=0.5	EPS= 1.0	EPS= 2.0	EPS=0.5	EPS =1.0	EPS = 2.0
2	0.000	0.000	0.005	0.000	0.000	0.004	0.904	0.659	0.642
3	0.000	0.000	0.001	0.000	0.000	0.000	0.137	0.075	0.271
4	0.000	0.000	0.001	0.000	0.000	0.000	0.040	0.023	0.207
	Denmark			*Finland*			*France*		
Dimension	EPS=0.5	EPS= 1.0	EPS= 2.0	EPS=0.5	EPS= 1.0	EPS= 2.0	EPS=0.5	EPS =1.0	EPS = 2.0
2	0.067	0.158	0.421	0.158	0.408	0.235	0.000	0.000	0.031
3	0.005	0.032	0.119	0.013	0.102	0.250	0.000	0.000	0.031
4	0.003	0.008	0.086	0.001	0.033	0.283	0.000	0.000	0.039
	Greece			*Iceland*			*Ireland*		
Dimension	EPS=0.5	EPS= 1.0	EPS= 2.0	EPS=0.5	EPS= 1.0	EPS= 2.0	EPS=0.5	EPS =1.0	EPS = 2.0
2	0.001	0.002	0.000	0.002	0.003	0.212	0.290	0.284	0.038
3	0.000	0.000	0.000	0.000	0.000	0.041	0.123	0.105	0.018
4	0.000	0.000	0.000	0.000	0.000	0.024	0.094	0.034	0.024
	Italy			*Germany*			*Japan*		
Dimension	EPS=0.5	EPS= 1.0	EPS= 2.0	EPS=0.5	EPS= 1.0	EPS= 2.0	EPS=0.5	EPS =1.0	EPS = 2.0
2	0.010	0.194	0.670	0.000	0.000	0.001	0.000	0.017	0.268
3	0.002	0.054	0.575	0.000	0.000	0.000	0.000	0.006	0.289
4	0.001	0.010	0.264	0.000	0.000	0.000	0.000	0.000	0.264
	Portugal			*Spain*			*Sweden*		
Dimension	EPS=0.5	EPS= 1.0	EPS= 2.0	EPS=0.5	EPS= 1.0	EPS= 2.0	EPS=0.5	EPS =1.0	EPS = 2.0
2	0.441	0.114	0.021	0.968	0.942	0.329	0.306	0.683	0.128
3	0.040	0.005	0.060	0.616	0.762	0.202	0.028	0.373	0.120
4	0.012	0.001	0.083	0.056	0.606	0.107	0.016	0.199	0.161
	UK			*US*					
Dimension	EPS=0.5	EPS= 1.0	EPS= 2.0	EPS=0.5	EPS= 1.0	EPS= 2.0			
2	0.000	0.000	0.058	0.000	0.000	0.076			
3	0.000	0.000	0.021	0.000	0.000	0.016			
4	0.000	0.000	0.008	0.000	0.000	0.000			

A matter needing further clarification concerns the power of the five tests employed in this study. As documented in Ashley and Patterson (2006), the BDS test has relatively high power against all the alternatives, making it a reasonable choice as a 'non-linearity screening tests' for routine use. The results of the BDS test, in significance level (*p*-value), are also reported in Table 3. As indicated by the results of BDS test, based on the two free parameters in the BDS test, namely embedding dimension (m) and metric bound/proximity parameter (ε), the null hypothesis that the elements of the balancing item are *iid*, can be rejected for Austria, Australia, France, Greece, Japan, Iceland, Germany, New Zealand, the UK, and the US. For Canada, Denmark, Finland, Ireland, Italy, Portugal, Netherlands, Norway, Spain and Sweden, most of the *p*-values are greater than 0.05, indicating acceptance of the null hypothesis of linearity. However, mixed findings are found from different dimensions and EPS (BDS test) for Canada, Denmark, Finland, Ireland, Italy, Japan, Netherlands, Norway, Portugal, and Sweden. A study by Tang *et al* (forthcoming) confirms that Japan's balancing item on the balance of payments accounts is non-linear in nature over the monthly observations from 1985 to 2004, as suggested by the linearity test proposed by Luukkonen *et al* (1988).

Table 4: Summary of Results

	ARCH	*GARCH*	*TAR*	*General Linearity Test*	
	McLeod-Li	*Engle*	*Tsay*	*Bicovariance*	*BDS*
US	X	X	X	X	X
Canada	X	X	X	X	π
Australia	X	X	π	X	X
Japan	X	π	π	π	X
Austria	X	X	π	X	X
Denmark	π	π	π	π	π
Finland	π	π	π	π	π
France	X	X	X	X	X
Germany	X	X	X	X	X
Greece	X	X	π	π	X
Iceland	π	X	X	X	X
Ireland	π	π	X	X	π
Italy	π	π	X	X	π
Netherlands	π	π	π	π	π
Norway	π	π	π	π	π
Portugal	π	X	X	X	π
Spain	π	*p*	X	π	π
Sweden	π	*p*	X	X	π
UK	X	X	X	X	X
New Zealand	π	X	π	X	X

Note: p denotes acceptance of the null of iid, and X rejection at the 5 percent level of significance.

Table 4 summarises the results of the five tests. A general finding is that the linearity assumption is validated empirically for Denmark, Finland, Netherlands, and Norway. In other words, non-linearity in various forms is found for 16 of 20 industrial countries' balancing items on their balance of payments accounts.

4. Concluding remarks

This study aims to test the possible hidden structure, in particular non-linearity, contained in the balancing item series using a sample of 20 industrial countries. The results of the five non-linearity tests show most of the balancing items in industrial countries' balance of payments accounts would contradict the assumption of linearity. In other words, the balancing item series for 16 of 20 industrial countries is non-linear in nature, and only Denmark, Finland, Netherlands, and Norway would corroborate the assumption of linearity. The evidence of non-linearity suggests that past values can explain its current behaviour, but the relationship is in nonlinear form, especially to forecast the balancing item for the 16 industrial economies. In other words, to capture the dependencies using a linear model (such as an AR(p) model), will miss hidden structures in the series. An implication of this finding is that the studies assuming a linear balancing item require further investigation before it can be generalised, such as the study by Duffy and Renton (1971), Fausten and Brooks (1996), Tombazos (2003), Fausten and Pickett (2004), Tang (2005, 2006a, 2006, 2007b), and Tang and Lau (2007).

However, there are two issues concern for further study. First, though this study does not specify the nonlinear model (such as ARCH, GARCH, TAR, two state Markov, Quadratic models, and Cubic models) for capturing the time series behaviour of the balancing item series, researchers can use the p-values from this study to determine the adequacy of certain models, as proposed by Ashley and Patterson (2006). Second, it is worth investigating and identifying the source of the non-linearity in the balancing item on the balance of payments accounts. It helps to reduce the possible 'errors' and 'omissions' in both recorded debit and recorded credit of balance of payments accounts, such as trade account and current account. However, further study is required in order to address the above-stated drawbacks.

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Endnotes

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2 According to Potter (1999, p506), lack of autocorrelation in a time series does not imply that the time series cannot be predicted. Indeed some perfectly predictable time series have zero autocorrelations at all lags.

3 The toolkit can be downloaded from Richard Ashley's webpage at http://ashleymac.econ.vt.edu/ashleyhome.html, while instructions and interpretations of all the tests are given in chapter 3 of Patterson and Ashley (2000).

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