E C O N O M I C S   B U L L E T I N

Mean Reversion of Balance of Payments¡GEvidence from Sequential Trend Break Unit Root Tests

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Abstract

We analyze the G7 countries data set of real balance of payments series. The unit root tests with an endogenously determined break date in the trend function proposed by Zivot and Andrews (1992) is employed to characterize the balance of payments series. The empirical results show that allowing for a break in the trend function could alter the outcome of the standard unit root tests for some series.

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1. Introduction

The analytical model introduced by the famous papers of Mundell (1962, 1963) and Fleming (1962), which gave rise to the term "Mundell-Fleming model", is a very popular approach to examining the impact of various polices in an open economy. One of the key assumptions of Mundell-Fleming model is that the balance of payments (BOP) is zero in equilibrium; that is, the trade balance equals the net capital outflow. However, there is very little attention on the characteristic of BOP time series. If BOP is mean reverting, it follows that the BOP will return to its trend path over time and the assumption of Mundell-Fleming model is reasonable. On the other hand, if BOP follows a random walk process, any shock or innovation has a sustained effect. Thus the future BOP cannot be predicted based on its historical movements and the analytical approach of Mundell-Fleming model must be modified.

This paper will investigate the issue that whether the BOP is best characterized by following a random walk or mean reverting process. We employ the unit root tests with one structural break in the trend function proposed by Zivot and Andrews (1992) to examine the random walk hypothesis for the BOP of G7 countries. The results of the unit root tests without structural break show that the BOP follows a random walk process for Germany, Italy, Japan and United States. However, most of the G7 countries, the BOP series will support the mean reversion hypothesis when the unit root tests are allowing for one structural break in the trend function.

This paper proceeds as follows. Section 2 covers a description of data and econometric methods used in this paper. The empirical results are presented in Section 3. And finally the last section offers a conclusion.

2. The data and the empirical methodology

2.1. The data

The data set, obtained from the International Monetary Fund's *International Financial Statistics* (*IFS*), comprises quarterly observations for G7 countries, including Canada (CAN), France (FRA), Germany (GER), Italy (ITA), Japan (JPN), United Kingdom (UK) and United States (USA). The sample period is from 1981:1 to 2006:3. Two indexes are employed to measure the equilibrium of BOP. One, denoted by $BOP1$, is defined as summing up the net balance in current account, capital account and financial account.[1] Allowing for the statistical discrepancy, we define the other index, $BOP2$, as overall balance which adds the net errors and omissions to the previous

[1] International Monetary Fund has reorganized the items in BOP and newly established financial account in 1997. See *Balance of Payments Manual* published by IMF and compare the difference between the 4th edition and the 5th edition. Because the financial account in the 5th edition is roughly equivalent to the capital account in the 4th edition, $BOP1$ before 1997 is calculated by summing up the net balance of current account and capital account.

$BOP1$.

All the accounts in BOP are measured in billions of US dollars. The indexes employed in this paper, $BOP1$ and $BOP2$, are deflated by the consumer price index of each country and then seasonally adjusted by moving average method.[2] Time series plots of seasonally adjusted $BOP1$ and $BOP2$ for each country are shown in Figure 1. The descriptive statistics are presented in Table 1.

Table 1: Descriptive statistics, 1981:1-2006:3

	Canada	France	Germany	Italy	Japan	UK	USA
$BOP1$							
Mean	0.5232	-0.3286	-1.6959	1.5429	8.4642	-2.2099	-10.3377
Maximum	8.8075	54.3306	57.5260	27.2292	158.4803	25.2335	68.4948
Minimum	-7.7136	-52.3399	-55.6969	-17.6923	-27.7437	-26.6195	-66.8678
Standard deviation	3.6958	10.5590	13.4045	7.0497	20.2883	9.8961	27.5594
Skewness	-0.1473	0.1378	-0.0897	0.3123	4.4857	-0.2411	0.2325
Kurtosis	2.4722	14.5141	8.4397	4.6418	31.4146	3.1301	2.6738
$BOP2$							
Mean	0.0619	-0.0339	0.0030	-0.0050	7.9688	-0.8504	-5.2569
Maximum	5.4381	8.2312	61.2846	17.9107	146.0140	15.0207	24.6048
Minimum	-5.2979	-24.3619	-23.7867	-27.9341	-16.5754	-15.5535	-42.5392
Standard deviation	2.0365	4.1725	8.2613	6.6831	18.1593	4.4319	11.9687
Skewness	0.1604	-2.2229	3.5609	-0.7220	4.9184	0.0319	-0.8600
Kurtosis	3.5443	13.9184	32.0513	6.4582	35.0474	4.7942	3.9448

[2] The other method to measure the BOP may be the ratio of the BOP to GDP. However, this paper is the test for the unit root of the BOP time series for each country separately. The trend has been included in the regression. We think it is not necessary to move the scale effect by dividing the GDP when the unit root is irrelevant to the comparisons among countries.

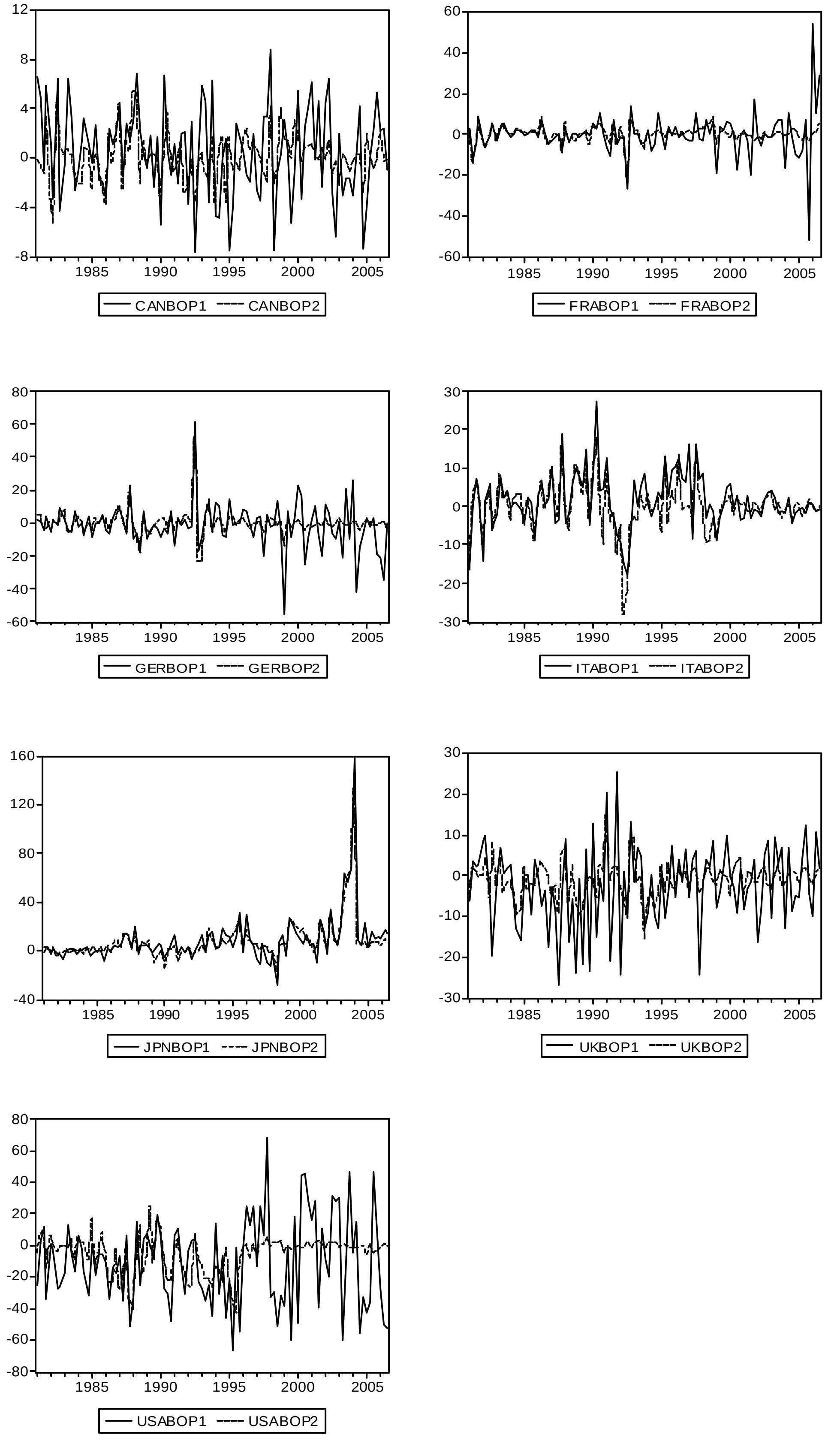

Figure 1: Plots of BOP time series

2.2. The econometric methodology

The prevalent approach to examining the random walk hypothesis is unit root tests. To provide a benchmark, we start by the Augmented Dickey-Fuller (ADF) unit root tests. The ADF regressions are:

$$\Delta y_t = m + a \cdot y_{t-1} + \sum_{j=1}^{k} c_j \cdot \Delta y_{t-j} + e_t \tag{1}$$

$$\Delta y_t = m + a \cdot y_{t-1} + b \cdot t + \sum_{j=1}^{k} c_j \cdot \Delta y_{t-j} + e_t \tag{2}$$

where y_t refers to the $BOP1$ or $BOP2$ time series in each country, Δy_{t-k} is the lagged first difference, $t = 1,2,\ldots,T$ is an index of time. Equation 1 and 2 have $a = 0$ as the null hypothesis of a unit root in y_t, and $a < 0$ as the alternative hypothesis. If the null hypothesis is rejected, Equation 1 means that y_t is a mean stationary series and Equation 2 indicates that y_t is trend stationary.

The sufficient lags of Δy_t are included in ADF unit root tests to yield approximately white noise residual. There are two data-dependent methods to select the lag parameter k. The first one originally implemented by Perron (1989) is a general to specific recursive procedure based on the value of the t-statistic on the coefficient of the last lag. It starts with a predetermined upper bound $k_{\max}$. If the last included lag is significant, $k_{\max}$ is selected. However, if $k_{\max}$ is insignificant, the number of lags is reduced by one until the last lag in the estimated autoregression is significant. Hayashi (2000, p594) suggested the formula $k_{\max} = \text{int}(12(T/100)^{0.25})$ as lag selection rules of upper bound. In this paper, we use the approximate 10% asymptotic critical value of 1.60 to assess the significance of the last lags and $k_{\max} = 12$ is set according to Hayashi's formula.

It must be noted that the other method to select the lag order is the minimum of Akaike Information Criterion or Schwartz Bayesian Criterion. Ng and Perron (1993) indicated that the information-based criteria tend to select very parsimonious models leading to tests with serious size distortions. For the reason, we use general to specific approach of Perron (1989) to select the lag parameter k.

Perron (1989) showed that the standard unit root tests are biased towards non-rejection of the unit root hypothesis if the data are characterized by the stationary processes with one break in the trend function. Perron (1989) also developed procedures that test for a unit root allowing for a one-time structural change in the trend. However, the break dates reported in Perron (1989) were chosen ex-ante and not modified ex-post. Some papers have focused on this issue and proposed test procedures that relax the exogeneity assumption about the determination of the break date. Zivot and Andrews (1992) extended Perron's (1989) model by endogenizing the choice of break date from the data. We will apply the versions of Zivot and Andrews (1992) to investigate the unit root hypothesis for BOP series.

We first assume that the one-time change in the structure occurring at time $TB\,(1 < TB < T)$. In the notation of Perron (1989), Model A has the following representations:

$$\Delta y_t = m + a \cdot y_{t-1} + b \cdot t + q \cdot DU_t + \sum_{j=1}^{k} c_j \cdot \Delta y_{t-j} + e_t \qquad (3)$$

Model B is depicted as:

$$\Delta y_t = m + a \cdot y_{t-1} + b \cdot t + g \cdot DT_t + \sum_{j=1}^{k} c_j \cdot \Delta y_{t-j} + e_t \qquad (4)$$

And Model C can be written in the form as:

$$\Delta y_t = m + a \cdot y_{t-1} + b \cdot t + q \cdot DU_t + g \cdot DT_t + \sum_{j=1}^{k} c_j \cdot \Delta y_{t-j} + e_t \qquad (5)$$

DU_t is an indicator dummy variable for mean shift occurring at time TB, and DT_t is the corresponding trend shift variable where

$$DU_t = \begin{cases} 1 & \text{if } t > TB \\ 0 & \text{otherwise} \end{cases}$$

$$DT_t = \begin{cases} t - TB & \text{if } t > TB \\ 0 & \text{otherwise} \end{cases}$$

Model A (the "crash'' model) allows for a one-time change in the intercept of the trend function. Model B (the "changing growth '' model) specifies a change in the slope of the trend function. Model C combines the changes in the intercept and slope of the trend function. The null hypothesis for a unit root in y_t imposes the restriction on the coefficient that $a = 0$ in each model. Under the null hypothesis of a stationary fluctuation around the trend function, we have the following specification: $a < 0$.

Zivot and Andrews (1992) suggested the region ($0.15T$ and $0.85T$) as the searching interval for the break date in order to exclude the beginning or the end points of the sample. The break date must be chosen to give the least favorable result for the null hypothesis. Therefore we select the break date recursively by choosing the value of TB that minimizes the t-statistic for testing for $a = 0$ in the appropriate autoregression.

3. Empirical results

The results for the unit root tests without structural break, Equation 1 and 2, are reported in Table 2. The $BOP1$ series may follow a random walk process for the cases of Germany and Italy with trend, Germany and Japan without trend. The $BOP2$ series is stationary except in the case of United States with trend.

Table 2: Augmented Dickey-Fuller (ADF) unit root tests

	Canada	France	Germany	Italy	Japan	UK	USA
$BOP1$							
ADF (with trend)	-3.8748**	-4.7677*	-2.1101	-3.0723	-4.2446*	-12.5871*	-4.2127*
$P-$value	0.0170	0.0010	0.5330	0.1189	0.0056	0.0000	0.0063
Lag order (k)	10	8	12	6	6	0	8
ADF (without trend)	-3.7720*	-4.7515*	-2.1102	-3.0231**	-1.1394	-4.2242*	-4.1453*
$P-$value	0.0045	0.0002	0.2412	0.0363	0.6972	0.0010	0.0013
Lag order (k)	10	8	6	6	11	3	8
$BOP2$							
ADF (with trend)	-4.7914*	-3.7481**	-9.9197*	-3.8294**	-3.7902**	-4.3592*	-2.9401
$P-$value	0.0009	0.0239	0.0000	0.0191	0.0214	0.0000	0.1550
Lag order (k)	2	8	1	7	10	9	7
ADF (without trend)	-4.7834*	-3.7699*	-9.9202*	-3.7701*	-4.1848*	-3.8056*	-2.7566***
$P-$value	0.0001	0.0045	0.0000	0.0045	0.0011	0.0040	0.0685
Lag order (k)	2	8	1	7	1	9	7

1. The symbols *, ** and *** indicate significance at 1%, 5% and 10% statistical level.
2. Critical values are from MacKinnon (1991).

To consider the possible structural break in the trend function, we implement Zivot and Andrews' sequential break unit root tests. The results for Model A, B, C are shown in Table 3, 4, 5 respectively. The critical values provided by Zivot and Andrews (1992) depend on the relative location of the break date in the sample (denoted by $l = TB/T$). However, there is not much variation in the critical values. Therefore we only report the critical values for t_a corresponding to a break date at mid-sample ($l = 0.5$). In Table 3 and 5, the results show that the null hypothesis is rejected in $BOP1$ and $BOP2$ for Model A and C. In Table 4, for Model B, the null hypothesis is rejected except $BOP1$ of Germany.

Zivot and Andrews didn't provide the critical values for testing for $q = 0$ or $g = 0$. We test the significance of q or g by standard t-statistic. The change in the intercept of trend function (q) is significant for most of the BOP series. However, the change in the slope of the trend function (g) is not so obvious.

We conclude that the BOP follows a stationary process for most of the G7 countries. Comparing the difference in the results between the standard ADF unit root tests and Zivot and Andrews' sequential break unit root tests, we find that allowing for a break in the trend function may alter the outcome of the standard unit root tests for some series.

Table 3: Zivot and Andrews (1992) test for unit root: Model A

	Canada	France	Germany	Italy	Japan	UK	USA
$BOP1$							
TB	1997:2	1992:2	1991:1	1998:1	2002:4	1984:2	1996:1
l	0.6	0.5	0.4	0.7	0.9	0.2	0.6
a	-2.1057*	-3.6872*	-2.1911*	-0.6870*	-2.1172*	-1.2830*	-1.6305*
	(-4.5600)	(-5.1759)	(-6.5584)	(-4.5307)	(-6.1187)	(-13.1581)	(-5.1878)
q	3.6106**	-7.7079***	19.4486*	-5.2024**	44.5094*	-8.6992**	35.8790*
	(2.2822)	(-1.8525)	(3.6431)	(-2.1527)	(4.7405)	(-2.5102)	(3.0173)
k	10	8	4	4	10	0	8
$BOP2$							
TB	1995:4	1994:2	1989:4	1990:2	2002:4	1993:3	1995:4
l	0.6	0.5	0.4	0.4	0.9	0.5	0.6
a	-0.9854*	-3.6872*	-1.4918*	-0.8926*	-2.0397*	-1.9207*	-0.6591**
	(-5.1648)	(-5.1759)	(-10.1302)	(-4.6398)	(-5.6227))	(-5.4118)	(-4.1907)
q	1.4922***	-7.7079***	4.7596	-6.7232*	30.2179*	-5.7306*	15.3327*
	(1.8340)	(-1.8525)	(1.6131)	(-2.8654)	(3.8407)	(-3.0753)	(3.2999)
k	2	8	1	7	10	9	7

1. The t-statistics are given in parentheses.
2. The 1%, 5% and 10% critical values for t_a corresponding are -4.32, -3.76 and -3.46.
3. The symbols *, ** and *** indicate significance at 1%, 5% and 10% statistical level.

Table 4: Zivot and Andrews (1992) test for unit root: Model B

	Canada	France	Germany	Italy	Japan	UK	USA
$BOP1$							
TB	1995:1	1993:3	1995:4	1996:2	2000:4	1986:4	2002:4
l	0.6	0.5	0.6	0.6	0.8	0.2	0.9
a	-1.8402**	-3.5012*	-2.2320	-0.6532**	-2.3871*	-1.2893*	-1.3754**
	(-4.1053)	(-5.0874)	(-3.2566)	(-4.1971)	(-5.2635)	(-13.3977)	(-4.4474)
g	0.0790	0.2801***	-0.6860**	-0.1249	3.1713*	0.6653*	-1.7228
	(1.3203)	(1.7982)	(-2.5277)	(-1.2841)	(3.8797)	(2.9552)	(-1.6147)
k	10	8	12	4	10	0	8
$BOP2$							
TB	1999:4	1984:3	1992:3	1992:3	2000:1	1994:4	1993:3
l	0.7	0.2	0.5	0.5	0.8	0.5	0.5
a	-0.9188*	-1.2484*	-1.4694*	-0.7671***	-2.1439*	-1.5479**	-0.8174**
	(-4.8443)	(-8.5728)	(-9.9831)	(-3.9447)	(-4.7249)	(-4.3518)	(-3.9765)
g	-0.0314	-0.1520	-0.1205	0.1021	1.7437*	0.0392	0.5128**

	(-0.7837)	(-0.7748)	(-1.0739)	(1.0245)	(2.9314)	(0.5648)	(2.4286)
k	2	1	1	7	10	9	8

1. The t-statistics are given in parentheses.
2. The 1%, 5% and 10% critical values for t_a corresponding are -4.55, -3.96 and -3.68.
3. The symbols *, ** and *** indicate significance at 1%, 5% and 10% statistical level.

Table 5: Zivot and Andrews (1992) test for unit root: Model C

	Canada	France	Germany	Italy	Japan	UK	USA
$BOP1$							
TB	2002:3	1994:3	1991:1	1994:3	1998:4	1989:4	2002:2
l	0.8	0.5	0.4	0.5	0.7	0.4	0.8
a	-1.3158*	-3.8047*	-2.2073*	-0.7083**	-2.8954*	-2.0895*	-1.8164*
	(-8.9300)	(-5.3644)	(-6.5673)	(-4.5169)	(-5.5018)	(-6.4666)	(-5.4528)
q	-4.9532	7.1173***	18.2033*	4.8006***	-37.8595*	17.8975*	51.9800*
	(-2.3625)	(1.6742)	(3.1993)	(1.8598)	(-3.0705)	(3.9153)	(3.0471)
g	0.4223**	0.2741***	-0.1440	-0.1144	3.7179*	0.9014*	-4.8169*
	(2.1117)	(1.8086)	(-0.6483)	(-1.2489)	(4.2667)	(3.6793)	(-3.2817)
k	1	8	4	4	10	4	8
$BOP2$							
TB	1988:4	1994:2	1992:4	1991:1	1997:3	1993:3	1995:4
l	0.3	0.5	0.5	0.4	0.7	0.5	0.6
a	-1.0286*	-1.2708*	-1.5071*	-1.2888**	-1.9014**	-1.9163*	-1.0045**
	(-5.2622)	(-8.9486)	(-10.2225)	(-4.8099)	(-4.6414)	(-5.3378)	(-4.8373)
q	-1.8971**	3.0789***	-5.7166***	-11.2438*	-8.1991	-5.7633*	16.2536*
	(-2.0738)	(1.9328)	(-1.7507)	(-3.5269)	(-1.0746)	(-3.0420)	(3.5549)
g	-0.0759	0.0082	-0.1405	-0.2117	1.2261*	-0.0081	0.4511**
	(-1.5806)	(0.1530)	(-1.2580)	(-1.5583)	(2.6968)	(-0.1204)	(2.2614)
k	2	1	1	10	10	9	8

1. The t-statistics are given in parentheses.
2. The 1%, 5% and 10% critical values for t_a corresponding are -4.90, -4.24 and -3.96.
3. The symbols *, ** and *** indicate significance at 1%, 5% and 10% statistical level.

4. Conclusion

This paper intends to characterize the BOP time series. The standard ADF unit root tests show the BOP may follow a random walk process in some series. However, for most of the G7 countries, the BOP is trend stationary when the unit root tests are allowing for one structural break in the trend function. This implies that the assumption of Mundell-Fleming model about the equilibrium of BOP is appropriate.

The crucial feature of this paper is that we use the recursive t-statistic on the last lag to choose the order of the estimated autoregression. This method is urgently recommended by Perron. Besides we employ the Zivot and Andrews' sequential break unit root tests to endogenize the choice of break date. We have no attempt to show what happens in the break date. The purpose of this paper is to suggest that allowing for a break in the trend function could alter the outcome of the standard unit root tests.

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