

The empirical results of Market Efficiency (Gregory and Hansen test)

(SWF/US\$ foreign exchange market)

Part 2: Gregory and Hansen cointegration tests with structural breaks

Considering the existence of regime change in the long-run relationship, the Gregory and Hansen (1996) test (GH test), a structural-breaking cointegration, is applied to examine the efficiency of foreign exchange rate. The results of GH tests are shown as Table 1. All of the ADF^* , Z_α^* and Z_t^* test statistics reject the null hypothesis, which means the existence of a cointegration with a structural break between S_{t+3} and $F_{t,3m}$.

Table 1 Gregory-Hansen cointegration tests

Test statistic	A	B	C
ADF^*	-7.2754*** [2001M7]	-6.6944*** [2001M7]	-7.1939*** [2010M6]
Z_α^*	-81.6022*** [2001M7]	-73.6647*** [2001M7]	-79.2511*** [2001M2]
Z_t^*	-6.8842*** [2001M7]	-6.4861*** [2001M7]	-6.7825*** [2010M6]

Notes: *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. A, B, and C are the three models types of Gregory and Hansen (1996), and the critical values are from Table 1 of Gregory and Hansen (1996). The numbers in brackets are the estimated structural break dates.

(critical value as Appendix A, and output of three models as Appendix B)

The results of the GH test are shown in Table 3. All the ADF^* , Z_α^* , and Z_t^* test statistics reject the null hypothesis at the 5% significant level, which means the existence of a cointegration with a structural break S_{t+3} and $F_{t,3m}$. Most structural breaks of the cointegration are around 2001m7.

Hence, we set up a dummy variable D1 to represent the structural break on 2001m7, and the FMOLS is applied to estimate the parameters of cointegration. Table 2 presents the results of FMOLS being based on Model A and equation (2).

$$S_{t+3} = 0.0339 - 0.0346 \times D1 + 0.9646 \times F_{t,3m} \quad (2)$$

Table 2 FMOLS test results			
Variable	Coefficient	t-Statistic	Prob.
FSW	0.964632***	33.88160	0.0000
D1	-0.034681	-2.122835	0.0352
C	0.033971	1.873413	0.0627

To confirm whether the coefficient of $F_{t,3m}$ in Eq. (2) is equal 1, Wald test is applied to examine it. In table 3, the result of Wald test shows that the null hypothesis, the coefficient of $F_{t,3m}$ is one, is rejected at the 5% significant level, which supports market efficiency of foreign exchange market of Swiss Franz.

Table 3 Wald test for the coefficient of $F_{t,3m} = 1$

χ^2 Statistics	P value
1.543180	0.2141

Appendix A Critical value of Gregory and Hansen cointegration tests

A.W. Gregory, B.E. Hansen / Journal of Econometrics 70 (1996) 99–126

109

Table 1
Approximate asymptotic critical values

	Level	0.01	0.025	0.05	0.10	0.975
$m = 1$	ADF^*, Z_1^*					
	C	– 5.13	– 4.83	– 4.61	– 4.34	– 2.25
	C/T	– 5.45	– 5.21	– 4.99	– 4.72	– 2.72
	C/S	– 5.47	– 5.19	– 4.95	– 4.68	– 2.55
	Z_2^*					
	C	– 50.07	– 45.01	– 40.48	– 36.19	– 10.63
	C/T	– 57.28	– 52.09	– 47.96	– 43.22	– 15.90
	C/S	– 57.17	– 51.32	– 47.04	– 41.85	– 13.15
$m = 2$	ADF^*, Z_1^*					
	C	– 5.44	– 5.16	– 4.92	– 4.69	– 2.61
	C/T	– 5.80	– 5.51	– 5.29	– 5.03	– 3.01
	C/S	– 5.97	– 5.73	– 5.50	– 5.23	– 3.12
	Z_2^*					
	C	– 57.01	– 51.41	– 46.98	– 42.49	– 14.27
	C/T	– 64.77	– 58.57	– 53.92	– 48.94	– 19.19
	C/S	– 68.21	– 63.28	– 58.33	– 52.85	– 19.72
$m = 3$	ADF^*, Z_1^*					
	C	– 5.77	– 5.50	– 5.28	– 5.02	– 2.96
	C/T	– 6.05	– 5.79	– 5.57	– 5.33	– 3.33
	C/S	– 6.51	– 6.23	– 6.00	– 5.75	– 3.65
	Z_2^*					
	C	– 63.64	– 57.96	– 53.58	– 48.65	– 18.20
	C/T	– 70.27	– 64.26	– 59.76	– 54.94	– 22.72
	C/S	– 80.15	– 73.91	– 68.94	– 63.42	– 26.64
$m = 4$	ADF^*, Z_1^*					
	C	– 6.05	– 5.80	– 5.56	– 5.31	– 3.26
	C/T	– 6.36	– 6.07	– 5.83	– 5.59	– 3.59
	C/S	– 6.92	– 6.64	– 6.41	– 6.17	– 4.12
	Z_2^*					
	C	– 70.18	– 64.41	– 59.40	– 54.38	– 22.04
	C/T	– 76.95	– 70.56	– 65.44	– 60.12	– 26.46
	C/S	– 90.35	– 84.00	– 78.52	– 72.56	– 33.69

These critical values are based on the response surface

Appendix B (the output of GH cointegration and FMOLS test)

Model A (or model 2)

THE GREGORY-HANSEN COINTEGRATION TEST

MODEL 2: Level Shift	
ADF Procedure	
t-stat	-7.275482***
Lag	1.000000
Break	2001M07
Phillips Procedure	
Za-stat	-81.60220***
Za-break	2001M07
Zt-stat	-6.884257***
Zt-break	2001M07

Estimation Equation: $Y = C(1)*D1 + C(2)*FSW + C(3)$

Substituted Coefficients:

$$\text{LnSSW}_{t+3} = -0.034681*D1 + 0.964632*\text{LnFSW}_t + 0.033971$$

Dummy variable : D1= 0 before 2001m7 ; D1= 1 after 2001m7

Dependent Variable: LNSSW(3)

Method: Fully Modified Least Squares (FMOLS)

Date: 11/05/18 Time: 19:35

Sample (adjusted): 1999M02 2014M02

Included observations: 181 after adjustments

Cointegrating equation deterministics: C

Long-run covariance estimate

(Bartlett kernel, Newey-West fixed bandwidth = 5.0000)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNFSW	0.964632	0.028471	33.88160	0.0000
D1	-0.034681	0.016337	-2.122835	0.0352
C	0.033971	0.018133	1.873413	0.0627
R-squared	0.945147	Mean dependent var		0.182964
Adjusted R-squared	0.944531	S.D. dependent var		0.215069
S.E. of regression	0.050653	Sum squared resid		0.456692
Long-run variance	0.004093			

Equation: Untitled (model A)

Test Statistic	Value	df	Probability
t-statistic	-1.242248	178	0.2158
F-statistic	1.543180	(1, 178)	0.2158
Chi-square	1.543180	1	0.2141

Null Hypothesis: $C(1)=1$

Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
-1 + C(1)	-0.035368	0.028471

Restrictions are linear in coefficients.

Model B (or model 3)

THE GREGORY-HANSEN COINTEGRATION TEST
MODEL 3: Level Shift with Trend

ADF Procedure	
t-stat	-6.694417***
Lag	1.000000
Break	2001M07
Phillips Procedure	
Za-stat	-73.66478***
Za-break	2001M07
Zt-stat	-6.486153***
Zt-break	2001M07

stimation Equation: $Y = C(1)*D1 + C(2)*FSW + C(3) + C(4)*@TREND$

Substituted Coefficients:

$$\text{LnSSW}_{t+3} = 0.816629*FSW_t - 0.025792*D1 + 0.106130 - 0.000625*@TREND$$

Dummy variable: D1= 0 before 2001m7 ; D1= 1 after 2001m7

Dependent Variable: LNSSW(3)

Method: Fully Modified Least Squares (FMOLS)

Date: 11/05/18 Time: 19:49

Sample (adjusted): 1999M02 2014M02

Included observations: 181 after adjustments

Cointegrating equation deterministics: C @TREND

Long-run covariance estimate (Bartlett kernel, Newey-West fixed bandwidth
= 5.0000)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNFSW	0.816629	0.063795	12.80080	0.0000
D1	-0.025792	0.015497	-1.664293	0.0978
C	0.106130	0.036052	2.943814	0.0037
@TREND	-0.000625	0.000264	-2.366683	0.0190
R-squared	0.951796	Mean dependent var		0.182964
Adjusted R-squared	0.950979	S.D. dependent var		0.215069
S.E. of regression	0.047618	Sum squared resid		0.401336
Long-run variance	0.003484			

Model C (or Model 4)

THE GREGORY-HANSEN COINTEGRATION TEST

MODEL 4: Regime Shift

ADF Procedure	
t-stat	-7.193969***
Lag	1.000000
Break	2010M06
Phillips Procedure	
Za-stat	-79.25116***
Za-break	2001M02
Zt-stat	-6.782573***
Zt-break	2010M06

The result of FMOLS

Estimation Equation: $= C(1)*FSW + C(2)*D2 + C(3)*D2*FSW + C(4) + C(5)*@TREND$

Substituted Coefficients:

$LnSSW_{t+3} = 0.867673 * LnFSW_t - 0.032039 * D2 - 0.363859 * D2 * LnFSW_t + 0.068039 - 0.000542 * @TREND$

Dummy variable: D2= 0 before 2010m6 D1= 1 after 2010m6

Dependent Variable: LNSSW(3)

Method: Fully Modified Least Squares (FMOLS)

Date: 11/05/18 Time: 20:41

Sample (adjusted): 1999M02 2014M02

Included observations: 181 after adjustments

Cointegrating equation deterministics: C @TREND

Long-run covariance estimate (Bartlett kernel, Newey-West fixed bandwidth= 5.0000)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNFSW	0.867673	0.067222	12.90761	0.0000
D2	-0.032039	0.019161	-1.672097	0.0963
D2*LNFSW	-0.363859	0.161219	-2.256921	0.0252
C	0.068039	0.036642	1.856857	0.0650
@TREND	-0.000542	0.000274	-1.975485	0.0498
R-squared	0.951521	Mean dependent var		0.182964
Adjusted R-squared	0.950419	S.D. dependent var		0.215069
S.E. of regression	0.047889	Sum squared resid		0.403631
Long-run variance	0.003406			