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Exchange Rate Uncertainty and Trade Flows of LDCs: Evidence from Johansen's Cointegration Analysis

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This paper investigates the long run relation between a measure of exchange rate uncertainty and trade flows of LDCs by employing Johansen's cointegration technique and exclusion test. In most cases, exchange rate uncertainty is found to have significantly negative effect on LDCs trade flows.

I. Introduction

In a very recent comprehensive study in this journal Bahmani-Oskooee and Payesteh (1993) investigated the response of the trade flows to exchange rate uncertainty in six developing countries. When standard econometric method was used, they found that exchange rate uncertainty had adverse effect on the trade flows of LDCs. However, when they employed Engle- Granger (1987) method of cointegration, the evidence disappeared and they concluded:

> In light of these new developments in the literature one should consider our cointegration results preliminary. More cointegration analysis is recommended for future research on this issue, perhaps using different techniques such as Johansen and Juselius (1990) method. (pp. 201)

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As a matter of fact, Engle and Granger (1987) method to detect cointegration has been criticized on the ground that it cannot identify the multiple cointegrating vectors that may exist among set of variables. Because of such a deficiency, the multivariate cointegration technique proposed by Johansen (1988) and Johansen and Juselius (1990) is said to be superior. Macdonald and Taylor (1993) argue that Johansen's test may be viewed as more accurate in its ability to reject a false null hypothesis.[1]

Therefore, the purpose of this paper is to apply Johansen-Juselius method of cointegration to determine whether there is any long-run relationship between trade flows of LDCs and their determinants that include a measure of exchange rate volatility. Section I provides a brief explanation of Johansen (1988) and Johansen and Juselius (1990) technique. Since the models are similar to those of Bahmani-Oskooee and Payesteh (1993), only a short account will be provided. Thus, Section II presents the models and our empirical results that mostly support the notion that in the long-run, exchange rate uncertainty is detrimental to the trade flows of LDCs. Section III concludes.

II. The Methodology

As indicated, since our concern is long-run, the methodology is based on the cointegration technique which establishes whether there is a long-run equilibrium relationship between set of variables. Johansen (1988) and Johansen and Juselius (1990) define a distributed lag model of a vector of variables, X as

$$X_t = \pi_1 X_{t-1} + \pi_2 X_{t-2} + \cdots + \pi_k X_{t-k} + \varepsilon_t \qquad (1)$$

where X is a vector of N *stationary* variables and ε_t is an independently and identically distributed N dimensional vector with zero mean and Ω variance matrix. However, since most economic variables are

1. The literature is already reviewed by Bahmani-Oskooee and Payesteh and need not be repeated here.

non-stationary, Johansen and Juselius suggest rewriting (1) in first difference form in a fashion similar to the Augmented Dickey Fuller (ADF) test as below:

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} + \Gamma_2 \Delta X_{t-2} + \cdots + \Gamma_{k-1} \Delta X_{t-k+1} - \pi X_{t-k} + \varepsilon_t \quad (2)$$

where $\Gamma_i = -I + \pi_1 + \pi_2 + \cdots + \pi_i \quad (i = 1, \cdots, k)$

and $\pi = -(I - \pi_1 - \pi_2 - \cdots - \pi_k)$.

In this setup the long-run or cointegrating matrix is given by π which is an $N \times N$ matrix and includes number of r cointegrating vectors between the variables in X. Usually r is the rank of π. In general if X consists of I(1) variables (variables that achieve stationarity after being differenced once), at most r must be equal to N-1, i.e., $r \leq N-1$ (Hall, 1989).[2] If we define two matrices α and β (both $N \times r$) such that $\pi = \alpha\beta'$, the rows of β will form the r cointegrating vectors. Johansen and Juselius (1990) demonstrate that β, the cointegrating vector can be estimated as the eigenvalues found by solving

$$| \lambda s_{kk} - S_{ko} S_{oo}^{-1} S_{ok} | = 0 \quad (3)$$

where $S_{ij} = T^{-1} \sum_{t=1}^{T} R_{it} R'_{jt} \quad i, j = 0, k$

In turn, R_{ot} is set of residuals from regressing ΔX_t on the lagged differences of ΔX_t and R_{kt} is set of residuals from regressing X_{t-k} on the lagged differences. Using the eigenvalues obtained from solving (3), Johansen and Juselius prove that one can test the hypothesis that there are at most r cointegrating vectors by calculating two likelihood test statistics known as *trace* and λ-max statistics outlined by equations (4) and (5) respectively:

2. An I(1) variable is a variable that achieves stationarity after being differenced once.

$$\text{Trace} = -T \sum_{i=r+1}^{N} \text{Ln}(1 - \lambda_i), \tag{4}$$

$$\lambda - \max = -T \ln(1 - \lambda_{r+1}), \tag{5}$$

where $\lambda_{r+1}, \cdots, \lambda_N$ are the estimates of N - r smallest eigenvalues.

III. Empirical Results

In this section we apply Johansen-Juselius' cointegration technique to study the study the long-run equilibrium relation between volume of trade (imports and exports) and a measure of exchange rate uncertainty in presence of other determinants of the trade flows. Following the literature (say Bahmani-Oskooee 1986), we assume that import and export demand equations take the following forms:

$$\text{Log } M_t = F[\text{Log}(PM/PD)_t, \text{Log } NEX_t, \text{Log} T_t, \text{Log } \sigma_{Rt}) \tag{6}$$

and

$$\text{Log } X_t = F[\text{Log } (PX/PXW)_t, \text{Log } NEX_t, \text{Log } YW_t, \text{Log } \sigma_{Rt}) \tag{7}$$

where M = volume of imports; PM = import prices; PD = domestic price level; NEX = nominal effective exchange rate; Y = domestic income; σ_R = measure of exchange rate volatility; X = volume of exports; PX = export prices; PXW = world export price level; YW = world income.

Note that there are two modifications in (6) and (7) as compared to the models in Bahmani-Oskooee and Payesteh (1993). One modification makes our models more general and the other one increases the scope of our analysis. While Bahmani-Oskooee and Payesteh included either *real* effective exchange rate or relative prices, but not both, we include both relative prices and *nominal* effective exchange rate. Second, while they included variability measure of exchange rate at its level, we include the Log of variability measure, i.e., Log σ_R rather than σ_R

itself. Using the ADF test to determine stationarity of each variable, Bahmani-Oskooee and Payesteh (1993, Table 3) showed that $\sigma_R \sim I(0)$ for Korea, Pakistan, and the Philippines and I (1) for Greece, Singapore, and South Africa. However, when the ADF test was applied to Log σ_R, it turned out to be I (1) for all countries, except the Philippines. This increases the scope of our analysis to carry out the Johansen's technique for five rather than only three countries. In addition, when the ADF test was applied to the new variable, log of nominal effective exchange rate denoted logNEX, for all countries it was found to be integrated of order one or I (1).[3] All in all, the ADF test applied to all variables revealed that except for LogX, Log(PX/PXW) and Log σ_R of the Philippines, all remaining variables for all six countries were I (1). However, rather than excluding the Philippines, we keep it in the sample, but review her results with caution.[4]

As far as sign of each variable is concerned, it is expected that the price terms will carry negative coefficients. Defined as number of units of foreign currency per unit of domestic currency, the NEX variable is expected to carry a positive coefficient in the import demand equation and a negative coefficient in the export demand model. The income terms could carry negative or positive coefficients depending on the relative sensitivity of the demand for traded goods and the production of the trade-substitute goods. Finally, if exchange rate volatility (σ) is to deter the trade, it should carry a negative coefficient in both models.

We are now in a position to apply the Johansen-Juselius method to test for cointegration among the I (1) variables included in equations (6) and (7). One thing we need to decide is how many lags should be employed in the procedure. When quarterly data are used, as in this paper, it is a common practice to start with four lags. Table 1 reports the results of λ-max test and Table 2 the results of *trace* test.

Concentrating on Table 1 and the result of λ-max test, it is

3. The data base is the same as that of Bahmani-Oskooee and Payesteh (1993). The new variable, i.e., nominal effective exchange rate NEX is from source b of their appendix.

4. For the formulation of the ADF test see Bahmani-Oskooee and Payesteh (1993, pp. 197). Actually, the results of the ADF test for all variables except Log NEX and Log σ_R are already reported in Table 3 of Bahmani-Oskooee and Payesteh.

evident that the likelihood ratio test that there is no cointegrating vector (r=0) among variables of import demand and export demand equations is rejected for all countries. This is due to the fact that the calculated λ-max statistic for r = 0 is larger than its critical value. The same is true if we shift to the trace test in Table 2. Comparing the calculated statistic for $r \leq 1$, $r \leq 2$, etc and using at least one of the tests and the 10% critical value, we are safe to conclude that there is evidence of one cointegrating vector among the variables of import demand in the results for Singapore; two cointegrating vectors in the cases of Greece, Korea, and South Africa; and three vectors in the results for Pakistan and the Philippines. As for the variables of export demand equation, there is evidence of two cointegrating vectors in the cases of Greece and Pakistan, three cointegrating vector in the cases of Korea and Singapore; and five vectors in the results for the Philippines and S. Africa.

The next step is to report the cointegrating vectors. It is a common practice to report the cointegrating vector that is associated with the largest eigenvalues of the stochastic matrix. In order to interpret the estimated cointegrating vectors, we also normalize them on the dependent variable LogM and LogX, by setting their estimated coefficients equal to -1. This practice enables us to read the signs and elasticities directly from cointegrating vectors. Table 3 reports the results for the import demand equation, and Table 4 for the export demand equation. Since our concern is to determine whether exchange rate uncertainty has any impact on the trade flows, we carry out the likelihood ratio test of whether we can restrict the coefficient of $\log\sigma$ to zero. Johansen (1988, p. 237) and Johansen and Juselius (1990, p. 194) show that the LR test of restriction is based on the estimates of eigenvalues of unrestricted and restricted cointegrating space according to

$$-2\mathrm{Ln}(Q) = T\sum_{i=1}^{r} \ln\{(1-\lambda_i^*)/(1-\lambda_i)\} \qquad (8)$$

where r is the number of cointegrating vectors, $\lambda*$ is the eigenvalue of the i-th vector from the restricted space and λ is the eigenvalue of the i-th vector from unrestricted cointegrating space. They show that quantity (8) is distributed as χ^2 with r(p-s) degrees of freedom where r is the number of cointegrating vectors, p is the dimension of unrestricted cointegrating space and s is the dimension of restricted space. In the case of import and export demand equations, p = 5 and in each case since we are restricting one coefficient to zero, it leaves the dimension of restricted space to s = 4. Thus, in Tables 3 and 4, the degrees of freedom for each χ^2 statistic reported inside a bracket next to Log σ variable is actually equal to r (5 - 4) = r, i.e., number of cointegrating vectors in each case.[5]

Concentrating on Table 3 first, we gather that the null hypothesis of restricting the coefficient of Log σ to zero is rejected in the cases of Greece, Pakistan, and South Africa. In these three cases there is at least one cointegrating vector in which Log σ carries negative co-efficient. This is an indication of the fact that in the long-run exchange rate uncertainty has adverse effects on the imports of these countries. Other variables mostly carry their expected signs, thus, need no further explanations. Turning to the results of export demand equation reported in Table 4, it is very clear that the null of excluding log σ from cointegrating space is rejected in all cases (the calculated χ^2 is larger than its critical value) indicating that Log σ is a determinant in the export demand equation of all six countries. It is also clear that for each country, Log σ carries a negative coefficient in most cointegrating vectors indicating that it has a long-run adverse effect on their exports. These results are different from those reported by Bahmani-Oskooee and Payesteh (1993) who used Engle-Granger method.

Ⅳ. Summary and Conclusion

The literature on the effects of exchange rate uncertainty on the trade flows of less developed countries is very poor. Few authors who have attempted to assess the experiences of less developed countries have used non-stationary data and standard method of estimation. One study has applied Engle-Granger method for cointegration of variables

5. Note that in two cases (export function of the Philippines and South Africa) where r = p = 5 the exclusion test outlined by quantity (8) cannot be applied. In these two cases, in calculating quantity (8) we assumed r = 4.

in the import and export demand models and provided evidence supporting no cointegration.

In this paper after pointing out the limitations of Engle-Granger method, we employed the Johansen-Juselius technique to test for cointegration among all the variables involved in the trade models of LDCs, including a measure of exchange rate uncertainty. After showing that all variables included in import and export demand equations are cointegrated, we used exclusion test of Johansen and Juselius and provided evidence that exchange rate uncertainty has adverse effect on the trade flows of less developed countries.

Table 1. LR test based on Maximal Eigenvalue of the Stochastic Matrix (λ -max).

Null	r = 0	r≤ 1	r≤ 2	r≤ 3	r≤ 4
Alternative	r = 1	r = 2	r = 3	r = 4	r = 5
A. Import Demand Equation					
Greece	43.20	23.39	14.58	9.93	3.46
Korea	56.72	23.61	13.98	10.53	5.95
Pakistan	75.68	42.16	19.45	10.67	4.98
Philippine	40.39	31.05	20.79	9.41	7.00
Singapore	55.74	21.46	10.77	9.00	5.29
S. Africa	35.25	26.08	12.82	10.49	4.10
B. Export Demand Equation					
Greece	34.71	24.83	13.29	10.00	3.24
Korea	91.47	30.78	20.04	10.10	5.97
Pakistan	46.29	24.72	18.67	4.54	3.20
Philippine	42.63	19.87	16.11	15.18	8.43
Singapore	48.02	32.87	15.31	9.83	7.40
S. Africa	41.00	29.99	16.07	10.77	7.85
95% Critical Value	34.40	28.14	22.00	15.67	9.24
90% Critical Value	31.66	25.56	19.77	13.75	7.52

Note : All results are produced by MFIT3.0, an statistical package by Pesaran and Pesaran (1991).

Table 2. LR test based on Trace of the Stochastic Matrix (trace test).

Null	r = 0	r ≤ 1	r ≤ 2	r ≤ 3	r ≤ 4
Alternative	r ≥ 1	r ≥ 2	r ≥ 3	r ≥ 4	r ≥ 5
A. Import Demand Equation					
Greece	93.58	50.37	26.98	12.39	3.46
Korea	110.81	54.08	30.47	16.49	5.95
Pakistan	152.96	77.28	35.11	15.66	4.98
Philippine	108.73	68.34	37.29	16.50	7.08
Singapore	102.29	46.53	25.08	14.30	5.29
S. Africa	88.76	53.50	27.42	14.59	4.10
B. Export Demand Equation					
Greece	86.08	51.37	26.53	13.24	3.24
Korea	158.38	66.91	36.13	16.07	5.97
Pakistan	97.44	51.15	26.43	7.75	3.20
Philippine	102.22	59.59	39.72	23.61	8.43
Singapore	113.43	65.41	32.54	17.23	7.40
S. Africa	105.69	64.69	34.69	18.63	7.85
95% Critical Value	76.06	53.11	34.91	19.96	9.24
90% Critical Value	71.86	49.65	32.00	17.85	7.52

Note : See note to Table 2.

Table 3. Cointegrating Vectors Normalized on the Log M.

Import Demand Equation						
		+	−	+	−	
Country	Log M	Log Y	Log(PM/PD)	Log NEX	Log σ	(χ^2)
Greece	-1.00	0.776	-1.64	-0.001	-0.13	(6.99)*
	-1.00	3.573	-2.96	0.128	0.41	
Korea	-1.00	0.299	-2.11	0.341	0.03	(0.26)
	-1.00	0.356	-2.28	0.357	0.04	
Pakistan	-1.00	1.135	-1.72	0.116	0.04	(23.05)*
	-1.00	0.974	3.15	1.550	-0.46	
	-1.00	1.632	-0.41	0.537	-0.14	
Philippine	-1.00	1.569	-3.05	0.079	-0.01	(2.69)
	-1.00	0.425	0.65	-0.479	0.17	
	-1.00	4.952	-5.49	1.391	0.79	
Singapore	-1.00	1.291	0.32	-1.228	0.06	(1.61)
S. Africa	-1.00	-5.790	13.79	-1.225	-1.66	(18.94)*
	-1.00	2.304	-1.24	0.392	0.01	

Notes : a. Number inside the bracket next to each coefficient is the χ^2 statistic testing the null hypothesis of restricting that coefficient to 0 in all cointegrating vectors.

b. At the 10% level of significance, the critical value of $\chi^2_{(1)}$ = 2.70; $\chi^2_{(2)}$ = 4.60; $\chi^2_{(3)}$ = 6.25; $\chi^2_{(4)}$ = 7.78.

c. * indicates significant χ^2 statistic indicating that the null of restricting the coefficient to 0 is rejected.

Table 4. Cointegrating Vectors Normalized on the Log X.

	Import Demand Equation					
		+	−	−	−	
Country	Log M	Log YW	Log(PM/PXW)	Log NEX	Log σ	(χ^2)
Greece	-1.00	-6.652	-0.07	-1.08	-0.85	(13.03)*
	-1.00	-11.85	-24.3	-0.05	-1.01	
Korea	-1.00	-0.171	-1.01	-1.53	0.58	(24.60)*
	-1.00	1.498	-0.18	-2.04	-0.11	
	-1.00	3.061	-1.73	-0.01	-0.51	
Pakistan	-1.00	-13.59	4.68	-8.09	-0.46	(7.16)*
	-1.00	207.9	58.4	37.5	-30.3	
Philippine	-1.00	10.50	7.13	-0.54	-0.36	(8.71)*
	-1.00	3.30	-0.67	0.27	-0.29	
	-1.00	2.14	-1.12	0.21	0.22	
	-1.00	4.65	-1.05	0.89	0.22	
	-1.00	0.39	-0.61	0.24	-0.09	
Singapore	-1.00	9.89	3.88	-1.54	0.99	(25.46)*
	-1.00	4.28	-1.60	2.58	-0.06	
	-1.00	3.01	-1.66	1.92	-0.38	
S. Africa	-1.00	6.07	-0.32	1.13	0.16	(20.64)*
	-1.00	-13.30	9.29	-4.75	-1.70	
	-1.00	2.45	-2.89	0.91	0.11	
	-1.00	0.94	-1.02	-0.21	-0.17	
	-1.00	13.88	-9.38	5.34	0.37	

Notes: a. Number inside the bracket next to each coefficient is the χ^2 statistic testing the null hypothesis of restricting that coefficient to 0 in all cointegrating vectors.

b. At the 10% level of significance, the critical value of $\chi^2_{(1)} = 2.70$; $\chi^2_{(2)} = 4.60$; $\chi^2_{(3)} = 6.25$; $\chi^2_{(4)} = 7.78$.

c. * indicates significant χ^2 statistic indicating that the null of restricting the coefficient to 0 is rejected.

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