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EXCHANGE RATES AND INTERNATIONAL RESERVES: A THRESHOLD ERROR CORRECTION AND A THRESHOLD GRANGER CAUSALITY ANALYSIS

Abstract: *During the last three decades, globalization has become one of the most important issues in the world economies. Capital flows to developing countries increased dramatically. During this period many economies witnessed financial crises due to a sudden stop of capital flows. This paper investigates the relationship between international reserves and exchange rates in the Turkish economy by using the threshold error correction model and the threshold granger causality test. I found that there is a bi-directional causality between international reserves and the exchange rate of Turkey, in other words, that international reserves and exchange rate are jointly determined and affected.*

Key words: *Threshold error correction, Threshold Granger causality, Exchange rates, International reserves.*

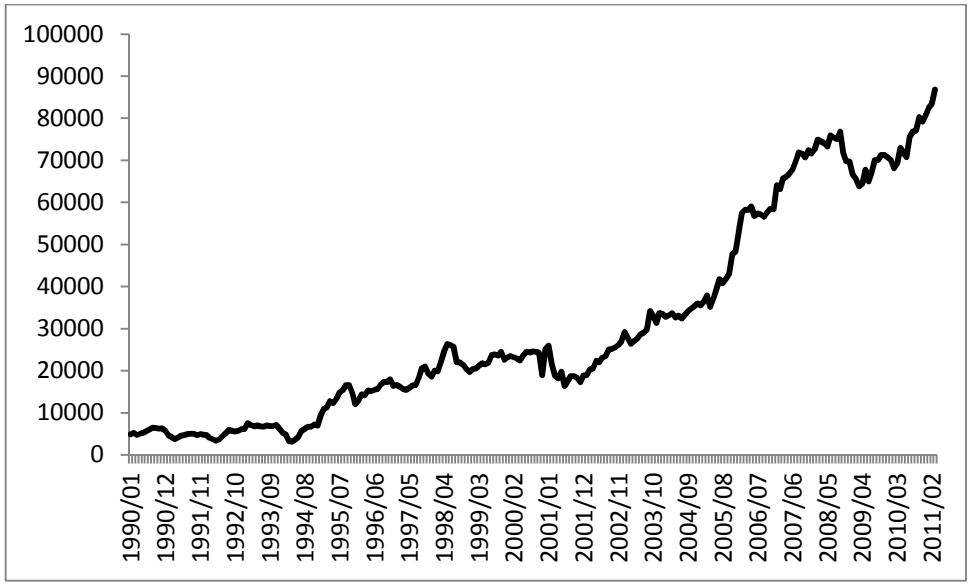
JEL Classification: F31,C22,C32

1. Introduction

During the last three decades, globalization has become one of the most important issues in the world economies. With the support of technological development, globalization, in particular, affects developing countries. In this regard, capital flows to developing countries during the last three decades increased dramatically. Capital flows can be utilized for growth but are coupled with instability. International capital flows are often thought to play a destabilizing role in developing economies, especially in the case of a financial crisis precipitated by sudden reversals of capital flows. (Neumann et.al. 2009) Countries averse to the cost of a sudden stop of capital flows will tend to manage precautionary savings, in the form of international reserves and these reserves may provide a line of defense against a sudden stop of capital flows. (Aizenman et.al. 2007) Countries will tend

to hold more foreign exchange reserves in order to smooth the vulnerability impact of domestic and foreign shock, make exchange rate arrangements to correct international payment difficulties, implement a foreign debt service, increase the international credibility of the country and cope with speculative attacks. (Kasman and Ayhan 2008)

Figure 1. International Reserves of Turkey



When looking at the Turkish economy, the Turkish government announced a trade and financial liberalization program in 1980. The Turkish economy became entirely liberalized in 1989, with the Turkish Lira (TL) becoming convertible. As seen in Figure 1, reserves showed an upward trend after the financial liberalization. After the financial sector became liberalized, the Turkish economy was able to provide enough foreign capital inflow, except during the Gulf crisis in 1991 and the Russian crisis in 1998. The Turkish economy witnessed two financial crises in the near past. While the first crisis occurred in January 1994, the second occurred in February 2001. Both crises were followed by rapid reserve depletions, a sharp and unexpected devaluation and a switch to a new exchange rate regime. (Kasman and Ayhan 2008)

The question of whether and how liberalization affects economies has been the subject of extensive debate. While some research asserts that liberalization promotes growth (Summers 2000; Arteta et. al. 2001) other studies assert that liberalization is bad for stability (Furman and Stiglitz 1998; Leblang 2003; Bordo et al 2001). Ahmad and Pentecost (2009) modeled the long run relationship

between exchange rates and international reserves in a sample of African countries over the period 1980:01 through 2004:04. The authors used the threshold co-integration technique. The results indicated that a long run dynamics exist between rates and international reserves. Aizenman and Marion (2003) explored the econometric and theoretical interpretations for the relatively high demand for international reserves by countries in the Far East and the relatively low demand by some other developing countries. They showed that reserve holdings over 1980 – 1996 seem to be the predictable outcome of a few key factors, such as the size of international transactions, their volatility, the exchange rate arrangement, and political considerations. Kasman and Ayhan (2008) investigated the relationship between exchange rates and foreign exchange reserves in Turkey, using monthly data over the period 1982:01 – 2005:11. They used unit root and co-integration tests with structural break. The results indicated that there is a long run relationship between foreign exchange reserves and exchange rates.

The objective of this paper is to investigate the linkage between the exchange rate and international reserves. Unlike past research studies, this paper uses the threshold error correction model and the threshold granger causality test to examine the relationship between the exchange rate and international reserves.

The remainder of the paper is organized as follows. Section 2 briefly discusses methodology. Section 3 presents the data and the empirical evidence of threshold vector error correction models. In section 4, the results are presented and discussed.

2. Methodology

2.1. Threshold Co-integration

The concept of co-integration is based on the idea that non-stationary variables may possess long run equilibrium relationships and have a tendency to move together in the long run. Co-integrated variables can be characterized by an error correction model, which describes how the variables respond to deviations from the equilibrium.

A standard error correction model (VECM) assumes linearity and symmetric adjustment which can be interpreted as an adjustment that occurs every time period. Balke and Formby (1997) combine non-linearity and co-integration as the concept of threshold co-integration. This model allows for nonlinear adjustment to long run equilibrium. A threshold VECM can be written as:

$$\Delta x_t = \begin{cases} A_1' X_{t-1}(\beta) + u_t & if \quad w_{t-1}(\beta) \leq \gamma \\ A_2' X_{t-1}(\beta) + u_t & if \quad w_{t-1}(\beta) > \gamma \end{cases}$$

Where,

$$X_{t-1}(\beta) = \begin{pmatrix} 1 \\ w_{t-1}(\beta) \\ \Delta x_{t-1} \\ \Delta x_{t-2} \\ \vdots \\ \Delta x_{t-l} \end{pmatrix}$$

γ is a threshold parameter, x_t is a p-dimensional $\mathrm{I}(1)$ time series which is co-integrated with one $p\ x\ 1$ co-integrating vector β, $w_t(\beta) = \beta' x_t$ is the $\mathrm{I}(0)$ error correction term A_1 and A_2 are coefficient matrices, u_t is an error term. The threshold error correction model can alternatively be written as,

$$\Delta x_t = A_1^{'} X_{t-1}(\beta) d_{1t}(\beta,\gamma) + A_2^{'} X_{t-1}(\beta) d_{2t}(\beta,\gamma) + u_t$$

Where

$$d_{1t}(\beta,\gamma) = 1(w_{t-1}(\beta) \leq \gamma)$$
$$d_{2t}(\beta,\gamma) = 1(w_{t-1}(\beta) > \gamma)$$

where $1(.)$ denotes the indicator function.

Hansen and Seo (2002) proposed a method to implement maximum likelihood estimation of the threshold model and developed a test for the presence of a threshold effect under the null hypothesis where there is no threshold so the model reduces to a conventional linear VECM. This test statistic can be denoted as,

$$\sup LM = \sup_{\gamma L \leq \gamma \leq \gamma U} LM(\tilde{\beta},\gamma)$$

Where $\tilde{\beta}$ is the estimate of β. $[\gamma_L, \gamma_U]$ is the search region set so that γ_L is the π_0 percentile of $\widetilde{w}_{t-1}$, and γ_U is the $(1-\pi_0)$ percentile. Andrews (1993) suggests setting π_0 between 0.05 and 0.15. To calculate the asymptotic critical values and p-values of the sup LM test, Hansen and Seo (2002) developed two bootstrap methods.

2.2. Threshold Granger Causality

Two regime threshold autoregressive distributed lag TADL (p,q,τ,d)model can be shown as,

$$y_t = \sum_{m=1}^{2}\left(a_m + \sum_{i=1}^{p} b_{mi} y_{t-i} I_{mt} + \sum_{j=1}^{q} c_{mj}^{'} x_{t-j} I_{mt}\right) + e_t$$

where $I_{1t} = I(y_{t-d} > \tau)$ and $I_{2t} = 1 - I_{1t}$, $x_t = (x_{1t}, \ldots., x_{kt})^{'}$ is a kx1 vector at time t. The threshold model and the granger causality analysis have been combined by Li (2006). This paper considers the three null hypotheses given by,

$H_0^0 = c_{11} = c_{21} \ldots.. = c_{1q} = c_{2q}$
$H_0^1 = c_{11} = \cdots = c_{1q}$
$H_0^2 = c_{21} \ldots.. = c_{2q}$

Where H_0^0 implies that none of the covariates has predictive content in the two regimes, H_0^i implies no predictive content in regime i, i=1,2.

According to Li (2006) all hypotheses are tested based on the Wald statistic, written as,

$$W = \left(R\hat{\theta}\right)^{'}\left[R\left(\sum z_t z_t^{'}\right)^{-1}\left(\sum \hat{e}_t^2 z_t z_t^{'}\right)\left(\sum z_t z_t^{'}\right)^{-1} R^{'}\right]^{-1}\left(R\hat{\theta}\right)$$

Where R is the selection matrix for the null hypotheses, θ are parameters estimates, $z_t = \partial f(\theta)/\partial\theta$, $f = E(y_t/\Omega_{t-1})$ and $\hat{e}_t$ is the OLS or NLS residuals. Li (2006) also showed that $W \sim \mathcal{X}^2(m)$, where m is the number of restrictions and standard asymptotic results are applicable.

3. Data and Empirical Evidence

The data which are used in this paper consist of the exchange rate (ER) and International reserves (RES). The monthly data for Turkey covering the period 1990:01 to 2011:03 have been collected from the Central Bank of the Republic of Turkey. All data was converted into natural logarithmic form before the empirical analysis.

We begin our analysis by providing the univariate properties of the variables of interest using the standard ADF and PP unit root tests.

Table 1. Unit Root Test Results

Series	ADF	PP
LNER	-0.021077	0.071135
LNRES	-3.067294	-2.697683
ΔLNER	-10.10582*	-10.13091*
ΔLNRES	-12.99357*	-12.87779*

* indicates a 1% level of significance.

The tests results support the hypothesis that the exchange rate and international reserves are integrated of order one. Given that the integration of the two series is of the same order, we continued to test whether the two series are co-integrated over the sample period.

An important stage in the TAR methodology is the selection of lag lengths. These can be estimated with the help of information criteria. The order of the lag selected by Akaike Information Criterion (AIC) is estimated with a lag 2. Using the Sup LM test proposed by Hansen and Seo (2002), the validity of threshold co-integration versus linear co-integration is investigated. Sup LM test results are summarized in Table 2.

Table 2. Sup LM Test Result

		LNRES – LNER	
Test Statistic	25.11863	p value	0.0492
Critical Values	0.90%	23.42696	
	0.95%	25.07227	
	0.99%	28.70107	

p values are calculated by bootstrap with 5000 replications.

The Sup LM tests indicate the validity of threshold co-integration between the exchange rate and international reserves of Turkey. Based on Table 2, the threshold vector error correction model can be conducted for these variables. Table 3 shows the threshold error correction model results.

Table 3. Threshold Error Correction Model Result

Dependent Variables :	ΔLNRES		ΔLNER	
	$w_{t-1} \leq \gamma$	$w_{t-1} > \gamma$	$w_{t-1} \leq \gamma$	$w_{t-1} > \gamma$
Variable	Parameters	Parameters	Parameters	Parameters
w_{t-1}	-0.0191[c]	-0.0061[a]	0.0078	-0.0044[a]
Constant	-0.0227	0.0758[a]	-0.0012	0.0570[a]
LNRES(-1)	0.2387[b]	0.0261	-0.2675[a]	-0.0928[b]
LNRES(-2)	0.2022	-0.0747	0.0196	0.0805[c]
LNER(-1)	-1.0741[c]	-0.0771	0.5113[c]	0.3744[a]
LNER(-2)	1.4587[a]	-0.0002	0.7260[a]	-0.1814[a]
γ	1.699253			
% of Observation	19.40	80.60		

[a], [b] and [c] indicate a 1%, 5% and 10% level of significance, respectively.

The results of Table 3 clearly suggest that the estimated threshold is 1.699253. Based on this threshold parameter, the threshold vector error correction model is divided into two regimes. The first regime would occur when the deviation from long run equilibrium is below the threshold parameter. This regime includes 19.40% of observation. Because of this reason, this regime can be called the unusual regime. On the other hand, when the deviation from long run equilibrium is above the threshold parameter, the second regime would occur. This regime has 80.60 percent of the observation and can be called the typical regime. Significant error correction effects appear in the international reserves equation. This finding indicates that adjustment will occur in the two regimes of the international reserves equation. In the exchange rate equation, a significant error correction effect only appears in the second regime.

The next step of the empirical analysis is to investigate the causality relationship between international reserves and the exchange rate. To do this, the threshold granger causality test proposed by Li (2006) has been used. Table 4 presents the test results.

Table 4. Granger Causality Test Results

	H_0^0	H_0^1	H_0^2
LNRES ↔ LNER	8.310128[c]	7.905737[b]	0.404391
LNER ↔ LNRES	27.63346[a]	18.84185[a]	8.791603[b]

[a], [b] and [c] indicate a 1%, 5% and 10% level of significance, respectively.

Results in Table 4 indicate that there is a bi-directional causality between international reserves and the exchange rate. There is only one insignificant parameter in the second regime of the international reserves equation. In the light of this finding, it can be said that international reserves and the exchange rate are

jointly determined and affected except the second regime of international reserves equation.

Conclusion

This paper applied the threshold vector error correction model proposed by Hansen and Seo (2002) and the threshold granger causality test proposed by Li (2006) to examine the casual relationship between international reserves and the exchange rate of Turkey. Based on sup LM test results, it has been found that threshold co-integration is a feasible way to capture the relationship. Using this finding, a threshold error correction model has been conducted. As a final step of this paper, the threshold granger causality test has been employed. The finding obtained from this test indicate that there is bi-directional causality between international reserves and the exchange rate of Turkey except the second regime of international reserves equation, in other words, while exchange rates determined by international reserves, international reserves partially determined by exchange rates.

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