*Advances in Management & Applied Economics, vol. 5, no.5, 2015, 55-70*
*ISSN: 1792-7544 (print version), 1792-7552(online)*
*Scienpress Ltd, 2015*

# The Exchange Market Contagion in an Asymmetric Framework before and after Abenomics

**Chien-Chung Nieh[1] and Hsun-Fang Cho[2]**

## Abstract

This study analyzes the contagion caused by the currency depreciation war in a multivariate time varying asymmetric framework, focusing on countries competing with Japan for trade during the Abenomic period. We employed not only the linear models of Engle and Granger (1987), and the Johansen (1988) co-integration models but also the Enders and Siklos (2001) asymmetric threshold co-integration model to investigate whether the contagion effects between Japan's exchange rate market and the exchange rate markets of major countries in completion with Japan for export markets before and after Abenomics for the period 2011-2014 existed. The empirical evidence confirms a contagion effect particularly in Asian countries where there is export competition with Japan with the exception of South Korea during Abenomics. The contagion of the Japanese yen depreciation is not transmitted to Australia, the Euro zone (France, Germany, Italy, and Netherlands), Qatar, Saudi Arabia, and USA in competitive trade with Japan. We can apparently find the effect of yen devaluation only occurred in the region of Asia close to Japan and does not spread Europe and America. In general, our results support the contagion phenomenon for Abenomics. Nevertheless, the effect of the contagion is regional not global.

**JEL classification numbers:** C32, F31, G01, G15
**Keywords:** Abenomics, Contagion, Currency depreciation war, Momentum threshold autoregressive (M-TAR)

## 1 Introduction

Globalization and deregulation of financial markets promotes prosperity in the global economy. The trend of trade liberalization has also led to more frequent financial dealings. However, the impact of a shock to the finance, economy, and the politics in one country

---

[1]Department of Banking and Finance of Tamkang University, Taiwan.
[2]Department of Banking and Finance of Tamkang University, Taiwan.

Article Info: *Received* : July 2, 2014. *Revised* : July 31, 2015.
*Published online* : October 15, 2015

often crosses to countries in the same region or countries in other regions, which result in a regional or a global economic crisis, such as the Mexico peso crisis in 1994, the Asian financial crisis in 1997, the Russian financial crisis in 1998, the U.S. Dot-com bubble in 2000-2002, and the global financial crisis in 2007-2008. Currency crises have occurred repeatedly over the past twenty years. Researcher has investigated how attacks of speculative behavior create a currency crisis in one country; the market volatility tends to spread to other countries in the specific region and elsewhere. Researchers and academic institutes have proposed that exogenous events, and shock transmission explains this phenomenon, generally referred to as contagion. The recent crisis-contagion theory is ardently discussed by the academic authorities and policy makers, especially in light of the frequent economic and financial crises all over the world.

As we all know, the Japanese economy has been depressed for 26 years since the asset bubble burst in 1989 (The Nikkei 225 index reached its highest point at 38,913). The Japanese economy required a stimulus to escape from this pattern of long-term sluggish growth. The Liberal Democratic Party (LDP) overwhelmingly won a general election which took place in Japan on December 16th, 2012. Abe Shinzo regained the power to govern as Prime Minister on December 26th, 2012. His prescription for economic reactivation was referred to as Abenomics which is a new economics policy regime and a new term – Abenomics – that is used to refer to the three pillars or arrows for the Japanese economy and economic policy. The first arrow is the unconventional monetary policy; the second arrow is the expansionary fiscal policy and the third arrow is the economic growth strategies. The Japanese government tried to revive its economy through implementing bold economic policies that will pull its economy out of prolonged deflation. The Abenomics policy led to a dramatic weakening of the Japanese yen. According to Figure 1, the yen became about 25% lower against the U.S. dollar in the second quarter of 2013 compared to the same period in 2012, with an extremely loose monetary policy being followed. The Bank of Japan adopted a policy of quantitative easing aimed at creating a sharp depreciation of the yen. This caused Japan's trading competitors to become afraid that their exports are uncompetitive. These countries joined together with a policy of competitive devaluation of currencies in order to maintain export competitiveness. Japan triggered a currency war causing contagion in competitive devaluation of currencies. Understanding this issue is one of the purposes of this study by investigating the effect of the sharp depreciation of the yen during the period of Abenomics. Therefore, the general discussion about contagion explores how to define contagion t in the first and then considers how to measure contagion.

In terms of the definition, generally, the influential definitions of contagion refer to a significant increase in cross-market linkages after a shock to one country or group of countries and a cross-market correlation. Otherwise, where there is a continued market correlation at high levels, this is considered to be "no contagion, only interdependence" (Forbes and Rigobon, 2002, Bekaert et al., 2005). Commonly, contagion refers to the spread of financial disturbances from one country to others. The literature on financial contagion has literally exploded since the publication of the paper by Forbes and Rigobon (2002) stimulated extensive debate and discussion. Much of the extant empirical literature on contagious currency crises stresses the phenomenon of regional contagion. Lee and Kim (1993), Forbes and Rigobon (2002), Dungey, Fry, González-Hermosillo, and Martin (2006), Lucey and Voronkova (2008), and Arouria, Bellalahb, and Nguyenc (2009) about the transmission effect and the contagion effect were based on the backgrounds of several crises since the late 1990s, such as those in Mexico (1994), Thailand (1997), Russia (1998), and Argentina (1999). Calvo and Reinhart (1996) reported correlation shifts during the Mexican

Crisis, while Baig and Goldfajn (1999) supported the contagion phenomenon during the East Asian Crisis.

In the light of the need to quantify contagion, during recent last years, scholars have been using more advanced techniques to measure contagion. For example, Patton (2006) pioneered the study of time-varying copulas for modelling asymmetric exchange rate dependence. Bartram et al. (2007) estimated time-varying copula dependence models for 17 European stock market indices, following the methodology of Patton (2006). In the recently developed area of regime-switching copulas, Rodriquez (2007) modeled dependence with switching-parameter copulas to study financial contagion and provides evidence of changing dependence and asymmetry during the Asian and the Mexican crises. Okimoto (2008) estimated regime-switching copulas for the US–UK pair and found that the bear regime was better described by an asymmetric copula with lower dependence. In terms of other empirical literature, Caporale, Cipollini, and Spagnolo (2005) modeled the conditional variance by the application of both heteroskedasticity and endogeneity biases and invented a common shock to deal with the omitted variable problem. They found the existence of contagion within the stock markets in Hong Kong, Japan, South Korea, Singapore, Taiwan, and Malaysia during the 1997 Asian Financial Crisis. The findings were consistent with the crisis-contingent theories of stock market linkages. Bekaert, Harvey, and Ng (2005) also reported that co-integration relationships did exist among the Asian stock markets during the period of the 1997 Asian Financial Crisis, which demonstrated a contagion effect. Li and Lam (1995), Koutmos (1998), and Chiang (2001) pointed out that co-integration between stock markets was asymmetric; Wang and Lin (2005), Shen, Chen, and Chen (2007), and Chang (2008, 2010) further employed the asymmetric co-integration test for their empirical studies. This paper presents a theory for analyzing whether inter-country trade can be responsible for the transmission of a currency crisis, which has important implications for understanding the empirical phenomenon in general and possibly also its regional dimensions.

To investigate how the asymmetric adjustment phenomenon influences the contagion effect or the transmission effect, we apply the asymmetric threshold co-integration method to compare the transmission effect or the contagion effect from the Japanese exchange rate market to the exchange rate markets of import and export countries trading with Japan in the pre-Abernomics and during the Abenomic period; therefore, asymmetric adjustments could exist in an upward status (positive impact) or a downward status (negative impact). How do the two phenomena influence the transmission effects or contagion effects of the exchange rate markets? Do different correlations, co-movement, interdependence, or contagion effects exist during currency depreciation? These issues were seldom discussed in previous literature; therefore, we decided to explore these problems by the asymmetric threshold co-integration model. What is the impact of the Japanese yen depreciation on the countries which have a trade relationship with Japan during the period of Abenomics? Is co-integration strengthened during the great depreciation? The issue of the contagion effect in some countries in Asia, Europe and America, which we have selected for this paper, is carefully examined.

The structure of the paper is organized as follows. Section 2 presents data description and the econometric method. Section 3 shows empirical results. Finally, concluding remarks are stated in Section 4.

# 2 Data Description and the Econometric Method

## 2.1 Data and Variables

The study aims to investigate the asymmetric contagion effect of the Japanese exchange rate on the exchange rate of the major export and import countries trading with Japan[3] such as European countries including Germany, France, Netherlands, and Italy, Asian countries consisting of China, South Korea, Thailand, Saudi Arabia, Taiwan, Malaysia, Hong Kong, Indonesia, Singapore, United Arab Emirates, and Qatar, North America including the United States, Canada and Australia. Because the four European countries have adopted the euro (€) as their common currency and sole legal tender, the currencies of these countries are identical utilizing the euro (€) in this study. The exchange rates are quoted in the paper employs the price per unit of US dollar expressed in the currency of the target country. Here, the US dollar is called the "Fixed currency", while other country's currencies are referred to as a "Variable currency". The exchange rate of the Unite States adopts the U.S. Dollar Index[4]. All of the variables in this study are taken from logarithms.

In order to sufficiently investigate the long equilibrium relationship of variables, this research utilizes sample data over four years. Therefore, daily data arranged in 5-day weeks is selected for this dissertation from 1st January2011 to 31st December 2014 and downloaded from the Datastream database for exchange rates of nineteen countries including sixteen currencies. A total of 1,043 observations are obtained for each variable, which are utilized to analyze the extent of co-movements and contagion effect of exchange rare depreciation from Japan to other countries. To account for the impact of Abenomics on the exchange rates of countries importing and exporting to Japan, The study conducts a process of analysis observing all variables over the same period. Table 1 displays the descriptive statistics showing the exchange rates of all the countries investigated.

The study wants to investigate the influence of the implementation before and after Abenomics. The periods before and after Abenomics need to be defined for observing whether there exists significant difference between two periods. According to Prime Minister Yoshihiko Noda's announcement, the House of Representatives was dissolved by Prime Minister Yoshihiko Noda on November 16th, 2012 as so this marks the cut off point for the pre-Abenomic period. After that, the Japanese exchange rate started to dramatically depreciate as illustrated in Figure 1. The period before Abenomics is defined as being from January 1st, 2011 to November 16th, 2012 to provide a total of 490 daily observations. The period of Abenomics is defined as being from November 19th, 2012 to December 31st, 2014 with 553 days of daily data. We, therefore, compared the estimated results for the different periods.

All variables are transformed into natural logarithms namely $LER_{i,t} = lnER_{i,t}$. Where ER is the abbreviation for exchange rate. t denotes the time period of observation. i represents observed the countries. The equation can be expressed as:

---

[3]For more details regarding the information, the reader is referred to the website of the observatory of economics complexity: Source: https://atlas.media.mit.edu/en/profile/country/jpn/

[4]The US Dollar Index (USDX, DXY) is an index (or measure) of the value of the United States dollar relative to a basket of foreign currencies, often referred to as a basket of US trade partners' currencies. Source: https://en.wikipedia.org/wiki/U.S._Dollar_Index

$$\Delta LER_{i,t} = \left(lnER_{i,t} - lnER_{i,t-1}\right) \times 100 \quad (1)$$

where $\Delta LER_{i,t}$ , $i = 1,2 \ldots 16$ represents the variables in the first difference.

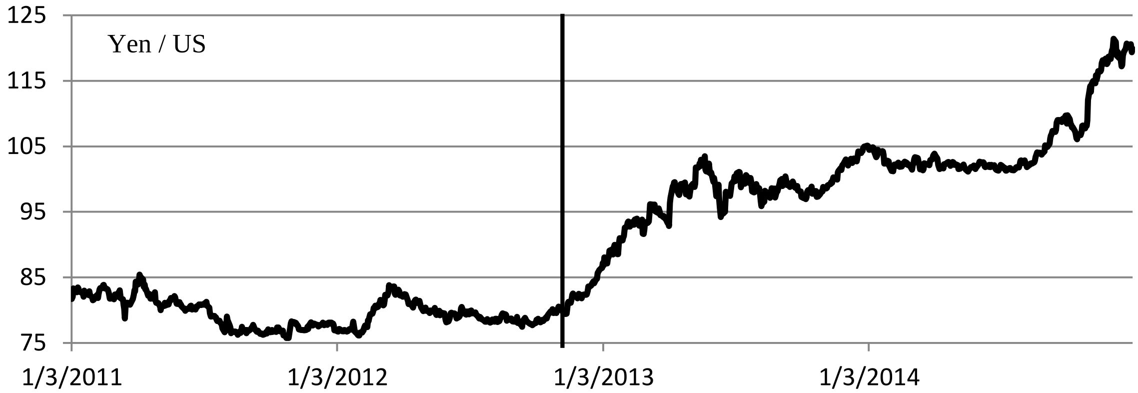


Figure 1: The graph of Japanese yen from 2011 to 2014

Table 1: Summary statistics for return on exchange rates

| | **Mean** | **Max.** | **Min.** | **Std. Dev.** | **Skewness** | **Kurtosis** | **J-B** | **Obs.** |
|---|---|---|---|---|---|---|---|---|
| **Japan** | 0.037 | 3.710 | -2.327 | 0.586 | 0.655 | 7.763 | 1,059*** | 1,043 |
| **Australia** | 0.021 | 4.108 | -3.277 | 0.666 | 0.283 | 6.454 | 532*** | 1,043 |
| **Canada** | 0.015 | 2.955 | -1.962 | 0.467 | 0.165 | 6.228 | 457*** | 1,043 |
| **China** | -0.006 | 0.499 | -0.586 | 0.100 | -0.101 | 7.947 | 1,064*** | 1,043 |
| **Euro** | 0.010 | 2.104 | -2.307 | 0.550 | 0.064 | 4.519 | 101*** | 1,043 |
| **Hong Kong** | -0.0002 | 0.149 | -0.222 | 0.027 | -0.301 | 13.547 | 4,845*** | 1,043 |
| **Indonesia** | 0.031 | 3.139 | -1.726 | 0.370 | 0.457 | 11.509 | 3,180*** | 1,043 |
| **Malaysia** | 0.013 | 1.681 | -2.648 | 0.402 | -0.187 | 6.293 | 477*** | 1,043 |
| **Qatar** | 0.000 | 0.078 | -0.072 | 0.010 | -0.052 | 19.968 | 12,501*** | 1,043 |
| **Saudi Arabia** | 0.0001 | 0.073 | -0.076 | 0.005 | -0.136 | 104.519 | 447,455*** | 1,043 |
| **Singapore** | 0.003 | 2.140 | -2.290 | 0.359 | 0.368 | 9.151 | 1,666*** | 1,043 |
| **South Korea** | -0.002 | 2.797 | -1.709 | 0.472 | 0.606 | 6.092 | 479*** | 1,043 |
| **Taiwan** | 0.008 | 1.540 | -0.851 | 0.202 | 0.703 | 9.954 | 2,185*** | 1,043 |
| **Thailand** | 0.008 | 1.47 | - | 0.306 | -0.245 | 6.975 | 697*** | 1,04 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2 | 2.267 | | | | | 3 |
| **United Arab Emirates** | 0.000 | 0.011 | -0.011 | 0.002 | 0.343 | 10.946 | 2,762*** | 1,043 |
| **US** | 0.013 | 1.866 | -1.861 | 0.431 | 0.182 | 4.696 | 131*** | 1,043 |

Notes:
1. Std. Dev. denotes the standard error. Max. represents the maximum. Min. is the minimum. Obs. is the observation
2. J-B denotes the Jarque–Bera normality test.
3. *** indicates significance at the 1%, respectively.

## 2.2 Econometric Method

The Engle and Granger (1987) threshold autoregressive (TAR) and momentum threshold autoregressive (M-TAR) models for unit root testing to permit unit root tests within a multivariate framework, and to allow for nonlinear adjustments were generalized by Enders and Siklos (2001). They are better in picking up these asymmetries than the linear models of Engle and Granger (1987) or the Johansen (1988) co-integration models. The methodology involves enforcing two procedures where the first stage estimates a long-run relationship based on:

$$Y_t = \alpha + \beta X_t + \mu_t \tag{2}$$
$$\Delta\mu_t = \rho\mu_{t-1} + \sum_{i=1}^{k} \phi_i \Delta\mu_{t-1} + \varepsilon_t \tag{3}$$

where $Y_t$ and $X_t$ are two I(1) series, t denotes the time period, $\mu_t$ is a stationary random variable that denotes deviation from the long-term equilibrium, assuming that a long-run relationship exists. $\alpha$, $\beta$, $\rho$ and $\phi_i$ are estimated parameters. $\varepsilon_t$ is a white noise disturbance term. $k$ is the number of lags.

In the first stage of estimating the long-term relationship between the variables, the regression is normalized on the downstream variable $Y_t$. In the second stage, the residuals $\mu_t$ are utilized to enforce a cointegration test. The number of lags is chosen by the Akaike information criterion (AIC), Schwarz Bayesian information criterion (SBC), or Ljung–Box Q test, so that there is no serial correlation in the regression residuals. If the null hypothesis of $H_0\colon \rho = 0$ is rejected, then the two variables are regarded as to be linearly co-integrated. The above co-integration tests assume symmetric transmission. Enders and Siklos (2001) declared a two-regime threshold co-integration method to permit asymmetric adjustments in the co-integration test. To introduce asymmetry in the adjustment to the long-term equilibrium, the adjustment process is dependent on a change in $\mu_t$, ($\Delta\mu_t$). The residuals from Eq. (3) are utilized to evaluate a model of the form. The next stage requires estimation of two parameters, $\rho_1 and\ \rho_2$ in the following equations:

$$\Delta\mu_t = I_t\rho_1\mu_{t-1} + (1 - I_t)\rho_2\mu_{t-1} + \sum_{i=1}^{l} \gamma_i \Delta\mu_{t-i} + \varepsilon_t \tag{4}$$

where $I_t = [T_t, M_t]$, such that:

$$T_t\text{: TAR } = \begin{cases} 1 & if\ \mu_{t-1} \geq \tau \\ \\ 0 & if \mu_{t-1} < \tau \end{cases} \tag{5}$$

$$M_t\text{:M-TAR} = \begin{cases} 1 & if\ \Delta\mu_{t-1} \geq \tau \\ \\ 0 & if \Delta\mu_{t-1} < \tau \end{cases} \tag{6}$$

where $\varepsilon_t$ is a white-noise disturbance. $I_t$ is the Heaviside indicator function. $l$ is the lag term which is again specified to interpret serial correlation in the residuals and it can be chosen by the AIC, SBC, or Ljung–Box Q test. $\tau$ is the threshold value, which is priorly unknown and has to be estimated. The threshold value is endogenously decided by using the Chan (1993) grid search method to find out an estimate of the consistent threshold value. The Heaviside indicator $I_t$ can be specified by two alternative definitions of the threshold variable, either the lagged residual ($\mu_{t-1}$) or the change of the lagged residual ($\Delta\mu_{t-1}$). Equations (4) and (5) denote the threshold autoregressive model (TAR). Equations (4) and (6) represent the momentum threshold autoregressive model (M-TAR). Enders and Granger (1998) found the M-TAR model was particularly valuable when adjustment was asymmetric such that the series displayed more "momentum" in one direction than the other. In the TAR model, the adjustment is modified by $\rho_1\mu_{t-1}$ that $I_t = T_t$= 1 when the residual according to equation (5) is above the threshold value $\tau$ and by the term $\rho_2\mu_{t-1}$ that $T_t$= $I_t$= 0 when the residual is below the threshold value. In the M-TAR model, the adjustment is modeled by $\rho_1\mu_{t-1}$ that $I_t = M_t$= 1 when the residual according to equation (6) is above the threshold value $\tau$ and by the term $\rho_2\mu_{t-1}$ that $M_t$= $I_t$= 0 when the residual is below the threshold value.

Since there is generally no consensus about which specification should be used, it is suggested that the proper adjustment mechanism is chosen through the model selection criteria of AIC and SBC (Enders and Siklos, 2001). The model with the lowest AIC and SBC will be utilized for further analyses. Insights into asymmetric adjustments in the context of a long-term co-integration relationship can be acquired through two tests on the coefficients estimated from the threshold co-integration equations. First, Enders and Granger (1998) and Enders and Siklos (2001) concluded that in either case, under the null hypothesis of no convergence, the F-statistic for the null hypothesis of $H_0: \rho_1 = \rho_2 = 0$ had a nonstandard distribution. Enders and Granger (1998) also found that if the series is stationary, the least square estimates of $\rho_1$ and $\rho_2$ have an asymptotic multivariate normal distribution. We test the null hypothesis of $H_0: \rho_1 = \rho_2 = 0$ for a co-integration relationship, and rejection implies the existence of a cointegration relationship between the two variables. Second, if the null hypothesis of no co-integration is rejected, it would enable us to advance to further test for symmetric adjustment of the null hypothesis, which is $H_0: \rho_1 = \rho_2$. We proceed with the asymmetric threshold cointegration test and symmetric adjustment test by using the standard F-statistic. Rejection of the null hypothesis indicates the existence of an asymmetric adjustment process between the two variables.

# 3 Empirical Results

## 3.1 Advanced Non-linear ESTAR[5] Unit Root Test

The conventional linear unit root tests[6] might have a lower power when they are applied to a finite sample. In this situation, the advanced non-linear ESTAR unit root test is found to be of great help provided that they permit an increase in the power of the order of the integration analysis by allowing for asymmetric adjustment to the equilibrium level. The results of the nonlinear unit root test are provided in Table 2. As can readily be seen from the table, the results of the test suggest that the null hypothesis of the unit root is rejected in the circumstance of the first difference at the 1% significant level for most variables of all exchange rate markets in this paper.

Table 2: Results of the non-linear unit root test

| | **Level** | **First difference** |
|---|---|---|
| **Japan** | 0.762(0) | -32.69(0)*** |
| **Australia** | 0.149(0) | -4.656(3)*** |
| **Canada** | -0.064(0) | -2.397(5)** |
| **China** | -2.338(0)** | -33.05(0)*** |
| **Euro** | -1.525(4)** | -9.589(5)*** |
| **France** | -1.354(4) | -16.46(3)*** |
| **Germany** | -1.264(4) | -11.10(5)*** |
| **Hong Kong** | -2.672(1)** | -29.41(0)*** |
| **Indonesia** | 0.437(5) | -12.55(4)*** |
| **Italy** | -1.376(4) | -16.54(3)*** |
| **Malaysia** | -0.327(4) | -17.66(3)*** |
| **Netherlands** | -1.293(4) | -11.85(5)*** |
| **Qatar** | -6.817(4)*** | -17.64(6)*** |
| **Saudi Arabia** | 1.232(5) | -19.85(4)*** |
| **Singapore** | -2.560(0)** | -34.32(0)*** |
| **South Korea** | -2.247(3)** | -17.48(2)*** |
| **Taiwan** | -1.061(2) | -19.47(1)*** |
| **Thailand** | -1.368(1) | -31.19(0)*** |
| **United Arab Emirates** | -18.53(0)*** | -33.55(1)*** |
| **US Index** | -0.332(1) | -33.99(0)*** |

Notes:
1. *** , **and * denote significance at 1%, 5% and 10% levels, respectively.
2. The numbers in the parentheses are the appropriate lag lengths selected by MAIC (modified Akaike information criterion) suggested by Ng and Perron (2001).
3. The simulated critical values for different K were tabulated in Kapetanios et al.(2003) (Table 1 as of p. 364).

[5]We employ the exponential smooth transition autoregressive (hereafter, ESTAR) unit root tests proposed by Kapetanios et al. (2003).

[6]The conventional linear unit root tests include the Augmented Dickey-Fuller (Dickey and Fuller, ADF, 1981), test, Phillips, the Perron (Phillips and Perron, PP, 1988) test, and the Kwiatkowski-Phillips-Schmidt-Shin (Kwiatkowski et al., KPSS, 1992) test.

## 3.2 Engle-Granger Co-integration Test

We can conclude that all variables are integrated of the same order after running unit root tests. The next task is to check for co-integration so the co-integration test is utilized to analyze the data. This approach is executed to investigate the long-run equilibrium relationship between variables. The results of the Engle-Granger co-integration relationship between Japan and the exchange rates of other countries over the entire period, the period of the pre-Abenomics, and the period of during-Abenomics, and the null hypothesis of no co-integration is shown in Table 3. The results of the Engle-Granger ADF statistics show that there are co-integration relationships between Japan's exchange rate and the exchange rates of Canada, Hong Kong, Qatar, and United Arab Emirates over the entire period. Furthermore, the results show that there are co-integration relationships between Japan and Australia, Canada, Hong Kong, Qatar, Saudi Arabia, United Arab Emirates during the pre-Abenomic period. As shown in the table, the results show that there are co-integration relationships between Japan and Hong Kong, Qatar, and United Arab Emirates in the during-Abenomics period. It can be seen from Table 3 that there is a significant increase in the co-integration relationships between Japan's exchange rate and the exchange rates of Hong Kong and the United Arab Emirates around the time that Abenomics were applied; this result does not support the contagion theory by Dornbusch et al. (2000) and Forbes and Rigobon (2001).

Table 3: Results of the Engle-Granger test for co-integration

| | **Entire period** | **Pre-Abenomics** | **During Abenomics** |
|---|---|---|---|
| | **Engle-Granger ADF Statistic** | **Engle-Granger ADF Statistic** | **Engle-Granger ADF Statistic** |
| **Australia** | -2.945(0) | -3.131(0)* | -2.362 (0) |
| **Canada** | -3.139(0)* | -3.276(0)* | -3.009 (0) |
| **China** | -0.947(0) | -2.094(1) | -1.022(0) |
| **Euro** | -1.819 (0) | -2.845(0) | -1.055(0) |
| **Hong Kong** | -3.207 (1)* | -3.835(0)** | -4.231(2)*** |
| **Indonesia** | -1.725(0) | -2.465(2) | -1.457(0) |
| **Malaysia** | -2.595(0) | -2.721(0) | -2.502(0) |
| **Qatar** | -7.263(3)*** | -9.582(1)*** | -5.973(1)*** |
| **Saudi Arabia** | 2.593(10) | -4.647(4)*** | -0.302(12) |
| **Singapore** | -2.818(0) | -2.344 (0) | -2.757(0) |
| **South Korea** | -2.279 (0) | -2.241 (0) | -1.245(0) |
| **Taiwan** | -2.160(2) | -2.623(2) | -2.589(0) |
| **Thailand** | -2.000(0) | -2.370(0) | -1.968(0) |
| **United Arab Emirates** | -13.75(1)*** | -10.93(1)*** | -12.35(0)*** |
| **US Index** | -1.752(1) | -2.822(0) | -0.781(1) |

Notes:
1. The numbers in the parentheses are the appropriate lag lengths selected by minimizing AIC.
2. The critical values of the Engle-Granger ADF Statistics are taken from Engle and Yoo (1987).
3. *, ** and *** denote significance at the 10%, 5% and 1% significance levels, respectively.

It is clear from Table 4 that the results of the Johansen maximum eigenvalue co-integration test for the entire period are that there are co-integration relationships of one co-integrating rank between Japan's exchange rate and the exchange rates of Hong Kong, Qatar, and United Arab Emirates. As can be seen from the table, there are co-integration relationships of two co-integrating ranks between Japan and Hong Kong, Saudi Arabia, and United Arab Emirates in the pre-Abenomics period. The evidence for the during-Abenomics is shown in Table 4; the empirical evidence shows that Japan and Hong Kong, Qatar, and the United Arab Emirates have cointegration relationships of one rank. According to the results, it does not support the contagion theory by Dornbusch et al. (2000) and Forbes and Rigobon (2001).

Table 4: Results of the Johansen maximum eigenvalue co-integration test

| | Rank | Entire period | Pre-Abenomics | During Abenomics |
|---|---|---|---|---|
| | | **Max-Eigen statistic** | **Max-Eigen statistic** | **Max-Eigen statistic** |
| **Australia** | r=0 | 13.76 | 11.78 | 14.91 |
| | r≦1 | 4.057** | 4.747** | 4.235** |
| **Canada** | r=0 | 9.874 | 11.71 | 11.93 |
| | r≦1 | 3.110 | 4.930** | 3.514 |
| **China** | r=0 | 3.532 | 5.402 | 4.421 |
| | r≦1 | 1.881 | 4.014** | 1.056 |
| **Euro** | r=0 | 5.346 | 10.62 | 11.24 |
| | r≦1 | 3.364 | 4.685** | 0.0354 |
| **Hong Kong** | r=0 | 26.77** | 19.31** | 27.444** |
| | r≦1 | 3.162 | 5.751** | 3.486 |
| **Indonesia** | r=0 | 6.431 | 7.468 | 4.398 |
| | r≦1 | 2.941 | 6.680** | 2.476 |
| **Malaysia** | r=0 | 9.461 | 9.693 | 11.00 |
| | r≦1 | 4.563** | 3.391 | 3.408 |
| **Qatar** | r=0 | 68.63** | 62.41 | 30.82** |
| | r≦1 | 3.212 | 4.881** | 3.476 |
| **Saudi Arabia** | r=0 | 9.388 | 41.25** | 13.28 |
| | r≦1 | 0.367 | 5.038** | 0.3259 |
| **Singapore** | r=0 | 7.980 | 8.443 | 12.59 |
| | r≦1 | 3.258 | 4.337** | 2.876 |
| **South Korea** | r=0 | 5.771 | 7.155 | 11.82 |
| | r≦1 | 3.428 | 3.597 | 1.728 |
| **Taiwan** | r=0 | 5.495 | 10.32 | 12.53 |
| | r≦1 | 3.793 | 2.546 | 2.340 |
| **Thailand** | r=0 | 6.400 | 6.390 | 6.593 |
| | r≦1 | 4.785** | 3.851** | 5.143** |
| **United Arab Emirates** | r=0 | 149.0** | 81.88** | 74.33** |
| | r≦1 | 3.192 | 4.892** | 3.408 |
| **U.S.** | r=0 | 5.823 | 11.39 | 11.96 |
| | r≦1 | 3.592 | 4.721 | 0.024 |

## 3.3 Results of the Threshold Co-integration Test

Enders and Granger (1998) and Enders and Siklos (2001) proposed two models for the threshold co-integration test, namely, the TAR model and the M-TAR model. This study adopts the M-TAR model. Enders and Granger (1998) suggested that when asymmetrical adjustments occurred in the data series, the determination of the Heaviside indicator function might also be decided by the first difference value of error correction term on the period $t-1\ (\Delta\varepsilon_{t-1})$. Boucher (2007) pointed out that the speed of convergence of parameter estimation by using the M-TAR model would be faster than that of the TAR model. Table 5 presents the results for the threshold co-integration relationship between the exchange rate market of Japan and the exchange rate markets of observed countries in this study. The null hypothesis of no co-integration $(F_c)$ and symmetric adjustment $(F_A)$ are also shown in Table 5. The empirical evidence shows that the null hypothesis of no co-integration $(F_C)$ is rejected at the 10% significant level for the entire period, which indicates the existence of long-run equilibrium relationships between Japan's exchange rate and exchange rates of other countries. What is more, the null hypothesis of symmetric adjustment $(F_A)$ is rejected at the 10% significant level in the entire period except for China, the Euro, and Malaysia, suggesting that there is a significant threshold of co-integration and asymmetric adjustment between the two variables considered. The null hypothesis of no co-integration $(F_C)$ is rejected in the pre-Abenomics of Table 5 with the exception of China, Indonesia. Furthermore, the null hypothesis of symmetric adjustment $(F_A)$ is rejected, suggesting that there exists asymmetric adjustments between Japan and Euro, Hong Kong, Qatar, Saudi Arabia, Singapore, South Korea, Taiwan, and the U.S.. Moreover, Japan has co-integration relationships $(F_C)$ with all observed countries during the Abenomics period except for the Euro. In terms of asymmetric adjustment $(F_A)$, there is an asymmetric relationship between Japan and other countries during the Abenomics except Euro, Malaysia, Saudi Arabia, Taiwan. By further comparisons of the $F_C$ statistics in the pre-Abenomics period and the during-Abenomics period shown in the (10) column of Table 5, we have found that the co-integration relationships significantly increased between Japan exchange rates and the exchange rates of observed countries in the study except Australia, Euro, Qatar, Saudi Arabia, and South Korea. The result shows that there is a "contagion effect" or "transmission effect" between the Japanese exchange rate and the exchange rates of observed countries in the study, but there is only an "interdependence effect" between Japan and Australia, Euro, Qatar, Saudi Arabia, and South Korea. Forbes and Rigobon (2001) defined the contagion of the international financial markets as a significant increase in cross market linkages or co-movement between one market and others after a shock or during a crisis, and our results supported the "contagion effect" between Japan exchange rate market and parts of exchange rate markets in the surveyed countries in our study. In addition, by further comparisons of the $F_A$ statistics in pre-Abenomics and during-Abenomics in the (11) column of Table 5, we have found that the asymmetry in the co-integration relationships has also significantly increased after the end of Abenomics between Japan and most of the observed countries in the paper. The result shows that a result of Abenomics was the quick transmission of massive amounts of negative information between many exchange rate markets. This led to higher risk aversion among international investors.

According to the empirical results, we find out that there are quite large differences between utilizing the Enders-Siklos' asymmetric threshold test (M-TAR), and the Engel-Grange and Johansen co-integration tests with the Enders-Siklos test producing better results. It is apparent from Table 3 and Table 4 that the co-integration relationships between the Japanese exchange rates and exchange rates of surveyed countries during the Abenomics period do not significantly increase. Some researched results demonstrate that the relationships between international exchange markets should have a closer co-integration correlation when the emergence of severe risk impacts the global economy. We are unable to obtain results showing the co-integration degree increases when we apply the Engel-Grange and Johansen co-integration tests because the hypotheses of the two co-integration tests rely on a symmetric adjustment process. However, the result of the Enders-Siklos asymmetric threshold co-integration shows that there is a significant increase in the co-integration correlation during the Abenomics period between the Japanese exchange rate and the exchange rate of the surveyed countries in the study. The co-integration relationships are regarded as a trend of mutual movement. After Abenomics, the co-integration relationships increased between Japanese exchange rates and the exchange rates of Canada, China, Hong Kong, Indonesia, Malaysia, Singapore, Taiwan, Thailand, United Arab Emirates, and the U.S.. The results also illustrate that exchange rate depreciation in Japan caused contagion effect. That can also be called the phenomena of competitive depreciation of exchange rates. However, there are only interdependent effects between Japan and Australia, Euro, Qatar, Saudi Arabia, South Korea. During Abenomics, Asian countries in competition with Japan to export adapted their currency devaluation to promote competitive advantage for export products. However, the exchange rate relationship between Japan and South Korea during Abenomics is lower than that in the pre-Abenomics. Because the prices of the products of South Korea export had a more competitive advantage than that of Japanese exports, there is a little bit influence in short term during Abenomics, however, the effect of the depreciation of Japan exchange rate to South Korea exchange rate is insignificant in long term.

Table 5: Results of the Enders-Siklos test for threshold co-integration

| | Entire period | | | Pre-Abenomics | | | During Abenomics | | | Co-integration statistics | Asymmetric Statistics | Contagion Yes/No? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1)$F_c$ | (2)$F_A$ | (3)$\gamma$ | (4)$F_c$ | (5)$F_A$ | (6)$\gamma$ | (7)$F_c$ | (8)$F_A$ | (9)$\gamma$ | (10)=(7)-(4) | (11)=(8)-(5) | |
| **Australia** | 6.378*** | 4.418** | 0.0049 | 6.217*** | 2.179 | 0.0015 | 5.476*** | 5.406** | 0.0024 | Decrease | Increase | No |
| **Canada** | 5.649*** | 3.827* | -0.0038 | 5.260*** | 2.186 | -0.0049 | 5.464*** | 3.285* | -0.0037 | Increase | Increase | Yes |
| **China** | 2.668* | 0.667 | 6.5e-04 | 1.296 | 1.845 | 1.5e-04 | 2.776* | 4.683** | 8.2e-04 | Increase | Increase | Yes |
| **Euro** | 2.570* | 2.646 | 0.0019 | 2.383* | 3.020* | -0.0023 | 1.435 | 1.136 | -4.1e-04 | Decrease | Decrease | No |
| **Hong Kong** | 12.59*** | 15.15*** | -7.3e-05 | 6.178*** | 8.183*** | -3.9e-05 | 10.79*** | 8.907*** | -6.3e-05 | Increase | Increase | Yes |
| **Indonesia** | 3.504** | 3.540* | -0.0051 | 0.728 | 1.454 | 5.6e-04 | 3.690** | 5.015** | -0.0050 | Increase | Increase | Yes |
| **Malaysia** | 4.441** | 2.682 | 0.0014 | 3.951** | 1.457 | -0.0042 | 3.978** | 1.855 | 8.5e-04 | Increase | Increase | Yes |
| **Qatar** | 54.57*** | 15.99*** | 5.5e-05 | 46.44*** | 14.20*** | 5.7e-05 | 24.84*** | 13.27*** | -1.3e-06 | Decrease | Decrease | No |
| **Saudi Arabia** | 10.03*** | 5.760** | -2.2e-05 | 34.54*** | 4.907** | 1.1e-05 | 8.143*** | 2.234 | 2.2e-05 | Decrease | Decrease | No |
| **Singapore** | 6.133*** | 5.132** | 0.0020 | 4.097** | 3.374* | 0.0020 | 5.170*** | 4.051** | -0.0015 | Increase | Increase | Yes |
| **South Korea** | 4.612** | 4.065** | -0.0038 | 3.816** | 3.885** | -0.0038 | 3.641** | 5.110** | 5.0e-04 | Decrease | Decrease | No |
| **Taiwan** | 3.183** | 3.364* | 0.0015 | 3.670** | 2.941* | 0.0023 | 4.482** | 2.334 | 0.0013 | Increase | Decrease | Yes |
| **Thailand** | 5.609*** | 7.089*** | 0.0022 | 3.813** | 2.572 | -0.0013 | 4.384** | 5.386** | -0.00275 | Increase | Increase | Yes |
| **United Arab Emirates** | 94.60*** | 4.984** | 1.4e-05 | 49.97*** | 0.654 | -1.4e-05 | 60.87*** | 13.40*** | 1.6e-08 | Increase | Increase | Yes |
| **U.S.** | 3.507** | 4.542** | 0.0016 | 3.263** | 4.208** | -0.0046 | 6.612*** | 11.79*** | -2.0e-04 | Increase | Increase | Yes |

Notes:

1. The lag-length of difference Ks selected by minimizing AIC; r is the estimated threshold value.
2. $F_c$ and $F_A$ denote the F-statistics for the null hypothesis of no co-integration and symmetric adjustment. Critical values of co-integration test are taken from Enders and Siklos (2001).
3. *, ** and *** denote significance at the 10%, 5% and 1% significance levels, respectively.

## 4 Conclusion

In this paper, we propose the linear models of Engle and Granger (1987) or the Johansen (1988) co-integration models and threshold co-integration of Enders and Siklos (2001), in order to investigate financial contagion. This threshold co-integration approach goes beyond linear co-integration models, analyses the nonlinear adjustment of financial time-series, and enables us to overcome the estimation error problems of asymmetries. This enables us to analyze the behavior among exchange rate markets when at least one of them is under financial crisis (crisis country). To check the robustness of the co-integration results, we also apply the M-TAR model which can capture an accumulation of changes in the disequilibrium relationship between variables below and above the threshold followed by a sharp movement back to the equilibrium position. We successfully apply the threshold co-integration methodology to the investigation of contagion effect of Japanese yen devaluation. This study focuses on major trade countries of Japan. To test the existence of contagion in the exchange rate markets, this paper uses Japan as the crisis country and Abenomics as triggering off a currency depreciation war. We then estimate the correlations between the crisis country and all other countries which are surveyed in this study during both stable and crises periods. Therefore, we split the estimation procedure into subgroups in order to compare the impact and the magnitude of the spread of the crises in each individual country. This paper contributes to the literature in the following aspects. First, we introduce the momentum threshold autoregressive (M-TAR) model of Enders and Siklos (2001) into the multivariate framework that allows us to capture the correlation dynamics and asymmetries in a more flexible and realistic way than the linear models of Engle and Granger (1987) and the Johansen (1988) co-integration models that have been proposed in the study. Second, we compare the contagion effect of the Japanese yen depreciation crisis before and after the Abenomics period, and find that most countries with export trade with Japan follow the depreciation of the yen in applying threshold co-integration model. Third, the empirical evidence confirms a contagion effect particularly in Asian countries in competition with Japan except South Korea to export. The prices of the export products of South Korea are far lower and more competitive than that of Japan so the exchange rate of South Korea is not influenced by the Japanese yen devaluation during the period of Abenomics. Therefore, the contagion of Japanese yen depreciation does not transmit to Australia, Euro (France, Germany, Italy, and Netherlands), Qatar, Saudi Arabia, and the USA with trade competition countries of Japan. We can apparently find out the effect of yen devaluation just only occurred in Asian area of being close to Japan and does not spread Europe, America and other countries. Furthermore, Australia is the largest exporting country of iron ore in the world. However, Japan is the second largest importing country of iron ore. Depreciation of the yen favored Australian iron ore exports during Abenomics. In addition, Japan is the third largest importing country of crude petroleum all over the world. Saudi Arabia is the largest exporting country of crude petroleum. Devaluation of the yen is an advantage to Saudi Arabia. Qatar also received the same benefit as Saudi Arabia. In general, our results support the contagion phenomenon for Abenomics. Nevertheless, the effect of the contagion is regional not global.

## References


[1] M. E. H. Arouria, M. Bellalahb and D. K. Nguyenc, The co-movements in international stock markets: new evidence from Latin American emerging Countries, *Applied Economics Letters*, **18**, (2009), 1 - 6.

[2] T. Baig and I. Goldfajn, Financial market contagion in the Asian crisis, *IMF Staff Papers*, **46**, (1999).

[3] S. M. Bartram, S. J. Taylor and Y.-H. Wang, The Euro and European financial market dependence, *Journal of Banking & Finance*, **31**, (2007), 1461 - 1481.

[4] G. Bekaert, C. R. Harvey and A. Ng, Market integration and contagion, *Journal of Business*, **78**, (2005), 39 - 69.

[5] C. Boucher, Asymmetric adjustment of stock prices to their fundamental value and the predictability of US stock returns, *Economics Letters*, **95**, (2007), 339 - 347.

[6] S. Calvo and C. M. Reinhart, Capital flows to Latin America: is there evidence of contagion effects?, In: G. Calvo, M. Goldstein and E. Hochreiter, (Eds.), Private Capital Flows to Emerging Markets, *Institute for International Economics*, Washington, DC, (1996).

[7] G. M. Caporale, A. Cipollini and N. Spagnolo, Testing for Contagion: A Conditional Correlation Analysis, *Journal of Empirical Finance*, **12**, (2005), 476 - 489.

[8] S. K. Chan, Consistency and limiting distributions of the least squares estimators of a threshold autoregressive model, *Annals of Statistics*, **21**, (1993), 520 - 533.

[9] S. Chang, Asymmetric Cointegration Relationship among Asian Exchange Rates, *Economic Change and Restructuring*, **41**, (2008), 125 - 141.

[10] S. Chang, Effects of Asymmetric Adjustment among Labor Productivity, Labor Demand, and Exchange Rate Using Threshold Cointegration Test, *Emerging Markets Finance and Trade*, **46**, (2010), 55 - 68.

[11] M. H. Chiang, The Asymmetric Behavior and Spillover Effects on Stock Index Returns: Evidence on Hong Kong and China, *Pan Pacific Management Review*, **4**, (2001), 1 - 21.

[12] D. A. Dickey and W. A. Fuller, Likelihood ratio statistics for autoregressive time series with unit root, *Econometric*, **49**, (1981), 1057 - 1072.

[13] R. Dornbusch, Y. C. Park and S. Claessens, Contagion: Understanding How It Spreads, *The World Bank Research Observer*, **15**(2), (2000), 177 - 197.

[14] M. Dungey, R. Fry, B. González-Hermosillo and V. Martin, Contagion in international bond markets during the Russian and the LTCM crises, *Journal of Financial Stability*, **2,** (2006), 1 - 27.

[15] W. Enders and C. W. J Granger, Unit-root tests and asymmetric adjustment with an example using the term structure of interest rates, *Journal of Business and Economic Statistics*, **16**(3), (1998), 304 - 311.

[16] W. Enders and P. L. Siklos, Cointegration and threshold adjustment, *Journal of Business and Economic Statistics*, **19**(2), (2001), 166 - 176.

[17] R. Engle and S. Yoo, Forecasting and Testing in Co-integration Systems, *Journal of Econometrics*, **35**, (1987), 143 - 159.

[18] R. F. Engle and C. W. Granger, Co-integration and error correction: Representation, estimation, and testing, *Econometrica*, **55**, (1987), 251 - 276.

[19] K. Forbes and R. Rigobon, Measuring Contagion: Conceptual and Empirical Issues, *The International Bank for Reconstruction and Development organizing conference of World Bank on International Financial Contagion: How it Spreads and How it Can Be Stopped*, (2001).

[20] K. J. Forbes and R. Rigobon, No contagion, only interdependence: measuring stock market comovements, *Journal of Finance*, **57**, (2002), 2223 - 2261.

[21] S. Johansen, Statistical Analysis of Cointegration Vectors, *Journal of Economic Dynamics and Control*, **12**(3), (1988), 231 - 254.

[22] G. Kapetanios, Y. Shin and A. Snell, Testing for a unit root in the nonlinear STAR framework, *Journal of Econometrics*, **112**, (2003), 359 - 379.

[23] G. Koutmos, Asymmetries in the Conditional Mean and the Conditional Variance: Evidence from Nine Stock Markets, *Journal of Economics and Business*, **50**, (1998), 277 - 290.

[24] D. Kwiatkowski, P. C. B. Phillips, P. Schmidt and Y. Shin, Testing the Null Hypothesis of Stationarity against the Alternative of a Unit Root: How Sure are We that Economic Time Series Have a Unit Root?, *Journal of econometrics*, **54**(1), (1992), 159 - 178.

[25] S. B. Lee and K. J. Kim, Does the October 1987 crash strengthen the co-movements among national stock markets?, *Review of Financial Economics*, **3**, (1993), 89 - 102.

[26] W. K. Li and K. Lam, Modelling Asymmetry in Stock Returns by a Threshold Autoregressive Conditional Heteroscedastic Model, T*he Statistician*, **44**, (1995), 333 - 341.

[27] M. B. Lucey and S. Voronkova, Russian equity market linkages before and after the 1998 crisis: Evidence from stochastic and regime-switching cointegration tests, *Journal of International Money and Finance*, **27**, (2008), 1304 - 1324.

[28] S. Ng and P. Perron, Lag length selection and the construction of unit root tests with good size and power, *Econometrica*, **69**, (2001), 1519 - 1554.

[29] T. Okimoto, New evidence of asymmetric dependence structures in international equity markets, *Journal of Financial and Quantitative Analysis*, **43**, (2008), 787 - 815.

[30] A. J. Patton, Modelling asymmetric exchange rate dependence, *International Economic Review*, **47**, (2006), 527 - 556.

[31] P. C. B. Phillips and P. Perron, Testing for a Unit Root in Time Series Regression, *Biometrica*, **75**(2), (1988), 335 - 346.

[32] J. C. Rodriquez, Measuring financial contagion: a copula approach, *Journal of Empirical Finance*, **14**, (2007), 401 - 423.

[33] C. H. Shen, C. Chen and L. Chen, An Empirical Study of the Asymmetric Cointegration Relationships among the Chinese Stock Markets, *Applied Economics*, **39**, (2007), 1433 - 1445.

[34] C. Wang and C. A. Lin, Using Threshold Cointegration to Examine Asymmetric Price Adjustments between ADR's and Their Underlying Securities—The Case of Taiwan, *South African Journal of Economics*, **73**, (2005), 449 - 461.