"Modeling Financial Contagion: Approach-based on Asymmetric Cointegration"

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DR n°2012-21
Modeling financial contagion: approach-based on asymmetric cointegration

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Juin, 2012

Abstract

We analyze the financial contagion using an approach based on cointegration with asymmetric adjustment TAR and M-TAR. To capture the contagion effect, we consider regime change in the adjustment of the error correction term. We have introduced Threshold Autoregressive model (TAR) and Momentum Threshold Autoregressive model (M TAR) in adjustment mechanism of the error correction model with assumption that the error term exhibits self-excite jump. Our empirical study required the selection of four markets indices such as the CAC40, the FTSE 100, the S&P500 and NIKKEI225. We used these markets to understand the mechanism of shock propagation during the 2007 crisis. The results demonstrate the transmission of shocks by pure contagion from the S&P500 to FTSE100 and the CAC40. In contrast, we found a shocks transmission in the bond of interdependence from the S&P500 to NIKKEI225.

Classification JEL: C22 ; G01 ; G15

Keywords: financial contagion; nonlinear cointegration; TAR and M-TAR models, non-linear ECM

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1. Introduction

According to Forbes and Rigobon (2001a), we can define financial contagion as a significant increase in market linkages after the completion of a shock to one country or group of countries. Eichengreen and al. (1996) provides another definition: <<The contagion is a significant increase in the probability of a crisis in a country, conditional on the achievement of a crisis in another country>>. Finally, we can also talk about contagion referring to the occurrence when co-movements are not explained by fundamentals. Moreover, contingent crisis theories imply that the transmission of shocks is done solely via new channels created during the crisis period. This idea follows the work of Forbes and Rigobon (2001). The Non-Crisis-Contingent Theories shows that the transmission is performed through strong trade links, but also by mechanisms of endogenous liquidity shocks. Masson (1999) discusses the change in investor expectations. In other words, the presence of market crisis, may change the beliefs of investors about the stability of another market that will eventually cause the collapse of this market. Before the work of Forbes and Rigobon, theoretician of financial contagion analysis had failed to mention modification of transmission channels in financial contagion.

We focus our work in the dynamics of financial contagion by examining the four indexes of financial markets. Threshold cointegration and error correction models with adjustment TAR and M-TAR are employed. Our study focuses on the analysis of contagion between the CAC40, FTSE100, S&P500 and NIKKEI225 during the crisis of summer 2007 in the United States. Responsibility for the U.S. market as starting point of systemic risk in the 2007 crisis, we assume that the shock was born in the United States, (so the ground zero). We note also that our approach is inspired by the VAR model applied to the financial contagion of Favero-Giavazzi (2002), Ayadi, Boudhina, Khalloudi and Sandretto (2006), and asymmetric cointegration strategy estimation of Enders and Siklos (2001). The analysis of the markets interdependence is carried out using the cointegration test develop by Engle and Granger (1987). As for the analysis of pure contagion, we use the asymmetry in the model fit error correction and cointégration threshold model of Enders and Siklos (2001). The non-linearity in the adjustment during the crisis period compared to the period of peace justifies the generation of new shock propagation channels.

This article is organized as follows: in section 2, we develop interdependence and contagion modeling. The third section is dedicated to the empirical framework and finally in a fourth time we conclude.
2. Modeling financial contagion and interdependence

Our study consists of two steps. First, we test the long term interdependence with the linear cointegration and symmetric error correction model. Then, we test the contagion by analyzing the generation of new transmission channels during the crisis by using asymmetric cointegration.

2.1. Modeling the interdependence: Linear cointegration and long term equilibrium relationship

The test of the hypothesis of cointegration requires ex-ante, estimate of the equilibrium long-run relation of exogenous and endogenous variables (Engle and Granger, 1987). If we consider the equation of long-run equilibrium defined by:

$$ V_t = \alpha_0 + \beta_1 X_t + \zeta_t \quad (1) $$

With:
- $V_t$ the endogenous variable. In our study it refers to the market index on which the contagion is analyzed. This variable can be the CAC40, the FTSE 100 or the Nikkei225.
- $X_t$ is the exogenous variable. This variable is the S&P500, the market at the origin of the contagion.
- $\zeta_t$ the random error term. This variable captures the effect of non observable regression.
- $\beta_1$ the elasticity of transmission. If the residuals from the linear combination of variables $V_t$ and $X_t$ are stationary, then we can conclude the existence of a stable long-term relationship. According to the Johansen procedure, if it turns out that the hypothesis of cointegration is accepted, then a error correction model is estimated. We examine the dynamics of short-term to reconcile the short-term and long-term horizon. The error correction model has the following form:

$$ \Delta V_t = \lambda + \sum_{k=1}^{n} \alpha_k \Delta V_{t-k} + \sum_{k=1}^{n} \beta_k \Delta X_{t-k} + \phi \zeta_{t-1} + \epsilon_t \quad (2) $$

Where $\phi$ is the adjustment speed of $V_t$, and $\beta_k$ is the elasticity of transmission of the short term.

This dynamic allows us to know if there is a restoring force to the long-run equilibrium. In the event that we can show that the two markets are cointegrated, then we conclude the existence of permanent propagation channels of shocks between the two markets. According to the non-contingent theories to crisis, this means that the two markets are linked by relations of interdependence (Forbes and Rigobon (2001)). In other words, the mechanisms through which propagate a shock, is via the real and financial linkages between two markets.
2.2. Modeling of financial contagion

2.2.1. Threshold cointegration and nonlinear adjustment

In a second step, we ignore the assumptions that the long-run equilibrium is unique and adjustment to the equilibrium is symmetric. Now, we consider following:

- The balance of long-term is multiple
- The adjustment from the equilibrium is asymmetric.

This specification, as described by Granger and Lee (1989) and Escribano and Pfann (1998) allow us to estimate the asymmetric adjustment of short-term dynamics. We model this process by the approach developed by Enders and Siklos (2001). We analyze the asymmetry of adjustment in our series by the estimated coefficients and the error term of the threshold cointegration relationship. In this case the error correction model is represented by the equation:

\[
\Delta V_t = \sum_{k=1}^{n} \alpha^+_k \Delta V_{t-k}^+ + \sum_{k=1}^{n} \alpha^-_k \Delta V_{t-k}^- + \sum_{k=1}^{n} \beta^+_k \Delta X_{t-k}^+ + \sum_{k=1}^{n} \beta^-_k \Delta X_{t-k}^- + \phi_I \zeta^+_{t-1} + \phi_2 (1-I_t) \zeta^-_{t-1} + \varepsilon_t
\]

(3)

Let \( \Delta V_{t-1}^+ = V_{t-1} - V_{t-2} \), if \( V_{t-1} > \zeta_{t-2} \) and \( \Delta V_{t-1}^- \), if \( V_{t-1} < V_{t-2} \). The asymmetry is at the level of error correction \( \zeta_t \) that must be split into two elements, \( \phi_1 \zeta^+_{t-1} \) and \( \phi_2 \zeta^-_{t-1} \). In this way it is possible to model two important situations. We base this on the fact that \( \zeta^-_{t-1} \) is the balance of stability period and \( \zeta^+_{t-1} \) is the crisis equilibrium term. These are error terms of equilibrium. We test the hypothesis that these channels have been changed during the crisis. Indeed, we test the nonlinearity of the error correction model.

After this, we test the asymmetry in the adjustment of the cointegrating relationship in the long term using the strategy employed by Enders and Siklos (2001). They propose to test the null hypothesis of symmetry of the coefficients \( (\phi_1 = \phi_2) \) against the alternative of asymmetry \( (\phi_1 \neq \phi_2) \) using the usual Fisher test.

They propose to test the null hypothesis of no cointegration \( (H_0 : \phi_1 = \phi_2 = 0) \), against the alternative of cointegration with TAR or M-TAR adjustment using two tests. Fisher’s test, denoted \( \Phi \) is used to test the null hypothesis. The critical values of this test are provided by the authors. Moreover, it is possible to test the null hypothesis \( (\phi_1 = \phi_2) \) with the standard Fisher test. If \( \phi_1 \) is statistically different of \( \phi_2 \), then the null hypothesis of linearity is rejected. With such, we can conclude that there is a non-linearity in the process of adjustment error correction model. If we perform this test during the crisis and detect asymmetry in the adjustment, we can conclude that there is a transmission of shocks in the market \( V_t \) by
contagion generated by the market $X_t$. Otherwise, we will discuss the case of interdependence between our two markets. When the error term $\zeta_{t+1} = 0$, that is to say $\phi_1 = 0$ and $\phi_2 = 0$, we test the transmission channels, by following the approach of Ayadi, Boudhina, Khalloudi and Sandretto (2006). We calculate the coefficient of co-movement $\rho = \frac{\Delta Y_{t+1}}{\Delta X_{t+1}}$ during periods of peace and crisis, if there is significant difference we conclude that there is contagion.

### 2.2.2. Model of Enders and Siklos (2001)

The approach of Enders and Siklos is achieved when the threshold cointegration vector is not known. The critical values of these tests have been proposed by the authors using methods of Monte Carlo simulation. If the residuals from the equilibrium relationship of long-term follow an autoregressive process threshold with two regimes, then we can define the following explicit form:

$$\Delta \zeta_{t-1} = I_t \phi_1 \zeta_{t-1} + (1 - I_t) \phi_2 \zeta_{t-1} + \sum_{i=1}^{p-1} \gamma_i \Delta \zeta_{t-1} + \varepsilon_t$$  \hspace{1cm} (4).$$

Where:
- $\zeta_t$ is the residue obtained from the equation of long-term is identically and independently distributed and $P$ the number of lags. $\phi_1$ and $\phi_2$ are coefficients.
- $I_t$ is the indicator function defined as follows:

$$I_t = \begin{cases} 1 & \text{if } \zeta_{t-1} \geq \tau \\ 0 & \text{if } \zeta_{t-1} < \tau \end{cases}$$  \hspace{1cm} (5).$$

- $\tau$ Represents the threshold value for determining the break and $\varepsilon_t$ is independent of $\zeta_j$, $j < t$. Petrucelli and Woodford (1984) showed that the necessary conditions for stationary of $\zeta_t$ are $\phi_1 < 0$, $\phi_2 < 0$ et $(1 + \phi_1)(1 + \phi_2) < 1$, and for all values of $\tau$. If these conditions are met, then $\zeta_t = 0$ is considered long-term equilibrium of the system.

To better capture the dynamic adjustment $\zeta_{t-1}$ to the equilibrium value of long-term, we replace the equations (4) and (5) by equations (6) and (7) and we arrive at the Momentum Threshold Autoregressive (M-TAR) as follows:
\[
\Delta \zeta_{t-1} = I_t \phi_1 \zeta_{t-1} + (1 - I_t) \phi_2 \zeta_{t-1} + \sum_{i=1}^{n-1} \gamma_i \Delta \zeta_{t-1} + \varepsilon_t
\]  

(6).

With

\[
I_t = \begin{cases} 
1 & \text{if } \Delta \zeta_{t-1} \geq \tau \\
0 & \text{if } \Delta \zeta_{t-1} < \tau 
\end{cases}
\]  

(7).

The error correction model with TAR and M-TAR are estimated after determining the number of delay and autocorrelation test. Using Monte Carlo simulation, we can test the hypothesis of no cointegration against the hypothesis of cointegration with threshold adjustment. The test can be done either with the TAR model or M-TAR or with other alternative methods. To perform the test, we test hypothesis:

\[ H_0 : \phi_1 = \phi_2 = 0 \] (Hypothesis of no cointegration)

Against the alternative \( H_1 \) : (Hypothesis of cointegration with asymmetric adjustment). The threshold cointegration is analyzed by testing the null hypothesis of unit root \( H_0 : \phi_1 = \phi_2 = 0 \) using the special Fisher test of Enders and Siklos (2001) noted \( \Phi \) whose critical values of this test are provided by the authors. When this value calculated by Fisher is higher than the critical table of Enders and Siklos (2001), then we reject the null hypothesis of no cointegration and we accept the hypothesis of cointegration with threshold. If hypothesis of threshold cointegration is accepting, we estimate the error correction model asymmetric following:

\[
\Delta V_t = \sum_{k=1}^{n} \alpha_k^+ \Delta V_{t-k}^+ + \sum_{k=1}^{n} \alpha_k^- \Delta V_{t-k}^- + \sum_{k=1}^{n} \beta_k^+ \Delta X_{t-k}^+ + \sum_{k=1}^{n} \beta_k^- \Delta X_{t-k}^- + \phi_1 I_t \zeta_{t-1}^+ + \phi_2 (1 - I_t) \zeta_{t-1}^- + \varepsilon_t 
\]  

(10.)

\[
I_t = \begin{cases} 
1 & \text{if } \zeta_{t-1} \geq \tau \\
0 & \text{if } \zeta_{t-1} < \tau 
\end{cases}
\]  

(11.) or \[
I_t = \begin{cases} 
1 & \text{if } \Delta \zeta_{t-1} \geq \tau \\
0 & \text{if } \Delta \zeta_{t-1} < \tau 
\end{cases}
\]  

(12.)
\( \alpha, \beta \) are the coefficients of elasticity, \( n \) the number of lags and \( \zeta_t \) is the error term. \( \phi_1 \) and \( \phi_2 \) are the speeds of adjustment. The asymmetry in the adjustment is examined using the usual \( F \)-test applied to the null hypothesis \( H_0: \phi_1 = \phi_2 \).

Following the work of Enders and Granger (1998) and Enders and Siklos (2001), asymmetry in the cointegration of the series have been improved. The test is performed in two cases: considering the value \( \tau = 0 \), but also when the value \( \tau \) is unknown (see summary below).

First situation: when we consider the case of a threshold equal to zero \( \tau = 0 \), we can easily infer the coefficients \( \phi_1 \) and \( \phi_2 \).

Second situation: when the threshold is unknown, it must be determined. Therefore, finding the threshold value which coincides with the optimal value of threshold is not obvious. It is determined by the method described by Chan (1993). To estimate the optimal threshold, we use the approach proposed by Chan (1993). Indeed, the author shows that it is possible to obtain a good estimator of the threshold from the minimization of the sum of square of residuals. The strategy as described by the author is to estimate the equation of the long-term relationship \( V_t = \zeta_t + \beta_1 X_t + \epsilon_t \) and extract the residuals from this regression. Then, the estimated residuals are sorted in ascending order. The 15% of the highest values and the lowest are excluded and 70% of the remaining values are considered as candidate thresholds. Subsequently, the equation

\[
\Delta \zeta_{t-1} = I_t \phi_1 \zeta_{t-1} + (1 - I_t) \phi_2 \zeta_{t-1} + \sum_{i=1}^{n} \gamma_i \Delta \zeta_{t-i-1} + \epsilon_t \tag{14}
\]

is estimated for each threshold candidates. Finally, the threshold is derived from the minimization of the sum of square of residuals.

Enders and Siklos (2001) propose to test the hypothesis that the coefficients \( \phi_1 \) and \( \phi_2 \) are jointly different. This is done using the standard statistical of Fisher and the Fisher statistic called \( \Phi^2 \).

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1. For more details see the article of Enders and Granger (1998)
2. The critical tables are proposed by Enders and Siklos (2001)
**Procedure:**

The estimation as described by the authors consists of three main steps.

Step 1: compute regression of the long-term relationship of two variables $V_t$ and $X_t$, integrated $I(1)$.

$$V_t = \zeta_t + \beta_1 X_t + \varepsilon_t \quad (8).$$

Then, keep the residue of this regression in the sequences of $\zeta_t$. Depending on the type of asymmetry, we make a choice in the form of the indicator function

$$I_t = \begin{cases} 1 & \text{if } \zeta_{t-1} \geq \tau \\ 0 & \text{if } \zeta_{t-1} < \tau \end{cases} \quad (9)$$

Or

$$I_t = \begin{cases} 1 & \text{if } \Delta \zeta_{t-1} \geq \tau \\ 0 & \text{if } \Delta \zeta_{t-1} < \tau \end{cases} \quad (10)$$

In the case that the threshold $\tau = 0$ for the indicator function, we estimate equation 11:

$$\Delta \zeta_{t-1} = I_t \phi_1 \zeta_{t-1} + (1 - I_t) \phi_2 \zeta_{t-1} + \varepsilon_t \quad (11).$$

It holds the largest value of the t-statistic for the null hypothesis or we use the Fisher statistic for the joint hypothesis $\phi_1 = \phi_2 = 0$.

Step 2: If the alternative hypothesis of stationarity is accepted, it is possible to test the symmetry of adjustment.

Step 3: Analyze the residuals from the regression error term, to see
\[ \Delta \zeta_t = I_t \phi_1 \zeta_{t-1} + (1-I_t) \phi_2 \zeta_{t-1} + \gamma_1 \Delta \zeta_{t-1} + \ldots + \gamma_p \Delta \zeta_{t-1} + \epsilon_t \] (12).

With

\[ I_t = \begin{cases} 1 & \text{if } \zeta_{t-1} \geq \tau \\ 0 & \text{if } \zeta_{t-1} < \tau \end{cases} \] (13).

In the case of M-TAR model, we replace the indicator function (9) by (10).

If the residuals are correlated, then we must return, to step 2.

3. Analysis of contagion and interdependence:

3.1. Database study

We used the daily price indices of four countries observed from 2000 to 2011: this is the CAC40 for France, for the UK it the FTSE100, S&P500 for the United States and for Japan NIKKEI. To carry out the study of contagion, we fired two sub-samples: the period of 2005-2006 identified as the period of tranquility and the period July 2007 to 2008 identified as a period of market stress (period marked by the subprime crisis in the U.S.A).

Markets correlation

\begin{tabular}{lrr}
 & \multicolumn{2}{c}{\textit{S \& P500}} \\
\hline
\textit{Correlation} & \multicolumn{2}{c}{\textit{CAC40}} & \multicolumn{2}{c}{\textit{FTSE100}} & \multicolumn{2}{c}{\textit{NIKKEI}} \\
\hline
\textit{Correlation} & \multicolumn{2}{c}{0.7936733} & \multicolumn{2}{c}{0.7730261} & \multicolumn{2}{c}{0.2875441} \\
\hline
\end{tabular}

3. These data are from the Euronext.
Evolution of S&P500, CAC40, FTSE100 and NIKKEI225, 2007-2008

The correlation test between the volatility of CAC40, FTSE100, the NIKKEI225 and the S&P500, show the following: 1. low correlation (0.29) between the S&P500 and NIKKEI225; and 2. Strong correlation between the CAC40 and S&P500 (0.79), FTSE100 and S&P500 (0.77). These show that we are in times of market stress with a polarization of investor expectations. Furthermore, volatility indexes that represent investor psychology are mounted to 80.86 for the S&P500 in 2008, 78.05 for the CAC40, FTSE100 and 78.69 for NIKKEI225 in the same period of 2008.

Our tests were performed with the software R. The study of stationarity is conducted on the logarithm of the series in level and first difference using the Dickey-Fuller (ADF), Phillips-Perron (PP) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS). The results of these tests are provided in Tables 1 and 2. The results in Table 1 confirm for majority of tests, the acceptance unit root in the different series. In Table 2, tests reject the presence of unit root in the series in difference. We conclude that our series are integrated $I(1)$.
Table 1: Unit root test of the series in logarithms

<table>
<thead>
<tr>
<th></th>
<th>ADF</th>
<th>Prob</th>
<th>KPSS</th>
<th>Prob</th>
<th>PP $z(\alpha)$</th>
<th>Prob</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Series in level</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$CAC40$</td>
<td>-2.7196</td>
<td>0.2737</td>
<td>7.7999</td>
<td>0.01</td>
<td>-17.6569</td>
<td>0.1247</td>
</tr>
<tr>
<td>$FTSE100$</td>
<td>-2.9912</td>
<td>0.1587</td>
<td>7.7788</td>
<td>0.01</td>
<td>-18.2699</td>
<td>0.0975</td>
</tr>
<tr>
<td>$S &amp; P500$</td>
<td>-2.941</td>
<td>0.18</td>
<td>1.6931</td>
<td>0.01</td>
<td>-502.6243</td>
<td>0.01</td>
</tr>
<tr>
<td>$NIKKEI$</td>
<td>-1.8573</td>
<td>0.6387</td>
<td>7.1342</td>
<td>0.01</td>
<td>-6.1621</td>
<td>0.766</td>
</tr>
</tbody>
</table>

ADF: Augmented Dickey-Fuller. PP: Phillips-Perron. KPSS: Kwiatkowski-Phillips-Schmidt-Shin. The lag is determined from the Akaike criterion. With critical probability 5%.

Table 2: Unit root test of the series in first difference

<table>
<thead>
<tr>
<th></th>
<th>ADF</th>
<th>Prob</th>
<th>KPSS</th>
<th>Prob</th>
<th>PP $z(\alpha)$</th>
<th>Prob</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Series in first differences</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta CAC40$</td>
<td>-9.2201</td>
<td>0.01</td>
<td>0.0333</td>
<td>0.1</td>
<td>-538.8723</td>
<td>0.01</td>
</tr>
<tr>
<td>$\Delta FTSE100$</td>
<td>-8.879</td>
<td>0.01</td>
<td>0.0304</td>
<td>0.1</td>
<td>-594.095</td>
<td>0.01</td>
</tr>
<tr>
<td>$\Delta S &amp; P500$</td>
<td>-9.6529</td>
<td>0.01</td>
<td>0.3381</td>
<td>0.1</td>
<td>-502.151</td>
<td>0.01</td>
</tr>
<tr>
<td>$\Delta NIKKEI$</td>
<td>-8.1337</td>
<td>0.01</td>
<td>0.0897</td>
<td>0.1</td>
<td>-510.8972</td>
<td>0.01</td>
</tr>
</tbody>
</table>

ADF: Augmented Dickey-Fuller. PP: Phillips-Perron. KPSS: Kwiatkowski-Phillips-Schmidt-Shin. The lag is determined from the Akaike criterion. With critical probability 5%.

After the analysis of stationarity, now we proceed with the analysis of the standard cointegration between the S&P500 and other indices: FTSE100, CAC40 and NIKKEI225.
3.2. Analysis of the interdependence

We perform the analysis of cointegration following the two-step approach of Engle and Granger on residue of long-term relationship. Then we proceed to the test statistics developed by Johansen (1988) and Johansen and Juselius (1990).

We group the results in Tables 3 for testing Engle and Granger. For Johansen test, the result are stored in tables 4, 5, 6. The choice of the number of delay is based on the criterion of minimization of AIC and BIC. The results demonstrate the existence of cointegration between pairs of series by the rejection of the null hypothesis of non-stationarity of the residuals of the regression of long-term.

Table 3: Standard cointegration test

<table>
<thead>
<tr>
<th></th>
<th>ADF</th>
<th>Prob</th>
<th>PP</th>
<th>Prob</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CAC40 – S &amp; P500</strong></td>
<td>-4.6716</td>
<td>0.01</td>
<td>-99.4358</td>
<td>0.01</td>
</tr>
<tr>
<td><strong>NIKKEI – S &amp; P500</strong></td>
<td>-8.2334</td>
<td>0.01</td>
<td>-1286.102</td>
<td>0.01</td>
</tr>
<tr>
<td><strong>FTSE100 – S &amp; P500</strong></td>
<td>-3.1837</td>
<td>0.04</td>
<td>-70.3122</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Null hypothesis: non-stationarity and critical probability 5%

The Johansen test whose results are reported in Tables 4, 5, 6 was performed using the $\lambda_{max}$ statistic. The results clearly demonstrate the existence of cointegrating relationship between the indices at the 5 % and 1%.

Table 4: Johansen test for NIKKEI225-S&P500

<table>
<thead>
<tr>
<th>Test de la trace Hypothèse nulle</th>
<th>statistique de la trace</th>
<th>valeur critique (5%)</th>
<th>valeur critique (1%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R≤1</td>
<td>3.57</td>
<td>12.25</td>
<td>16.26</td>
</tr>
<tr>
<td>R=0</td>
<td>48.98</td>
<td>25.32</td>
<td>30.45</td>
</tr>
</tbody>
</table>

The critical values of the test are read from the tables of Osterwald-Lenum (1992).
Table 5: Johansen test for FTSE100-S&P500

<table>
<thead>
<tr>
<th>Test de la trace Hypothèse nulle</th>
<th>statistique de la trace</th>
<th>valeur critique (5%)</th>
<th>valeur critique (1%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R≤1</td>
<td>5.60</td>
<td>12.25</td>
<td>16.26</td>
</tr>
<tr>
<td>R=0</td>
<td>76.84</td>
<td>25.32</td>
<td>30.45</td>
</tr>
</tbody>
</table>

Table 6: Johansen test for CAC40-S&P500

<table>
<thead>
<tr>
<th>Test de la trace Hypothèse nulle</th>
<th>statistique de la trace</th>
<th>valeur critique (5%)</th>
<th>valeur critique (1%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R≤1</td>
<td>6.30</td>
<td>12.25</td>
<td>16.26</td>
</tr>
<tr>
<td>R=0</td>
<td>82.36</td>
<td>25.32</td>
<td>30.45</td>
</tr>
</tbody>
</table>

The existence of cointegration relationship leads us to estimate the coefficient of linear error correction adjustment model for all cointegrating relationships above. The results of this estimation are given in Table 7. Indeed, there are forces to balance the market CAC40, FTSE100 and NIKKEI225 in case of deviation created by the U.S. market materialized here by the S&P500. Adjustment factors that bring the system to its long-term equilibrium state are all negative and significant t-statistic.

Table 7: Adjustment of symmetric error correction model

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>φ</td>
<td>-0.05212</td>
<td>-0.0384267</td>
<td>-0.074946</td>
</tr>
<tr>
<td>t – stat</td>
<td>(-2.538)</td>
<td>(-2.018)</td>
<td>(-3.162)</td>
</tr>
<tr>
<td>R² adj</td>
<td>0.1446</td>
<td>0.0307</td>
<td>0.1002</td>
</tr>
</tbody>
</table>

In summary, it appears that the cointegrated character of our indices is evident, so they are linked by a relationship of long-term equilibrium. This means that a deviation of the market's steady state triggers a process of self-balancing for a return to average. There is interdependence.
3.3. Analysis of financial contagion

The analysis of asymmetry in the error correction model adjustment is performed with the TAR model and then by the M-TAR model. The threshold $\tau$ and the delay of cointegration are determined and then introduced into the model for estimation. The threshold can be set at $\tau = 0$, or can be derived (in this case $\tau \neq 0$). The delay is determined using the criterion of AIC and BIC. We focus in case with $\tau \neq 0$. Using the method of Chan (1993), it provides threshold values $\tau = 0.005$ for the regression of $CAC40 - S & P500^4$, $\tau = 0.001$ for $FTSE100 - S & P500$ and $\tau = -0.010$ for $NIKKEI - S & P500$ when using the M-TAR model as regime change model. As against the use of alternative TAR model gives the following thresholds: $\tau = -0.017$ for $CAC40 - S & P500$, $\tau = 0.013$ for $FTSE100 - S & P500$ and $\tau = 0.021$ for $NIKKEI - S & P500$. Finally, the model results in asymmetric error correction are shown in Table 8 for TAR adjustment and Table 9 for the M-TAR adjustment. Whatever the type of adjustment model (TAR or M-TAR), results show that the adjustment factors are significant. In addition, we find that the standard Fisher tests reject the hypothesis ($\phi_1 = \phi_2$) for the CAC40 and FTSE100 at 5%. These results show that there is asymmetry adjustment between the two indices (CAC40 and FTSE100) and S&P500. However, the results of symmetric test ($\phi_1 = \phi_2$) for S&P500 and NIKKEI225 show that coefficient are not significantly different. Thus, we conclude that there is symmetry adjustment. Finally, the results discussed in the context of asymmetric adjustment are also checked in TAR models and confirmed by the M-TAR model.

---

4. For all regressions on the indices, the S&P500 is taken as the endogenous variable
Table 8: Error correction model with TAR adjustment

<table>
<thead>
<tr>
<th></th>
<th>CAC40</th>
<th>FTSE100</th>
<th>NIKKEI</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\phi_1$</td>
<td>-0.044</td>
<td>-0.24</td>
<td>-0.074</td>
</tr>
<tr>
<td>$t-stat$</td>
<td>(-1.76)</td>
<td>(-3.577)</td>
<td>(-1.73)</td>
</tr>
<tr>
<td>$\phi_2$</td>
<td>-0.024</td>
<td>-0.149</td>
<td>-0.145</td>
</tr>
<tr>
<td>$t-stat$</td>
<td>(-0.901)</td>
<td>(-2.423)</td>
<td>(-3.283)</td>
</tr>
<tr>
<td>$R^2_{adj}$</td>
<td>0.113</td>
<td>0.2996</td>
<td>0.0184</td>
</tr>
<tr>
<td>$treshold : \tau$</td>
<td>0.017</td>
<td>0.013</td>
<td>0.021</td>
</tr>
</tbody>
</table>

$F-tests(\Phi)$

<p>| | | | |</p>
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<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>($\phi_1 = \phi_2 = 0$)</td>
<td>9.079</td>
<td>13.13</td>
<td>6.494</td>
</tr>
</tbody>
</table>

$F-tests(\phi_1 = \phi_2)$

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<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>2.913</td>
<td>7.442</td>
<td>1.282</td>
</tr>
</tbody>
</table>

$Prob$          | 0.000102| 2.274e-15| 0.1994 |

Critical value $H_0 = \phi_1 = \phi_2 = 0$ : 5.58 (10%).
Table 9: Error correction model with M-TAR adjustment

<table>
<thead>
<tr>
<th></th>
<th>CAC40</th>
<th>FTSE100</th>
<th>NIKKEI</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \phi_1 )</td>
<td>0.039</td>
<td>-0.225</td>
<td>-0.079</td>
</tr>
<tr>
<td>( t-stat )</td>
<td>(0.887)</td>
<td>(-3.394)</td>
<td>(-2.282)</td>
</tr>
<tr>
<td>( \phi_2 )</td>
<td>-0.051</td>
<td>-0.158</td>
<td>-0.224</td>
</tr>
<tr>
<td>( t-stat )</td>
<td>(-2.487)</td>
<td>(-2.514)</td>
<td>(-3.42)</td>
</tr>
<tr>
<td>( R^2_{adj} )</td>
<td>0.02807</td>
<td>0.18</td>
<td>0.1002</td>
</tr>
<tr>
<td>treshold : ( \tau )</td>
<td>0.005</td>
<td>0.001</td>
<td>-0.010</td>
</tr>
</tbody>
</table>

\( F - tests(\Phi) \)

\( (\phi_1 = \phi_2 = 0) \)

<p>| | | | |</p>
<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>11.50</td>
<td>12.99</td>
<td>7.083</td>
<td></td>
</tr>
</tbody>
</table>

\( F - tests(\phi_1 = \phi_2) \)

<p>| | | | |</p>
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<th></th>
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</thead>
<tbody>
<tr>
<td>2.996</td>
<td>7.387</td>
<td>1.357</td>
<td></td>
</tr>
</tbody>
</table>

Prob \(6.556\ e-05\) \(3.014\ e-15\) \(0.1538\)

Critical value for \(H_0 = \phi_1 = \phi_2 = 0\) : 5.58 (10%).

Indeed, the indices CAC40, FTSE100, and NIKKEI225 do not react the same way after an asymmetric shock in the S & P500. Shock from the S&P500 during the 2007 to 2008 changes the transmission channels. Consequently, there’s a new transmission channel for the CAC40, FTSE100 during crisis period. This situation is characterized by the presence of two coefficients \( \phi_1 \) and \( \phi_2 \). In contrast, the transmission of shocks from the S&P500 to NIKKEI225 during the same period did not cause the creation of a new channel. In crisis-contingent theory, we conclude that there is a link of contagion in the direction of S&P500 toward FTSE100 and CAC40. As for NIKKEI225, the transmission of shock from the S&P500 is made through the link of interdependence. We can conclude that the results are consistent with the declines in these markets between 01/01/2008 and 24/10/2008. The decline of CAC40 (- 43.11 %) and FTSE100 (-39, 86 %) is the result of contagion. Asymmetric transmission is exhibited by the results. During the summer 2007 crisis in the US, the asymmetric transmission analysis show that a 1% declines in the S&P500 causes a decrease of 19% for the FTSE100, 25% for the CAC40 and 14% for NIKKEI225. In contrast, we notice a transmission rate of 10% for the FTSE100, 16% for the CAC40 and 14% for NIKKEI225 during the period of tranquility. These results show that there is an intensification of the transmission between the CAC40, FTSE100 and the shocks generator S&P500. Consequently, the shocks propagation mode is changed in period of high volatility. This provides evidence for the transmission of shocks by pure contagion between those markets. In comparison, there has been insignificant change in the mode of shocks transmission between NIKKEI225 and the S&P500 in 2007(see table 10).
Table 10: Asymmetric transmission with M-TAR

<table>
<thead>
<tr>
<th></th>
<th>Transmission before crisis</th>
<th>Transmission during the crisis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\alpha$</td>
<td>$\alpha$</td>
</tr>
<tr>
<td>CAC40</td>
<td>-0.16</td>
<td>-0.25</td>
</tr>
<tr>
<td>FTSE100</td>
<td>-0.10</td>
<td>-0.19</td>
</tr>
<tr>
<td>NIKKEI</td>
<td>-0.13</td>
<td>-0.14</td>
</tr>
</tbody>
</table>

4. Conclusion

In this paper, we analyzed the contagion between the CAC40, the FTSE 100, the S&P500 and NIKKEI225 during the crisis of summer 2007, using a new modeling approach. For this, we have used the method of asymmetric cointegration and the dynamic adjustment of long-run equilibrium. We took into account the fact that the residuals from the long-term relationship exhibit a regime change with a sudden break. To capture the regime change in the adjustment of the error term, we introduced threshold autoregressive models: Type Threshold autoregressive (TAR) and Momentum Threshold Autoregressive (M-TAR). Results indicate the transmission of shocks by pure contagion between the FTSE100, the CAC40 and S&P500, which means that transmission is via temporary channels. This is unlike the index NIKKEI225 where we found a transmission of price shocks by the bond of interdependence of the S&P500 to NIKKEI225. Thus, there are permanent channels between S&P500 and NIKKEI225.

Overall, it should be noted that the measure of the risk of contagion and its forecast will be a major asset for the systemic risk management. In other words, the control of this risk will allow central banks to implement policies more effective intervention in cases of market stress. Considering the results obtained in this paper, we can say that it is important to use a policy of introducing financial transaction tax between the French financial market, the UK and the U.S.A financial market. However between the Japanese and U.S. markets, moreover, we can use a policy of taxation on financial transactions in the event of market stress and a hedging policy by international diversification. As an opening, we suggest the diagnosis of dynamic adjustment of short-term by taking into account the hypothesis of regime change of the error term by using smooth transition or a change in regime type Markov switching process.
Références

Gilles Dufrénot and Valérie Mignon. récent developpements in Nonlinear Cointegration with application to macroeconomics and finance


ANNEXES

Graphics 11: Thresholds for the relationship CAC40-S & P500
Graphics12: Thresholds for the relationship FTSE100-S&P500
Graphics 13: Thresholds for the relationship NIKKEI225-S&P500
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