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Financial Contagion Crisis Effect of Subprime on G7: Evidence through the Adjusted Correlation Test and Non-linear Error Correction Models (ECM)

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Abstract The objective of this study is to test the presence of the contagion phenomenon during the US subprime crisis. We adopt the test of adjusted correlation coefficients between markets and propose a new procedure which involves testing the non-linearity of the propagation mechanisms shocks, estimated with a model of long-term interdependence. We apply this methodology to the financial markets which measure the risk perception. Our results prove the existence of some cases of the contagion phenomenon between the financial markets of G7 countries.

Keywords: *sub-primes financial crisis, contagion, correlation, nonlinear error correction models*

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1. Introduction

During the last two decades, localised episodes of financial disorder, rapid dispersion across borders, sometimes without obvious fundamental justification, caught the interest of numerous researchers. With colourful media designations such as the Russian virus or the Asian flu, each crisis propagated similar to a contagious disease, rapidly affecting not only neighbouring but also distant markets. As these events became the object of a rising number of theoretical and empirical analyses, the 'contagion word' (Ahlgren and Antell, 2010)[1] began to frequently emerge in the financial literature.

The economic and financial turmoil engulfing the world marks the first crisis of the current era of globalization (Jean Pisani-Ferry and Indhira Santos, 2009). The financial crisis of 2007–2008, also known as the Global Financial Crisis and 2008 financial crisis, is considered by many economists the worst financial crisis since the Great Depression of the 1930s. It resulted in the threat of total collapse of large financial institutions, the bailout of banks by national governments, and downturns in stock markets around the world. In many areas, the housing market also suffered, resulting in evictions, foreclosures and prolonged unemployment. The crisis played a significant role in the failure of key businesses, declines in consumer wealth estimated in trillions of U.S. dollars, and a downturn in economic activity leading to the 2008–2012 global recession.

The issue of contagion in financial markets is of crucial importance and there is a wide literature dealing with its causes and effects. Numerous recent papers focusing on contagion comprise Forbes and Rigobon (2002), Kodres and Pritsker (2002), Kaminsky et al. (2003), Allen and Gale (2004), Brunnermeier and Pedersen (2005, 2009), and many others. From a research outlook, the recent crisis in the sub-prime asset backed market provides a near-ideal 'laboratory' for studying the role that contagion may play in financial markets when an asset class becomes severely upset.

The main objective of this study is to present in a first step, the overview of empirical literature that aims to test the existence of the contagion phenomenon. In a second step, we will attempt to distinguish between the cases of interdependences (or fundamental contagion)[2] and 'shift contagion'[3] during the US sub-prime crisis. In this regard, the question that arises is the following: Is the transmission of this crisis between the stock markets of

1 Ahlgren and Antell (2010) defined contagion as "a significant immediate of shocks between financial markets in times of crisis".

2 Interdependence defined as the transmission of shock through the real and financial or political channels or after a common shock from the reaction of a rapid decline in global aggregate demand or a significant change in prices of raw materials or remarkable change in exchange rates between major currencies. It also means that the transmission mechanisms after a shock are not significantly different from those before the crisis (Forbes and Rigobon, 2000).

3 According to Forbes and Rigobon (2000, 2002) and Edwards (2000), 'Shift contagion' means that the propagation shocks from one country to another is done by the crucial role played by the investor's behaviours and expectations, i.e., the occurrence of a crisis in one country pushes investors or banks to revise their expectations about other countries and reduce their financial positions across the board even if the actors have no positions in the country 0. It also means there is a change of the transmission mechanisms of shock during or just after the crisis, and the shock propagates through a channel that did not exist during the stability period (Forbes and Rigobon, 2000).

G7 countrie an act of ‘shift contagion’ or only interdependence between these markets?

The remainder of paper is organised as follows: Section 2 is devoted to the literature review. Section 3 clarifies the methodology; Section 4 presents data bases and the results of the adjusted correlation test and the nonlinear ECM.

2. Contagion Measurement: A Review

It should be noted that a vast theoretical and empirical literature has been devoted to studying the contagion phenomenon. It is not only to examine the channels of transmission, but also to seek a measure of contagion and to analyse its evolution over time. The theoretical literature has been, therefore, interested in the manner in which shocks are transmitted from one country to another, while the empirical literature has tested the existence or not the contagion phenomenon. There are different methods and approaches that can be used to detect the existence of a contagion effect caused by financial crises. So, we can divide the principal empirical work that investigated the international transmission of shocks into two types:

2.1. Correlation: A Measure of Contagion

The links between the stock index returns are measured by their correlation coefficients. The basic assumption is to test whether the correlation coefficients increase significantly after a shock. The contagion is presented if correlation increases significantly during the crisis period since this increase suggests strengthening of links or transmission mechanisms between the two markets. But, if this increase was not statistically significant, it is only a phenomenon of interdependence and not of contagion. King and Wadhwani (1990) studied the relationship between the USA, UK and Japan during the period of financial market crash in 1987 and they found that the correlation between international equity had increased significantly after the crash of 1987. In the same context, Calvo and Reinhart (1996) found an increase in the correlation coefficient between international asset markets after the Mexican crisis. These authors propose a procedure to adjust the correlation coefficients, and testing the presence of contagion during the crisis of October 1987, the Mexican crisis and the Asian crisis, they concluded “No contagion only interdependence”. Similarly, applying the same correlation approach, Forbes and Rigobon (2000) tested the increased significance of the adjusted correlation coefficients for heteroscedasticity bias. They concluded that the spread of the Asian crisis was only due to the interdependence between financial markets and not from the ‘shift contagion’. By contrast, Baig and Goldfajen (1999) tested the significant increase in correlation coefficients between the stock markets, rate of interest, sovereign debt and foreign exchange markets of Malaysia, Thailand, Indonesia, Korea and Philippines. They found the presence of ‘shift contagion’ on stock markets and exchange markets, as they found that Thailand has not played an important role in the process of contagion during the Asian crisis despite the fact that it had been the primary source of the crisis.

2.2. Co-integration THEORY

The co-integration theory allows the study of non-stationary series, whose combination is linear and stationary. It allows specifying a stable relationship in the long term by jointly analysing the dynamics of short-term variables. Changes in long-term relationships between two stock markets are measured as if they were the increase of the co-integration coefficient. In this context, Longin and Solnik (1995) studied 7 OECD countries from 1960 to 1990 and have found that the average correlation of stock market statistics between the USA and other countries increased from 0.36 over the 30 years. As a result, most of the observed events of contagion from the Mexican crisis are events of short-term (3 months) and co-integration techniques are unable to detect such dynamics. Similarly, Masih and Masih (1999) applied the co-integration techniques toseries of daily stock market indices of four OECD countries and four Asian countries. Their results also confirmed the contagion hypothesis.

From the preceding discussion, we will verify the following hypothesis during the US sub-prime crisis:

Hypothesis: The propagation of this crisis between the financial markets of USA and the BRIC countries is an act of ‘shift contagion’ and not of interdependence between markets.

3. Empirical Analysis

3.1. Methodology and Objectives of Study

According to Forbes and Rigobon (2000): “the contagion as a significant increase in market co-movement after a shock to one country (or group of countries)”. If the increased co-movement is not significant, this reflects the continuous strong links between the economies that existed in all states of the world. In this case, the co-movements between two markets are measured by their correlation coefficient.

Therefore, our objective will be to distinguish empirically the case of ‘shift contagion’ and the case of interdependencies continuity in the context of US sub-prime crisis. To do this, we proceed through two tests. The first is to test the increase of correlation coefficients between the stability and crisis periods. Secondly, we propose a new econometric approach to test the stability propagation mechanisms. We test the non-linearity of the structural shocks like Favero and Giavazzi (2002). However, we believe these shocks move through a long-term co-integration relationship between financial markets. Compared with previous work related to the debate interdependence/contagion, this new approach focuses on the use of long-term interdependence in the identification of contagion. It also allows us to solve the problems of crisis periods defined by using the total period in our estimates. The examined markets are as follows: USA, UK, France, Germany, Japan, Italy and Canada

3.2. Data and Estimation Techniques

3.2.1. Data

The data used are daily returns of stock indices[1] of seven countries, namely USA, UK, France, Germany, Japan, Italy and Canada. The study period is divided into two sub-periods[2], the so-called stability period, which runs from April 10, 2006 to July 31, 2007, and a period of turmoil and crisis that starts with the date of onset of the sub-prime crisis in the US housing market, i.e., from August 1, 2007, until December 30, 2008.

3.2.2. Estimation Techniques

3.2.2.1. Adjusted Correlation Test

In this case, the co-movements between two markets are measured by their correlation coefficients. Several works, such as Corsetti et al. (2002), Loretan and English (2000), Forbes and Rigobon (2002), showed that the increase of correlation coefficient between two financial series may be biased by the effect of changes in the variability of the market originated shock which causes a heteroscedasticity problem. An adjustment is, therefore, necessary, in order to correct this bias. Accordingly, we will use the adjustment of Forbes and Rigobon (2002). Xt and Yt are two financial series identifying the returns of assets in two different markets. Therefore, in order to examine the relationship between yields in different markets, we will use the following simple linear model:

$$y_t = \alpha + \beta x_t + \varepsilon_t \qquad (1)$$

Where $E(\varepsilon t) = 0$, $E(\varepsilon t^2) < \infty$, $E(xt\varepsilon t) = 0$, Forbes and Rigobon (2002) suggest to measure the correlation coefficient by:

$$\rho_{(x_t y_t)} = \frac{\operatorname{cov}(x_t, y_t)}{\sigma_{x_t}\sigma_{y_t}}$$

The adjusted coefficient is then ρ^*, as:

$$\rho^* = \frac{\rho}{\sqrt{1+\delta[1-(\rho)^2]}};$$

Where

$$\delta = \frac{V^c(x_t)}{V^t(x_t)} - 1$$

'*c*' and '*t*' indicate, respectively, the periods of crisis and tranquillity. Indeed, '*δ*' is the relative increase of the variance of *x* between the two periods (crisis and stability). Having calculated the adjusted correlation coefficient for each pair of countries in the sample, we test statistically its increase during the crisis period to see whether or not it is the 'shift contagion'. 5 Thus, to test statistically the increase of adjusted correlation coefficient, we use the following alternative hypotheses:

$$\begin{cases} H_0 : \rho_1^* = \rho_2^* \\ H_1 : \rho_1^* > \rho_2^* \end{cases}$$

Where ρ_1^* is the adjusted correlation coefficient during the crisis period, and ρ_2^* is the adjusted correlation coefficient during the stable period.

So, to test these hypotheses, we use a Student test used by Collins and Biekpe (2002) where the statistic is:

$$t = (\rho_1^* - \rho_2^*)\sqrt{\frac{n_1 + n_2 - 4}{1-(\rho_1^* - \rho_2^*)^2}}$$

Where 't' follows a Student to (n1 + n2 – 4) degrees of freedom.

Therefore, *if we accept H1, i.e., the correlation coefficient between the two markets has significantly increased between the stability period and the crisis period, it is the evidence of 'shift contagion'. On the contrary, if we retain the null hypothesis H0, it is evidence of interdependence between the two markets.*

3.2.2.2. Co-integration, Linear ECM and Modelling Contagion via the Nonlinear ECM

(i) Linear ECM

The co-integration test explores that if the linear combination zt of two non-stationary series xt and yt [t = time (Daily data of indices)] is stationary, the two series are said co integrated (Engel and Granger, 1987).

The equation:

$$y_t = \alpha + \beta x_t + \varepsilon_t \qquad (1)$$

Represents the relationship of long-term equilibrium between yt and xt. Thus, there is an ECM representation which helps to reconcile the temporal horizons for short and long term, represented as follows:

$$\Delta y_t = \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + \sum_{i=1}^{q} \lambda_i \Delta x_{t-i} + \delta z_{t-1} + \varepsilon_t \qquad (2)$$

Where Xt and Yt are the series of two markets, zt–1 is the error of long-term equilibrium relationship, δ is the adjustment speed towards the long-term equilibrium. ε t is the error term.

(ii) Non-linear ECM: new test of contagion

The non-linearity in the ECM has its origins in the work of Granger and Lee (1989), this representation was subsequently developed by Escribano and Pfann (1998). These models consider that the linear ECM is based on restrictive conditions as follows:

- The long-term equilibrium is unique.
- The adjustment compared to the equilibrium is symmetric.

However, the hypothesis of uniqueness of the equilibrium does not check the economic reality that considers the existence of asymmetric situations such as stability and crisis, resulting in an equilibrium multiplicity. This is modelled by the non-linear ECM (asymmetric) causing the asymmetry term in the error correction zt which will be divided into two parts: positive and negative. It allows the creation of two situations each characterised by an adjustment specific speed.

<u>The model developed by Escribano and Pfann (1998).</u>

Escribano and Pfann (1998) divided the error correction term, in the ECM model, into two parts positive and negative such as:

$$z_{t-1}^{+} = \begin{cases} z_{t-1} & if \quad \Delta z_{t-1>0} \\ 0 & \quad No \end{cases}$$

$$z_{t-1}^{-} = \begin{cases} z_{t-1} & if \quad \Delta z_{t-1<0} \\ 0 & \quad No \end{cases}$$

Therefore, the ECM representation developed by Escribano and Pfann (1998) will be:

$$\Delta y_t = \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + \sum_{i=1}^{q} \lambda_i \Delta x_{t-i} + \delta_1 z_{t-1}^{+} + \delta_2 z_{t-1}^{-} + \varepsilon_t \qquad (3)$$

Where Xt and Yt represent the series of two markets, t 1 z+ − and t 1 z− − are two equilibrium situations, each one characterised by an specific adjustment speed δ1 and δ2, and εt constitutes the error term.

The estimate of non-linear ECM provides, in fact, additional information about the asymmetry between the adjustment towards tranquillity equilibrium and the adjustment towards crisis equilibrium in the case of a co integration long term. According to Escribano and Pfann (1998), if δ1 is statistically different from δ2, we accept the hypothesis of the existence of a significant asymmetry in the ECM model. If not, we retain the original model (2), i.e., the specification of the linear adjustment mechanism. Thus, we diagnose a logic of contagion when we identify a non-linearity in the adjustment toward equilibrium during the crisis period compared to the stability period. The non-linearity is due, in this case, to the increase in the response of a market to shocks from other markets, which defines the contagion.

Contagion proof

We recall that our work is based on the definition of contagion by Forbes and Rigobon (2000): "The contagion is a significant increase in the links between the markets after the completion a shock to a country or group of countries". In this work, we represent these links by the co-movements between stock markets. Xt and Yt are, respectively, the daily stock indices series of the country source of crisis and the affected country. The test of contagion is to examine the behaviour of co-movements between these two sets of stock market indices before and after the crisis. Formally, in this case, these co-movements are modelled by the relationship of long-term equilibrium, represented by the equation yt = a + bxt + ztyt when xt and yt are co-integrated.

They describe, in the existence case of co-integration relationship, the distribution of the term of error correction 'zt–1' of two elements t 1 z+ − and 1, t z− − which leads to two situations:

1st Situation: $\Delta z_{t-1} > 0 \Longrightarrow \dfrac{\Delta x_{t-1}}{\Delta y_{t-1}} < \dfrac{1}{b}$

2end Situation: $\Delta z_{t-1} < 0 \Longrightarrow \dfrac{\Delta x_{t-1}}{\Delta y_{t-1}} > \dfrac{1}{b}$

Where 'b' is the ratio between the variations in market returns to equilibrium. We propose that the second situation is, in fact, the increase in co-movements between changes in stock indices (the links between stock markets) of two countries, which proves the existence of contagion as defined by Forbes and Rigobon (2000). Indeed, this increase is captured by the coefficient δ2. Therefore, for accepting the existence of contagion transmitted from xt to yt, δ1 and δ2 (model (3)) must be significantly different.

A sufficient condition will be statistical significance of coefficient δ2. In fact, this condition permits to grasp the importance of the second situation and to confirm our proposition.

4. Results

4.1. Descriptive Statistics

We note as well as the coefficient of Kurtosis is very high (Kurtosis > 3), it confirms of a great probability the occurrence of the extreme values. In the same way, the coefficient of Skewness is negative (except for the United States, France, Germany, Italy) and different from zero for all the indices, this coefficient corroborates the asymmetry of the outputs. This asymmetry results in the fact that volatility is lower after a rise than after a fall of profitability since a negative shock has more effect than a positive shock.

In short, these statistics shows the existence of a leptokurtic form of the empirical distributions and that all these characteristics are specific to the financial variables at high frequencies.

Table 1. Descriptive statistics

Country	Indices	Average	Maximum	Min	Standard deviation	Skewness	Kurtosis
United States	Dow-Jones IA	-0.036302	10.50835	-8.200513	1.575675	0.062125	13.01538
France	CAC 40	-0.070072	10.59459	-9.471537	1.74415	0.181886	11.57035
Germany	Dax 30	-0.030749	10.79747	-7.433464	1.642407	0.344651	13.21147
Canada	S&P TSX	-0.03868	9.370274	-9.787954	1.652971	-0.66781	11.4947
Italy	MIB 30	-0.098658	10.87425	-8.599092	1.609062	0.272448	13.00782
Japan	Nikkei 225	-0.086709	13.23458	-12.11103	1.983608	-0.45152	11.78266

4.2. Results of Adjusted Correlation Test

The estimation of adjusted correlation coefficients during the stability and crisis periods, and the results of student tests are presented, respectively, in Table 2–Table 4.

The use of the adjusted correlation test permits to determine the country source of contagion. These countries are represented at the top of the tables. This helps us to comment on the results with further details about the meaning of contagion.

From Table 2–Table 4, we see a significant increase of the correlation coefficient between stock markets of G7 countries. Moreover, the majority of t-student of adjusted correlation coefficients is significant at 5% and 10%. We interpret this increase as evidence of 'shift contagion', i.e., the contamination of crisis occurs through the role played by fundamentals coupled with the existence of a contagion process related to the changes impact in the investor's behavior (speculators) and the others financial agents (institutional investors).

We can conclude according to these results the presence of phenomenon of contagion between the emergent stock exchange markets because of the significant increase in the these coefficients between the quiet period and the period of crisis.

As we discussed before, the use of the coefficients of correlation adjusted makes it possible to fix the country likely to be the source of contagion. These countries are represented in top of these three tables. This thus helps us to comment on the results with more precise details on the direction of the contagion.

Table 2. Matrix of adjusted correlation coefficients during the stability period (April 10, 2005–July 31, 2007)

	U SA	Canada	France	Germany	UK	Italy	Japan
USA	1	0.1386	0.0568	0.036	0.0498	0.0055	0.0086
Canada	0.1682	1	0.0579	0.0246	0.0382	0.0418	0.0701
France	0.0753	0.0629	1	0.0557	0.0963	0.0915	-0.0085
Germany	0.0546	0.0306	0.0637	1	0.231	0.0932	-0.0198
UK	0.0619	0.039	0.0904	0.1913	1	0.0693	-0.0182
Italy	0.0069	0.043	0.0866	0.0772	0.0699	1	-0.0012
Japan	0.0114	0.0756	-0.0084	-0.0172	-0.0193	-0.0013	1

Table 3. Matrix of adjusted correlation coefficients during the crisis period (August 1, 2007–December 30, 2008)

	U SA	Canada	France	Germany	UK	Italy	Japan
USA	1	-0.0596	0.1361	0.1764	0.131	-0.0677	-0.0281
Canada	-0.0726	1	0.0353	-0.0015	0.0179	0.0795	0.0426
France	0.1792	0.0384	1	0.5675	0.3642	-0.0635	-0.0344
Germany	0.2622	-0.0019	0.6191	1	0.4054	-0.0757	-0.0476
UK	0.1623	0.0182	0.3446	0.3421	1	-0.0804	-0.0054
Italy	-0.0848	0.0817	-0.0601	-0.0627	-0.081	1	0.0694
Japan	-0.037	0.0459	-0.0342	-0.0413	-0.0057	0.0729	1

Table 4. Student test results

	U SA	Canada	France	Germany	UK	Italy	Japan
USA	0	-5.298	**2.0831**	**3.7146**	**2.1343**	-1.925	-0.966
Canada	-6.5001	0	-0.5922	-0.6882	-0.5335	0.9881	0
France	**2.7369**	-0.644	0	**15.6028**	**7.2834**	-4.113	-0.6804
Germany	**5.5599**	-0.856	**17.49**	0	**4.6402**	-4.489	-0.7275
UK	**2.6416**	-0.545	**6.8837**	**3.9962**	0	-3.968	0.335
Italy	-2.4147	1.016	-3.8872	-3.7007	-3.9991	0	1.8582
Japan	-1.272	-0.778	-0.6757	-0.632	0.3544	1.9509	0

Note: The values in fat represent the acceptance of the assumption H_1: the coefficient is significantly increased between the period of peace and the period of crisis.

First of all, according to Table 2 and Table 3 we show the significant increase in the coefficients of correlation adjusted between the stock exchange markets: American, French, German, British, Italian, Canadian and Japanese. We interpret this increase as being a proof of contagion.

In Table 4, we fixed the likely countries of beings a source of contagion for the developed and emergent countries. First of all, we detected the source of pure contagion of the United States towards three stock exchange markets of three large countries developed with knowing France, Germany and the United Kingdom. Thus, all the coefficients of correlation adjusted of the United States as country originating in the crisis with these three countries are significant. From the United States and France, the values of T of student relating to the increase in the correlations between these two markets, are about 2.0831 and 2.7369. These values are statistically significant with the threshold of 5%. From the United States and Germany, the values of T of student concerning the increase in the correlations between these two markets, are about 3.7146 and 5.5599. These values are also statistically significant with the threshold of 5%. From the United States and the United Kingdom, the values of T of student relating to the increase in the correlations between these two markets, are about 2.1343 and 2.6416. These values are also statistically significant with the threshold of 5%. France and of Germany, the values of T of student concerning the increase in the correlations between these two markets, are about 15.6028 and 17.4901. These values are also statistically significant with the threshold of 5%. France and the United Kingdom, the values of T of student relating to the increase in the correlations between these two markets, are about 7.2834 and 6.8837. These values are also statistically significant with the threshold of 5%.

From Germany and the United Kingdom, the values of T of student relating to the increase in the correlations between these two markets, are about 2.0831 and 2.7369. These values are also statistically significant with the threshold of 5%. From Italy and Japan, the values of T of student relating to the increase in the correlations between these two markets, are about 1.8582 and 1.9509. These values are statistically significant with the threshold of 10%.

4.3. Non-linear ECM Results

Before asking the existence question of such a co-integration relationship, it is necessary to test the stationary (absence of a unit root) of the series studied by using the Augmented Dickey-Fuller (ADF), Phillips-Perron (PP) and KPSS (Table 5).

From the ADF, PP and KPSS stationary test on the stock indices series of different countries in the sample, we find that all series are integrated in order 1 (I(1)) at the level of 5%. This result reveals the possibility of co-integration relations between the various stock market indices used. Nevertheless, the existence of a co-integration relationship can be interpreted as the presence of permanent propagation channels of shocks between countries in the sample. In this case, we estimate the non-linear ECM (asymmetric), using the approach of Escribano and Pfann (1998). Table 6 provides the results of the bivariate co-integration tests between the studied performances of linear indices. The results of the adjustment coefficients estimates of the two components of the asymmetric error term, namely zt+1 and 1, zt−1 the results of Wald tests of these two coefficients as well as our conclusions on the existence of 'shift contagion' are also presented in Table 6.

Table 5. unit root tests

countries	level			Firstdifference		
	ADF	PP	KPSS	ADF	PP	KPSS
USA	-1.101605	-1.097763	2.819645	-17.72313	-30.96656	0.233339
Canada	-1.927291	-1.832105	0.653323	-17.91527	-17.64085	0.449296
France	-1.125912	-0.982834	2.580850	-25.66668	-25.57387	0.427632
Germany	-0.893116	-0.721063	0.622116	-19.15504	-19.04443	0.137298
UK	-1.716457	-1.782860	0.533522	-15.97166	-30.91355	0.108417
Italy	-1.601132	-1.629271	1.672839	-21.01958	-21.00451	0.192846
Japan	-1.691240	-1.868000	2.514439	-25.56281	-33.87643	0.253121

Note: The critical values are equal to (–2.87) for the ADF test and PP and (o.463) for the KPSS at 5% level

The results indicate that all residues (zt) are stationary since ADF statistics are below the critical value. This confirms the existence of a co-integration relationship between the linear series of stock indices using the approach of Engel and Granger (1987). The existence of co-integration relations between the series shares stochastic trends in the long term. However, the estimation of the non-linear ECM according to the approach of Escribano and Pfann (1998) gave values whose majority are negative and significant, indicating the existence of diagrams of correction towards equilibrium. Some exceptions exist ($\delta i > 0$, for $i = 1, 2$) which are not consistent with the econometric intuition because a coefficient of adjustment towards equilibrium must be negative.

Regarding the test of Fisher, we note in this table only the existence of 31 cases of asymmetries among 41 ECM co-integration relations. This non-linearity is contained primarily in the relationship between USA, France, Germany, UK and Italy.

We conclude, firstly, that the contamination of American, French, German, English, Italian and Canadian markets to the Japanese market is not the subject of a 'shift contagion', but rather a simple interdependence between these markets. Secondly, the crisis transmission between the financial markets of USA, France, Germany, UK, Italy and Canada is an act of 'shift contagion'. It should be underlined here, that this result is consistent both with the role played by the fundamentals and with the existence of a contagion process related to the impact of changes on investors' beliefs. This result confirms our previous results from the adjusted correlation approach.

5. Summary and Conclusion

The US sub-prime crisis provides an ideal occasion for studying the contagion effect in financial markets. In this study, we propose a new procedure to test the non-linearity in the propagation of financial shocks in order to measure the existence of contagion in the stock markets of USA, France, Germany, Japan and UK due to the sub-prime crisis in the USA. Unlike previous work, we tested the non-linearity of structural shocks in the ECM model in order to identify the contagion exist.

Our results from the application of adjusted correlation test on stock market and the estimated non-linear ECM (asymmetric) indicate that the unfolding of sub-prime crisis leads us to assume that the crisis in August 2007 would have serious repercussions on stock markets of the USA, France, Germany, Canada, UK and Italy in the months that followed.

However, these impacts are described as 'shift contagion'. In this case, the contamination of crisis occurs through the role played by fundamentals coupled by the existence of a contagion process related to the impact of changes on the investor's behavior (speculators) and other financial agents (institutional investors). Alternatively, the occurrence of a crisis in one country may affect or change the investors' expectations in another country, destabilise the equilibrium of its economy and even trigger a crisis, i.e., the occurrence of a crisis in one country pushes investors or banks to revise their expectations about other countries and reduce their financial positions across the board even if the actors have no positions in the country 0. Contrary to the case of Japan, these impacts were not of 'shift contagion'. Indeed, they were transmitted through financial channels of the permanent links that existed both in the stability and crisis period.

However, it should be noted that the contagion analysis basis of correlation coefficient is very sensitive to the choice of the stability and crisis period. Usually, the first period is marked by a high number of observations in contrast to the second where the shock can last a few weeks.

It could be more interesting in future research to study this phenomenon on various markets (stock market, market sovereign debt, foreign exchange market, money market…) by focusing on the causality inter-markets relationships, for exploring the importance of interactions between markets.

Table 6. Estimation results of non-linear ECM

	ADF	critical value (5%)	Co-integration	δ1 (t-student)	δ2 (t-student)	Wald test H0: δ1=δ2 (probability)	Contagion
USA=> CAN	-10.30225	-1.9400	**yes**	0.079010 (2.260545)	-0.031260 (-0.850756)	4.028034 (0.045214)	no
USA => FR	-10.83019	-1.9400	**yes**	0.169684 (5.285548)	0.142973 **(3.81706)**	5.636684 **(0.017913)**	**yes**
USA => GER	-10.74127	-1.9400	**yes**	0.183873 (5.873904)	-0.138652 **(-4.013082)**	19.17859 **(0.000014)**	**yes**
USA => UK	-11.24289	-1.9400	**yes**	0.129163 (3.398303)	-0.086565 **(-1.952583)**	11.59747 **(0.000706)**	**yes**
USA => IT	-9.842044	-1.9400	**yes**	0.069815 (1.787175)	-0.000285 (-0.006343)	1.167326 (0.280400)	no
USA => JAP	-10.86064	-1.9400	**yes**	0.032207 (0.599060)	-0.023839 (-0.352860)	0.056424 (0.812324)	no
FR=> USA	-10.83019	-1.9400	**yes**	0.066839 (1.625841)	-0.096898 **(-2.020460)**	5.739622 **(0.016902)**	**yes**
FR => CAN	-11.24576	-1.9400	**yes**	0.109559 (1.842298)	-0.099763 (-1.516296)	0.870219 (0.301099)	no
FR => GER	-10.85085	-1.9400	**yes**	0.139194 (4.348968)	-0.045045 (-1.227366)	12.58423 (0.000420)	no
FR => UK	-10.85085	-1.9400	**yes**	0.121595 (3.048498)	-0.162715 **(-3.387410)**	17.91448 **(0.000027)**	**yes**
FR => IT	-8.442402	-1.9400	**yes**	0.093033 (2.331623)	0.002371 (0.052856)	1.940405 (0.164158)	no
FR => JAP	-10.98248	-1.9400	**yes**	0.085759 (1.518114)	-0.077019 (-1.309441)	0.231119 (0.564487)	no
CAN=> USA	-10.30225	-1.9400	**yes**	0.105005 (2.168727)	-0.161047 **(-3.163967)**	12.21907 **(0.000509)**	**yes**
CAN => FR	-11.24576	-1.9400	**yes**	0.017708 (1.462834)	-0.003952 (-0.295111	1.206888 (0.272405)	no
CAN => GER	-10.20755	-1.9400	**yes**	0.108801 (4.508047)	-0.066503 **(-2.521696)**	20.54283 **(0.000007)**	**yes**
CAN => UK	-9.776935	-1.9400	**yes**	0.131764 (2.857333)	-0.048126 (-0.923805)	5.810173 (0.016244)	no
CAN => IT	-10.79499	-1.9400	**yes**	0.119678 (3.162581)	0.114161 (2.610034)	0.007838 (0.929485)	no
CAN => JAP	-10.08001	-1.9400	**yes**	0.073539 (1.603287)	-0.089806 **(-1.782792)**	4.916940 **(0.026981)**	**yes**
GER=> USA	-10.74127	-1.9400	**yes**	0.110454 (2.517105)	-0.111789 **(-2.308174)**	9.735047 **(0.001898)**	**yes**
GER => UK	-10.73667	-1.9400	**yes**	0.119341 (2.936040)	-0.106130 **(-2.389546)**	12.08297 **(0.000547)**	**yes**
GER=> IT	-8.883706	-1.9400	**yes**	0.062670 (1.430775)	-0.023003 (-0.476575)	1.442870 (0.230166)	no
GER => JAP	-10.89670	-1.9400	**yes**	0.109918 (1.960892)	-0.019027 (-0.336587)	2.284682 (0.131202)	no
UK=> USA	-11.24289	-1.9400	**yes**	0.144938 (3.888292)	0.015674 (0.360493)	4.329264 (0.037901)	no
UK => CAN	-9.776936	-1.9400	**yes**	0.121903 (3.214737)	-0.070422 (-1.643921)	4.221630 (0.211812)	no
UK=> FR	-10.66736	-1.9400	**yes**	0.325692 (10.02895)	0.218904 **(5.597261)**	3.812604 **(0.051349)**	**yes**
UK => GER	-10.73667	-1.9400	**yes**	0.223206 (7.178253)	0.114397 **(3.366947)**	4.808415 **(0.028718)**	**yes**
UK => IT	-9.286764	-1.9400	**yes**	-0.018224 (-0.477274)	0.050257 (1.123634)	1.145220 (0.284997)	no
UK => JAP	-10.84781	-1.9400	**yes**	0.010589 (0.192420)	-0.011785 (-0.193563)	0.065114 (0.798679)	no
IT=> USA	-9.842044	-1.9400	**yes**	0.116694 (2.357075)	-0.073413 (-1.291391)	5.345316 (0.021127)	no
IT => CAN	-10.79499	-1.9400	**yes**	0.025361 (0.590042)	-0.072821 (-1.465819)	1.924472 (0.165897)	no
IT => FR	-8.442402	-1.9400	**yes**	0.049683 (1.179163)	-0.138862 **(-2.931130)**	7.526011 **(0.006269)**	**yes**
IT => GER	-8.883707	-1.9400	**yes**	0.039880 (0.944358)	-0.056396 (-1.211908)	1.960273 (0.162019)	no
IT => UK	-9.286764	-1.9400	**yes**	0.147200 (3.272786)	-0.041546 (-0.784437)	6.194436 (0.013095)	no
IT => JAP	-9.454469	-1.9400	**yes**	0.031895 (0.568401)	-0.071310 (-1.172690)	1.330452 (0.249200)	no
JAP=> USA	-10.86064	-1.9400	**yes**	-0.002992 (-0.103361)	-0.036661 (-1.133851)	0.515991 (0.472846)	no
JAP=> CAN	-10.08001	-1.9400	**yes**	0.024120 (0.728795)	0.127482 **(3.507351)**	3.781609 **(0.052302)**	**yes**
JAP=> FR	-10.98248	-1.9400	**yes**	0.075617 (2.774134)	0.008109 (0.285731)	2.534670 (0.111915)	no
JAP=> GER	10.89670	-1.9400	**yes**	0.110384 (3.840630)	-0.013893 (-0.478856)	8.072308 (0.004653)	no
JAP=> UK	-10.84781	-1.9400	**yes**	0.006871 (0.336544)	-0.007288 (-0.323414)	0.189646 (0.663374)	no
JAP => IT	-9.454469	-1.9400	**yes**	0.067809 (2.461174)	0.015785 (0.528684)	1.402352 (0.236815)	no

Note: 1 Yes*: Cases of 'Shift contagion' (statistical significance of $\delta 2$ and probability of having $\delta 1 \neq \delta 2$ is significant at 5% (10%)).*No*: Cases of interdependence 2* Representation A => B means that B is the variable affected by the contagion.

Notes

1. These two periods were also used by Paulo Horta, Carlos Mendes and Isabel Vieira (2008). "Contagion effects of the US Subprime Crisis one Developed Countries", Cefage-ue Working Papers 2008_08, University of Evora, Cefage-ue (Portugal).
2. The data come from the financial site Yahoo/finance: www.yahoo.fr we in addition, checked these data by comparing them with the data provided by other authors, starting from www.econstats.com.

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