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STOCK EXCHANGES INDUSTRY CONSOLIDATION AND SHOCK TRANSMISSION

Julien IDIER

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Stock exchanges industry consolidation and shock transmission[1]

IDIER Julien[2]
Banque de France & Centre d'économie de la Sorbonne, Université Paris 1

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[2] Corresponding author: julien.idier@banque-france.fr_address: 41-1391 DGEI-DIR-RECFIN-31 rue croix des petits champs-75049 Paris cedex 01_tel: +331 42 92 37 19

Abstract

Stock exchange industry consolidation is at work since many years and has recently accelerated through competition for order flows, agreements and mergers. However, consolidation may not mean that all shocks are transmitted to every place. Therefore, following Forbes and Rigobon (2002) we distinguish convergence (as interdependence) from contagion. Long run interdependence is analyzed through overlapping rolling cointegration and shocks on correlations through multivariate GARCH models. The models are estimated on daily data from January 1 1994 and April 30 2006. We consider the DAX30, the CAC40, the FTSE100 and the NYSE indexes. We identify stock exchanges convergence between European places. However we mainly witness a leading role of the US market even after the euro area creation. Finally, dynamic correlations still exert local shocks while others are effectively transmitted.

Key Words: Equity market integration, Cointegration, Multivariate GARCH models.

Résumé

La consolidation de l'industrie des sociétés de bourse est en marche depuis de nombreuses années et a récemment accéléré via la concurrence pour les flux d'ordres, des accords et fusions. Cependant, la consolidation ne signifie pas que tous les chocs sont transmis à toutes les places. Ainsi, dans le prolongement de Forbes et Rigobon (2002), nous distinguons la convergence (ou interdépendance) de la contagion. L'interdépendance de long terme est analysée par de la cointégration mobile et les chocs de corrélations grâce à une modèle GARCH multivarié. Les modèles sont estimés sur des données journalières entre le 01/01/94 et le 30/06/2006. On considère le DAX30, le CAC40, le FTSE100 et le NYSE. On détecte ainsi la convergence des marchés. Néanmoins, nous observons le rôle leader du marché américain et ce aussi après la création de la zone euro. Enfin, les corrélations dynamiques montrent que nous avons certains chocs locaux alors que d'autres sont effectivement transmis.

Key Words: Intégration des marchés boursiers, Cointégration, Modèles GARCH multivariés.

Subject Classification: C32 F36 G15

Non technical summary

The paper studies long and short run dependencies between asset markets from 1994 to 2006 at a daily frequency. We consider four stock exchanges, Euronext, New-York Stock Exchange (NYSE), London Stock Exchange (LSE) and Deutsche Börse and their corresponding leading indexes (CAC, NYSE, FTSE, DAX). Since the merger of several European stock exchanges giving birth to Euronext, a wave of consolidation is witnessed in the particular industry of stock exchanges. Demutualization imposes stock exchanges to respond to competitive incentives like trading cost, information disclosure or product diversification. This process was first observed in the United States during the XXth century with the survival of only five US regional exchanges. This was mainly driven by new information technologies and the ability of dealing by the phone. Nowadays, the point is that consolidation is not only national but also cross-border. Moreover, it is not only between European countries (sharing the same currency) but also between American and European places.

In this context the paper addresses two main issues. First, shocks on equity prices impact capital allocation between countries. In a monetary union framework, competition between stock exchanges may create asymmetries and weaken countries where stock exchanges are inefficient. Second, the euro creation could create a new European strength among European stock exchanges and may facilitate agreements between European places due to currency risk annihilation. This may weaken the traditional leading role of the US market.

From the methodological point of view, the paper considers rolling cointegration technics and multivariate General AutoRegressive Heteroskedastic (GARCH) models to take into account interdependence and contagion. From a standard theoretical microstructure model (Hasbrouck (1995)) we generalized price processes to a Vector Error Correction Mechanism (VECM) that we complete with an asymmetric BEKK-GARCH model on residuals (from Baba- Engle- Kraft- Kroner in Engle and Kroner (1995)). This approach is convenient to analyze dynamic correlations obtained from the estimated conditional variance-covariance matrices.

Empirical results show that the US market is globally the leading place on the sample 1/1/94-4/30/06. Nevertheless, we observe a period between 2000 and 2002 during which this leading role was weakened. The LSE index is always follower on the sample while CAC and DAX indexes, notably between 2000 and 2002 exert some kind of resistance. Moreover, we effectively observe local shocks on European followers places while shock affecting US market are mainly transmitted. Finally, from the estimation of the VECM-GARCH we observe that correlations between European places move towards unity while correlations between US and European places does not really exert trends. This may sustain transatlantic merger or agreement between stock exchanges from a product diversification point of view.

Résumé non technique

Le papier étudie les dépendances de court et long termes entre marché d'actifs, à une fréquence journalière. On considère quatre bourses d'échanges, Euronext, New-York Stock Exchange (NYSE), London Stock Exchange (LSE) et Detutsche Börse ainsi que leur principal indice respectif (CAC, NYSE, FTSE, DAX). Depuis la fusion de plusieurs places européennes donnant naissance à Euronext, nous constatons une vague de consolidation dans le secteur particulier de l'industrie des bourses d'échange. La démutualisation impose aux sociétés de bourse de répondre à des incitations compétitives du type coût de transaction, divulgation d'information ou diversification de produits. Ce phénomène fut déjà observé au cours du XX^{ème} en ce qui concerne le marché américain avec seulement cinq places régionales ayant survécu aux bourses nationales. Ce processus fut principalement la conséquence des nouvelles technologies de communication et la capacité des agents à négocier par téléphone. Aujourd'hui, l'élément clé est que la consolidation n'est pas seulement nationale mais trans-frontalière. De plus, elle n'implique pas seulement des pays européens entre eux (du fait d'une même monnaie) mais s'exerce notamment entre des marchés américains et européens.

Dans ce contexte, le papier soulève deux questions principales. Primo, les chocs sur les prix d'actifs impactent les allocations de capital entre les pays. Au sein d'une union monétaire, la concurrence entre places boursières peut créer des assymmétries et fragiliser les pays dotés de places boursières inefficaces. Secundo, la création de l'euro et l'anihilation du risque de change pourrait créer une nouvelle résistance européenne des marchés face à la suprématie américaine traditionnelle. Ceci pourrait également faciliter les accords et fusions entre places boursières européennes et réduire l'impact du marché américain sur les places européennes.

D'un point de vue methodologique, le papier considère des techniques de cointegration mobile et des modèles multivariés de type GARCH (General AutoRegressive Conditionnal Heteroskedastic) pour prendre en compte à la fois l'interdépendance et la contagion. A partir d'un modèle standard de microstructure (Hasbrouck (1995)), on généralise le processus de prix pour lui donner la forme d'un VECM (Vector Error Correction Mechanism) que l'on complète d'une composante GARCH multivariée. Cette approche permet notamment l'analyse des corrélations dynamiques journalières entre indices boursiers, grâce à l'estimation des matrices de variance-covariance.

Les résultats empiriques montrent que le marché américain est globalement leader sur l'échantillon considéré entre 1/1/1994 et 30/4/2006. Néanmoins, on observe entre 2000 et 2002 une période de relative faiblesse de l'indice américain dans son rôle de leader. Le LSE est globalement suiveur du NYSE sur l'ensemble de l'échantillon alors que le CAC et le DAX montrent de temps à autre une certaine résistance notamment entre 2000 et 2002. De plus, les chocs affectant principalement les places européennes restent confinés à celles-ci, alors que les chocs affectant le marché américain sont effectivement transmis. Enfin, l'estimation du VECM-GARCH montre que les corrélations dynamiques convergent vers l'unité entre places européennes alors que les corrélations entre places européennes et américaines ne montrent pas de tendances. Ceci pourrait encourager les fusions et accords de type transatlantique du point de vue de la diversification de produits.

1. INTRODUCTION

The structure of financial markets has been deeply modified in the last twenty years because of financial globalization. Agents are now used to trade between financial products and countries. A new feature to be mentioned is the ongoing consolidation in the stock exchange industry. Indeed, since the demutualization, stock exchanges need to react to standard competitive incentives like diversification or cost efficiency. Euronext was the first example. It merges Brussels, Amsterdam, Paris, Lisbon and the derivative market of the London stock exchange (LSE). Recently, this consolidation process has accelerated between stock exchanges. However, it had been already witnessed in the United States during the XIXth and the XXth century. From more than one hundred places, only five US regional stock exchanges survive to the main national ones. This was mainly driven by regulation and progress in communication technologies (Arnold et al. (1999)). Now, a crucial point is that the process is cross-bordered between European exchanges but also between American and European ones (NASDAQ-LSE or NYSE-Euronext). Given this consolidation process and the associated acceleration in the exchanges, we expect a larger transmission of shocks with a potential modification in the previously established leader-follower links between places.

This paper focuses on shock transmission between places in a context of global consolidation. First, this question is relevant in Europe given that countries integrated in the euro area share a common currency. It is a major issue for European policy makers since integration may imply trade-offs between stock markets, and so capital allocations between countries, regions or sectors: this may weaken countries where stock markets are inefficient. Second, the euro may induce a new market strength of European markets, with less currency risk inside Europe and less heterogeneity in economic cycles. As a consequence, European places may loose their traditional follower tendency face to the American markets supremacy. Finally, if we consider one leader place and the others followers, we should not witness on the leading place any shock becoming global. However, confined shocks on follower places may still be observed. Consequently, this shock classification may help understanding how a place may be alternatively over time a leader or a follower, depending on the shock transmission.

The empirical analysis of this increasing interdependence and shock transmission between stock exchanges is conducted in the literature following three main methodologies.

The first one is a macroeconomic approach based on cointegration analysis: Kasa (1992) and Kanas (1998) reached the same conclusions finding few evidence of enough integration to not justifying international portfolio management. Billio, Lo Duca and Pelizzon (2005) introduce switching regimes in an error correction model to capture interdependence and contagion.

A second approach is based on microstructure models. Harris et al. (1995 & 2002) use the standard cointegration approach in a microstructure theoretical model of leader and follower prices. Using IBM prices on regional and national exchanges in the United States, they tackle with information flows in price determination. Hasbrouck (1995) uses the information sharing approach to analyze interactions between stock exchanges and detects leadership behaviors of the

US national exchanges on the US regional ones. Biais and Martinez (2004) focus their analysis on interactions between Euronext and Frankfurt. They show how Frankfurt is a leading place in Europe with the CAC40 following the DAX.

A third approach relies on correlation models. Forbes and Rigobon (2002) observe heteroskedasticity in the data and show how contagion is a transitory status while interdependence is a long run regime in volatility. Using multivariate GARCH models [see Engle and Kroner (1995), Kroner and Ng (1998), Engle and Sheppard (2001) and Bauwens, Laurent and Rambouts (2006)], Kearney and Potì (2005) analyze the dynamics of correlations between European equity indexes and find evidence for a structural break at the beginning of the monetary integration process.

In this paper, we contribute understanding how competition and consolidation process in the stock exchange industry may affect places and risk transmission. The aim of the paper is to analyze leader and follower behaviors between exchanges mixing these three approaches. From a standard theoretical microstructure model (Hasbrouck (1995)) we generalized price processes to a Vector Error Correction Mechanism (VECM) that we complete with an asymmetric BEKK-GARCH model on residuals.

Following Forbes and Rigobon (2002) our empirical analysis distinguishes interdependence and contagion. Interdependence is analyzed through a rolling overlapping VECM. By considering time-varying coefficients, we assume that interdependence may evolve over the time. This allows the determination of periods when the US market was more or less leader with respect to European places. Second, we analyze contagion introducing an asymmetric Multivariate General AutoRegressive Conditional Heteroskedastic model (AMV-GARCH). This new approach permits to dealing with both contagion and interdependence.

The outline of this paper is as follows. Section 2 presents details about the recent dynamics of stock exchange integration, and highlights the closer links between stock exchanges. These connections are not only between European places but between American and European places as well. Section 3 presents interdependence and shock transmission between stock exchanges. Section 4 deals with the data set and preliminary analyses. Section 5 focuses on the empirical results and section six concludes. More details in empirical results and graphs are given in appendixes.

2. THE RECENT DYNAMIC OF STOCK MARKET INTEGRATION

2.1. The role of new technologies

Stock market industries exert since their creation, especially in the United States, a natural incentive to compete. This is commonly referred as competition for order flow (Di Noia (1999)). The initial role of exchanges was to propose a unique and local place where financing, ownership and trading can occur (Arnold et al. 1999). Stock exchanges were first specialized in particular sectors like mining in San Francisco or AT&T in Massachusetts where the telephone was invented.

The first wave of stock market consolidation is witnessed in the United States and concerns the regional stock exchanges. Between 1920 and 1930 the development of new communication technologies initiated competition between stock exchanges. Attractiveness of stock exchanges finally mattered for traders and investors, such that competition surged through regulation, organization, information delivery and trading costs: market quality became the cornerstone of stock exchanges competition. In the American exchanges industry, competition resulted today to the survival of only four regional stocks exchanges[3] while more than one hundred were acting during the nineteenth.

In Europe, the London Stock Exchange (LSE) was the first one to initiate competition. LSE regulators allowed, in 1980, banks and financial institutions to compete for market dealership without regulating trade fees anymore. Moreover, they initiate computerized systems for quoting and order placements. Finally the SEAQ[4] International in London permitted listing of non-UK companies without the companies requests. This can be seen as a hurricane in other European places: Paris lost 50% of the volume of its blue chips and one third for the German ones (Benos and Crouhy, 1996). This created an incentive for reforms in the French and German stock exchanges, reducing trade and listing costs, and introducing new technologies in trade processes.

The natural incentive to compete and merge comes from the scope and scale economies. Once efficient information technology processes implemented (and assimilated to fixed cost and entrant barriers), seeking product diversification leads to competition between exchanges. This diversification can be applied to the class of product (stock and derivatives for example) and to the nationality of the company issuing stocks. That is why we witness many concentration processes today in exchanges, and particularly in Europe. Euronext is born from the merging of Paris, Brussels and Amsterdam in September 2000. In February 2002, Euronext merged with the Lisbon stock exchange. As a consequence, this wide panEuropean place diversified its offer to investors. In this line, Euronext merged as well in January 2002 with the London LIFFE market to be present in the trade of derivative. In parallel the Deutsche Börse initiate the creation of a worldwide market for options and derivatives (Eurex) with the Swiss stock exchange and recently with the American market through the creation of the Eurex US based in Chicago.

2.2. The role of the European legislation

Another strand of competition is the role played by the legislation. An example in the United States was the well known NYSE rule 390 which restricts competition and whom recent rescission motivates competition (Kam et al. (2003)). In Europe, the legislator adopted, in 1995, the Investment Service Directive supposed to improve and finally meet the conditions to enhance a single security market in Europe (Ramos (2003)). On the one hand this directive allows intermediaries to operate in other EU markets with no more regulatory burden. On the other hand the political counterpart was the 15.5 article which stipulates that a country can

[3] Chicago, Boston, Philadelphia, Cincinatti (called National Stock Exchange from 2003). The Pacific stock exchange is the last regional who had deasapeared in 2006 bought by the NYSE.

[4] Stock Exchange Automated Quotations.

prevent its national market from being introduced by a new market. This directive has finally improved the international activities of intermediaries but presents some lacks on the creation of an integrated security market. This directive has recently been completed by the ISD-2 also called the MiFID: Markets in Financial Instruments Directives. The first part of the directive (called level 1) was adopted in April 2004 by the European commission and parliament. The second level is still under work and the entire directive should be applicable at November the 1st 2007. The internal market commissioner Frits Bolkestein expressed his satisfaction to implement this directive. He declared the adoption of the directive "bad news for financial wide boys and [...] good news for ethical operators, for the market as a whole and for Europe's economy" (April 2004, parliament speech following the directive adopting vote). This directive directly tackles with the protectionist 15.5 article of the ISD-1. The application of this directive will deeply modified all the structure of the European exchanges industry for different reasons. First and mainly, MiFID gives firms, banks and especially exchanges a single passport to operate throughout the European union on the basis of their home country authorization. This should accelerate market rules harmonization through competition. Second, this directives mentions minimum standards and requirements to enhance investor protection at the European scale. Finally firms will have to disclose some information to the market about internalized transactions[5] to guarantee the best execution price to investors.

To summarize, the first wave of integration due to information technologies innovations and implementation is now completed by a regulatory process improving competition and leading to a rule harmonization that makes borders artificial. Recently the NASDAQ grew its ownership in the London Stock Exchange about 15% while Euronext and Deutsche Börse were competing to merge with LSE. Nonetheless a new merger between Euronext and Deutsche Börse should not take place since the New York stock Exchange starts negotiating with Euronext to create a $20.000 Billions turnover stock exchange: we do not know what level consolidation can reach.

The following analysis considers European and American stock exchanges. We try to exert, through dynamic correlations and cointegration, connections between European places in and out the monetary union.

3. THEORETICAL BACKGROUNDS

3.1. Dynamic cointegration and VECM

The theoretical background of this study relies on Vector Error Correction Mechanism (VECM) introduced by Engle and Granger (1987) and cointegration tests of Johansen and Juselius (1992) [JJ]. Cointegration is the cornerstone of several analyses of market integration. Kasa (1992) and Kanas (1998) among others use this concept. Bhattacharyya and Banerjee (2004) estimate a standard VECM on the main European, American and Asian indexes, showing how the Ameri-

[5] With a transaction volume up to the average size of the orders executed to the market to not rising risk bore by wholesale broker-dealer in their role of market makers.

can index is never influenced by other indexes. Davies (2006) exploits the idea that the level of integration between markets is evolving and considers a regime switching cointegration approach. From a microstructure point of view, Harris et al. (1995 & 2002) and Hasbrouck (1995) consider stock market integration through cointegration as well. Let consider an economy with a leader market (subscript L), and a follower one (subscript i). The respective log prices of a common traded asset is then given by:

$$
\begin{aligned}
p_{L,t} &= p_{L,t-1} + \varepsilon_{L,t} \\
p_{i,t} &= p_{L,t} + \varepsilon_{i,t} \ , \qquad (1)
\end{aligned}
$$

such that returns are stationary and log prices are cointegrated with $\beta = \left[\begin{smallmatrix} 1 \\ -1 \end{smallmatrix}\right]$ as the cointegrating vector. The price on the leading place follows a random walk while the follower price follows the contemporaneous leader price. This approach is restrictive since we do not know which place can be a leading one, and that we may have several leading places. Moreover we do not know the speed of adjustment. It may need more lags for the follower price to adjust the leading price. Thus a general approach would be to consider p_t as a $(N \times 1)$ vector containing a set of I(1) endogenous log index prices and following a Vector Autoregressive in level model (VAR) with S lags such that:

$$
p_t = \sum_{s=1}^{S} \Phi_s p_{t-s} + \mu + \varepsilon_t, \qquad (2)
$$

with Φ_s a $(N \times N)$ matrix of coefficients for lag s, μ a constant and ε the error term. This model can be rewritten as the following VECM:

$$
\begin{aligned}
\Delta p_t \quad = \quad & \left(\sum_{s=1}^{S} \Phi_s - I \right) p_{t-1} + \left(\sum_{s=2}^{S} \Phi_s \right) \Delta p_{t-1} + \left(\sum_{s=3}^{S} \Phi_s \right) \Delta p_{t-2} + \qquad (3) \\
& ... + \Phi_S \Delta p_{t-S+1} + \mu + \varepsilon_t,
\end{aligned}
$$

or

$$
\Delta p_t = \left(\sum_{s=1}^{S} \Phi_s - I \right) p_{t-1} + \sum_{l=1}^{S-1} \Gamma_l \Delta p_{t-l} + \mu + \varepsilon_t, \qquad (4)
$$

where $\Gamma_l = - \sum_{s=l+1}^{S} \Phi_s$ and Δ is the first difference operator. The Johansen and Juselius (1992) cointegration test estimates the rank of the matrix $\Pi = \left(\sum_{s=1}^{S} \Phi_s - I \right) = \alpha\beta'$ to determine the number k of cointegrated vectors. We are particularly interested in the evolution of the Π matrix decomposed as a product of a $(N \times k)$ adjustment coefficient matrix (α) and a $(N \times k)$ long run coefficients matrix (β). Long run coefficients indicate the long run behaviors of indexes while the adjustment coefficients say how strong is the adjustment to this long run behavior. Each index is more or less influenced by the others, and this is understood as interdependence between places. Another approach to test for cointegration is the Engle and Granger methodology [EG]. This consists in the regression using OLS and then testing the residuals for white noise. The stationarity of the linear combination of the price is the condition to assert cointegration. In this case the estimated coefficients are said *super consistent* because they converge toward the true coefficient at a faster rate.

However, there is still a part in the process which is not explained by the model (ε_t). For example, a negative shock on the NYSE index may be transmitted or not to other places. Therefore we attempt to highlight unexpected shock transmission, which is not interdependence, through a MVGARCH extension of the model.

3.2. Multivariate volatility models

To analyze short run transmission of shocks we introduce a multivariate GARCH modelization in the VECM noise. Shocks impact not only returns (first moments) but also volatilities (second moments). Engle (1982) introduced autoregressive conditional heteroskedastic models to consider time-varying volatility. A formal extension is to consider a multivariate framework of these models to analyze transmission between assets and markets (see Bauwens, Laurent and Rombouts (2006)). A problem of these first extensions is the number of parameters to estimate. As a consequence, it was imposed some restrictions on the matrix parameters (VEC and BEKK models). These models allow the calculation of few parameters estimating a dynamic on the variances and covariances of the variables. Another strand in the literature considers directly correlations. Bollerslev (1990) uses constant conditional correlation (CCC) models while Engle and Sheppard (2002) define dynamic conditional correlation (DCC) models. CCC models assume that correlations between variables are constant over the time while DCC models assume time varying correlations. To reduce the number of parameters, DCC models impose the same dynamic for each correlation allowing estimations for large basket of assets. In this paper, we consider four indexes, at a daily frequency, and we specify one dynamic for each covariance without a huge number of parameters to estimate. In particular, we consider a BEKK formulation with an added asymmetric component as in Kroner and Ng (1998). Formally we have:

$$\varepsilon_t = \sqrt{H_t} u_t \ , \tag{5}$$

with H_t the $(N \times N)$ conditional variance-covariance matrix and with u_t is a Gaussian white noise with $N(0, I_N)$ distribution.

H_t is defined as:

$$H_t = D_t R_t D_t \ , \tag{6}$$

such that

$$D_t = diag \left\{ \sqrt{h_{ii,t}} \right\} \ , \tag{7}$$

where $h_{ii,t}$ represents each element of the diagonal of the H_t matrix and R_t is a $(N \times N)$ correlation matrix. We use the diagonal Baba-Engle-Kraft-Kroner (BEKK) representation of multivariate GARCH derived by Engle and Kroner (1995):

$$H_t = (\bar{H} - B'\bar{H}B - G'\bar{H}G) + B'\varepsilon_{t-1}\varepsilon'_{t-1}B + G'D_{t-1}R_{t-1}D_{t-1}G. \quad (8)$$

We consider B and G as $(N \times N)$ diagonal coefficient matrices and $\bar{H}$ the $(N \times N)$ unconditional covariance matrix. Moreover, we add an asymmetric component, assuming that common negative shocks on markets may have a stronger impact on volatilities and covariances. We define the $(N \times N)$ $\Im_t$ matrix as follows:

$$\Im_t = \begin{pmatrix} I_{[\varepsilon_{1,t}<0]} & 0 & 0 & 0 \\ 0 & I_{[\varepsilon_{2,t}<0]} & 0 & 0 \\ 0 & 0 & ... & 0 \\ 0 & 0 & 0 & I_{[\varepsilon_{N,t}<0]} \end{pmatrix},$$

with $I_{[\varepsilon_{j,t}<0]} = 1$ if $\varepsilon_{j,t} < 0$ and $\eta_t = \Im_t \cdot \varepsilon_t$.

Following Kroner and Ng (1998), we allow asymmetries in the model by considering the dynamics of the variance-covariance matrix as follows:

$$\begin{aligned} H_t &= (\bar{H} - B'\bar{H}B - G'\bar{H}G - A'\Im'\bar{H}\Im A) \\ &\quad + B'\varepsilon_{t-1}\varepsilon'_{t-1}B + G'D'_{t-1}R_{t-1}D_{t-1}G + A'\eta_{t-1}\eta'_{t-1}A \ , \end{aligned} \quad (9)$$

with A a diagonal parameter matrix reflecting asymmetries. We assume the variance covariance matrix is positive definite since $(\bar{H} - B'\bar{H}B - G'\bar{H}G - A'\bar{H}A) > 0$. The dynamics of the correlations from the asymmetric BEKK model are obtained from:

$$R_t = D_t^{-1}H_tD_t^{-1} \ . \quad (10)$$

Finally the model is estimated through maximizing the log likelihood written as:

$$\log(L(A, B, G; \Delta p_1 ... \Delta p_N)) = -\frac{1}{2}\sum_t (T\log(2\pi) + \log(|H_t|) + \varepsilon'_t H_t^{-1}\varepsilon_t) \ . \quad (11)$$

The number of estimated parameters is three times the number of considered prices. If we thus consider four stock exchanges indexes, we have twelve parameters to estimate. The MVGARCH extension on the VECM residuals permits to analyzing the unexpected shock transmission in a dichotomous way from the analysis of interdependence in the conditional mean. We make the hypothesis that correlations may have a particular pattern (negative for example) even if interdependence is greater for the last years. In fact, stronger market integration should not mean that all shocks are transmitted or have the same effects between places.

4. DATA AND PRELIMINARY ANALYSIS

4.1. Market data

We obtain from Reuters and Datastream daily market data for four markets (NYSE, CAC, DAX, FTSE) from January the 4^{th} 1994 to April the 30^{th} 2006 (3214 observations). Due to jet lag, we consider indexes at 10 a.m in the morning for European places and closing prices in New York. Indeed, when Paris, Frankfürt and London close, in Europe, the American stock exchanges are still opened. Consequently, some market information from the United States, during the European overnight closing period, is incorporated into European prices only the day after. This may create misleading follower behavior. To circumvent this problem, the prevailing day t price is the 10 a.m price in t+1 for European markets (at London time for the three European exchanges) and the closing day t price for the US market. Therefore, European prices reveal what they would have been once the entire US day information would be incorporated into prices. Moreover, we circumvent the problem in a way that we are particularly interested in the dynamic cointegration and dynamic correlations.

Due to national celebrations, Christmas days, Easter holidays or special events, some markets are closed while others are opened. Thus, we consider on these days, index returns are null for the closed markets, since we do not have information flows coming from this place. FTSE index serves to test whether belonging to the euro area is a necessary point to be a leading place in Europe. Precisely, we wonder whether several exchanges can really survive the integration process. The recent evolutions concerning the concentration process of stock exchanges tend to answer "no". Moreover, we previously saw how integration is not only at work at the European level, but at the global level with American places taking part of the European consolidation process. Usual statistics are provided in Table 1.

	CAC	**DAX**	**FTSE**	**NYSE**
Mean	0.025	0.029	0.017	0.034
Median	0.044	0.050	0.038	0.015
Q5	-5.01	-5.53	-3.98	-3.01
Q95	2.20	2.36	1.62	1.46
Standard deviation	1.420	1.543	1.093	0.923
Skewness	-0.259	-0.441	-0.326	-0.249
Kurtosis	7.128	8.540	9.297	7.375
Jarque-Bera	2319.407	4215.195	5367.839	2597.981

Table 1: Usual statistics for index returns (%), January the 4^{th} 1994 - April the 30^{th} 2006

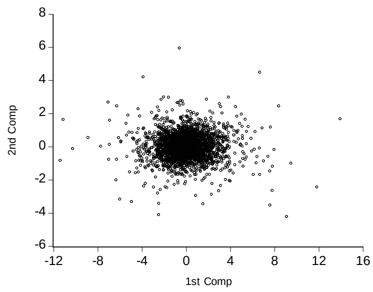
Table 1 shows that daily returns are positive in mean but vary in a wide range, approximately from -11% to 10%. The medians reveal that more than 50% of the daily returns for all indexes were positive. The skewness associated with each of the returns are negative, which means that we usually have a long left tails. In other words, negative shocks are more substantial than positive shocks. Finally, the daily returns distribution is leptokurtotic (kurtosis greater than 3) which can be attributed to some peaks in the volatility. This is reflected by the Jarque Bera test which indicates that returns do not follow a Normal distribution, with a statistic far from zero. This is a common feature of financial data due to the presence of heavy tails for example. Our aim is to consider information flows between places such that we are interesting in correlation processes. Table 2 provides sample correlations:

	CAC	**DAX**	**FTSE**	**NYSE**
CAC	1			
DAX	0.879	1		
FTSE	0.808	0.797	1	
NYSE	0.572	0.577	0.569	1

Table 2: Sample correlations between returns (%), January the 4^{th} 1994 - April the 30^{th} 2006

First, correlations are all positive. Correlations between European places are stronger than correlations of European markets with the NYSE. The highest is obtained between the DAX and the CAC. Then, the correlations FTSE-CAC and FTSE-DAX are quite similar around 0.80. Finally, sample correlations with the NYSE are slightly greater than 0.5 and similar for each European place.

Graph 1 and Table 3 present a Principal Component Analysis (PCA). We obtain that 78% of the variance in returns is explained by the first component. Together, the two first main components explain more than 90% of the index returns variance.

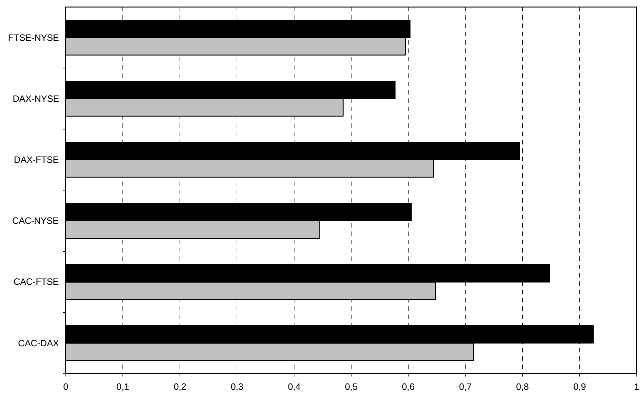


Graph 1: Principal Component Analysis on returns (%), January the 4^{th} 1994 - April the 30^{th} 2006

	1^{st} Comp	**2^{nd} Comp**	**3^{rd} Comp**	**4^{th}Comp**
Eigenvalue	3.12	0.54	0.22	0.12
Variance Prop.	0.78	0.13	0.06	0.03
Cum Variance Prop	0.78	0.91	0.97	1

Table 3: Principal Component Analysis on returns (%), January the 4^{th} 1994 - April the 30^{th} 2006

Thus, there are narrow links between places. Stock exchange industry consolidation and market integration have accelerated these last years, and encourage markets to move closely. Graph 2 presents correlations in 1994 and correlations in 2005. The largest increase is obtained for the CAC-NYSE correlation which rose by 35% to reach 0.6. It is followed by the CAC-FTSE correlation which rose by 30% to reach 0.84. DAX-FTSE and DAX-NYSE correlations jump respectively by 23% and 18%. Finally, CAC-DAX increased by 30% to attain 0.92, the highest correlation.



Graph 2: Correlations between returns (%) in 1994 (grey) and 2005 (black)

This shows how stock exchange integration is not only between European places. Correlation between CAC and NYSE presents the highest positive variation between 1994 and 2005. We are thus interested in the evolution of these correlation processes not only in Europe but at the global level. However, this market integration process can be analyzed on two levels: the direct transmission on returns and the risk transmission through volatilities. Section 5 deals with long run trends dynamics through rolling overlapping cointegration first, and then with dynamic correlation processes. Therefore, we must previously consider series stationarity and the window size to run the rolling VECM analysis on returns.

4.2. Stationarity and rolling window size selection for the VECM

We perform stationarity tests on log index prices and returns. Non-stationarity in financial data is well documented in the literature. However, Granger and Starica (2004) show how financial data may be locally stationary or approximated by stationary analysis. A key question is to determine what is the long run on financial markets. At a daily frequency, can a week, a month, a year or several years be considered as long run? We want to exert from the data a common trend on the long run, and a necessary condition is to consider the data are non-stationary. We use the Augmented Dickey-Fuller (ADF) test and the Kwiatkowski- Phillips-Schmidt- Shin Test (KPSS). The ADF test accepts or rejects the null hypothesis of "unit root" while the KPSS considers that stationarity is the null hypothesis. The performance of the ADF test is critical. Indeed the rejection of the null hypothesis by the ADF test does not mean the variable does not have a unit root, but the information contained in the variable is not enough to conclude in favour of a unit root. Thus we decide to associate this test with the KPSS test.

The ADF test can be described as follows: let suppose an AR(p) process,

$$(1 - \Phi(L))y_t = \varepsilon_t \ , \tag{12}$$

with ε_t an error term and $\Phi(L)$ the lag polynomial of order p with coefficients ϕ_i (i=1 ... p). It can be rewritten as (proof in Hamilton (1994)):

$$y_t = \xi y_{t-1} + \sum_{s=1}^{p-1} \zeta_s \Delta y_{t-s} + \varepsilon_t \ . \tag{13}$$

The existence of one unit root implies $\xi = 1$. Finally, the ADF test consists in estimating this equation and test the null hypothesis of $\xi = 1$. Table 4 presents the test statistics performed on the entire sample for each index in levels and returns.

ADF Test	**CAC**	**DAX**	**FTSE**	**NYSE**
log(p)	-1.12	-1.37	-1.46	-1.49
Δlog(p)	-59.41*	-61.07*	-59.57*	-55.47*
critical value	-2.86	-2.86	-2.86	-2.86

Table 4: ADF test statistics for log prices and returns, January the 4^{th} 1994 - April the 30^{th} 2006

The logarithms of index prices are all I(1)[6]. The returns are thus stationary with a test statistic smaller than the critical value.

To confirm these conclusions we also perform the KPSS test. This test relies on the decomposition of the series in a random walk component, a time trend and an error term. If the series is trend stationary (null hypothesis), the variance of the random walk component should be zero. To test this, we run an auxiliary regression of the log indexes on a constant and a time trend. Then we test the variance of the constant term is null such that the series is trend stationary:

$$y_t = \mu_t + \beta t + \varepsilon_t, \tag{14}$$

$$\mu_t = \mu_{t-1} + u_t. \tag{15}$$

The test statistic is given by:

$$KPSS = \sum_{t=1}^{T} S_t^2 / \hat{\sigma}^2,$$

with S the partial sum defined as,

$$S_t = \sum_{s=1}^{t} \varepsilon_s, \tag{16}$$

and $\hat{\sigma}$ an estimator for the error variance.

[6]Additionnal not reported tests with time trend and constant or without trend and constant give the same conclusions.

The asymptotic distribution is not standard and the critical value is given as 0.146 at the 5% level. If the null hypothesis is stationary rather than trend stationary, the 5% critical value is 0.463. Table 5 displays the KPSS test statistics.

KPSS Test	CAC	DAX	FTSE	NYSE
log(p)	3.78	2.94	2.37	5.13
Δlog(p)	0.16*	0.17*	0.16*	0.19*
critical value	0.463	0.463	0.463	0.463

Table 5: KPSS test statistics for log prices and returns, January the 4^{th} 1994 - April the 30^{th} 2006

KPSS test confirms that series are all I(1)[7].

We perform as well unit root tests on a rolling window. We may suppose the log prices to be stationary on shorter periods. The ADF and KPSS tests are run on the basis of a 100, 300, 750 and 1000 days rolling window[8]. The 100 and 300 days rolling windows often show rejection of unit root in the data for the four considered indexes while the 750 and 1000 days rolling window reject rarely that series are I(1). Thus, we look for a linear combination of prices that is stationary. This is the definition of cointegration and is investigated later. We finally consider a VECM estimated on a rolling window of 750 days is optimal.

5. ESTIMATIONS AND EMPIRICAL RESULTS

5.1. Cointegration and long-run relation of index prices and returns

First, we investigate for cointegration on the entire sample and present the estimated long run relationship between the logarithms of the four indexes. The JJ test indicates that we cannot reject one cointegrated vector at the 5% level. This is in line with previous studies in favor of portfolio diversification. The estimated coefficients of the long run relation (Table 6) show that the CAC, FTSE and NYSE indexes vary in the same direction while the German one varies in the opposite sense[9]. The estimated signs underlines potential arbitrages between the NYSE and the DAX and between the CAC and the FTSE.

Variables	Coefficient	std. error
FTSE	0.569	0.046
DAX	-0.159	0.045
CAC	0.620	0.027
R^2=0.83		

Table 6: Long run coefficients from January the 4th 1994 to April the 30th 2006

The estimations of the adjustment coefficients to this long run relation show weak exogeneity

[7] Additionnal not reported tests with trend stationary as the null hypothesis give the same conclusions.
[8] Rolling ADF and KPSS tests are presented in Appendix 1 & 2.
[9] VECM estimations for the entire sample are provided in Appendix 3.

for the DAX and the NYSE. It would mean more independence for these two markets from the others. Nevertheless, we can suppose these influences are not constant over the time and may lead to biased conclusions. This suggests to implement a rolling model on the sample. Integration level of equity markets has changed for the last years such that long run and adjustment coefficients should not be constant.

Gill et al. (2005) estimate between 1990 and 2004 at a daily frequency a non-cointegrated VAR model on index returns and find significant price spillover between Paris and New-York, with a much more significant effects for the transmission from Paris to New-York. Moreover they find that inside Europe, Paris is the most influencing place. This is contradictory with Biais and Martinez (2004) who find a preponderance of Frankfort in Europe between 1998 and 2001 at a daily frequency as well. However, Antoniou et al.(2003) suggests that leader-follower relationships may change over the time such that the sample period is critical.

As a consequence, the size of the rolling window is crucial. In other words, how many days can be acceptable in term of long run relation? Harris et al. (2002) or Hasbrouck (1995) estimate their VECM on the entire sample, even on an intraday basis, not allowing the coefficients to vary. Usually these studies estimate and test cointegration for several years. From the previous section we considered the 750 days rolling windows as the optimal one for the integration of the data. Moreover, three years, on a daily basis, can be considered as a long term period for the stock markets. Integration is linked with institutional reforms and economic environment. For example, the economic downturn in 2000 was persistent and latent for several years with a gloomy outlook of the world economic situation. Another example may be the anticipations and adaptation facing the euro area creation, such that practitioners were to get used with new way of trading. Long term tendency in stock exchange may not be considered as short as are usual arbitrages between places. Therefore, three years seems reasonable in term of long run scale if we focus on the evolution and trends, divergent or common, in domestic macroeconomic fundamentals of the considered countries.

On the basis of this rolling window, JJ tests are performed and reported in Appendix 4. None or only one cointegrated vector is found, depending on the estimation period. The JJ test estimates a test statistic which varies around the critical value but often accepts one cointegrated relation. These conclusions are close from the EG test methodology by using ADF test or KPSS test. Both tests always accept long run residuals to be stationary except for the samples including data from July 2002 to October 2002.

5.2. Rolling VECM coefficient estimations

To analyze deeply these periods where rejection is observed, we estimate the rolling long run coefficients. Coefficients are sign varying on the sample for the French and German indexes and most of the time positive for the FTSE.[10].This would justify the use of models where coefficients are not assumed to be constant. Billio et al. (2003) for example uses a markov switching error

[10]The graphs of these estimates are reported in Appendix 5.

correction model.

From 1999 to 2002, the CAC was first driven by the US index (positive coefficient) while the German one was quite resistant. On one hand the decrease in the CAC coefficient from 2000 shows how the CAC starts to loose its follower tendency. On the other hand, the German index (with an increasing coefficient) exerts a "follower" tendency. This period would include different events like the 2000 market downturn or the euro area creation or the birth of Euronext. Finally, following that period, and until the beginning of 2006, coefficients are not really stable and more erratic like it is previously suggested by the cointegration tests rejection.

The adjustment coefficients, from the estimated rolling VECM, are also not stable[11]. A positive coefficient for European places means a follower behavior, while a negative one means resistance.

Precisely, we have three periods of interest. For the samples based on a rolling window of 750 days between 1994 and 2000 we have a positive adjustment coefficient becoming negative for the three years rolling samples between 2000 and 2004, and back positive from 2004. In other words, during the second half of the nineties the positive adjustments represent a *follower* dynamic of the European places: a rise in the US index implies a rise of the European index for the next period, in the short term dynamics. Nonetheless, during the second period the negative adjustment coefficient means some kind of European resistance to the 2000 stock market downturn. Adjustment coefficients are the strongest (and negative) for the period starting in 2000 with a minimum reached during the sample 2000-2003 for the CAC and FTSE and during 1999-2002 for the DAX. Thus resistant behaviors of European places are emphasized in period of troubles, especially during the 2000 market downturn. This may converge with the possible hypothesis that the monetary union implies more independency of European stock exchanges. Finally, during the third period the coefficient is newly positive and suggest that resistance was transitory. In fact, independence is detected after 2000 for European markets but it is still puzzling since the origin of this market strength can be both due to the European monetary union or/and a consequence of the 2000 new technologies bubble burst. The newly positive coefficient from 2004 tends to confirm that resistance was a transitory regime for European places.

Concerning the NYSE index, a negative coefficient means this index is less independent from the European indexes variations. During 2000-2003 it adjusts more significantly to European places in a sense that from an adjustment usually close from zero, we estimate the adjustment coefficient about -0.11 for the sample starting in mid-March 2000. If we interpret the right hand side of the long run relation as a representative composite index of the European equity markets, a rise by one hundred basis point of this fictive index induces a rise by 11 basis point for the American index. This shows how the NYSE is not that independent from the behavior of European places even if this potential rise is not that substantial.

To sum up, on several aspects, there is some kind of European resistance during the 2000 market downturn, which is detected by the estimation of the long run coefficients on that period.

[11] Graphes of the estimations are provided in Appendix 6.

However, this seems to be transitory, and finally the FTSE, DAX and the CAC follow the US stock market. Nonetheless, the American market does not seem to be completely blind to the European markets between 2000 and 2003. It suggests foreign market operators have facilities to make arbitrages between places: the bad wealth of American markets on that period creates incentives for arbitrages in favour of European places. However, at the end of the sample, the CAC , the FTSE and the DAX are followers.

Looking at the residuals obtained from the VECM estimated on the entire sample, we observe fat tails with a rejection of the null hypothesis of normality of the Jarque-Bera test. Moreover, residuals present serial and cross linear dependence correlation. This suggests to specify the VECM noise as a multivariate GARCH model.

Moreover, a crucial question is to now identify whether shocks affecting the US market are systematically transmitted to European places. Integration process analysis mainly confirms the leading role of the NYSE, except during the 2000 market downturn. Therefore we can imagine that all unexpected shocks on the US market is disseminated to European places, giving no much rational for arbitrages. For that purpose, the multivariate ARCH framework fit particularly well this issue.

5.3. Multivariate GARCH and correlations between places

To interpret the relative strength of European equity markets face the US market, we analyze correlations between indexes through a VECM-GARCH process. We include in this model the four indexes considered previously. We consider the VECM from the previous section (estimated on the entire sample, i.e. between January the 3^{rd} 1994 and April the 30^{th} 2006) extended by a MVGARCH on the residuals. This methodology is used by Gill, Osborn and Savva (2005) to estimate dynamic correlations following Capiello, Engle and Sheppard (2003). This allows the analysis of risk transmission. From previously, the variance and covariance equations can be written as follows:

$$h_{ij,t} = (1 - b_i b_j - g_i g_j - I[\varepsilon_{i,t-1} < 0] \times I[\varepsilon_{j,t-1} < 0] \times a_i a_j)\overline{h_{ij}} \quad (17)$$

$$+ b_i b_j \varepsilon_{i,t-1}\varepsilon_{j,t-1} + g_i g_j h_{ij,t-1} + a_i a_j \eta_{i,t-1}\eta_{j,t-1} \ , \quad (18)$$

with a_i , b_i and g_i elements of the diagonal matrices A, B and G. ε_t are the residuals from the VECM estimated on the entire sample and η_t are defined as $\Im \cdot \varepsilon_t$ as previously. Dynamic correlations are then:

$$\rho_{ij,t} = \frac{h_{ij,t}}{\sqrt{h_{ii,t} h_{jj,t}}} \quad (19)$$

Table 7 gives the diagonal matrices A, B and G estimations[12].

variable(i)	b_i	g_i	a_i
NYSE	0.1906 (0.008)	0.9736 (0.002)	0.0951 (0.010)
DAX	0.2021 (0.004)	0.9758 (0.001)	−0.0320 (0.010)
CAC	0.1911 (0.004)	0.9794 (0.001)	0.0100 (0.011)
FTSE	0.2098 (0.005)	0.9740 (0.001)	0.0165 (0.012)

Table 7: Estimated coefficients a,b and g from the multivariate GARCH Process, 04/01/1994 - 30/04/2006

From this, we calculate the persistence of the variance-covariance process for diverging and common positive shocks on one side and for common negative shocks on the other side:

$$Persistence_{ij}[I_{i,t-1} \times I_{j,t-1} = 0] = b_i b_j + g_i g_j \tag{20}$$

$$Persistence_{ij}[I_{i,t-1} \times I_{j,t-1} = 1] = b_i b_j + g_i g_j + a_i a_j, \tag{21}$$

with $I_{i,t} = I_{[\varepsilon_{i,t}<0]}$. Tables 8 and 9 provide the persistence of the processes:

$Persistence_{ij}[I_{i,t-1} \times I_{j,t-1} = 0]$	NYSE	DAX	CAC	FTSE
NYSE	0.9843	0.9885	0.9900	0.9883
DAX	0.9885	0.9929	0.9943	0.9928
CAC	0.9900	0.9943	0.9957	0.9939
FTSE	0.9883	0.9928	0.9939	0.9926

Table 8: Persistence for common positive shocks and diverging shocks , 04/01/1994 - 30/04/2006

$Persistence_{ij}[I_{i,t-1} \times I_{j,t-1} = 1]$	NYSE	DAX	CAC	FTSE
NYSE	0.9933	0.9855	0.9910	0.9898
DAX	0.9855	0.9940	0.9939	0.9922
CAC	0.9910	0.9939	0.9958	0.9941
FTSE	0.9898	0.9922	0.9941	0.9929

Table 9: Persistence for common negative shocks , 04/01/1994 - 30/04/2006

We find a highly persistence of daily conditional variance and covariance. The persistence of daily volatility is a well known feature in the empirical literature. Kearney and Poti (2005) estimate as well a persistence close to one on European indexes.

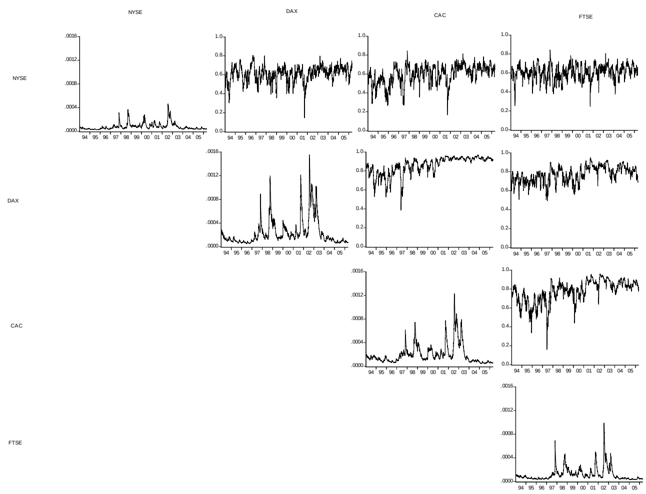
Persistence of the volatility is systematically higher when negative shocks are observed but persistence of covariance are not. The DAX index presents a negative asymmetric coefficient a_{DAX}. This implies that covariances are weaken when common negative shocks are observed on the DAX index and another one. We previously saw that the long run relation on the mean

[12] Explicit estimated equations for variances and covariances are reported in Appendix 7.

equation shows that the DAX may be used as an "arbitrage place" with a negative coefficient on a daily basis (for the entire sample). As a consequence, when a negative shock is observed on one place and on the DAX, this common "arbitrage" role does not take place anymore and the usual covariance is weaken. However, the weak significativity of this parameter may suggest at least there is no asymmetric effects on this place.

From the VECM of the previous section, we observed cross correlations between residuals. Now, auto-correlograms and cross-correlograms of the standardized residuals obtained in this model characterized by heteroskedasticity reveal no more serial and cross correlations linear dependence[13]. This show how the modelization of the variance covariance matrices permits to capturing all short term shock transmissions between stock exchanges.

This set of estimated parameters allows the computation of the conditional volatility and dynamic correlations. It is presented in graph 3[14].



Graph 3:Dynamic correlation estimates from the MVGARH(1,1), 04/01/1994 - 30/04/2006

The error term variances are not constant over the time, and so forth for the correlations. These graphs are interesting to interpret since we obtain a day to day analysis of the events that may make stock markets more volatile and the correlations between them unstable. A large part of the index movements are not captured by considering a simple multivariate model on the conditional mean. These graphs confirmed the hypothesis that market interdependence is one thing but the risk transmission is another. The two next subsections precisely exert the identifiable shocks witnessed in the volatility and correlation processes.

[13]We use both (1) the Q-stat test procedure and (2) the cross-correlogramms to compare residuals properties with and without the MVGARCH component. Not reported statistics, tests and graphs are available on request.

[14]They are additionnally reported in Appendix 8 and 9.

5.3.1. Volatility and periods of trouble

Firstly, we look at shocks on the volatility process, i.e. on the diagonal of graph 3. The CAC and DAX indexes are the most volatile followed by FTSE and NYSE. We globally observe four or five peaks in volatility (associated with periods of trouble), more or less common to every places.

The first one starts at the end of October 1997 on every places and lasts until January 1998. This may concern the Asian crisis with a peak in volatility around the 29^{th} and the 30^{th} of October. The second period of trouble is identified at the end of 1998 and the beginning of 1999. Actually, we firstly observe tension on the US market at the end of September 1998 which ends in December 1998. This period of trouble is also witnessed in European places but lasts longer with a peak in volatility during October 1998 and a persistence of volatility until February 1999. This may be linked with the implementation of the European single currency and the risk born on the market through this event. A third period of trouble occurs in 2000 in two steps. We first observe a peak in volatility during the first days of 2000 potentially linked with the fictive IT *big bug*: this is mainly witnessed in France and Germany between the 4^{th} and the 10^{th} of January. The second step for this volatile period is from the end of February to March. From the 20^{th} of February, we first observe in France an increase in volatility and then in the other markets around the 15^{th} of March. This seems to be a consequence of the IT 2000 bubble burst. Fourthly, a new period of trouble is witnessed in September 2001, and more precisely from the 18^{th}. This is directly linked with the re-opening of the US market following the terrorist attacks of 09.11 and the monetary policy decisions following this particular event. Finally, the last period of trouble, and the longer one, is witnessed between the end of July 2002 and April 2003. It may be a consequence of the Iraqi War II and the threats about it. It is then interesting to observe precisely how the different markets responded to this last event.

Indeed, this last period starts around the 25^{th} of July 2002 and corresponds to a substantial raise in suspicions about Iraq invasion: Tony Blair made it almost clear, on this day, face the UK parliament. This may correspond to the first peak witnessed in 2002. The second peak in volatility occurs on October the 16^{th}. This follows a speech of President Bush about his intentions against Iraq on October the 11^{th} and the adoption of the resolution concerning Iraq by the Senate on October the 15^{th}. The last peak in this period occurs in March 2003 when the Iraqi war was more and more obvious, and finally volatility peaks on the 18^{th}, 19^{th} and 20^{th} when started the "decapitation attack" of the Iraqi Freedom operation.

These different events, in a context of consolidation process, may imply greater correlations or, in a weaken form should not have real impact on the correlation processes. However, it is not the case. We can thus still wonder whether we may have local confined shocks, such that places may be more affected than others.

5.3.2. *Impact on dynamic correlations*

These identified shocks are now associated with some perturbations on the correlation dynamics. If the correlation dynamics are modified it could take the form of a rise in the case of a common shock or a drop if the shock is divergent. Consequently, if we match these identified shocks on volatility with the dynamic correlations, impacts are not that obvious and depend on the market considered.

Consequences of the Asian crisis are clearly observed in the correlation dynamics: correlations between European places and the US market surged between the 28^{th} of October and the 4^{th} of November 1997 to exceed 0.8 on every place by October the 29^{th}. This event was global, and investors behaved in a similar fashion (at the extreme case may be close from herding). This is in line with the leading role of the NYSE identified on that period on the conditional mean. The close relations between the US and Asian markets made the NYSE impacted, from whom risk had been transmitted to European places then, due to the US leading role.

The second event, that may be associated with the implementation of the European currency, produced a period of high volatility. This period lasted longer for the French and the German place. Thus CAC-NYSE and DAX-NYSE correlations dropped, reaching a threshold of 0.3, during the first days of 1999, while this was not really observed with the British index. This exerts possible cautiousness facing uncertainty about euro parity between currencies and so finally adjustment behaviors during the first days of 1999 in euro area stock exchanges. This also confirms the more or less blindness of the NYSE before 2000 to European places. The euro area creation effects were confined to European places without transmission to the US market.

Y2K and the potential fear about an IT bug, if observed on the volatility process, did not produce substantial effects on correlations. Nevertheless, the March 2000 bubble burst is witnessed with first effects on the CAC-FTSE correlation during the end of February. Then, during the first days of March, CAC-NYSE and DAX-NYSE correlations were the more negatively affected (correlation fell to 0.45). Correlations then started a new rise to attain 0.7 in mid-April. It exerts some kind of transitory resistance of the euro area places while it is not observed concerning the UK market. This was also obtained from the rolling VECM on the conditional mean. From 2000 the leading role of the NYSE was transitory weaken and showed some interest for the evolution of the euro area equity indexes.

The terrorist attacks of 09.11 is clearly observed on the correlation processes with the NYSE. Indeed, we witness on September the 19^{th}, the week following the break of US markets, a huge drop in correlations. With the CAC index, the correlation fell to 0.15, with the DAX to 0.16 and with the FTSE to 0.25 while these correlations were almost three or four times higher before 09.11. Moreover, we do not obtain such an impact on correlations between European places. The closing period of the American market following 09.11 induced a non synchronous absorption of the shock between equity markets. The fact that European places stayed opened while the US market was closed, made the correlations to fall (for example see Charles and Darné (2006)). As a consequence, 09.11 seems to be a "spurious" local shock caused by institutional intervention.

This is clearly due to the very special case of the 09.11 shock but it contributed to weaken the NYSE index on this period with higher market risk in the US.

The last event is the Iraqi tensions and war. It does not exert a real pattern before the 18^{th} of March when all correlations with the NYSE exceed the 0.8 ceiling for only the second time in the sample, after the Asian crisis. This date corresponds when the invasion of Iraq started. Thus, this event had global effects even for countries not imply in, like France. This suggests the new leading role of the US market, and the 2000-2002 European resistance was more transitory. This corroborates the VECM estimations with the drop in the US adjustment coefficient which was only transitory during this period. However, we observe a decrease in correlations between euro area considered indexes and coalition indexes from the beginning of 2003 (correlations for the French and German indexes decrease by 25% with the NYSE and by 16% with the FTSE).

Finally, it is worth noting that from the end of 1998, correlations between the CAC and the DAX converge to one, and in a weaken form, the same is remarkable for the DAX-FTSE and CAC-FTSE correlations. The monetary union would mean an emphasis of common shocks transmission between the French and German indices and so a higher correlation due to currency risk annihilation and the convergence of the economies. In the case of the United States, we do not observe a global increasing trend in correlations. They approximately vary around empirical correlations (previously estimated around 0.57). Several hypotheses could have prevailed for the United States. On one hand, the risk transmission is higher and correlations are higher, since the globalization process, and the fact that US markets are less independent from others during the last years. On the other hand, higher correlations and risk sharing between the European places can afford resistance face to shocks on American markets and weaken transatlantic correlations. The absence of one of this trend may be explained by compensatory effects.

6. CONCLUSION

Stock exchange industry consolidation is at work and motivates a large body of the literature to exert dynamics and connections between stock exchanges in the world. Recently, literature focuses on the introduction of regime switching models in cointegration models or DCC models (Billio, Lo Duca and Pelizzon (2005), Pelletier (2004) or Billio and Caporin (2005)). This paper considers both cointegration technics and dynamic correlations in a VECM-GARCH framework to deal with interdependence and contagion. These analysis fit in a crucial context of global equity market integration. Every market, European, American and tomorrow Asian are taking part of this consolidation dynamic. The recent alliance between the NASDAQ and the LSE or the discussions between the NYSE and Euronext make interesting to underline leader and follower behaviour between places. This paper considers two levels of transmission.

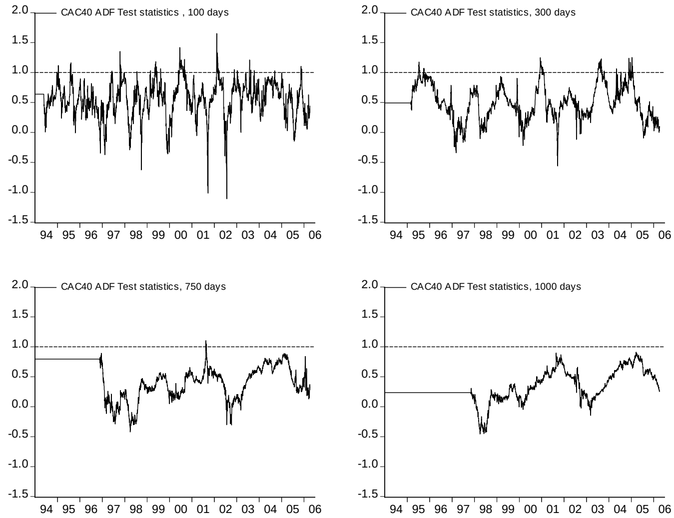
First, interdependence is directly examined through returns. The use of cointegration technics and multivariate models permits the analysis of information transmission in line with Harris et al. (1995) or Hasbrouck (1995). A notable thing is that we run this model on overlapping rolling window to observe the evolution of information transmission through returns during the last ten years. The use of rolling cointegration shows that rejection occurs mainly after 2000. Therefore, from 2000, we may not witness systematic market integration between stock exchanges. This corroborates the idea that from this period the US index weakens in its role of global market leader. This change may be consequences of the 2000 market downturn (the US market was the most affected), or the terrorist attack of 11.09. However, this weakness was transitory and the euro area creation had not significative permanent effects on the US market leading role.

Second, shock transmission is analyzed through volatilities. Multivariate GARCH models and correlations between indexes highlights shocks before and after 2000. We identify more accurately the different events affecting markets: Asian crisis; euro area birth; 2000 market downturn; September 11^{th} and Iraqi war II. The impacts show that the US index is leader on the global equity market, except during the period following the 2000 bubble burst. Before 2000, while the NYSE was a leading index, we witness two main shocks on equity market. The first one is the Asian crisis and had global effects. The second event is the euro area creation and is identified as a European confined shock without any effect on the US market. After 2000, the leading role of the NYSE is weaken, and we see that European places are quite resistant to the 2000 market downturn. Finally, from 2003, NYSE index recovered its leading role with global effect of the Iraqi War II even in places not taking part of the conflict. Nevertheless, a decreasing trend in dynamic correlations and the rejection of cointegration at the end of the sample may sustain the idea that euro area equity markets are partially gaining in independence. As a consequence, this relative independence may create incentive for European and American stock exchanges to merge in order to diversify their supply to investors.

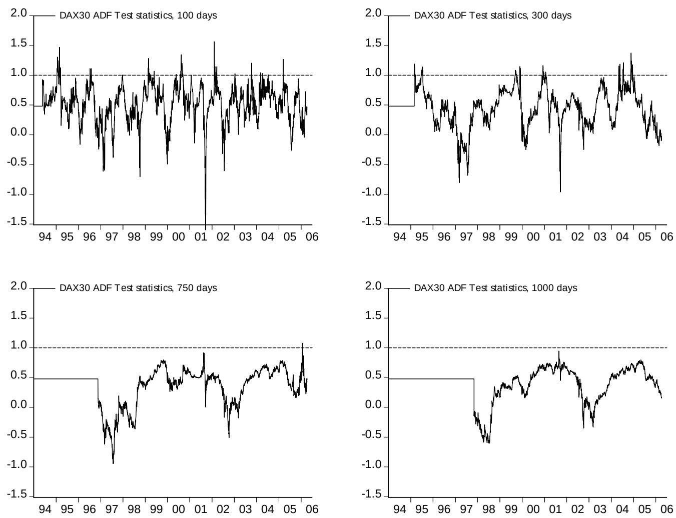
Appendix 1

ROLLING ADF TESTS (1)[15]

CAC



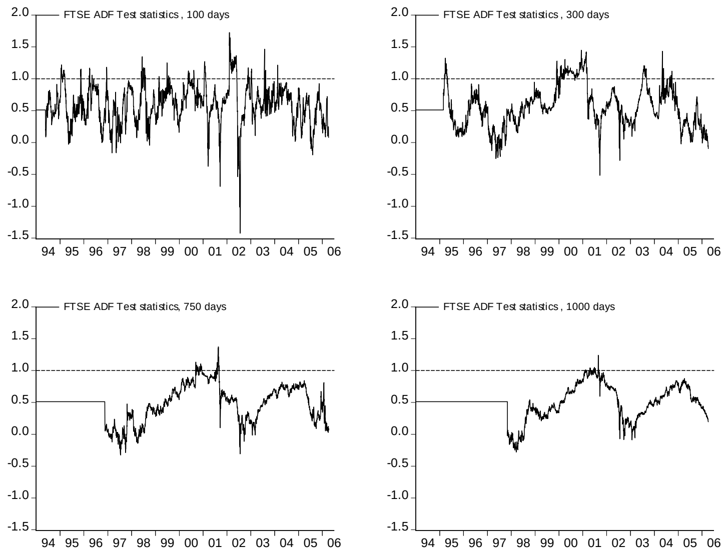
DAX



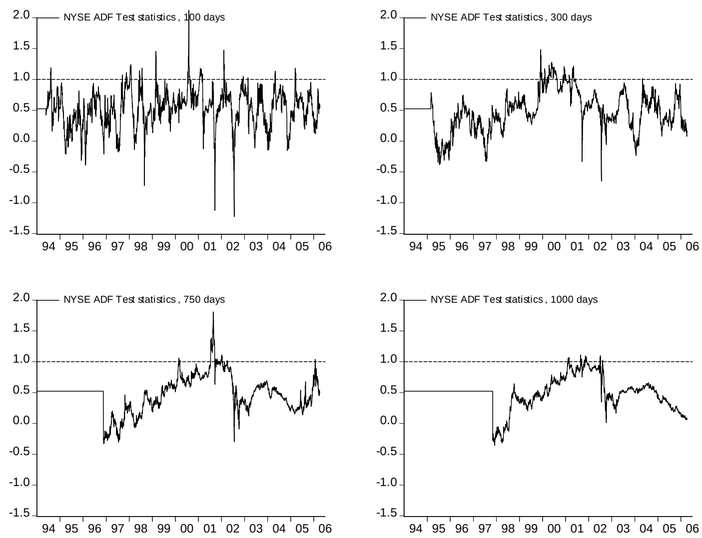
[15] Tests are run on rolling samples of 100, 300, 750 and 1000 days between 1994 and 2006. The test statistic is normalized by the critical value such that the null hypothesis of unit root is accepted if the test statistic is smaller than unity.

Rolling ADF Tests (2)

FTSE



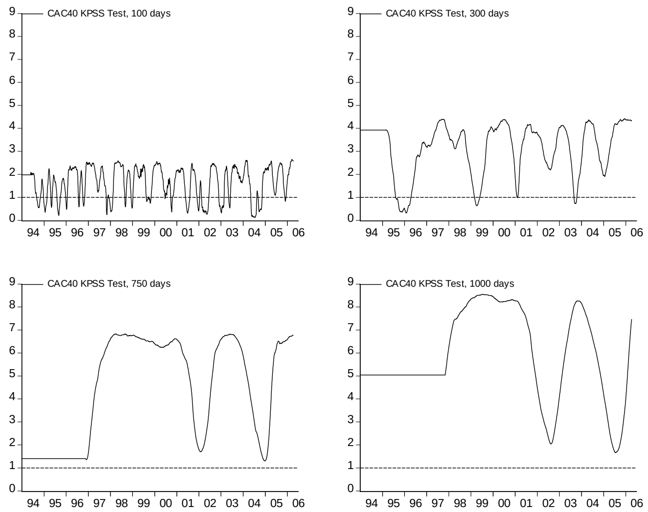
NYSE



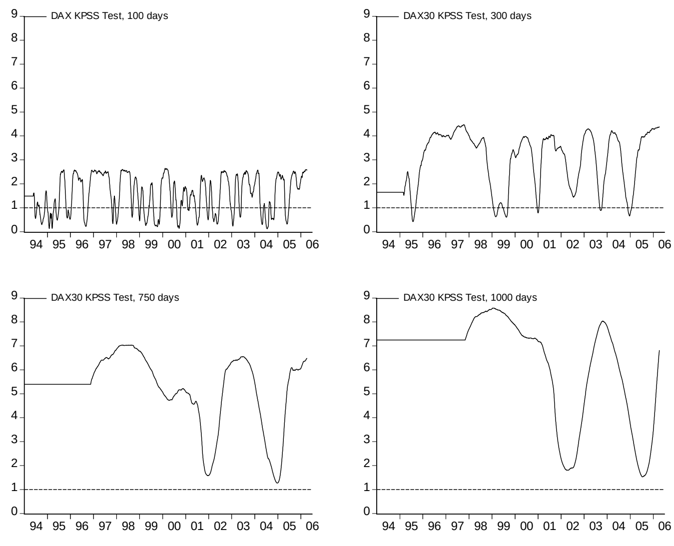
Appendix 2

Rolling KPSS Tests (1)[16]

CAC



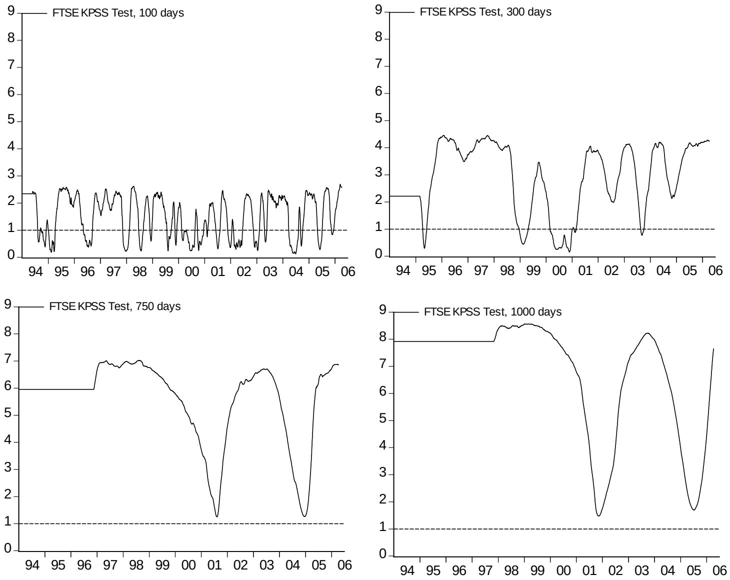
DAX



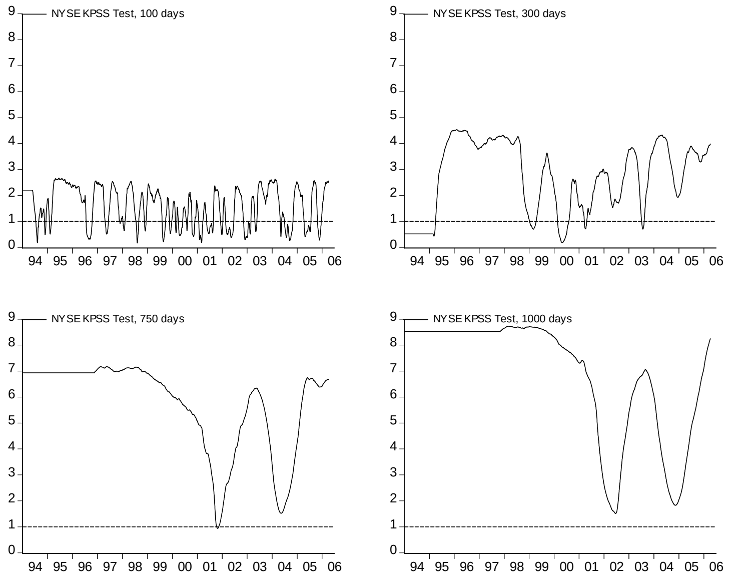
[16] Tests are run on rolling samples of 100, 300, 750 and 1000 days between 1994 and 2006. The test statistic is normalized by the critical value such that the null hypothesis of stationarity is rejected if the test statistic is greater than unity.

Rolling KPSS Tests (2)

FTSE



NYSE



Appendix 3

VECM Estimations[17]

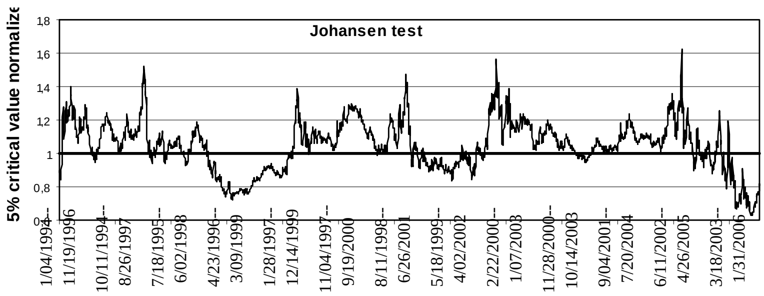
$$\Delta \ln \begin{pmatrix} NYSE \\ DAX \\ CAC \\ FTSE \end{pmatrix}_t = \alpha\beta'. \ln \begin{pmatrix} NYSE \\ DAX \\ CAC \\ FTSE \end{pmatrix}_{t-1} + \sum_{s=2}^{S} \Phi_s \Delta. \ln \begin{pmatrix} NYSE \\ DAX \\ CAC \\ FTSE \end{pmatrix}_{t-s-1} + \mu + \epsilon_t$$

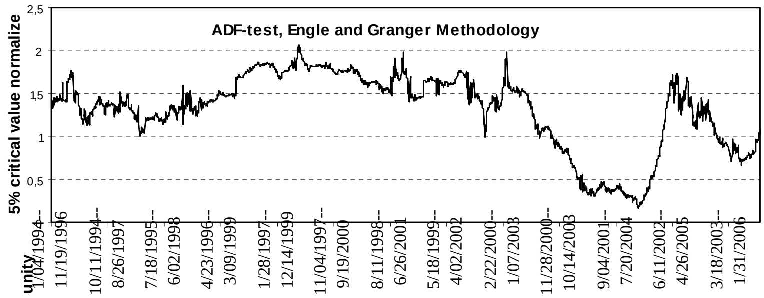
	$\Delta \ln$(**NYSE**)	$\Delta \ln$(**DAX**)	$\Delta \ln$(**CAC**)	$\Delta \ln$(**FTSE**)
$\Delta \ln$(**NYSE(-1)**)	**−0.182** (−7.91)	**−0.083** (−2.09)	−0.049 (−1.35)	−0.001 (−0.02)
$\Delta \ln$(**NYSE(-2)**)	−0.014 (−0.62)	**0.117** (2.90)	**0.068** (1.84)	**0.079** (2.78)
$\Delta \ln$(**NYSE(-3)**)	−0.035 (−1.49)	−0.004 (−0.10)	−0.02 (−0.54)	0.001 (0.35)
$\Delta \ln$(**NYSE(-4)**)	−0.027 (−1.26)	**−0.079** (−2.09)	**−0.094** (−2.72)	**−0.052** (−1.96)
$\Delta \ln$(**DAX(-1)**)	**0.080** (3.49)	−0.062 (−1.57)	0.015 (0.41)	−0.35 (−1.25)
$\Delta \ln$(**DAX(-2)**)	0.021 (0.93)	0.011 (0.28)	−0.014 (−0.37)	−0.031 (−1.09)
$\Delta \ln$(**DAX(-3)**)	**−0.046** (−1.98)	−0.06 (−1.51)	−0.065 (−1.78)	−0.033 (−1.17)
$\Delta \ln$(**DAX(-4)**)	−0.033 (−1.45)	−0.038 (−0.98)	−0.049 (−1.36)	**−0.066** (−2.38)
$\Delta \ln$(**CAC(-1)**)	0.046 (1.82)	0.053 (1.21)	−0.013 (−0.33)	**0.061** (1.98)
$\Delta \ln$(**CAC(-2)**)	0.033 (1.32)	0.049 (1.14)	0.053 (1.33)	0.038 (1.24)
$\Delta \ln$(**CAC(-3)**)	0.043 (1.72)	0.008 (0.196)	0.003 (0.079)	0.019 (0.61)
$\Delta \ln$(**CAC(-4)**)	0.037 (1.48)	0.063 (1.46)	0.044 (1.10)	**0.098** (3.19)
$\Delta \ln$(**FTSE(-1)**)	**0.120** (4.55)	−0.032 (−0.71)	−0.045 (−1.08)	**−0.079** (−2.49)
$\Delta \ln$(**FTSE(-2)**)	−0.042 (−1.59)	**−0.127** (−2.79)	**−0.128** (−3.04)	**−0.086** (2.67)
$\Delta \ln$(**FTSE(-3)**)	0.011 (0.41)	0.039 (0.87)	0.030 (0.72)	−0.029 (−0.92)
$\Delta \ln$(**FTSE(-4)**)	0.015 (0.56)	0.039 (0.85)	0.031 (0.75)	−0.034 (−1.07)
Intercept	**0.037** (2.37)	0.034 (1.26)	0.032 (1.27)	0.019 (1.04)
$\boldsymbol{\alpha}$	0.051 (0.43)	0.261 (1.29)	**0.374** (2.00)	**0.289** (2.01)
R^2	0.069	0.016	0.015	0.016

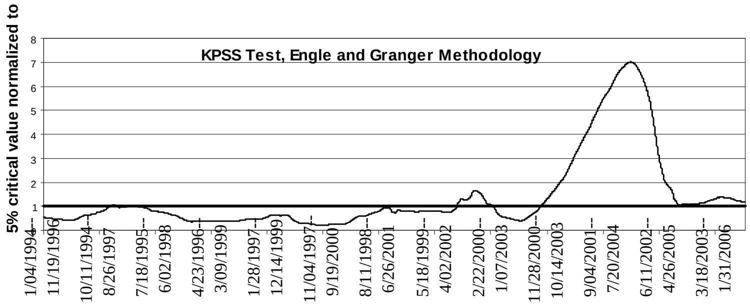
[17] VECM is performed on index returns (%) for the sample 01/07/1994 - 30/04/2006. Lag lenght is selected using the Akaike and Schwartz information criteria. The variable *coint* is obtained from the long run relation displayed in table 6 (β coefficients) between log indexes. The t-student are reported below the coefficients.

Appendix 4

Cointegration tests[18]



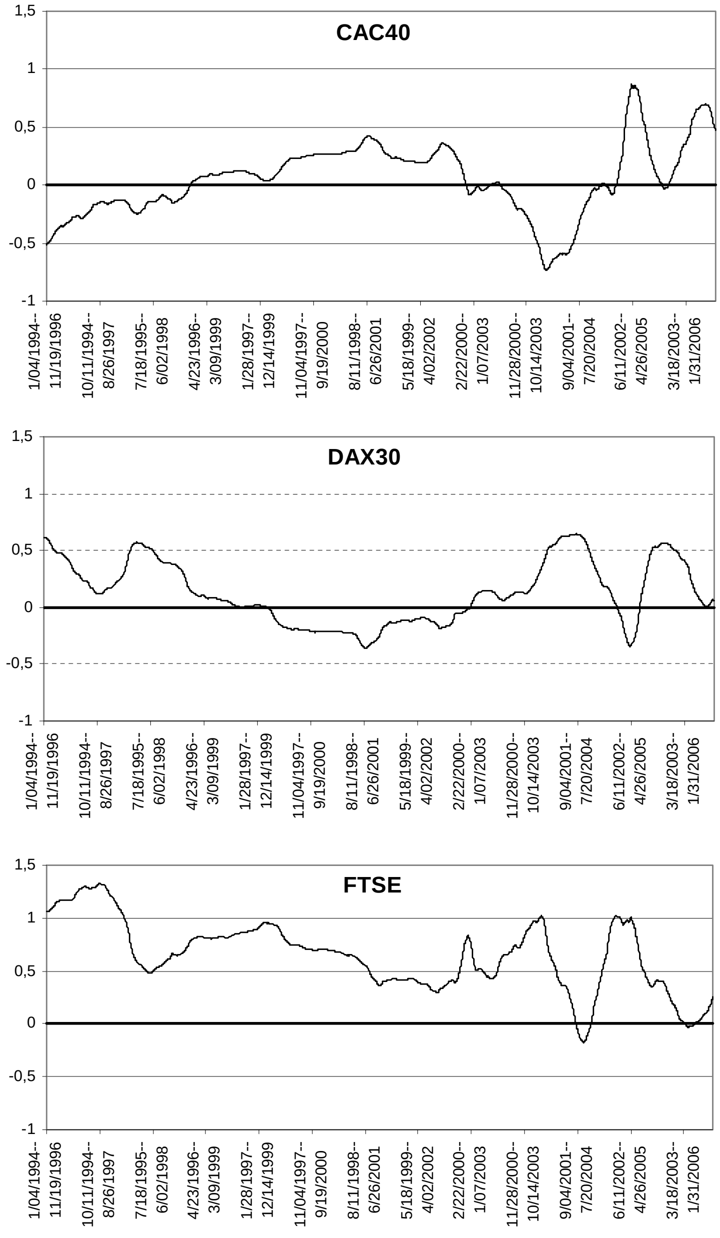




[18] JJ tests for cointegration and ADF-KPSS tests for white noise long run residuals are run on overlapping rolling windows of 750 days. Each critical value is normalized to unity such that: 1/ JJ tests conclude cointegration if test statistic is greater than unity; 2/ ADF tests conclude cointegration if test statistic is greater than unity. 3/ KPSS tests conclude cointegration if test statistics smaller than unity.

Appendix 5

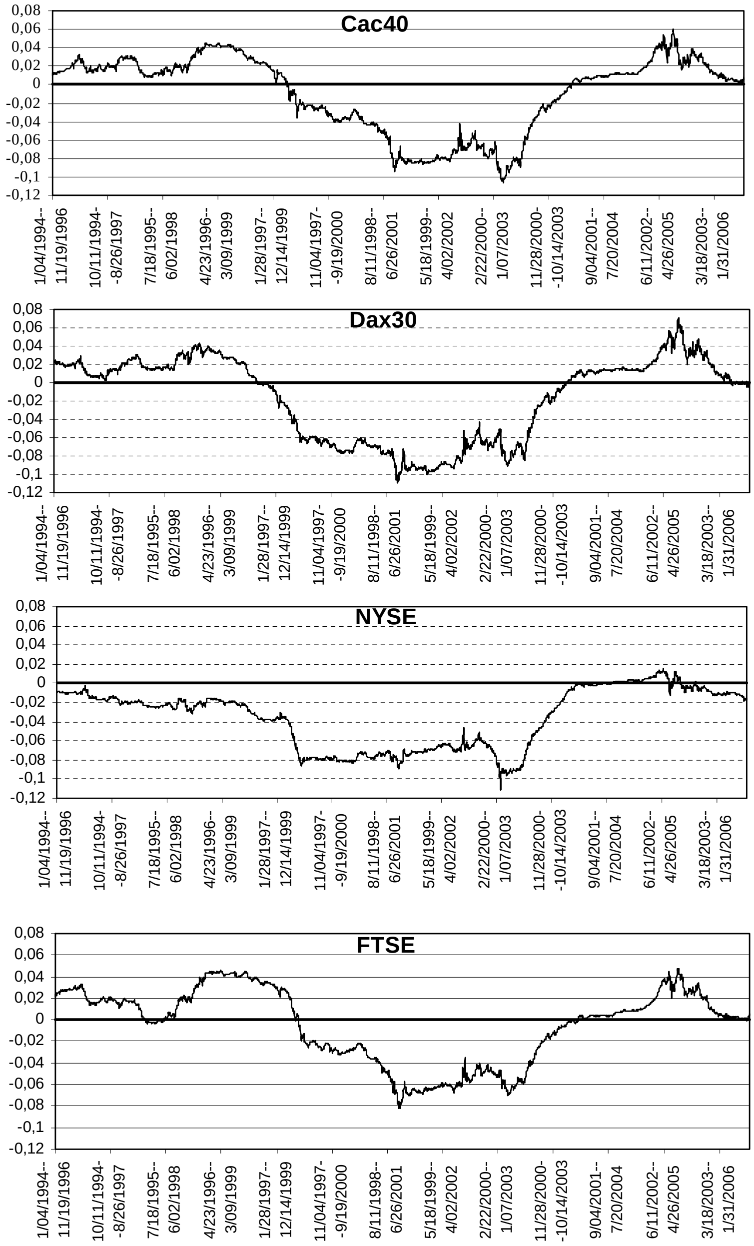
Long run coefficient estimations[19]



[19] Coefficients are obtained from OLS long run regressions of the log indexes. NYSE index is normalized to unity.

Appendix 6

ADJUSTMENT COEFFICIENT ESTIMATIONS[20]



[20] Adjustment coefficients are obtained from the overlapping rolling VECM on log indexes on the basis of 750 days, from 1994 to 2006.

Appendix 7

MVGARCH Estimation Results[21]

$$H_t = (\bar{H} - B'\bar{H}B - G'\bar{H}G - A'\Im'\bar{H}\Im A) + B'\varepsilon'_{t-1}\varepsilon_{t-1}B + G'D'_{t-1}R_{t-1}D_{t-1}G + A'\eta'_{t-1}\eta_{t-1}A \ .$$

$$h_{ij,t} = (1 - b_i b_j - g_i g_j - I_{i,t-1} \times I_{j,t-1} \times a_i a_j)\overline{h_{ij}} + b_i b_j \varepsilon_{i,t-1}\varepsilon_{j,t-1} + g_i g_j h_{ij,t-1} + a_i a_j \eta_{i,t-1}\eta_{j,t-1} \ ,$$

variable(i)	$\mathbf{b}_i\mathbf{b}_{NYSE}$	$\mathbf{b}_i\mathbf{b}_{DAX}$	$\mathbf{b}_i\mathbf{b}_{CAC}$	$\mathbf{b}_i\mathbf{b}_{FTSE}$
NYSE	0.0354	0.0384	0.0360	0.0430
DAX	0.0384	0.0418	0.0391	0.0467
CAC	0.0360	0.0391	0.0366	0.0437
FTSE	0.0430	0.0467	0.0437	0.0522

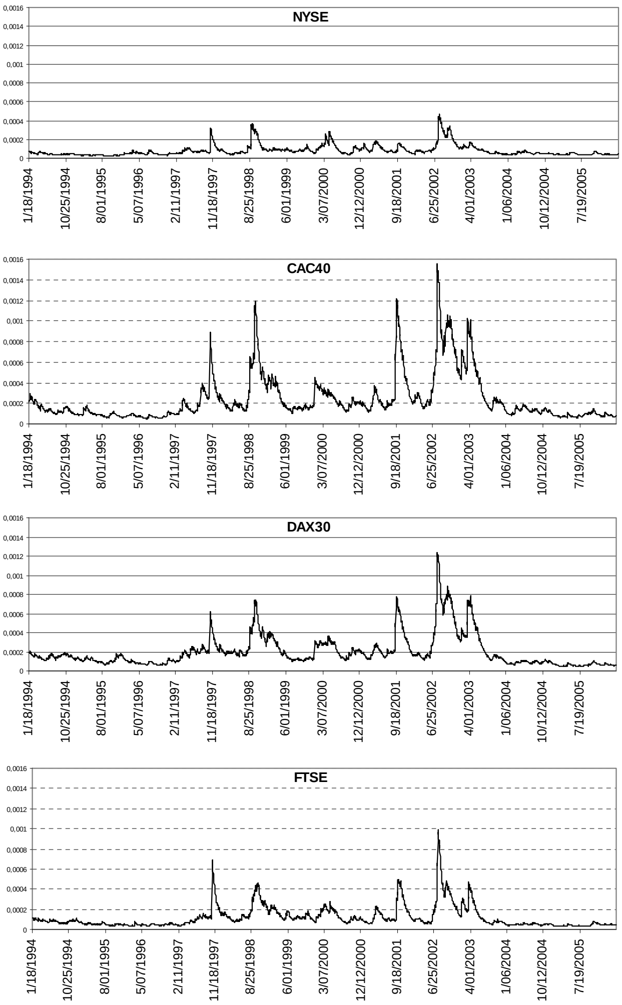
variable(i)	$\mathbf{g}_i\mathbf{g}_{NYSE}$	$\mathbf{g}_i\mathbf{g}_{DAX}$	$\mathbf{g}_i\mathbf{g}_{CAC}$	$\mathbf{g}_i\mathbf{g}_{FTSE}$
NYSE	0.9384	0.9406	0.9470	0.9377
DAX	0.9406	0.9429	0.9493	0.9400
CAC	0.9470	0.9493	0.9557	0.9463
FTSE	0.9377	0.9400	0.9463	0.9369

variable(i)	$\mathbf{a}_i\mathbf{a}_{NYSE}$	$\mathbf{a}_i\mathbf{a}_{DAX}$	$\mathbf{a}_i\mathbf{a}_{CAC}$	$\mathbf{a}_i\mathbf{a}_{FTSE}$
NYSE	0.0091	−0.003	0.0010	0.0016
DAX	−0.003	0.0010	−0.0003	−0.0005
CAC	0.0010	−0.0003	0.0001	0.0002
FTSE	0.0016	−0.0005	0.0002	0.0003

[21] Estimated parameter matrices are obtained from the MVGARCH implemented on the VECM residuals estimated between January the 4^{th} 1994 and April the 30^{th} 2006.

Appendix 8

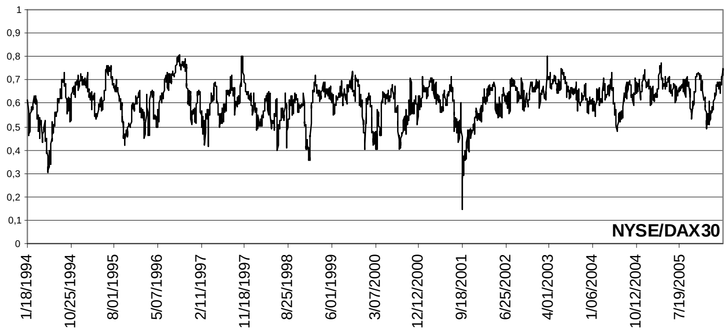
VOLATILITIES[22]

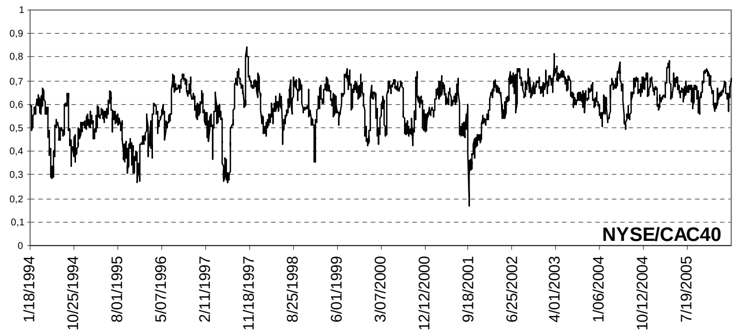


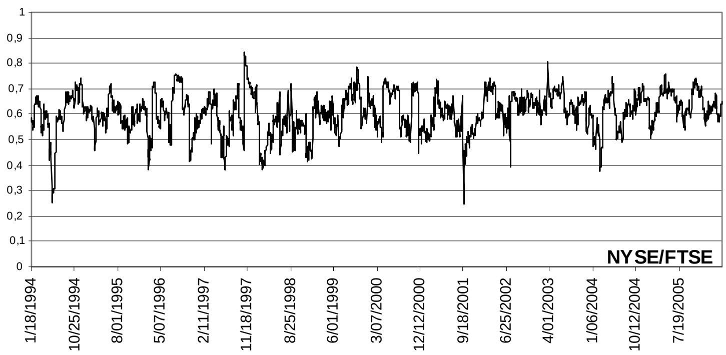
[22]Volatilities are obtained from the DCC model estimated on the VECM residuals between January the 4^{th} 1994 to April the 30^{th} 2006.

Appendix 9

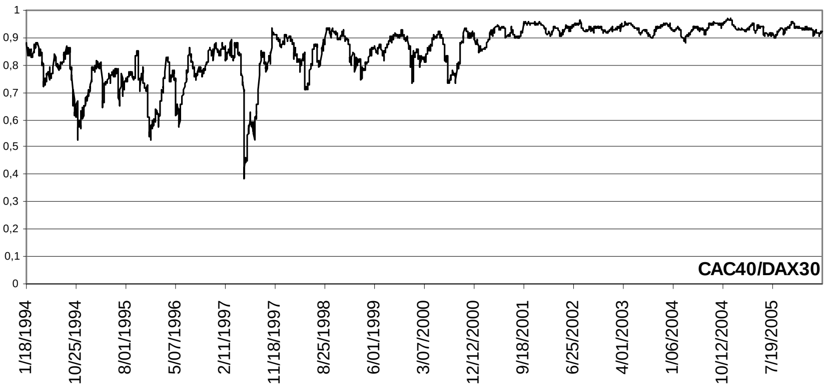
Dynamic correlations[23]

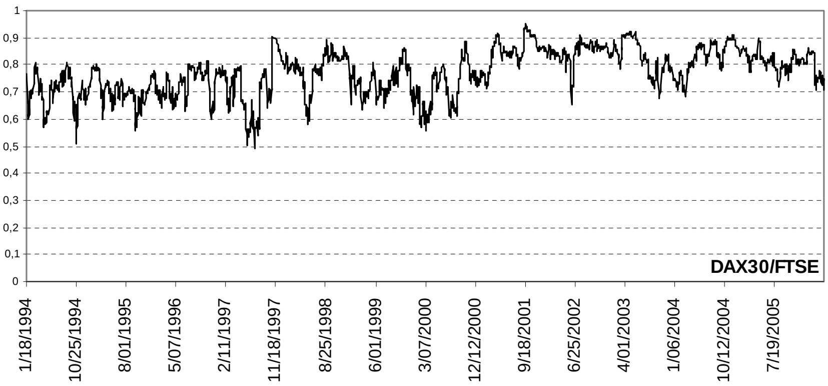


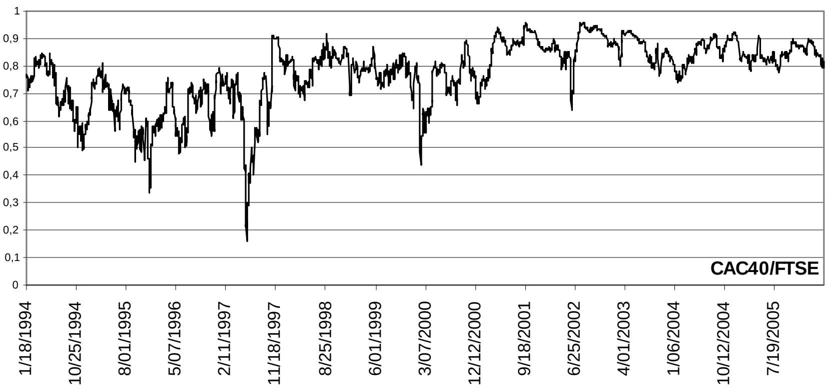




[23] Dynamic correlations are obtained from equation 8 of the DCC model estimated on a daily basis between January the 4^{th} 1994 and April the 30^{th} 2006.


CAC40/DAX30


DAX30/FTSE


CAC40/FTSE

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