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No contagion, only globalization and flight to quality

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No contagion, only globalization and flight to quality

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Abstract

In this article, tests for globalization and contagion are separated using an *ex* ante definition of crises, and contagion tests are neutralized with respect to globalization effects. A large database is constructed to study the stability of correlation matrices for four asset classes: equities, government bonds, investment-grade corporate bonds, and high-yield corporate bonds, in four geographical zones. Overall, the results confirm the instability of correlations and point to a combination of globalization and flight to quality, while emphasizing that contagion on the equity markets appears as an artifact due to globalization.

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1. Introduction

The interdependence of financial markets is a serious concern for investors looking to diversify their portfolios internationally. However, two analytical frameworks exist side by side on this issue. Some see economic globalization, coupled with the growing integration of financial markets, as the main reason for the uptrend in correlations among international stock markets. Others attribute the correlation movements to market contagion during crises.[1]

On the one hand, the globalization phenomenon, i.e., the general increase of correlations within asset classes and across geographical areas over the past decades, is well documented, both for equities[2] (Berben and Jansen, 2005; Morana and Beltratti, 2008) and for government bonds (Hunter and Simon, 2004). On the other hand, crises can be transmitted to markets other than those in which they originate, leading to a contagion effect. Empirical studies (Billio and Caporin, 2010; Corsetti et al., 2005; De Santis and Gérard, 1997; Hossein and Nossman, 2011; Lin et al., 1994; Wälti, 2003) find that correlations increased in equity markets during hectic periods, pointing to the presence of contagion. However, according to Hartmann et al. (2004), equity markets are twice as likely as bond markets to crash simultaneously.

[1] The existing definitions of contagion are reviewed by Pericoli and Sbracia (2003). In this paper, we follow Forbes and Rigobon (2002) who define contagion as "*significant increase in cross-market linkages after a shock.*" Some authors claim that contagion is driven by fundamentals (Erdorf and Heinrichs, 2011; Kodres and Pritsker, 2002), while others view contagion as created by over-reactions (Broner et al., 2006; Goldstein and Pauzner, 2004). The definition proposed by Forbes and Rigobon (2002) is wide enough to cover both possibilities. Moreover, this definition allows dealing with various types of shocks, which is consistent with the stance taken in this paper.

Besides, correlations across different asset classes are shown to decrease in times of crises, creating potential for diversification through asset allocation (Hunter and Simon, 2004; Smith, 2002). This is particularly the case for correlations between bonds and equities (Connolly et al., 2005). The contrast between the global increase within each asset class and the correlation decrease across asset classes seems to be explained by the effect known as "flight to quality" (Baur and Lucey, 2009; Hartmann et al., 2001; Inci et al., 2011), where investors shift funds towards safer assets, leading to "decoupling": higher correlations within the equity markets but negative correlations between government bonds and equities (Gulko, 2002). The decrease in equity and bond correlations during crises, attributable to flight to quality effects, may be present whether associated or not with contagion.

Contagion can be confused with globalization since both have a tendency to increase correlations among assets, especially during periods of high volatility coupled with bear markets (Chesnay and Jondeau, 2001; Longin and Solnik, 1995, 2001; Silvapulle and Granger, 2001). In a theoretical paper, Calvo and Mendoza (2000) show that globalization may promote contagion by weakening incentives for gathering costly information. On empirical grounds, Forbes and Rigobon (2002) deny the existence of contagion as such. They point to a high level of market co-movement in all periods, not only crises – a phenomenon they refer to as interdependence. Similar results are found by Flavin and Panopoulou (2009). Our paper attempts to go further in dissociating globalization and contagion phenomena by testing them separately while including all financial crises from 1978 to 2010.

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[2] However, using a new parsimonious risk-based factor model, Bekaert et al. (2009) find no upward trend in stock return correlations, except for the European markets.

Contagion and globalization are not necessarily mutually exclusive, but they are difficult to separate econometrically (Bekaert et al., 2005). One major problem consists in identifying precisely what constitutes a crisis period. For investors, though, the practical consequences will be different depending on whether these developments are attributable to increasing market globalization or to crisis contagion. In the first case, a gradual but unstoppable movement can be expected. In the second, investors will have to be especially careful when international volatility is high, because increased risk will be compounded by a decline in diversification protection. Optimal portfolio management depends on proper identification of the effects at work.

This article makes use of the tests for correlation stability laid down by Jennrich (1970) and refined by Goetzmann et al. (2005) through new advances in asymptotic theory. We propose an original empirical study that is broadly scoped in terms of geographical coverage and asset classes. We abide by established crisis definitions to avoid a personal classification that might be tainted by endogeneity.

Although most research has concentrated on equity markets, we broaden our scope to include government and corporate bonds, the latter being almost completely uncharted in the literature on globalization and contagion.[3] We also distinguish between investment grade (IG) and high yield (HY) bonds, so as to segment bond products according to whether they are primarily dependent on interest rate risk or on default risk. Furthermore, we simultaneously analyze the impact of 16 crises on asset markets

[3] with the exceptions of Annaert et al. (2006), Hunter and Simon (2004), and Smith (2002).

between 1978 and 2010. Securities are divided into 15 categories depending on their financial characteristics and geographical zone.

Our results confirm the presence of globalization, with several nuances. In particular, the bond market segments do not appear to be greatly affected. By contrast, contagion effects are not corroborated by the data when corrected for globalization. In addition, our findings suggest that the tendency towards flight to quality dominates during crisis periods.

The remainder of the article is organized as follows. Section 2 presents the tests for correlation stability that will be used in the empirical section. Section 3 describes the database. Sections 4 and 5 form the heart of the article, proposing globalization tests followed by contagion tests. In the latter case, the definition of crises necessitates some documentary research, which we describe in Appendix 1. Section 7 concludes.

2. Testing the stability of correlations between financial series

Correlations among financial data series are a key tool in portfolio management and risk control. Markowitz's classic model is based on knowledge of the entire covariance matrix of returns, and hence of all correlations within the set of securities analyzed. The assumption that these parameters remain stable over time guarantees the consistency of forecasts based on past data. But this stability has recently been challenged by a large body of econometric research (see, e.g., Engle, 2002; Okimoto, 2008; Osborn et al., 2008).

In recent years, analyses of the stability of variances, covariances and correlations have developed considerably. The main problem lies in identifying the observation dates corresponding to crises. Unfortunately, crises are generally identified by high volatility in one or more asset classes that are being tested for correlations, and splitting the sample *ex post* creates potential distortions through selection bias (Boyer et al., 1999). It is nevertheless possible to test the stability of correlations versus the onset of contagion during crises provided that these crises are delineated beforehand. Therefore, we identify crises based on their fundamental determinants, not on equity or bond volatility (see Appendix 1). This exercise, however, is delicate. In particular, the end dates of crises are difficult to assess. Indeed, a crisis typically starts with the outbreak of a major event, but ends with a slow return to normal market conditions. Once crises periods have been delineated, we test the null hypothesis of equality between all correlations across assets both during crises and normal periods.

To compare correlation matrices, we use the methodology proposed by Goetzmann, Li and Rouwenhorst (2005) (GLR) who generalize the Jennrich (1970) test[4] based on the chi-square distance between two correlation matrices. The GLR approach extends the Jennrich (1970) test by relaxing the restrictive requirement of normal distribution of the underlying return series.

Consider x the random vector composed of p asset returns. This vector has finite moments up to the fourth. Vector μ and matrix Σ denote its first and second centralized moments, respectively:

[4] The Jennrich (1970) test is applied by Kaplanis (1988) and Annaert *et al.* (2006), among others.

$$\mu = E(x), \quad \Sigma = E(x-\mu)(x-\mu)'$$

The full sample period is split into two sub-periods: period 1 of length n_1, and period 2 of length n_2. The true and sample correlation matrices for sub-period *k* (*k* = 1, 2) are denoted by P_k and $\hat{P}_k$, respectively. Browne and Shapiro (1986) and Neudecker and Wesselman (1990) provide the asymptotic distribution of correlation matrices under the assumption that the observation vectors are independently and identically distributed. Using this result on each subsample yields the existence of matrices Ω_1 and Ω_2 such that:

$$\sqrt{n_k}\, vec\left(\hat{P}_k - P_k\right) \xrightarrow{d} N\left(0, \Omega_k\right), \quad k = 1, 2 \tag{1}$$

Further, the GLR test makes it possible to check whether the correlation matrices of periods 1 and 2 are different. This test corresponds to the following hypotheses:

$$\begin{aligned} &H_0 : P_1 = P_2 = P \text{ and } \Omega_1 = \Omega_2 = \Omega \\ &H_1 : P_1 \neq P_2 \text{ or } \Omega_1 \neq \Omega_2 \end{aligned} \tag{2}$$

Under H_0, we have:

$$vec\left(\hat{P}_1 - \hat{P}_2\right) \xrightarrow{d} N\left[0, \left(\frac{1}{n_1} + \frac{1}{n_2}\right)\Omega\right] \tag{3}$$

Hence, GLR derive the chi-square test statistic used in this paper:[5]

$$\left[vec\left(\hat{P}_1-\hat{P}_2\right)\right]^T\left[0,\left(\frac{1}{n_1}+\frac{1}{n_2}\right)\Omega\right]^{-1}\left[vec\left(\hat{P}_1-\hat{P}_2\right)\right]\xrightarrow{d}\chi^2\left[rk\left(\Omega\right)\right] \qquad (4)$$

Although the GLR method simultaneously tests the equality of correlation matrices and of asymptotic covariance matrices,[6] this method remains the most effective way of dealing with the case of *p*-variate distributions where $p>2$. Moreover, GLR underline that return heteroskedasticity does not adversely affect their test because correlations are scale-free. Correlation matrices can, therefore, be computed from normalized series. This is a notable advantage of the GLR approach.[7]

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[5]Explicitly, matrix Ω is given by:

$$\Omega=\left[I-M_s\left(I\otimes P\right)M_d\right]\left(\Lambda^{-1/2}\otimes\Lambda^{-1/2}\right)V\left(\Lambda^{-1/2}\otimes\Lambda^{-1/2}\right)\left[I-M_d\left(I\otimes P\right)M_s\right]$$

with *I* the identity matrix, *P* the correlation matrix of the returns on the global sample period, Λ a matrix containing the diagonal elements of the covariance matrix of the returns, and:

$$M_d=\sum_{i=1}^{p}\left(E_{ii}\otimes E_{ii}\right)$$

$$M_s=\frac{1}{2}\left[I_{p^2\times p^2}+\sum_{i=1}^{p}\sum_{j=1}^{p}\left(E_{ij}\otimes E_{ij}'\right)\right]$$

$$V=E\left[\left(x-\mu\right)\left(x-\mu\right)'\otimes\left(x-\mu\right)\left(x-\mu\right)'\right]-\left[\left(vec\left(\Sigma\right)\right)\left(vec\left(\Sigma\right)\right)\right]$$

E_{ij} is a $p\times p$ matrix with 1 on $\left(i,j\right)$ and 0 elsewhere.

[6] Following Kim and Finger (2000), Ragea (2003) suggests broadening the range of possible distributions during crises and normal periods, using a mixture of normal distributions. Unfortunately, Ragea (2003) confines his study to the bivariate case where the stability of a single correlation coefficient is tested. Another option would be using covariance matrices rather than correlation matrices. However, as Kaplanis (1988) and d'Addona and Kind (2006) have noted, such an approach entails a massive rejection owing to the considerable variability of variances.

[7] Nevertheless, the test does not allow taking into account short-term movements in the correlation matrices.

3. Data

The database includes weekly returns to indices for equities, government bonds and corporate bonds, based on geography and, in the case of bond indices, on ratings. The series are the longest we could find for each asset class since the purpose is to study the impact of globalization which is, by definition, a long-term phenomenon.

Our analysis focuses on four geographical areas: the U.S., the Eurozone, Japan and the U.K. For equities, we use the indices constructed and supplied by Datastream (DS indices) for the period from August 1978 to December 2010. These indices are denominated in local currencies and include dividends. They are weighted and cover at least 75% of the total capitalization of the markets they represent.

For government bonds, we take the 10-year benchmark indices supplied by Datastream.[8] These indices, which include coupon returns, are usually based on a single bellwether, generally the last bond issued by the country's Treasury in a given maturity. Factors such as liquidity, issue size and coupons are also taken into account when choosing the index components. Weekly data are available from January 1980 onwards, except for Japan, where the series begins in January 1984.[9] Accordingly, the period under review goes from January 1984 to December 2010.

For corporate bonds, we use two categories: investment grade, with ratings between AAA and BBB^-, and high yield, rated from BB^+ to CCC. The indices are denominated

[8] For Eurozone, we use the German bond index.

in local currencies and include coupon returns. Convertible bonds are excluded. The weekly data cover the period between July 1998 and December 2010. They are sourced from Merrill Lynch (i.e. bids quoted by traders at the Merrill Lynch desk) at the market close.[10] All indices (both for bonds and for equities) have been hedged in dollars.[11]

[Insert Table 1 here]

As some data series (equities) are longer than others (HY bonds), the descriptive statistics in Table 1 have been established on the common observation period stretching from July 1998 to December 2010 (except for Japanese HY corporates) to allow for comparisons. Equities are the assets with the lowest annualized return, while HY corporate bonds display returns that are higher than those on IG bonds and equities. More interesting is the low level of standard deviations of IG and HY bond returns over the period. The reason probably lies in the weaker correlation between the interest rate component and the credit risk component, which move in opposite directions when the economic situation changes. This creates a compensating effect in corporate bond portfolios, decreasing the overall volatility at index level.

Skewness takes a negative value for all the assets under review, except for U.K. government bonds. Kurtosis exceeds the reference value of the normal distribution (equal to 3) for all countries and asset classes. This leptokurticity is typical of financial

[9] We choose weekly data to deal with a reasonably high frequency while avoiding the synchronization problems associated to daily data from markets located in different time zones.

[10] The indices have minor differences. For IG indices, we selected a maturity of 7 to 10 years. However, for HY indices, maturity was not proposed as a selection parameter, so there are small differences in durations.

[11] Here we take the viewpoint of a U.S. investor. However, currency hedging adds little volatility to the asset returns. Correlation matrices of hedged and unhedged returns show very few differences, so that considering local currency returns would deliver similar results.

data series. The non-normality of returns is confirmed by the Jarque-Bera test. Phillips-Perron tests (not reported here) confirm that all the series are stationary.

[Insert Table 2 here]

Table 2 shows all the correlations for the same period, marked by high equity market volatility, the "tech bubble" and a string of crises in bond markets and emerging economies. Broadly, correlations are significantly negative between equities and government bonds in all countries. By contrast, the correlations between high yielders and equities are significantly positive. This last result is consistent with the findings of several authors (Alexander et al., 2000; Fama and French, 1993). Co-movements between low-rated bonds and equities are commonly attributed to the importance of the credit risk component in HY bonds – a factor shared with equity returns. Likewise, correlations between IG bonds and equities are generally not significantly different from zero or are slightly negative. Within the same asset class, the strongest geographical correlations are found between the Eurozone and the U.K., with a maximum of 85% for equity markets and 83% for government bonds; and the weakest are those for Japan, as other research has shown (Berben and Jansen, 2005; Hunter and Simon, 2004).

4. Globalization tests

The recent literature tends to suggest that geographical correlations within asset classes have increased over the last 20 years. This is true for equities and government bonds. This situation is linked to the rise of globalization.

Relying on the approach presented in Section 2, we test the equality of correlation matrices using the GLR test. The sample is broken into two sub-periods of equal length. The break date thus varies according to the dataset under consideration. Since the aim of the test is to detect an evolving phenomenon, the precise break date is not vital. Moreover, the results are not affected if the date is shifted slightly. We have therefore opted for a symmetrical choice, which is more accurate.

[Insert Table 3 here]

Table 3 summarizes the globalization tests performed with our database according to the econometric setting in (3) and (4). The result of the test carried out on all asset classes (16 indices, minus Japanese HY bonds, for which data are unavailable) is given in the first row of Table 3. It shows that the differences in correlation between the two sub-periods are significant for all asset classes under consideration, thus confirming the impact of globalization on market interdependence.

But this finding, which confirms those established previously for international equity markets (Berben and Jansen, 2005; Chesnay and Jondeau, 2001), should be treated with caution. This is because the GLR test is bilateral, and the statistic measures the correlation differences, both positive and negative, between sub-periods. To give a clearer picture of the impact for each asset category, we show the correlation differences in Table 4: $\Delta\rho_{ij} = \rho_{ij}(\text{period 2}) - \rho_{ij}(\text{period 1})$.

[Insert Table 4 here]

If all the correlations had increased, the table would show positive items only. But this is certainly not the case. Taking a closer look, however, we can see that the negative items in Table 4 mainly concern the correlations between different types of asset. For example, the correlation between U.S. Treasuries and European equities fell 6.8%. Interpreting this type of observation is obviously problematic and the link with the intuitive idea of globalized financial markets[12] remains vague.

We therefore ran a second set of intra-asset class tests using the three 4X4 matrices and the 3X3 matrix from the lower rows of Table 3. The results point clearly to a globalization effect in the equity, government bond, and HY bond market but none whatsoever in the IG corporate bond markets. Accordingly, there appears to be no globalization in this bond market segment.

In terms of methodology, there is a major difference between the first test and the last four. Whereas the statistics from the former set mix geographical and inter-class globalization, the latter take account of purely geographical correlations only. In sum, our results point to globalization in equity markets combined with a reduction of correlation between equities and bonds. The data for same-type geographical corporate bonds lead us not to dismiss the stable correlation hypothesis.

[Insert Table 5 here]

Lastly, as a robustness check, we re-run the globalization tests excluding all crisis periods from the sample. The results displayed in Table 5 show few differences with

[12] In fact, the literature focuses mainly on the increasing correlations between equity markets. To our knowledge, the expected impact of globalization on inter-class correlations has not been addressed.

those in Table 3. This confirms the overwhelming evidence of globalization in international financial markets.

5. Contagion tests

Our definition of "crisis" is broad. It encompasses five types of movement: currencies, sovereign debt, events arising from a bond or equity crash, corporate bankruptcies or loss of confidence (Enron, WorldCom), and other crises of confidence, such as terrorist attacks. We have deliberately omitted crises of a purely banking nature unless they are related either to currency crises, where the impact on financial assets is more diffuse, or to economic crises such as recessions or oil shocks. The real difficulty lies in establishing precise timeframes for the crises we have selected.

The start and end dates used in this article (Table 6) have been chosen solely on the basis of previous papers (Appendix 1), thereby avoiding, at least partially,[13] the problem of endogeneity raised in Section 2. Admittedly, while the onset of a crisis is usually easy to identify, the end date is much harder to pinpoint. This awkward problem is highlighted by the Asian crisis (Appendix 1), which several authors have studied.

[Insert Table 6 here]

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[13] The reference to earlier paper does not fully protect our results from endogeneity biases, as the way other authors have dealt with this issue might well have consequences on our results. Nevertheless, as far as volatility tests are concerned, no full protection against endogeneity does exist currently. Moreover, endogeneity would push our test results toward the acceptance of contagion. Therefore, the fact that this paper ends up rejecting contagion testifies against the presence of any significant endogeneity bias.

Figure 1 plots the dates of the crises, regardless of type, and shows that the majority occurred from the 1990s onwards. This may be due to pure randomness or to a short-sighted choice of turbulent periods, i.e. a tendency to choose only the most recent crises.

[Insert Figure 1 here]

The GLR contagion test consists in comparing correlations among all markets, segregating crisis periods from other periods. This test draws on the assumption that all crises share at least some common features regarding correlation matrices. In fact, this is the very rationale for considering contagion as a general phenomenon applying to all sorts of crises. Conversely, if crises were singular events with no common features at all, then trying to find any kind of regularity, such as contagion across markets, would be pointless. However, the assumption that crises are associated to an overall increase in correlations is less stringent than it looks. Indeed, our test statistic computes only one correlation matrix for each type of regime (crisis and non-crisis) and then compares these matrices. Consequently, neither the crisis periods nor the quiet periods need to be uniform regarding within-period correlations.

Table 7 gives the results of the contagion tests. The results of the first four rows show that contagion is observed neither globally nor in the bond segments of the world markets.

[Insert Table 7 here]

Contagion in the equity market is significantly detected at the 5% level, but not at the 1% level. In light of this result, we wanted to rule out the possibility that globalization could spill over to contagion. Financial globalization at world level,[14] which basically corresponds to the closer synchronization of economic cycles, can manifest itself in different ways. If, in addition, there is a contagion effect, this compounds the globalization effect. Since the crises identified earlier, shown in Table 5 and Figure 1, are over-represented in the second half of the sample period, there is indeed a risk that globalization will be confused with contagion.

To overcome the awkward problem of identification, we adjust the time periods to ensure that, for the entire period tested, crises no longer appear systematically at the beginning or the end of the sample. If the crises are spread evenly over the time interval under consideration, then the globalization effect will be "neutralized". As reported in the last two columns of Table 6, adjusting the intervals does indeed affect the equity contagion result. Indeed, taking into account the adjusted sample period, contagion in the equity market is no longer significant, even at the 10% level. We therefore conclude that the contagion primarily detected in the unadjusted (full) sample period actually appears to be an artifact caused by globalization. This observation probably explains the confused interpretation of some of the results presented in the literature.

The mixed case of the equity-bond link is harder to deal with because, by nature, it cannot be segregated in a specific correlation matrix, since the matrix always includes geographical correlations between equities and bonds as well. Therefore, we adapted the GLR test to partial correlation matrices by isolating the cross-correlations only, i.e. correlations between assets of different categories. For instance, in the first reported test

[14] Or at least in so-called developed countries (Shackman, 2006).

of this category (see Table 6, second part, first row) the correlations between the U.S. sovereign and E.U. IG bonds are taken into account because the assets belong to different classes, while the correlations between the U.S. and E.U. sovereign bonds (same class assets) are excluded. In other words, these additional tests pick only on the pairs of securities that could generate flight-to-quality effects and rule out the ones that are more likely to be associated with contagion.

Among the six possibilities, only two lead to significant differences in correlation: GVT bonds/IG bonds and GVT bonds/equities. Moreover, these findings are not affected by the correction for globalization. Thus, crises do indeed affect the bond markets, but through cross-correlations, not intra-class correlations. Moreover, the presence of a flight to quality in times of crisis is observed with no doubt. Scared by turbulence, investors pull out of the markets they consider too risky and seek safety in reliable bond issuers, especially governments. This flight-to-quality effect drives risk premia higher and reduces the correlations – some already deeply negative – between asset categories. The movements can be very large. Table 8 shows the correlation differences between crisis and quiet periods for the two pairs of assets that tested positively for this effect.

[Insert Table 8 here]

In conclusion, to prepare for crisis periods, diversifying between equities and bonds while employing an appropriate fixed-income management strategy is just as important, if not more so, as managing the portion of the portfolio reserved for equities, even global equities. In this respect, there is good news for investors: even though equity volatility rises during periods of turmoil, it is offset – at least partially – by a steep fall in correlations with high quality bonds. The flight to quality acts as an antidote to the perverse effects of crises on the global financial markets. Detecting it should therefore help to prevent the harmful effects of stock market crises.

6. Conclusions

Correlations on financial markets are broadly unstable. Two main factors are usually cited to explain breaks in correlations: economic globalization and crisis contagion. Structurally, these two factors are very different. Confusing them would have a harmful impact on portfolio management. For analysts, therefore, distinguishing between globalization and contagion is a real challenge. However, econometric research often tries to detect one or other of the effects, without considering the possibility that the results could be misinterpreted. To avoid that pitfall, we have used a sequential process that considers, firstly, the possibility of globalization and, secondly, overlying contagion.

Empirically, the data examined in this study are original in at least two regards: the asset classes and the number of market crises. There is a vast literature on the behavior of international correlations in equity markets and, to a lesser extent, in the government bond market, but very little has been written about corporate bonds. We have split corporate bonds into IG and HY in order to measure more accurately the flight to quality that occurs in periods of high volatility – an occurrence that market practitioners are thoroughly familiar with. Although the literature on this subject is evolving rapidly, we are not aware of any other articles that address this topic in such a general framework.

Our second contribution is the exhaustive nature of our crisis study. We have not limited ourselves – as is often the case in the literature – to one or two crises, such as Russia, Asia, LTCM, or Subprime. Instead, we have dealt simultaneously with all identifiable crises in an effort to test as exhaustively as possible the assumption that asset correlations change during periods of turmoil. We selected the start and end dates of these periods with the utmost care, drawing on previous research but without using our database. In this way, we have been able to avoid the distorting effects of endogeneity, which would have arisen had we used realized volatilities to establish the dates.

In sum, our results confirm that globalization is present in all markets, with the borderline exception of corporate IG bonds. We therefore look for contagion, first disregarding the results of the globalization tests and then factoring them in. Contagion is immediately rejected for the fixed-income assets. Concerning equities, contagion is detected at the 5% level in the first test irrespective of globalization bias, but disappears when the appropriate correction is incorporated. Therefore, we conclude that contagion is an artifact caused by globalization. This no-contagion result is in line with the findings of both Forbes and Rigobon (2002) and Candelon *et al*. (2005).

Admittedly, we have considered only aggregate market classes in developed economies. Further work could concentrate on more disaggregated markets, such as individual countries belonging to the same world region (Europe, Asia, etc.). On the other hand, transition and emerging countries are fertile ground for applications of globalization and contagion tests. For instance, Dooley and Hutchison (2009) and Bartram and Bodnar

(2009) underline the impact of the recent financial crisis on emerging markets. Examining whether this evidence is attributable to globalization and/or contagion would indeed represent an interesting avenue for further research.

While globalization is a technologically – and economically – sound financial driver, contagion is often thought of as an easy way to represent the excess financial movements, i.e. those for which no fundamental explanatory variables have yet been found, as testified by the literature on speculative bubbles (Adam and Szafarz, 1993; Sornette and Malevergne, 2001; Salge, 1997; Szafarz, 2012). So, by cleaning the data from the globalization effect, we reduce as much as possible the residual volatility to be attributed to contagion.

Methodwise, the GLR test consists in opposing the null hypothesis of equal correlation matrices and the alternative of separate matrices, whatever the sign of the differences between entries. Conversely, the highly restrictive view states that globalization/contagion on a market must be characterized by an increase in correlations for *any* pair of securities in that market. A middle approach would be to introduce an asymmetric GLR-type test that makes it possible to consider only increases in correlations. Thus, a “signed” matrix generalization of the test used in this article would open up new horizons for investigating both globalization and contagion.

Moreover, the GLR test may suffer from distortions due to violations of the assumption of return independence. As pointed out by Corsetti et al. (2005), misspecifications in mean and/or variance dynamics can significantly bias correlation tests. A wider discussion could involve the link between increased correlations and the fat tail feature (see, e.g., Campbell et al., 2008).

Finally, the flight-to-quality effect has been shown to remain after globalization has been taken into account. This observation is good news for investors, who can partially hedge against the crises by benefiting from correlation reduction between risky assets and safer bonds (Brière and Szafarz, 2008). While the amplitude of this hedge deserves further investigation, the effect might decrease as traders realize that fleeing all risky assets ahead of an impending crisis is not the best option. In this respect, the flight to quality, like other market anomalies, is bound to disappear precisely because it has been identified. However, as pointed out by the behavioral finance stream of literature, some anomalies can prove self-fulfilling and persist much longer than expected under the rationality assumption. If indeed the flight to quality appears to be a consequence of irrational fears rather than of smart hedging attitudes during crises, then it will presumably last a long time.

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Appendix: Crises selected for study

In this study, we examine five types of crisis: (1) currency crises, (2) sovereign debt crises, (3) crises triggered by an equity or bond crash, (4) corporate bankruptcies or loss of confidence (e.g. the collapse of Enron), and (5) crises of confidence arising from severe external events (e.g. 9/11).

Currency crises

Mexico 1976

The onset of the Mexican crises is usually dated to August 31, 1976, when the authorities decided to allow the peso to float (Bordo and Schwartz, 1996). That decision sparked a dramatic rise in inflation. According to the authors, the crisis ended on October 26, 1976, when the authorities devalued the peso by 27% against the dollar.

Chile 1982

The Chilean crisis began on June 15, 1982, when the government devalued the peso by 18% (Bordo and Schwartz, 1996). The end of the crisis is generally dated to August 5, 1982, when the currency was left to float freely (De Gregorio, 1999; Cowitt, 1984).

Mexico 1982

The second Mexican crisis began on February 17, 1982, when the authorities announced a 30% devaluation of the peso. On 12 August 1982, the Mexican finance minister informed the chairman of the U.S. Federal Reserve, the Treasury Secretary and the managing director of the IMF that the country would be unable to meet its debt payments. The crisis then spread to other parts of Latin America, and by October 1983, 27 countries, including Brazil, Argentina and Venezuela, had either rescheduled their debt or were in the process of doing so. According to Bordo and Schwartz (1996), the crisis ended on September 1, 1982, when Mexico nationalized the banking system and imposed currency controls.

European Monetary System 1992

The EMS crisis began on September 16, 1992 when the Bank of England raised the base lending rate from 10% to 12% and announced the intention of raising it to 15% the next day (which it did not do). As a result, sterling dropped below its EMS floor rate. On September 19, the pound was ejected permanently from the exchange rate mechanism (ERM), followed by the Italian lira. In the aftermath, the currencies of Sweden, France, Spain and Portugal came under attack. The crisis ended with the adoption of an exchange rate mechanism very similar to a system of floating exchange rates, with the authorized fluctuation bands broadened to 15% (Bordo and Schwartz, 1996).

Mexico 1994

The crisis began on December 20, 1994 when Mexico decided to widen the peso's fluctuation band against the dollar. The end is generally dated to March 10, 1995 and the announcement of an austerity plan (Bordo and Schwartz, 1996; Whitt 1996). However, Candelon *et al*. (2005) say the crisis ended on December 31, 1994.

Asia 1997

According to the IMF, Chakrabarti and Roll (2002), and Dungey *et al.* (2004, 2006), the crisis began on July 2, 1997 when Thailand decided to allow the baht to float after it had come under attack on May 14 and 15. The Philippines, Hong Kong, South Korea, Malaysia, Indonesia and Singapore were caught in the downdraft. According to Kaminsky and Schmukler (1999), the end of the crisis can be dated to January 13, 1998, when investors were reassured by the announcement of government reforms in Indonesia and a merger between two Singapore banks, as well as by upbeat comments from Morgan Stanley strategists about the "end of the Asian bear market". Candelon *et al*. (2005) examined the Hong Kong crisis, which they situate in the period from October 17 to 31, 1997, while Caporale *et al.* (2005) deal with the entire Asian crisis. Lastly, Ball and Torous (2006) consider three possible durations for the crisis period: 1 year, 2 years and 3 years.

Brazil 1999

Dungey *et al.* (2006) say that the crisis began on January 13, 1999 with the devaluation of the real. It is hard to establish an end date because no landmark events occurred. However, the crisis is generally referred to as the "January 1999 Brazilian crisis". We have therefore taken the final date to be the end of January 1999.

<u>Sovereign debt crises</u>

Russia 1998

The Russian crisis began on August 17, 1998, when the country defaulted on its debt, and continued until September of that year, when another crisis was triggered by the collapse of the hedge fund LTCM. We have therefore considered these two crises jointly, setting the end date for both at the end of the LTCM crisis.

Argentina 2001

The crisis began on November 1, 2001 when Argentina announced a debt restructuring plan. On December 5, the IMF refused to release funds to help the country, and the Argentine president was forced to resign on December 20. On December 23, 2001 the country announced that it was in default. For investors, the announcement marked the end of the crisis, and emerging spreads began to narrow (BIS, 2002).

Crashes

1987 equity crash

The steep drop in prices that occurred on October 19, 1987 lasted just one day, but it took several months to return to pre-crash levels. It is therefore difficult to set a precise end date. We have assumed that the crisis lasted until December 7, 1987, the day that prices troughed but before the market began to rally.

1994 bond crisis

On February 4, 1994 the U.S. Federal Reserve announced it was increasing its policy rate, taking the bond market by surprise (BIS, 1995). The announcement triggered a wave of panic and resulted in a massive bond sell-off in all industrial countries. We have dated the end of the crisis to November 3, 1994 when the steep rise in long-term interest rates came to an end (by which time, 10-year yields in the U.S.A. had reached 8%).

2000 E-crash

Triggered by the crash in tech stocks, the equity meltdown began on March 28, 2000. We have dated the end of the crisis to April 14, 2000 when prices stopped falling. Thereafter, the market entered a period of stagnation.

Corporate bankruptcies and crises of confidence

LTCM 1998

The hedge fund Long Term Capital Management (LCTM) collapsed on September 23, 1998. Dungey et al. (2004) consider that the crisis ended when the U.S. Federal Reserve decided to cut interest rates in order to contain the fallout. The Fed's decision was taken unexpectedly between two FOMC meetings on October 15, 1998.

Enron 2001

The onset of the crisis can be dated to November 28, 2001 when Moody's Investor Services decided to downgrade Enron, taking it from investment grade to high yield. Although it was Moody's decision that sparked the mood of wariness which spread to all financial markets, signs that Enron was in trouble had emerged much earlier. On October 16, 2001 the company lowered its earnings guidance (BIS, 2002), and on November 8 it announced a retroactive adjustment to all its results since 1997. Enron filed for bankruptcy on December 2. It is extremely difficult to set a precise end date, and we consider that the crisis lasted throughout December.

WorldCom 2002

The crisis related to the bankruptcy of WorldCom began on June 25, 2002 when the company revealed accounting inaccuracies concealing losses of $3.8 billion in 2001 and 2002; it also announced 17,000 job cuts, equivalent to 20% of the workforce. WorldCom filed for bankruptcy on July 11, and its shares fell 80% over the next four months. Once again it is very hard to establish an end date because the loss of confidence was exacerbated by fears relating to terrorist attacks in May and June 2002 and to political tensions between India and Pakistan. According to the BIS (2002a), the most significant crisis-related market movements occurred between July 10 and 23. We therefore consider that the crisis lasted until end-July 2002.

Subprime 2007

The subprime crisis started on February 8, 2007 when HSBC announced the extra provisioning of funds to cover non-performing loans on subprime portfolios (BIS, 2007). This announcement was followed by the failure of several subprime lenders. The spreads on this market segment widened to 200 bp in two days. But since March 13, 2007 credit spreads have contracted again, signaling a decrease in market fears. This date has been taken as the end of the first episode of the subprime crisis.

Subprime 2008-2009

The second episode of the subprime crisis started in September 7, 2008, with the rescue by the U.S. government of mortgage lenders Fannie Mae and Freddie Mac, which account for about half of the outstanding mortgages in the U.S.A. This rescue represented one of the largest bailouts in U.S. history. According to Treasury Secretary Henry Paulson, the debt levels of these two “systemic” firms were jeopardizing the stability of the whole financial system. After this rescue operation, the subprime crisis spilled over and became the catalyst for a much broader global financial crisis. The markets reeled from the collapse or forced mergers/bailouts of Bear Stearns, AIG, Lehman Brothers, IndyMac Bank, Merrill Lynch, Wachovia, Washington Mutual, and many others (Brunnermeier, 2008). We date the end of the Subprime crisis at March 10, 2009, when the equity market started a new market rally.

Other crisis of confidence

9/11

The terrorist attacks on the USA on September 11, 2001 sparked a crisis of confidence across markets worldwide. It is hard to say precisely when the crisis ended, but we have considered that it lasted for the whole of September.

Tables

Table 1. *Descriptive statistics for the indices under study*

Weekly returns hedged in dollars

	USA	Eurozone*	UK	Japan
Government bond indices (July 1998 – December 2010)				
Mean	0.11%	0.11%	0.11%	0.09%
Annualized mean	**5.64%**	**5.63%**	**5.48%**	**4.61%**
Median	0.13%	0.15%	0.09%	0.10%
Min	-4.25%	-3.11%	-3.66%	-3.93%
Max	4.83%	2.34%	4.69%	3.24%
Standard deviation	1.07%	0.79%	0.87%	0.60%
Skewness	-0.30	-0.27	0.17	-0.51
Kurtosis	4.05	3.53	4.77	8.87
Jarque-Bera (proba)	40.95 (0.00)	15.88 (0.00)	90.47 (0.00)	989.29 (0.00)
IG corporate bond indices, (July 1998 – December 2010)				
Mean	0.12%	0.10%	0.10%	0.09%
Annualized mean	**6.46%**	**5.35%**	**5.00%**	**4.63%**
Median	0.17%	0.16%	0.13%	0.12%
Min	-6.69%	-4.68%	-5.88%	-3.56%
Max	3.62%	2.52%	4.63%	2.30%
Standard deviation	0.91%	0.68%	0.81%	0.55%
Skewness	-0.95	-1.08	-0.90	-0.60
Kurtosis	8.76	8.01	10.14	7.86
Jarque-Bera (proba)	1027.78 (0.00)	830.46 (0.00)	1512.94 (0.00)	697.68 (0.00)
HY corporate bond indices (July 1998 – December 2010)				
Mean	0.13%	0.11%	0.19%	-
Annualized mean	**6.82%**	**5.52%**	**9.68%**	-
Median	0.21%	0.18%	0.21%	-
Min	-10.86%	-13.08%	-8.57%	-
Max	5.50%	9.60%	5.97%	-
Standard deviation	1.10%	1.57%	1.31%	-
Skewness	-2.19	-1.29	-0.65	-
Kurtosis	24.72	15.91	10.36	
Jarque-Bera (proba)	13707.75 (0.00)	4840.32 (0.00)	1559.89 (0.00)	-
Equity indices (July 1998 – December 2010)				
Mean	0.10%	0.09%	0.10%	0.05%
Annualized mean	**5.43%**	**4.92%**	**5.27%**	**2.36%**
Median	0.24%	0.31%	0.27%	0.21%
Min	-18.14%	-18.01%	-19.82%	-20.18%
Max	12.53%	17.84%	13.39%	9.35%
Standard deviation	2.76%	3.06%	2.56%	2.84%
Skewness	-0.53	-0.28	-0.57	-0.70
Kurtosis	8.12	7.52	10.72	6.86
Jarque-Bera (proba)	761.69 (0.00)	578.61 (0.00)	1699.29 (0.00)	469.48 (0.00)

* Germany for equity and government bond indices.

The Jarque-Bera statistic is $\chi^2(2)$ distributed under the null hypothesis of normality of residuals.

Table 2. Correlation matrix for all asset classes,
Weekly returns hedged in dollars, July 1998 – December 2010

	US_GVT	EU_GVT	UK_GVT	JP_GVT	US_IG	EU_IG	UK_IG	JP_IG	US_HY	EU_HY	UK_HY	US_EQ	EU_EQ	UK_EQ	JP_EQ
US_GVT		75%***	71%***	29%***	78%***	58%***	46%***	29%***	-10%***	-16%***	-9%**	-26%***	-38%***	-32%***	-22%***
EU_GVT			83%***	31%***	57%***	75%***	59%***	32%***	-11%***	-12%***	-4%	-25%***	-33%***	-31%***	-24%***
UK_GVT				29%***	54%***	64%***	69%***	28%***	-9%**	-12%***	-5%	-19%***	-28%***	-23%***	-21%***
JP_GVT					21%***	25%***	18%***	93%***	-6%	-6%	-5%	-11%***	-17%***	-13%***	-25%***
US_IG						75%***	62%***	23%***	42%***	29%***	29%***	2%	-8%**	1%	5%
EU_IG							82%***	28%***	30%***	26%***	29%***	-1%	-9%**	-4%	0%
UK_IG								22%***	25%***	22%***	29%***	-3%	-8%**	-5%	-1%
JP_IG									-5%	-4%	-2%	-13%***	-21%***	-16%***	-24%***
US_HY										80%***	65%***	47%***	44%***	49%***	40%***
EU_HY											79%***	44%***	47%***	47%***	37%***
UK_HY												32%***	33%***	33%***	28%***
US_EQ													80%***	81%***	52%***
EU_EQ														85%***	54%***
UK_EQ															54%***
JP_EQ															

***, **, and *: significant at the 1%, 5%, and 10% thresholds, respectively.

Table 3. Results of the GLR (2005) globalization tests

Asset Classes	*Test periods*	*Test Stat*
All asset classes (15*15 matrix)	1998-2004 & 2004-2010	168.12***
GVT bonds (4*4 matrix)	1984-1997 & 1997-2010	239.30***
IG bonds (4*4 matrix)	1998-2004 & 2004-2010	9.38
HY bonds (3*3 matrix)	1998-2004 & 2004-2010	15.98***
EQ (4*4 matrix)	1978-1994 & 1994-2010	105.15***

***, **, *: significant at the 1%, 5%, and 10% thresholds, respectively.

<u>Table 4.</u> Correlation differences $\Delta\rho_{ij} = \rho_{ij}\,(2004 \text{ to } 2010) - \rho_{ij}\,(1998 \text{ to } 2004)$

Weekly returns hedged in dollars

	US_GVT	**EU_GVT**	**UK_GVT**	**JP_GVT**	**US_IG**	**EU_IG**	**UK_IG**	**JP_IG**	**US_HY**	**EU_HY**	**UK_HY**	**US_EQ**	**EU_EQ**	**UK_EQ**	**JP_EQ**
US_GVT		4.4%	-1.5%	26.1%	-29.1%	-24.6%	-29.7%	25.8%	-27.2%	-6.7%	-11.4%	-19.1%	-6.8%	-6.4%	-8.7%
EU_GVT			-4.0%	32.7%	-24.2%	-31.4%	-37.1%	32.1%	-33.0%	-21.5%	-27.5%	-31.1%	-19.3%	-17.8%	-20.0%
UK_GVT				28.5%	-25.6%	-37.4%	-36.9%	28.7%	-27.4%	-17.2%	-23.2%	-25.4%	-10.2%	-11.1%	-15.8%
JP_GVT					4.8%	5.4%	4.5%	3.2%	-15.0%	-18.3%	-14.5%	-14.3%	-9.1%	-11.7%	-11.3%
US_IG						1.7%	-6.8%	12.7%	18.2%	46.1%	26.4%	16.5%	27.4%	32.8%	27.5%
EU_IG							-6.2%	16.1%	12.8%	34.9%	24.4%	2.1%	11.7%	13.9%	16.0%
UK_IG								14.2%	4.8%	25.2%	19.6%	-1.5%	9.7%	10.0%	8.4%
JP_IG									-8.7%	-9.9%	-4.1%	-12.5%	-6.3%	-8.6%	-15.0%
US_HY										21.0%	2.8%	41.3%	34.6%	42.8%	35.5%
EU_HY											-8.5%	23.8%	17.3%	22.1%	34.5%
UK_HY												6.1%	0.1%	3.6%	12.6%
US_EQ													14.7%	13.3%	26.6%
EU_EQ														7.7%	25.6%
UK_EQ															24.6%
JP_EQ															

<u>Table 5.</u> Results of the GLR (2005) globalization tests, sample period excluding crises

Asset Classes	*Test periods*	*Test Stat*
All asset classes (15*15 matrix)	1998-2004 & 2004-2010	178.02***
GVT bonds (4*4 matrix)	1984-1997 & 1997-2010	87.47***
IG bonds (4*4 matrix)	1998-2004 & 2004-2010	12.50*
HY bonds (3*3 matrix)	1998-2004 & 2004-2010	23.57***
EQ (4*4 matrix)	1978-1994 & 1994-2010	124.21***

***, **, *: significant at the 1%, 5%, and 10% thresholds, respectively.

Table 6. Crises used in this study

	Start date	End date	Type of crisis
Chile 1982	15/06/1982	05/08/1982	Currency
Mexico 1982	17/02/1982	01/09/1982	Currency
Equity crash 1987	19/10/1987	07/12/1987	Market crash
EMS crisis 1992	16/09/1992	01/08/1993	Currency
Bond crash 1994	04/02/1994	03/11/1994	Market crash
Mexico 1994	20/12/1994	10/03/1995	Currency
Asia 1997	02/07/1997	13/01/1998	Currency
Russia and LTCM 1998	17/08/1998	15/10/1998	Sovereign debt + corporate bankruptcy
Brazil 1999	13/01/1999	31/01/1999	Currency
e-crash 2000	28/03/2000	14/04/2000	Market crash
Argentina 2001	01/10/2001	23/12/2001	Sovereign debt
9/11	11/09/2001	28/09/2001	Confidence
Enron 2001	28/11/2001	31/12/2001	Corporate bankruptcy
WorldCom 2002	25/06/2002	31/07/2002	Corporate bankruptcy
Subprime 2007	08/02/2007	13/03/2007	Housing market + Corporate bankruptcy
Subprime 2008	07/09/2008	03/10/2009	Housing market + Corporate bankruptcy

Table 7. Results of the GLR (2005) contagion tests (all crises)

Asset Classes	*Overall period*	*Test Stat overall period*	*Period adjusted*	*Test Stat period adjusted*
Global correlation matrix				
All asset classes (15*15 matrix)	1998-2010	138.94**	-	-
GVT bonds (4*4 matrix)	1984-2010	17.70***	-	-
IG bonds (4*4 matrix)	1998-2010	5.25	-	-
HY bonds (3*3 matrix)	1998-2010	8.79*	-	-
EQ (4*4 matrix)	1978-2010	27.98***	1998-2005	10.26
Cross-correlations only				
GVT and IG (8*8 matrix)	1998-2010	42.25***	1998-2005	32.47***
GVT and HY (6*6 matrix)	1998-2010	6.11	-	-
GVT and EQ (8*8 matrix)	1984-2010	30.67**	1984-2005	27.32**
IG and HY (6*6 matrix)	1998-2010	16.62*	-	-
IG and EQ (8*8 matrix)	1998-2010	12.48	-	-
HY and EQ (6*6 matrix)	1998-2010	10.81	-	-

***, **, *: significant at the 1%, 5%, and 10% thresholds, respectively.

Table 8. Correlation differences: $\Delta\rho_{ij} = \rho_{ij}(\text{crisis}) - \rho_{ij}(\text{no crisis})$

Weekly returns hedged in dollars, July 1998 – December 2010

	US_IG	EU_IG	UK_IG	JP_IG	US_EQ	EU_EQ	UK_EQ	JP_EQ
US_GVT	32.2%	3.6%	-1.1%	-37.2%	23.3%	9.6%	3.0%	32.2%
EU_GVT	10.0%	19.8%	17.8%	-42.7%	31.4%	24.7%	26.1%	10.0%
UK_GVT	11.2%	19.1%	25.2%	-43.9%	20.5%	19.6%	19.9%	11.2%
JP_GVT	-13.4%	-18.9%	-19.3%	1.9%	12.0%	24.8%	15.5%	-13.4%

Figure

<u>Figure 1</u>. Crises used in this study