MARCH 2017

STUDY OF MARKET SHOCK PROPAGATION

Risk and
Trend Mapping

AUTORITÉ
DES MARCHÉS FINANCIERS
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This study aims to contribute to a better understanding of price formation mechanisms when an important announcement is made to the market. It reports on the observations made by examining how seven recent major shocks propagated to different instruments — mainly French and European equities and equity index futures — and does not attempt to demonstrate a causal relationship between markets.

The focus of the analysis, which used data on trades in equities, equity indices and equity index futures contracts[1], was twofold: propagation in terms of magnitude and over time. The objective of the study was not to demonstrate a causal relationship between markets but to report on any observations made when searching for a recurring chronological sequencing in price formation between financial instruments.

A sensitivity analysis of French market instruments shows that the greater the number of large-capitalisation stocks in the index, the larger the impact of a shock: small-caps are more sensitive to microeconomic than macroeconomic information. The French stocks included in the Eurostoxx 50 are also more sensitive than shares on the Paris exchange that are not included in the pan-European index.

This analysis also shows that the CAC 40 moves virtually in lockstep with the Eurostoxx 50. While in the early 2000s, the Eurostoxx 50 would clearly move several seconds before the French national index, the gap between moves in the two futures contracts narrowed to milliseconds during the most recent shocks. It is no longer even possible to draw conclusions on price sequencing at this level of granularity without direct data from Eurex on the orders and transactions of participants trading in the Eurostoxx 50 futures.

Nevertheless, of the shocks under review, in the (one) case when trading was suspended in the Eurostoxx 50, CAC 40 prices wavered and its volumes were sharply down during the halt in the pan-European index. This underscored the importance the Eurostoxx 50 can have in decision-making by French market participants.

[1] Referred to as “futures” throughout this document.

1. INTRODUCTION AND OBJECT OF THE STUDY

The object of the study is to gain a better understanding of the price formation dynamics when comparing the European market as a whole with the French market during the propagation of a market shock. While maintaining a macro approach, an empirical and qualitative analysis, based on historical data, was performed using two criteria:

- ☐ impact of the shock in terms of magnitude
- ☐ propagation of the shock over time

In the case of series of price jumps[2], it was decided to analyse the propagation of shocks to different types of equity instruments: French and pan-European index futures and French cash equities. Insofar as it is not possible to isolate individual price movements, many market-influencing factors can be disregarded when sequences of jumps occur following an important news release, in which it is accordingly expected to observe a (temporary) chronological sequencing in price formation between instruments.

This study aims to report on the observations made when searching for this sequencing and does not attempt to demonstrate a causal relationship between markets.

An analysis was first performed, using historical trade data[3], of the chronological sequencing between the prices of the Eurostoxx 50 and CAC 40 futures, and then between prices of the CAC 40 futures and three of the French companies with the largest market capitalisations that are constituents of both the CAC 40 and Eurostoxx 50 (Sanofi, Total and BNP Paribas). Lastly, the study also covers the impact of a macroeconomic shock on segments of French equities with smaller market capitalisations (CAC Next 20, CAC Mid 60 and CAC Small 90).

The scope of the instruments studied is summarised below.

Scope

Type of instrument	Instrument or underlying
Equity index futures	Eurostoxx 50
	CAC 40
Equities	Sanofi
	BNP Paribas
	Total
Equity indices	CAC Next 20
	CAC Mid 60
	CAC Small 90

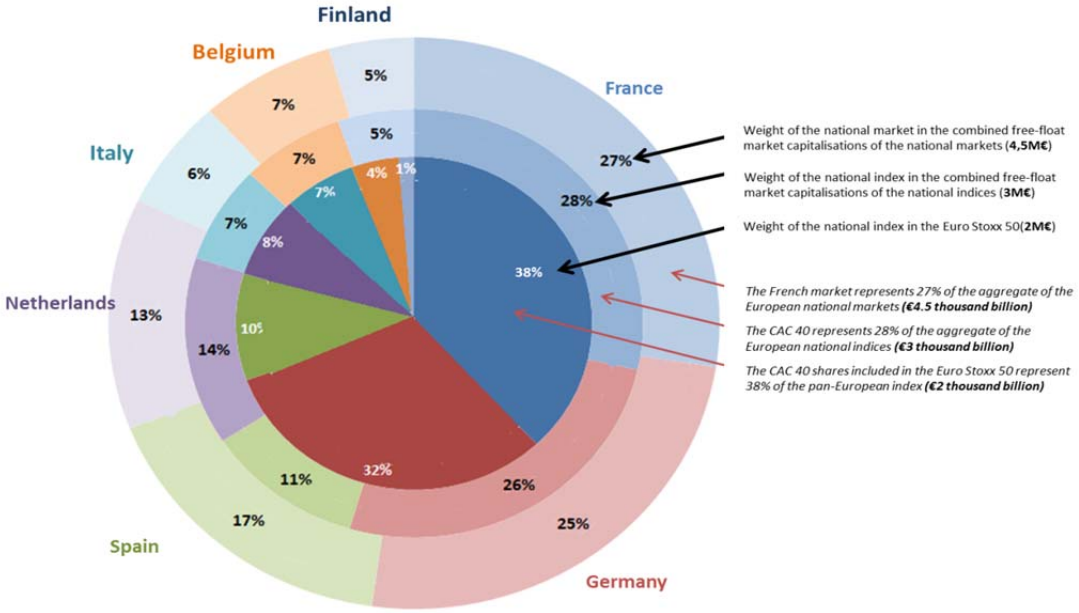
In the analysis of the shocks, attention was also paid to the trend in OAT and Euro-Bund futures, as these instruments can act as safe havens and are also arbitraged with the equity indices.

[2] In the paper we refer as price jump for either a sharp increase or a sharp drop in price.

[3] The study is based primarily on public data. The trade data used were first extracted from Thomson Reuters' Reuters Data Tick History (RDTH) tool and then, to fine-tune the internal RDTH time stamps, certain trade data were then retrieved directly from the Euronext (regulator data) and Eurex (public data) exchanges. All non-trade and non-order data are from Bloomberg. Free-float market capitalisation and index constituent data are as of 30 June 2016.

The chart below illustrates the composition of the Eurostoxx 50 and the national indices in the European markets[4].

Percentage of Eurostoxx 50 and national indices in the European markets

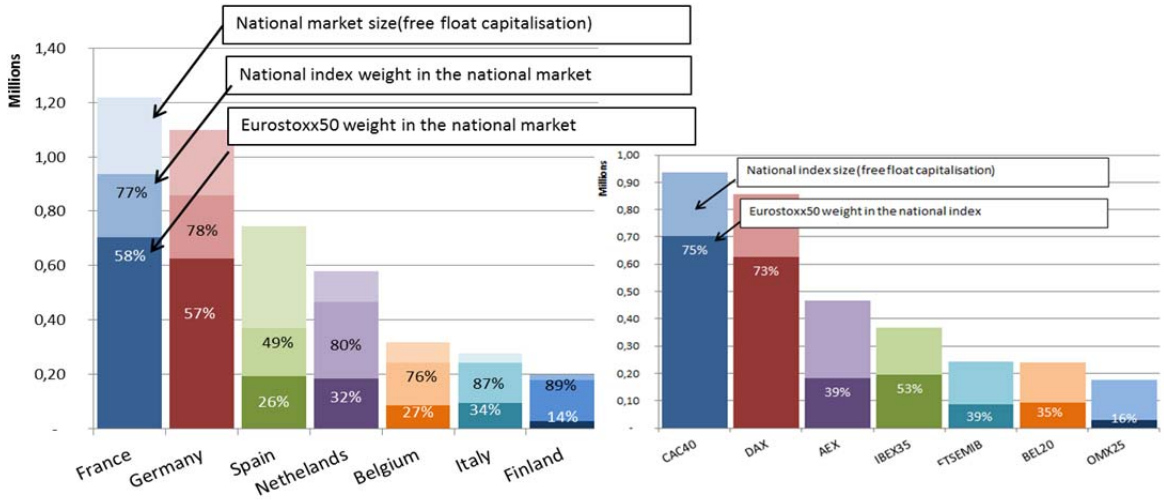


The chart shows that French stocks have the highest representation in the Eurostoxx 50 (38%), and in a higher proportion than that of the French market relative to all European markets (27%).

The graphs below illustrate the weight (in free-float market capitalisation terms) of the Eurostoxx 50 in the composition of the indices and the national reference markets.

Weight of the Eurostoxx 50 and of the national indices in the composition of the national markets

Weight of the Eurostoxx 50 in the composition of the national indices



At 75%, the weight of the Eurostoxx 50 is the highest in the composition of the French national index.

[4] Note that, while in free-float market capitalisation terms, the Euro Stoxx 50 represents 50% of the European equity market, the S&P 500 represents 80% of the U.S. equity market.

In addition, financial stocks accounted for 23.6% of the Eurostoxx 50 (before the exclusion of Deutsche Bank and Crédit Suisse in September 2016) and for 15.4% of the CAC 40. The pan-European index is therefore, in theory, more sensitive than the French national index to macroeconomic announcements having an impact on the banking sector (Monetary policy decisions, for example).

The aggregate weight of the 20 French stocks in both indices represents:
- ☐ 38% of the Eurostoxx 50
- ☐ 75% of the CAC 40

These percentages of stocks included in both the national benchmark and the pan-European index, in free-float market capitalisation terms, are the highest for France, which could explain the correlation between these two indices[5].

Furthermore, as trading in the Eurostoxx 50 futures is 10 times heavier[6] than in the CAC 40 futures[7], there may be an expectation that, in the event of an important announcement, **the Eurostoxx 50 would drive the propagation of a shock to the French national market.**

The propagation of a shock among the asset classes defined above was analysed for a set of dates on which an important announcement was made and had an impact on the market during the trading session; some of these announcements were expected while others were not.

Trading days selected for the study

Date	Anticipation of the shock Expected/Unexpected	Source of the shock	Start time*	End time**	Magnitude of the price jump in the CAC 40 futures
15/01/2015	Unexpected	Swiss central bank abandons the Swiss franc floor	10:50 a.m.	10:52 a.m.	-5.13%
24/06/2015	Unexpected	Greek debt negotiations	11:36 a.m.	11:37 a.m.	-1.19%
24/08/2015	Expected (as the shock originated before the French markets opened)	Chinese government allows its state pension fund to invest in the stock market	2:34 p.m.	2:52 p.m.	-5.18%
02/10/2015	Expected	ECB announcement	2:29 p.m.	2:50 p.m.	-3.25%
03/12/2015	Unexpected	False *Financial Times* tweet	1:40 p.m.	2:44 p.m.	-5.26%
03/12/2015	Expected	ECB announcement	1:40 p.m.	2:44 p.m.	-5.26%
10/03/2016	Expected	ECB announcement	1:45 p.m.	2:00 p.m.	3.11%

* Time at which the shock was observed to have begun
** Time at which the market stabilised or the price jump was observed to have ended

5 All else being equal, when the Euro Stoxx 50 falls by 1%, the CAC 40 falls by 0.75%; when the CAC 40 falls by 1%, the Euro Stoxx 50 falls by 0.38%.
6 With a tick size (i.e. the smallest change in an instrument's price) of EUR 10 for the Euro Stoxx 50 futures compared with EUR 5 for the CAC 40 futures, and a spread close to the tick size for both contracts, the Euro Stoxx 50 futures are a more cost-effective instrument for market makers than futures on the French national index.
7 Furthermore, there were 251,238 CAC 40 futures contracts outstanding (maturing in August) at end-July 2016 compared with 3,661,262 Euro Stoxx 50 futures contracts (maturing in September).

It should be noted that, with expected announcements, the market is already conditioned and prepared to accept or integrate the news whereas, with an unanticipated shock, the contagion mechanism is free to operate. For example, it has already been shown in a previous study[8] that high-frequency traders generally withdraw just before official ECB statements and are already prepared to adjust their positions based on the various possible scenarios.
The day after the Brexit referendum, 24 June 2016, was not selected as the result of the vote was announced pre-market and market participants were able to coordinate their trades on the different exchanges before the markets opened.

The remainder of this study consists of:

- a comparison of the magnitude of the shocks by instrument (Part 2);
- an analysis of the day of 3 December 2015, describing how the national indices responded to the one case, out of the seven under review, when the Eurostoxx 50 was suspended (Part 3); and
- an analysis of the other cases to identify whether the propagation to different instruments over time was gradual (Part 4).

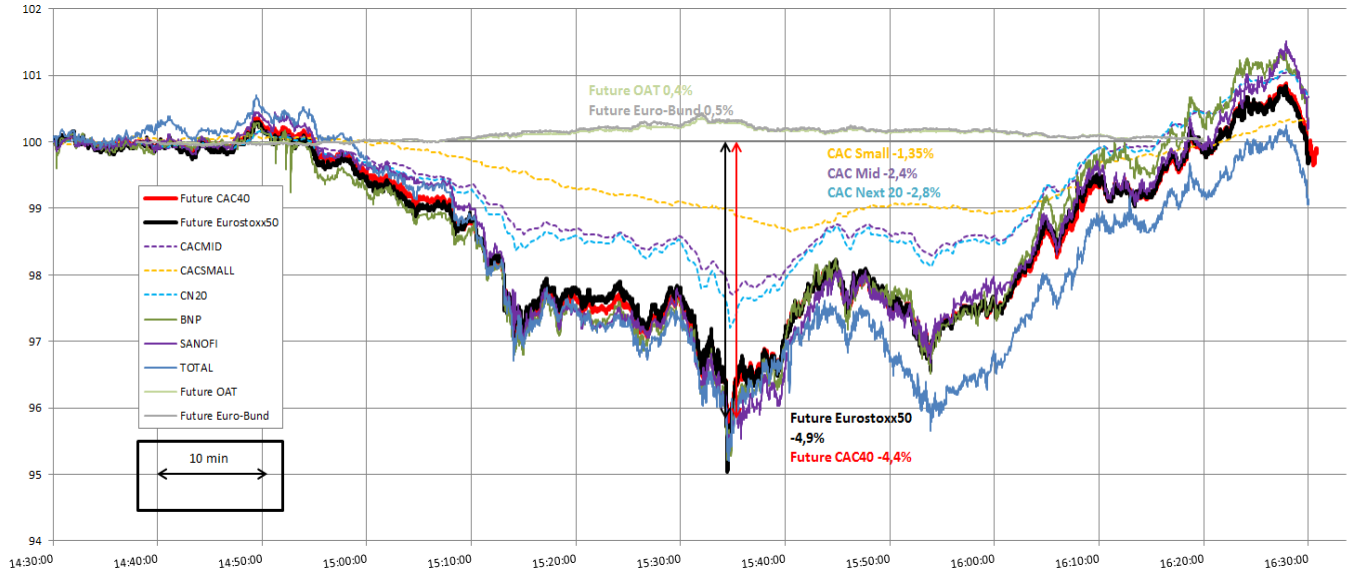
2. MAGNITUDE OF SHOCK PROPAGATION: FRENCH MARKET IS HIGHLY SENSITIVE

2.1. SHOCK INTENSITY LINKED TO MARKET CAPITALISATION SIZE

To assess the sensitivity of the different financial instruments to an important announcement, it is instructive to consider the intensity with which a price jump in the Eurostoxx 50 futures propagates to other instruments.

For example, the chart below shows the sequence for the shock of 24 August 2015 (stress caused by the collapse of the Chinese market against the backdrop of downward revisions to the global growth outlook and mounting uncertainties).

Impact of the shock of 24 August 2015 on the different instruments



Source: Reuters Data Tick History

8 See Study of the behaviour of high-frequency traders published on 26 January 2017 on the AMF's website.

Analysis of chart titled "Impact of the shock of 24 August 2015 on the different instruments": The magnitude of the change in the CAC 40 futures is fairly similar to that of the Eurostoxx 50 futures (-4.4% and -4.9%, respectively). The Sanofi, BNP Paribas and Total stocks also reacted with an intensity of close to -5%. However, the CAC Next 20, CAC Mid 60 and CAC Small 90 small- and mid-cap indices reacted with much lower intensity (-1% to -3%). In comparison, the shock had little impact on debt futures (0.41% for OAT futures and 0.50% for Euro-Bund futures).

For all the shocks analysed, the CAC 40 futures seemed to very closely replicate changes in the Eurostoxx 50 futures in terms of magnitude: on average, changes in the CAC 40 futures amounted to 97% of those of the pan-European index.

The CAC 40 companies with the largest capitalisations (Sanofi, Total and BNP Paribas) reacted to the shocks with an intensity similar to that of the Eurostoxx 50 futures, although it was slightly more pronounced for BNP Paribas (even when taking its beta of 112% into account, see below). This was due to the nature of the shocks under review: five of the seven shocks related to central bank announcements likely to have a greater impact on the banking sector.

Average change, in absolute terms, in the different financial instruments on the six dates under review

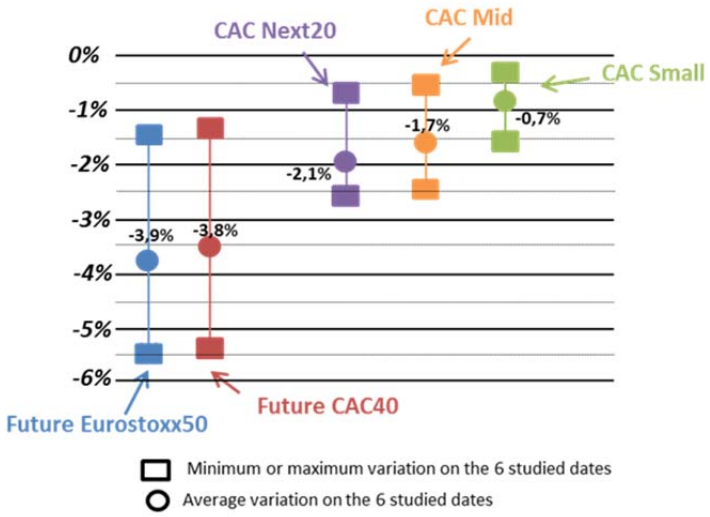
Instrument	Average change in absolute terms	Benchmark used	As % of benchmark	Beta[9]
Eurostoxx 50 Futures	3.95%	N/A	N/A	N/A
CAC 40 Futures	3.85%	Eurostoxx 50	97%	97%
Sanofi	3.81%	CAC 40	99%	95%
BNP Paribas	4.70%	CAC 40	122%	112%
Total	4.19%	CAC 40	109%	108%

It should be noted that, for the small- and mid-cap indices in the CAC family (Next 20, Mid 60, Small 90[10]), the higher the percentage of small-cap stocks, the less pronounced impact produced by the shock. Small-caps are less sensitive to the macroeconomic environment and react more strongly to their own specific events. This relationship between capitalisation and shock intensity stood out in all the price jumps observed (see chart below).

9 Beta is a security's sensitivity coefficient relative to a reference market (the CAC 40 in this case). It is calculated as the covariance between price history and benchmark history divided by the variance in the security's prices.

10 The CAC Next 20, Mid 60 and Small 90 had aggregate free-float market capitalisations of EUR 99 billion, EUR 106 billion and EUR 24 billion, respectively, at end-June 2016 (source: Bloomberg). The average free-float market capitalisations of these indices were EUR 4.9 billion, EUR 1.8 billion and EUR 0.3 billion.

Absolute changes in the CAC indices on the six dates under review



Lastly, debt futures moved marginally but inversely to the equity market, reflecting the traditional reallocation of equity investments to "risk-free" securities in the event of a sharp decline.

When an important announcement is made, the French market (the CAC 40 futures contract and large-caps in both the Eurostoxx 50 and CAC 40) tracks price moves on the Eurostoxx50 futures contract closely, in terms of magnitude.
Indices representing smaller-caps are less sensitive to macroeconomic shocks and therefore replicate the moves observed in the Eurostoxx 50 to a lesser degree than blue-chip indices.

2.2. SHOCKS HAVE MORE OF AN IMPACT ON THE FRENCH STOCKS INCLUDED IN THE EUROSTOXX 50

The expectation was that, when compared with French stocks included only in the national indices, French stocks also included in the Eurostoxx 50 would be more exposed to arbitrage strategies, and therefore more sensitive to a macroeconomic shock.

To analyse this sensitivity, a comparison of the impact of a shock on a pair of French stocks from the same sector was made. For the five pairs which were formed, one of which is a Eurostoxx50 constituent and the other is not. The results of the study are introduced in the table below.

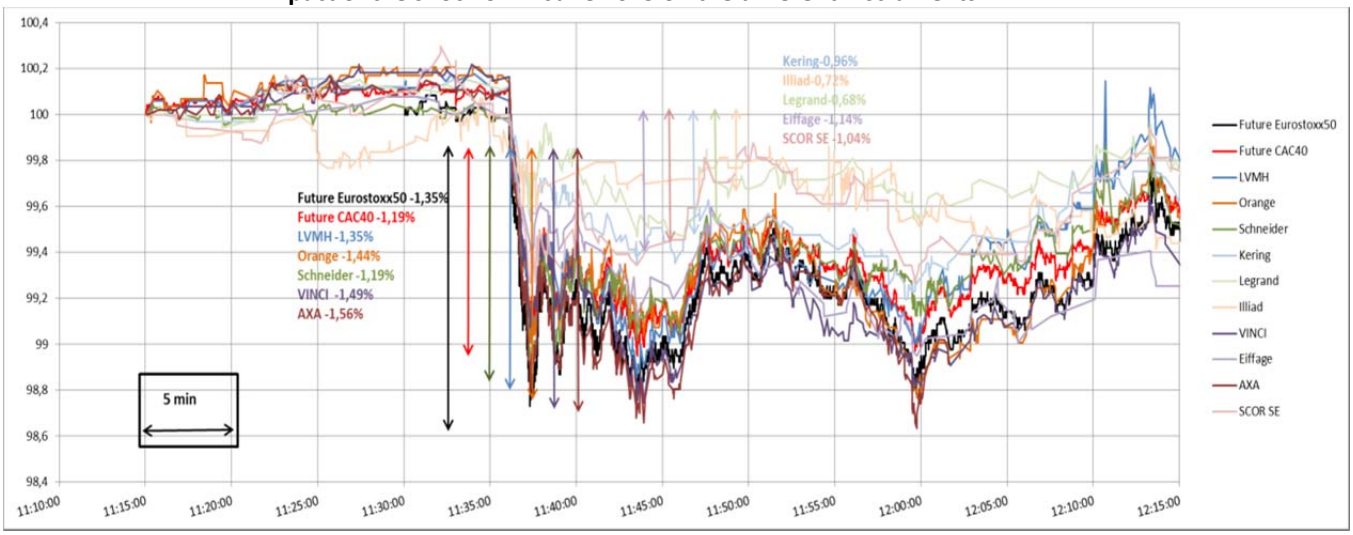
Description of the pairs

Stock in the pair included in the Eurostoxx 50	Free float (EURbn, at 30 June 2016)	Stock in the pair not included in the Eurostoxx 50	Free float (EURbn, at 30 June 2016)
Orange	29.4	***Iliad***	4.5
Schneider Electric	29.0	***Legrand***	12.1
LVMH	36.2	***Kering***	9.4
Vinci	32.6	***Eiffage***	4.8
AXA	43.1	***Scor***	4.7

Source: Bloomberg

The chart below illustrates the sequence for the shock of 24 June 2015 (tensions over Greek debt negotiations).

Impact of the shock of 24 June 2015 on the different instruments



Source: Reuters Data Tick History

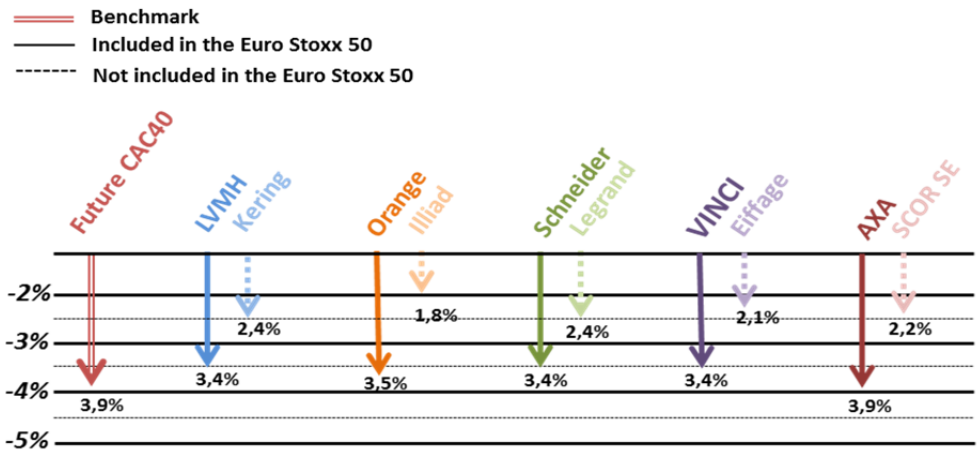
Analysis of chart titled "Impact of the shock of 24 June 2015 on the different instruments": While the CAC 40 futures fell by 1.19% (versus 1.35% for the Eurostoxx 50), each of the French stocks in the pairs included in the Eurostoxx 50 fell more sharply than the other stock that was not included in the pan-European index:

- LVMH -1.35% versus Kering -0.96%
- Orange -1.44% versus Iliad -0.72%
- Schneider -1.19% versus Legrand -0.68%
- Vinci -1.49% versus Eiffage -1.14%
- AXA -1.56% versus Scor -1.04%

The chart above clearly shows that French stocks that are also constituents in the Eurostoxx 50 are more sensitive to moves in the pan-European index than those that are not.

This holds true for all the dates analysed. The average change in these pairs is presented below.

Average change observed

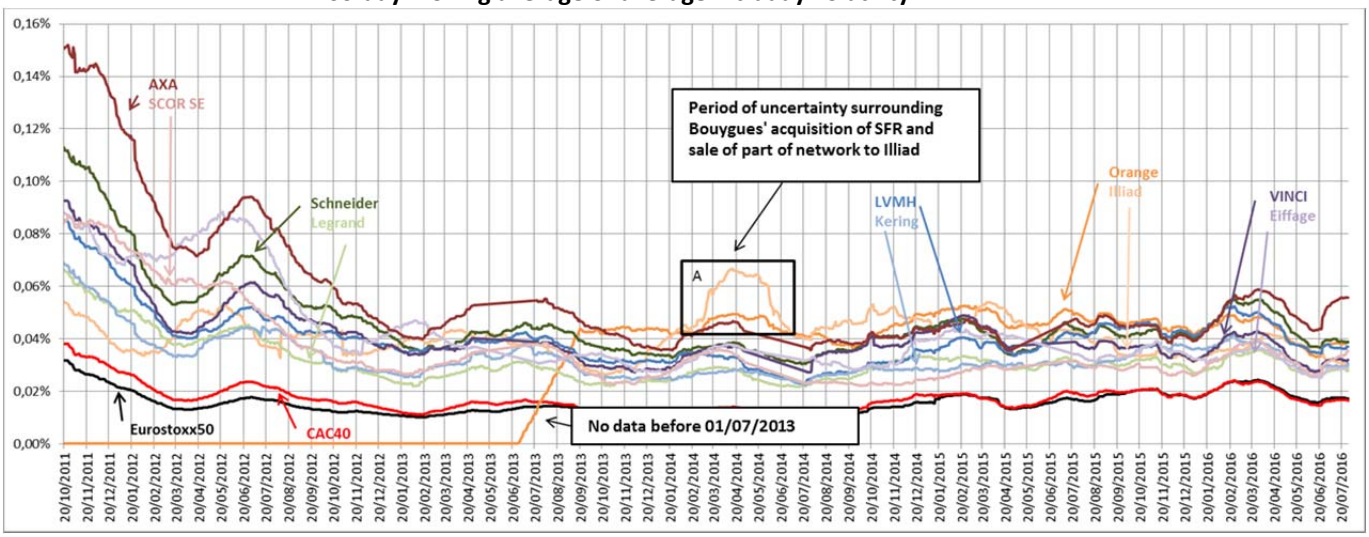


As was the case with the small- and mid-cap indices, the French shares not included in the Eurostoxx 50 are issued by companies that are smaller than their competitors that are included in the pan-European index, and may therefore be less sensitive to macroeconomic news.

Furthermore, the inclusion of the stocks in question in the Eurostoxx 50 leads to added arbitrage opportunities, which could also explain their higher sensitivity to shocks to the index.

The chart below illustrates the change in one-minute intraday volatility for the stock pairs analysed.

60-day moving average of average intraday volatility



Source: Reuters Data Tick History

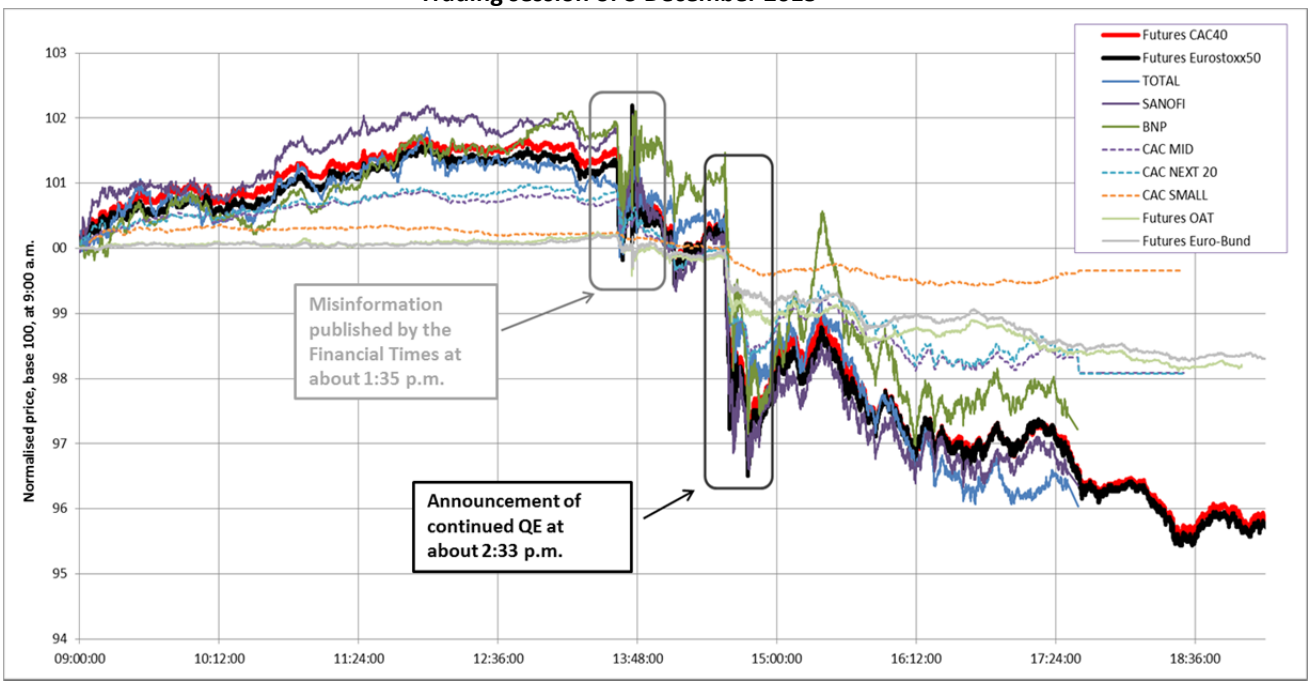
Analysis of chart titled "60-day moving average of average intraday volatility": Although the trend has been towards convergence since 2014, CAC 40 intraday volatility is greater/higher than that of the Eurostoxx 50. Additionally, the most volatile stock in each pair is the one listed in the Eurostoxx 50 (the period covered by Box A is somewhat unusual as, due to uncertainties surrounding Iliad's acquisition of part of SFR's network, the stock temporarily became more volatile than Orange).

When a shock is propagated, within a pair of stocks in the same sector, **the stock included in both a CAC index and the Eurostoxx 50 will be more sensitive than its peer which is included only in the French index.** Furthermore, historically, the **French stock included in the Eurostoxx 50 tends to be more volatile.**

3. THE FRENCH MARKET'S REACTION TO THE HALT IN TRADING IN THE EUROSTOXX 50

One of the trading days selected, 3 December 2015, was marked by two successive events (erroneous publication of misinformation by the *Financial Times* at 1:35 p.m. followed by the announcement that quantitative easing would continue at about 2:33 p.m.) that each caused a sharp drop in the market (see below). One of these shocks is of particular interest as it was accompanied by a temporary suspension of trading likely to highlight, first, which instrument takes the lead in the shock propagation mechanism and, second, how, and with how much of a lag, other asset classes react (notion of shock elasticity).

Trading session of 3 December 2015



Source: Reuters Data Tick History

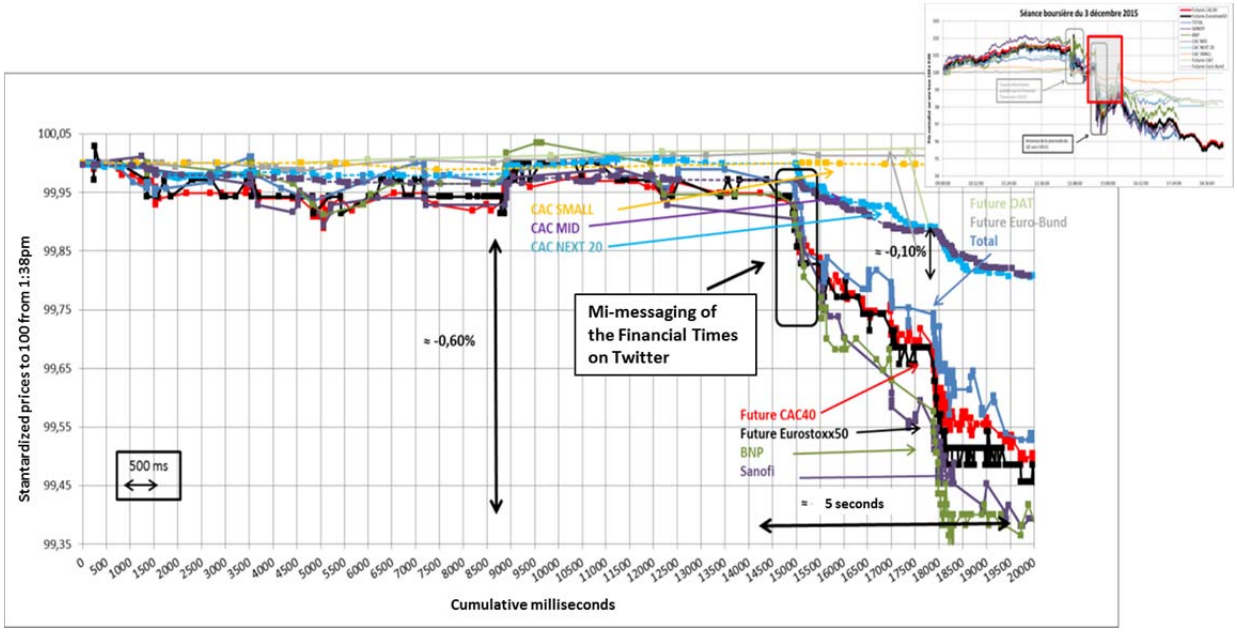
Analysis of chart titled "Trading session of 3 December 2015": The day of 3 December 2015 was marked by the erroneous publication of misinformation from the *Financial Times*' Twitter account a few minutes before the official statement from the European Central Bank (ECB), and then by the announcement that quantitative easing (QE) would continue at least until March 2017.

The market's reaction to each of these events is detailed below.

3.1. MARKET WAVERS ON HALT IN TRADING IN THE EUROSTOXX 50

On 3 December 2015, in the case of the first shock at around 1:35 p.m., equity index futures lost more than half a percent in just a few seconds. Furthermore, there was no difference in how the various instruments reacted as the market collapse spread: the decline appeared to be immediate across all stocks (see below).

Focus on the market's reaction after the false *Financial Times* tweet

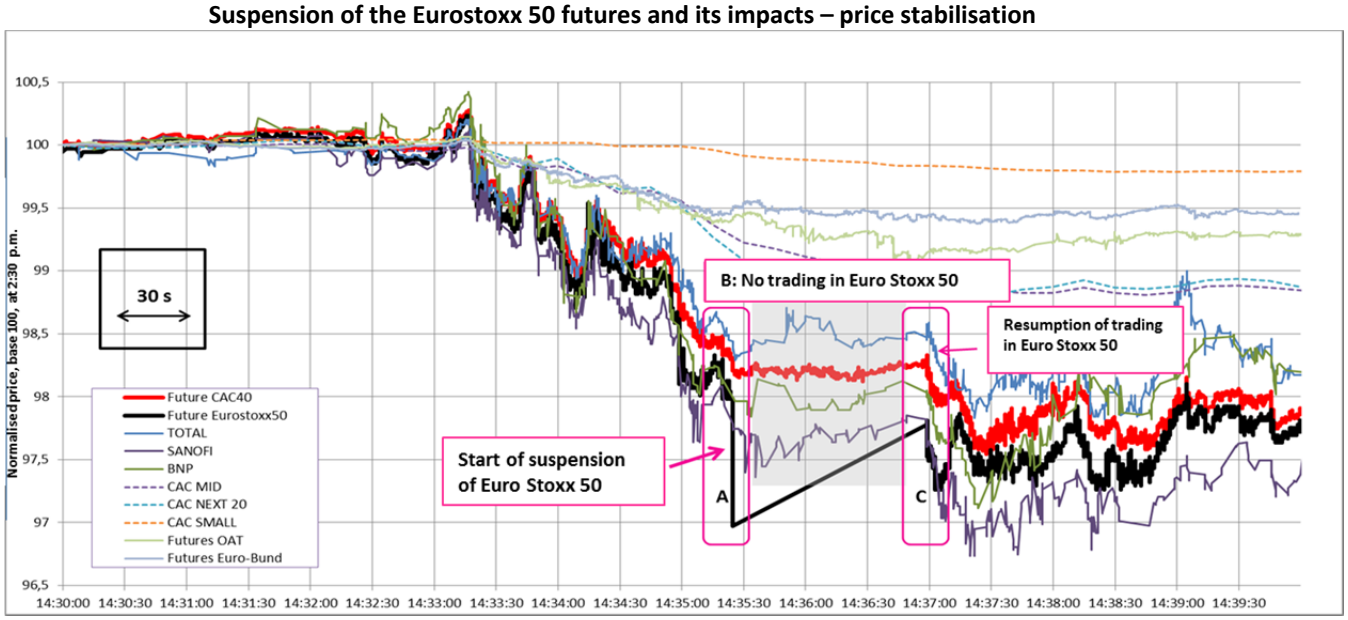


Source: Reuters Data Tick History

Analysis of chart titled "Focus on the market's reaction after the false *Financial Times* tweet: The market reacted strongly with equity index futures falling by about 0.60% and the CAC Next 20, CAC Mid 60 and CAC Small 90 by about 0.10%[11]. OAT and Euro-Bund futures were largely insensitive to this information.

With the second shock, there was a sudden collapse in the Eurostoxx 50 futures (see below); this index was ultimately halted at 2:35:25 p.m. for 1 minute and 34 seconds.

Suspension of the Eurostoxx 50 futures and its impacts – price stabilisation



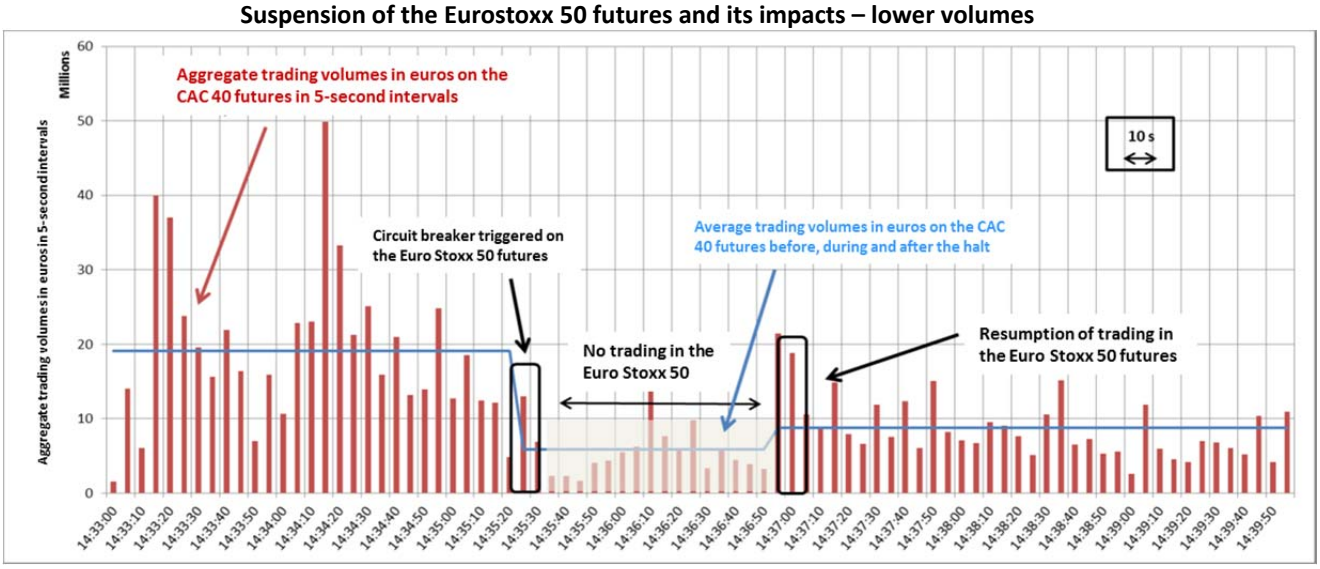
Source: Reuters Data Tick History

[11] As the CAC Next 20, CAC Mid 60 and CAC Small 90 are calculated every 15 seconds, they did not provide enough datapoints relative to the scale of the chart. In the above illustration, prices for these indices are therefore recalculated using the prices of the underlyings.

Analysis of chart titled "Suspension of the Eurostoxx 50 futures and its impacts – price stabilisation": During the halt (box B), it became clear that the other instruments were waiting for the Eurostoxx 50 to resume trading. The circuit breaker triggered on the Eurostoxx 50 futures had the effect of stabilising prices during the halt (see Part B above). The instruments began to fall again as soon as the Eurostoxx 50 futures resumed trading (see box C above). The CAC Mid 60 and CAC Small 90 proved less sensitive to this circuit breaker than the CAC Next 20. OAT and Euro-Bund futures barely reacted at all.

The chart below illustrates the change in trading volumes in euros on CAC 40 futures contracts around the time of the suspension of trading in the Eurostoxx 50.

Suspension of the Eurostoxx 50 futures and its impacts – lower volumes



Source: Reuters Data Tick History

Analysis of chart titled "Suspension of the Eurostoxx 50 futures and its impacts – lower volumes": The suspension of trading in the Eurostoxx 50 led to a temporary decrease in volumes on the CAC 40 futures during the halt.

Trading volumes for the CAC 40 futures while the Eurostoxx 50 was suspended represented only one-third of trading volumes before the halt. The extent of the decline at a time when the European benchmark was not trading raises the question of what share of the market arbitrageurs have on the French instrument[12].

The halt in trading in the Eurostoxx 50 led, during the suspension, to:

- ☐ price stabilisation on the CAC 40 futures and the constituents analysed (the Total, BNP Paribas and Sanofi shares)
- ☐ a decrease in trading volumes on the CAC 40 futures[13]

This sequence underscores the importance the Eurostoxx 50 can have in decision-making by participants in the French equity index futures and equities market.

This type of halt is infrequent and only happened once within the shocks analysed.

An analysis of how debt futures reacted to the announcements analysed (see Appendix) shows that sudden broad selloffs of equities are generally accompanied by a shift into debt, a less volatile, less risky asset class.

12 Arbitrageurs were not the only reason for the decline in volumes on the CAC 40 futures observed during the halt of the Euro Stoxx 50: the halt in the pan-European index may constitute information used in other strategies (e.g. trend following). At the very least, this event highlights the key role the Euro Stoxx 50 plays in price formation on the Paris market.

13 Trading volumes also fell for the stocks underlying the CAC 40 during the suspension of the Euro Stoxx 50, but to a lesser extent.

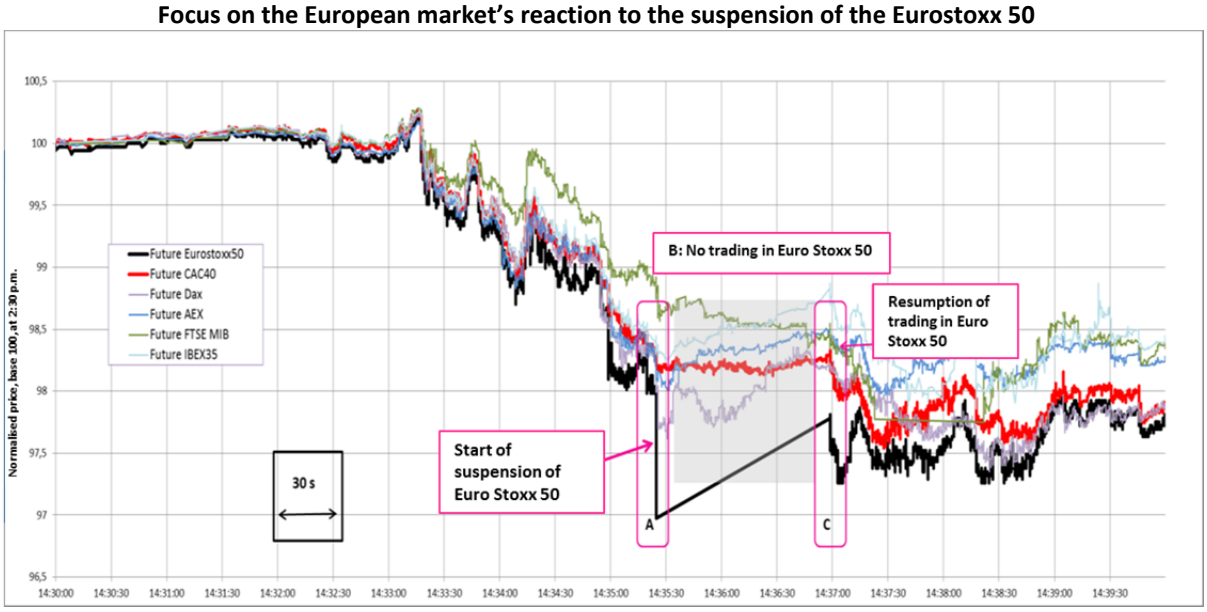
These flows are transferred fairly quickly, in a little less than half a second after the decline in the CAC 40 and Eurostoxx 50 futures, and the price of the OAT and Euro-Bund futures rises slightly.

3.2. COMPARISON OF THE INTERDEPENDENCIES BETWEEN NATIONAL INDICES AND THE EUROSTOXX 50

As the Eurostoxx 50 is also composed of German, Dutch, Italian and Spanish stocks, it is instructive to study whether the national indices of these countries have the same relationship with the pan-European index as the CAC 40 and, more specifically, as observed above, what happens during a halt in trading in the Eurostoxx 50.

The chart below illustrates the reaction of the European national indices during the suspension of the Eurostoxx 50 on 3 December 2015.

Focus on the European market's reaction to the suspension of the Eurostoxx 50



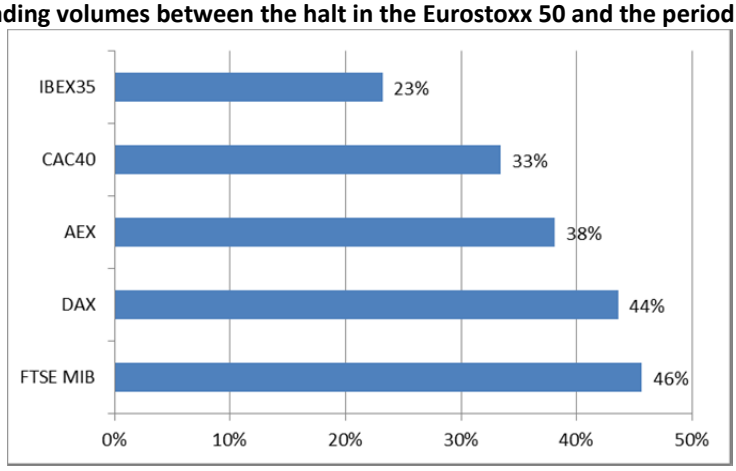
Source: Reuters Data Tick History

Analysis of chart titled "Focus on the European market's reaction to the suspension of the Eurostoxx 50": Although all European national index futures stabilised pending the resumption of trading in the Eurostoxx 50, it would seem that the CAC 40 was the most adversely affected by this suspension: its prices remained relatively static, in particular relative to the DAX (grey line).

The chart below shows, for each national index futures contract, the ratio of trading volumes in this future between the Eurostoxx 50 suspension period and the period[14] just before the circuit breaker.

[14] Trading volumes in euros are aggregated by 5-second interval during the halt in the Euro Stoxx 50 and two minutes before its suspension.

Ratio of trading volumes between the halt in the Eurostoxx 50 and the period just before



Source: Bloomberg

With the exception of the IBEX 35, the Spanish index futures, which was even less heavily traded than its European counterparts during the suspension, the CAC 40 was the index most affected by the halt in trading in the Eurostoxx 50[15].

For all the European national indices analysed, the suspension of trading in the Eurostoxx 50 led to:

- ☐ varying degrees of price stabilisation, but with a very strong stabilisation for the CAC 40 futures
- ☐ a decrease in trading volumes, which was particularly substantial for the CAC 40 futures

These observations show that, of all the national indices that share stocks with the Eurostoxx 50, the CAC 40 seems to be the most dependent on the pan-European index.

The reason for the French index's dependence on the pan-European index could be the weight in the CAC 40 of domestic stocks also included in the Eurostoxx 50 (75%), which is the highest among its European counterparts (see below). However, although the German and French stocks also included in the Eurostoxx 50 represent roughly the same weight in the Eurostoxx 50 and these shared stocks represent about three-quarters of each national index[16], when the Eurostoxx 50 was suspended, volumes of the German index futures fell to 44% of what had been trading before the suspension, compared with 33% for the CAC 40.

4. CHRONOLOGICAL SEQUENCING IMPERCEPTIBLE AT THE MILLISECOND LEVEL

To study the order of sequencing in the propagation of a shock, trades need to be analysed down to the millisecond.

The speed of an instrument's response to a shock depends in particular on two characteristics:

- liquidity (the Eurostoxx 50 futures is deeper than the CAC 40 futures contract)
- geographic location of the exchange relative to the sources of information (Frankfurt for the Eurostoxx 50 futures contract and London for the CAC 40 futures contract)

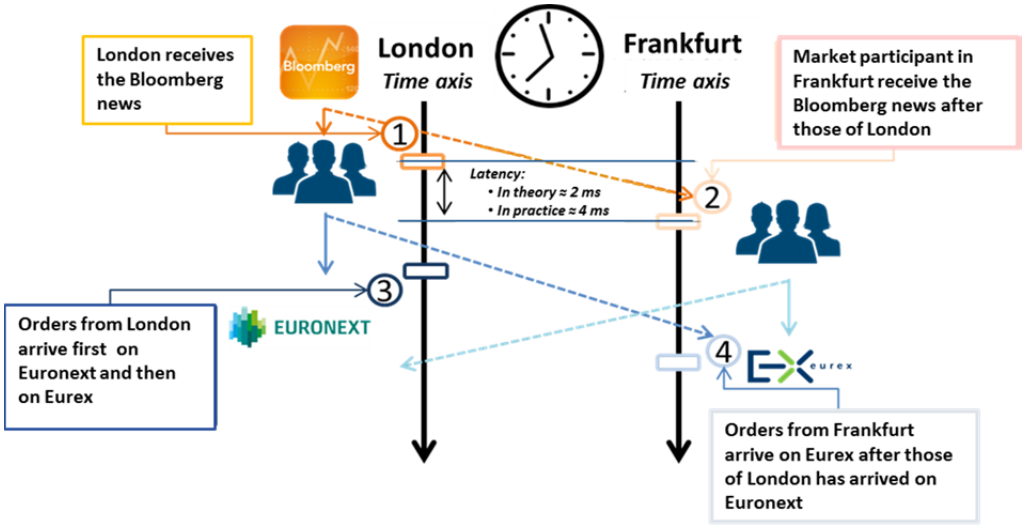
[15] However, no relationship could be established *for all national markets* between the extent to which their volumes fell during the suspension and the number of constituents also included in the Euro Stoxx 50.

[16] Domestic stocks also included in the Euro Stoxx 50 represent 73% of the DAX compared with 75% for the CAC 40. German stocks represent 32% of the Euro Stoxx 50 compared with 38% for French stocks.

The main channels of financial information, Bloomberg and Thomson Reuters, are located in London. Macroeconomic news that they disseminate therefore reaches participants located in London first and those in Frankfurt a little later. Additionally, as most high-frequency traders are located in London, they should be able to respond more quickly on Euronext, whose servers are also close to London, than on Frankfurt-based Eurex.

The chart below summarises how information is disseminated and the sequencing given the geographic location of the various participants.

Location of key participants

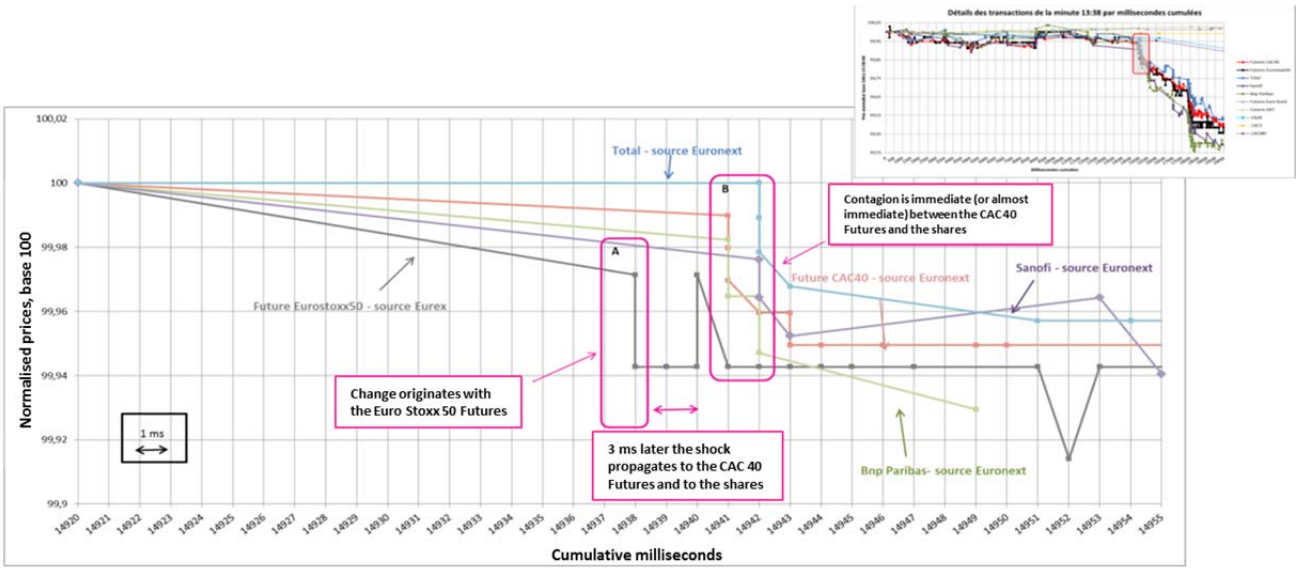


Analysis of chart titled "Location of key participants": As the majority of participants are in London, along with main information channel Bloomberg, it would be reasonable to expect that, when an announcement is made, the flow of trades made by arbitrageurs between the Eurostoxx 50 and the CAC 40 would reach Euronext before Eurex.

In reality, instances of the Eurostoxx 50 futures preceding the CAC 40 futures and vice versa were both observed in the shocks analysed.

As an example, the chart below shows one instance in which the Eurostoxx 50 futures preceded the CAC 40 futures (after publication of the false tweet by the *Financial Times* on 3 December 2015 at about 1:30 p.m.).

Example no. 1 in which the Eurostoxx 50 futures preceded the CAC 40 futures

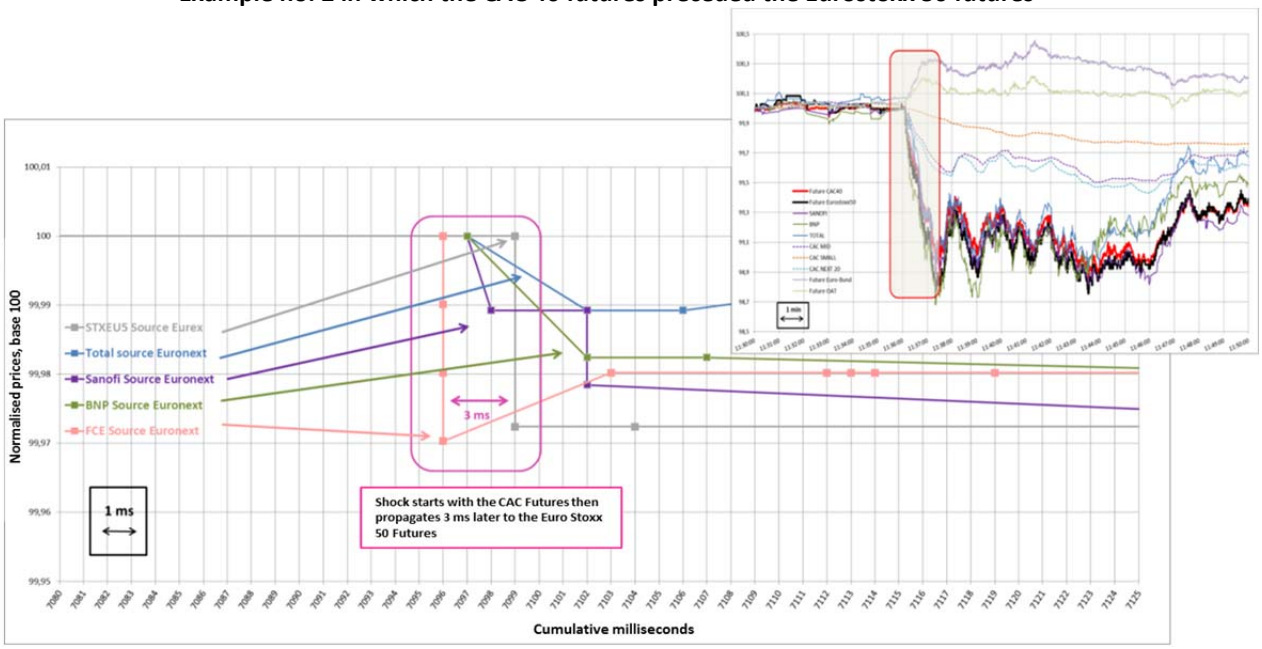


Source: Eurex - Euronext

Analysis of chart titled "Example no. 1 in which the Eurostoxx 50 futures preceded the CAC 40 futures": From boxes A and B, it is clear that the decline started first with the Eurostoxx 50 futures (A), then moved to the CAC 40 futures and the CAC shares (B) with a 3-millisecond delay. Note that in Part B, there does not seem to have been a delay in the market's reaction between the CAC 40 futures and the shares (Total, BNP Paribas, Sanofi).

The chart below shows an example where, in contrast, the CAC 40 futures preceded the Eurostoxx 50 futures (price jump in the day of 24 June 2015 at around 11:30 a.m. – against the backdrop of tensions over Greek debt negotiations).

Example no. 2 in which the CAC 40 futures preceded the Eurostoxx 50 futures



Source: Eurex - Euronext

Analysis of chart titled "Example no. 2 in which the CAC 40 futures preceded the Eurostoxx 50 futures": In the box, the first to react was the CAC 40 futures; 3 milliseconds later, the shock then propagated to the Eurostoxx 50 futures.

The analysis of price sequencing on the emergence of a shock is therefore not conclusive to determine which market was first to react as there were co-occurring cases in which the Eurostoxx 50 futures preceded the CAC 40 futures and vice versa.

When analysing price formation at the beginning of a shock, two types of sequencing were observed:

- ☐ the Eurostoxx 50 futures preceded the CAC 40 futures
- ☐ the CAC 40 futures preceded the Eurostoxx 50 futures

It is therefore impossible to conclude that there is a unique established chronological price sequencing at the millisecond level.

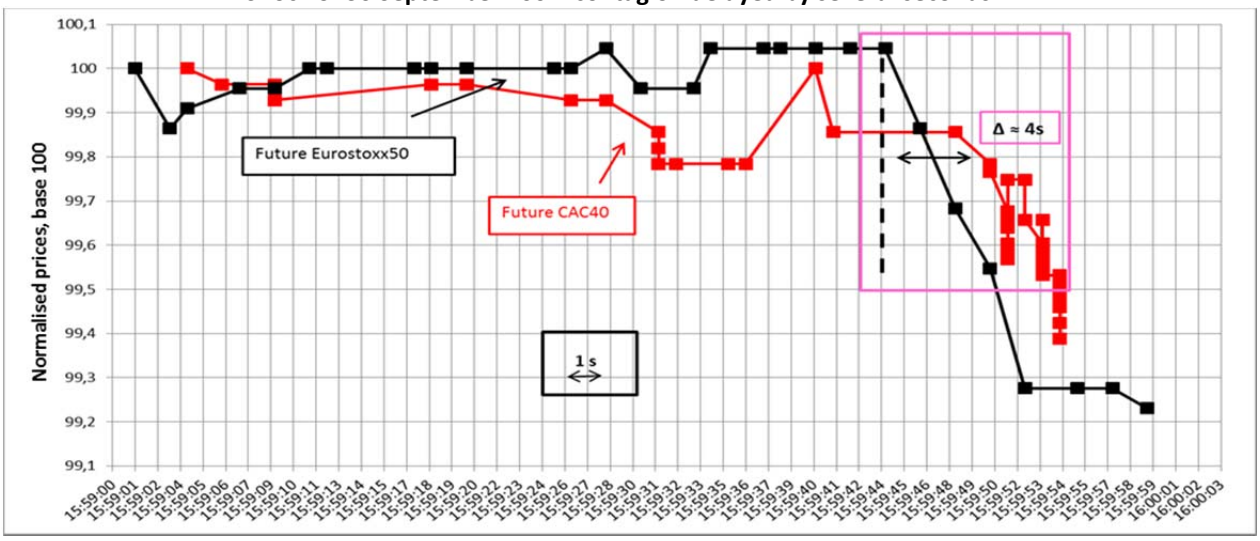
There are several possible explanations for the co-existence of the different price sequencings observed:

- First, it is possible that Eurex and Euronext are not synchronised to exactly the same time (lag on the order of a few tens of microseconds, or even a millisecond at most). In particular, it may be that the order matching engine for each platform slows when an influx of messages is generated by the news at the source of the shocks under review (delayed buffering). It is therefore possible that, below a certain granularity (a few milliseconds), the data timestamps are no longer reliable.
- Furthermore, it is not always the same traders who are responsible for propagating the different shocks under review. For example, we note that, for the two dates considered (3 December 2015 and 24 June 2015), it was not the same participant who was the most aggressive seller of the CAC 40 futures.

The shocks analysed occurred less than two years ago. For the sake of comparison, two older shocks were also analysed: one well before implementation of the Markets in Financial Instruments Directive (MiFID) and the emergence of high-frequency trading (HFT) in 2002, and a second one in 2008.

The chart below shows the shock analysed on one day in 2002.

Shock of 30 September 2002: contagion delayed by several seconds

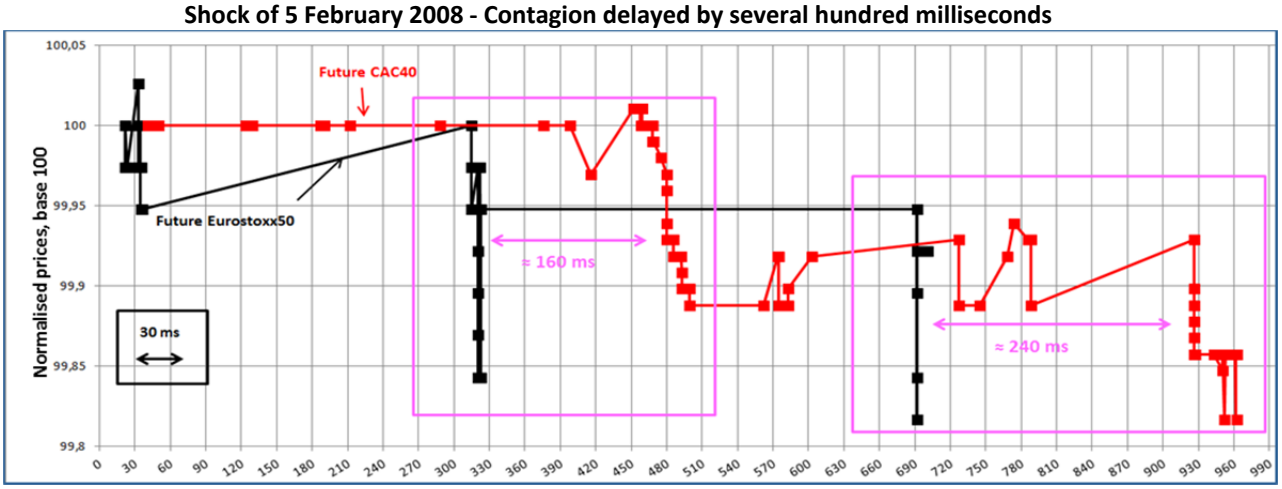


Source: Reuters Data Tick History

Analysis of chart titled "Shock of 30 September 2002: contagion delayed by several seconds": This shock stemmed from the publication of the Michigan Manufacturing Index, which posted its sharpest drop in eight months. It clearly shows that four seconds passed between when the Eurostoxx 50 futures began to fall and when the CAC 40 futures followed suit.

The chart below shows the shock analysed on one day in 2008.

Shock of 5 February 2008 - Contagion delayed by several hundred milliseconds



Source: Reuters Data Tick History

Analysis of chart titled "Shock of 5 February 2008 - Contagion delayed by several hundred milliseconds": At 1:55 p.m., the publication of the fast-falling ISM non-manufacturing index heightened concerns about a recession in the U.S. economy. It clearly shows that 160 to 240 milliseconds elapsed between when the Eurostoxx 50 futures began to fall and when the CAC 40 futures followed suit.

While at the beginning of the **2000s**, a **gap of several seconds** was observed, the start of high-frequency trading seems to have reduced this lag to around **several hundred milliseconds at the beginning of 2008**. In recent years, developments in high-frequency trading and in the automatic analysis of news flow (machine reading) continued to reduce this delay to the millisecond level such that **it is now no longer even possible to draw conclusions about price sequencing without nominative data from Eurex.**

5. CONCLUSION

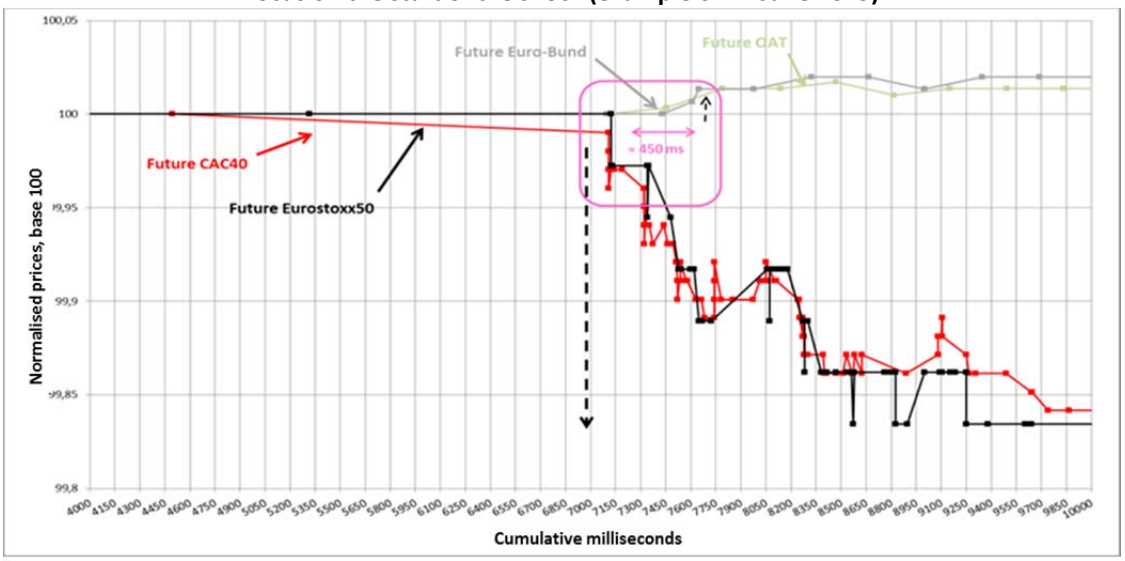
A study of shock propagation to different instruments tends to show, in one example, that the CAC 40 wavers when the Eurostoxx 50 is suspended and to underscore the importance the Eurostoxx can have in decision-making by French market participants. In contrast, an examination of the chronological sequencing of prices at the time of a shock is not conclusive: while the time lag observed a few years ago (on the order of several seconds in 2002, then several hundreds of milliseconds in 2008) made it possible to identify the source of the price formation during a shock, this is no longer the case now that the delay has been reduced to milliseconds given time stamp/time clock accuracy issues. Without data on orders and trades on the Eurostoxx 50 futures market, it is therefore not possible to successfully reconstruct the chain of events between platforms.

An analysis of the sensitivity (in terms of magnitude) of different instruments to a shock to the Eurostoxx 50 futures showed the French market to be highly reactive. Two characteristics were observed in this exercise: small- and mid-caps (as reflected in the CAC Next 20, Mid 60 and Small 90 indices) are less correlated to a macroeconomic shock than their peers from the CAC 40; they are more severely affected by their own specific factors. Lastly, a French stock included in the Eurostoxx 50 is more sensitive and more volatile (one-minute intraday volatility) than a stock in the same sector that is a constituent only of a CAC index. This reflects more generally the strength of the index, which is more important than the fundamental value of the underlying shares.

6. APPENDIX

6.1. PROPAGATION OF SHOCKS TO DEBT INSTRUMENTS (EXAMPLE OF 24 JUNE 2015)

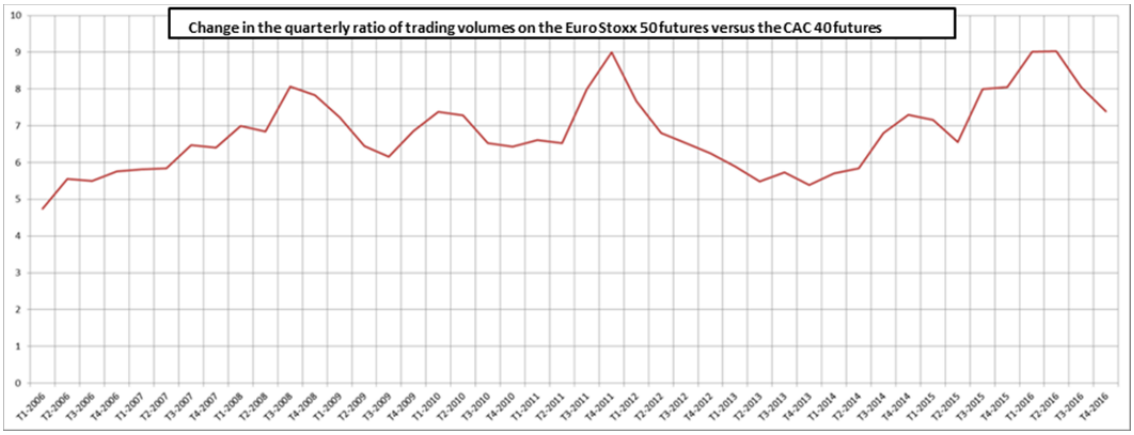
Focus on the start of the shock (example of 24 June 2015)



Source: Reuters Data Tick History

In the chart above, the dots representing debt futures were calculated using best limits in the futures book and not trades. From a millisecond angle, there are too few transactions on OAT and Euro-Bund futures to compare them to CAC 40 and Eurostoxx 50 futures during the period under review.

6.2. CHANGE IN THE RATIO OF TRADING VOLUMES ON THE EUROSTOXX 50 FUTURES RELATIVE TO THE CAC 40 FUTURES



Source: Bloomberg

The ratio of quarterly trading volumes on the Eurostoxx 50 futures relative to the CAC 40 futures, shown in the chart above, increased until early 2008 and then stabilised and hovered at about 7.