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# Contagion and the transmission of financial crises – implications for investors and regulators


Paper within Master Thesis in Finance

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Jönköping June 4th 2012

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# *Abstract*

The occurence of financial contagion can lead to hazardous results for financial institutions, financial markets as well as for the whole economy. Therefore it can have even serious economic effects on everybody´s life. That is why it is of great interest to deeper understand its characteristics. As classical finance theory seems not to give the best answers to this topic, the young academic field of behavioural finance can deliver new insights. The main purpose of this work is to provide an introduction mainly to professionals in portfolio and risk management and help them to tackle the problem of contagion at an early stage. Therefore not only aspects of behavioural finance are discussed, but the topic contagion is also brought into connection with network analyses and the current regulation process. Our paper can not answer all questions related to contagion, but it can help the reader to better understand its main aspects and enables him to delve deeper into this field.



**Keywords**: Contagion, investor behaviour, herding, network analysis, portfolio management, volatility

# 1 Introduction

Before the year 1997 the term contagion was mostly used in its biological definition as spreading a disease. After the currency crisis in Thailand in 1997 and its transmission to the East Asian neighbours like Malaysia or the Philippines and also to countries without any clear relationship to the Thai economy like Brazil and Russia in 1998, the word contagion became more popular in the language of finance. For the last 15 years several concepts and different ideas about how to exactly define contagion, how to measure it and through which channels it can spread, have emerged. Because of the negative effects of contagion investors as well as regulators have a high preference to contain shock transmissions. As classical finance seems not to give all suitable answers to contagion we are searching for new approaches given in behavioural finance and network economics. The paper can therefore contribute to these new scientific fields and can be seen as a good introduction for portfolio and risk managers who have to deal with the problem of contagion.

In the beginning we present an overview about some previous literature of contagion. We also work out the main definitions and the channels through which contagion can be occur. The four dominant channels are (I) the real sector, (II) the financial markets, (III) financial institution linkages, and (IV) the interaction between financial institutions and financial markets. Chapter three presents some insights about investor behaviour and the contribution of behavioural finance to explain contagion effects. We demonstrate that the efficient market hypothesis is wrong due to limitations for arbitrageurs. In addition we explain herding behaviour and other investor anomalies to describe the way investors are biased in their decision-making process. In chapter four we deduct two different testing methods for stock market contagion. The first method tests for a change in the correlation after the occurrence of a shock between two markets. The second method takes into account that volatility increases after a shock and therefore tests for volatility contagion. In chapter five we give some implications for portfolio and risk management. Therefore we concentrate our analysis on portfolio diversification and network techniques. Briefly we also point out a few proposals of Basel III. Finally we present our conclusions, an outlook for further research and some remaining open questions.

# 2 Literature review about contagion

Eichengreen, Hale and Mody (2001, p. 133) explain that "[r]esearch on contagion is dominated by two approaches. One focuses on changes in the likelihood of a devaluation or currency crisis in a country when similar events occur in neighbouring countries in the current or immediately preceding periods. The other looks for changes in the correlation of stock, bond and exchange-market returns across countries in periods of financial turbulence". In our paper we will concentrate on the second case and therefore perform a test for contagion through stock market relations in chapter 4.

The idea behind contagion is quite complex and there exist also several different ways of how to define contagion. A broader definition is provided by Pritsker (2000, p. 2) who delineates contagion "as a shock in one market or country, that is transmitted to another market or country". Whereas Forbes and Rigobon (2002) use a tighter definition of contagion and determine it as a significant increase in cross-market linkages occurring after a shock or a crisis. This definition is very useful for the testing procedure of contagion and will be the underlying idea for our empirical part in chapter 4. There is also a wide range of different definitions available by the World Bank. In a very restrictive way they define contagion as a transmission of shocks to other countries beyond any fundamental links.[1] In some literature this is also called excess co-movement and can be explained by investor behaviour like herding. In chapter 3 we use this definition to show that behvioural finance is helpful to explain the occurrence of shock transmission even if there are no fundamental reasons underlying.

Another important aspect in the literature about financial contagion is the different transmission channels. According to Claessens and Forbes (2001) and also Pritsker (2000) there are mainly four channels of contagion which are relevant to study: (I) the real sector, (II) the financial markets, (III) financial institution linkages, and (IV) the interaction between financial institutions and financial markets. Likewise one can differentiate between direct and indirect links.

[1] World Bank definitions of contagion: http://econ.worldbank.org/WBSITE/EXTERNAL/EXTDEC/EXTRESEARCH/EXTPROGRAMS/EXTMACROECO/0,,contentMDK:20889756~pagePK:64168182~piPK:64168060~theSitePK:477872,00.html

(I) The real sector

The real sector covers all activities in the economy that are related to aggregated supply and aggregated demand. It includes GDP, consumption and savings, the price level and the wage rates. Shocks in the real sector that are transferred from one country to another mainly use trade links. For example a strong reduction in aggregated demand in country i can lead to reduced imports from country j and therefore ceteris paribus also to a lower GDP of country j.

The transmission of a shock in the real sector can also be examined through the devaluation of exchange rates. Consider that two or more countries peg their exchange rates and that the central bank of each country is willing to defend the fixed system. This means that the central bank needs to sell its currency reserves if the real exchange rate would drop below the fixed rate. If all reserves are depleted the central bank has to consequently unpeg the exchange rate. A negative shock in the real sector in country i could make it less desirable to defend the fixed rate or might force its currency to devalue because of a speculative attack. This devaluation leads to a decreased competitiveness in country j, so that j might also want to devalue its currency or is simply the next potential victim of a speculative attack. The shock in the real sector can then be transmitted through this chain of speculative attacks as Obstfeld and Rogoff (1996) worked out.

(II) The financial markets

The financial markets cover all markets where buyers and sellers can trade financial assets. These assets can be stocks, bonds, derivatives, currencies or any other financial instrument that can be priced. A possible transmission of a shock is via the stock markets. Normally a regional shock in one country should have no impact on the prices in another stock market which are ideally determined by idiosyncratic risk and fundamentals only. But there might be phases when stock markets correlate much stronger than in normal times. And we can therefore also observe herding behaviour by market participants. In chapter 3.2 we will focus even more on this effect.

Another interesting aspect of contagion through the financial markets is the transmission through sovereign bonds. According to Constâncio (2011) the increase of the bond yields for Spain and Italy are a proof of contagion following the Greek debt crisis. Investors either shortened or simply reduced their exposures to the countries of concerns because they believed that these countries might face similar problems like Greece and that the debt sustainability of these countries could not be guaranteed in the long run. This behaviour has led to falling prices for Spanish and Italian government bonds and therefore increased their borrowing costs. As a result Spain's and Italy's sustainability to repay its government debt decreased and investors' expectation might be validated by a self-fulfilling prophecy.

(III) Financial institutions linkages

The financial institutions (FIs) cover all financial intermediaries like hedge and pension funds, insurance companies and banks. A possible transmission of a shock could follow through the broad interconnection between financial institutions. Therefore the failure of one institution can cause problems or even failures at its counterparties, for example due to the withdrawal of deposits by the bank who faces financial distress. Also bank customers can cause problems at the healthy banks when they think that the failure of another institution might be repeated at their own bank. If the confidence of the depositors into the banking system is low then this can cause bank runs which lead to the collapse of more than one bank, even if the other banks were under no financial distress.

The following factors are important if a shock from one financial institution to another one is transmitted and how strong this might be done. First of all the size and number of linkages between FIs plays an important role. Allen and Gale (2000) argue that a larger number of linkages make the banks more resilient to shocks. Counterintuitively this means that more links between financial institutions would be better to contain shocks than just a few significant links between them. For simplicity consider the following example in which we have just four different banks in our economy. They are labelled A, B, C and D. In the first case each institution takes deposits in only one other bank which is indicated by the arrow in the picture below. If bank A faces financial distress and withdraws part of (or all) deposits from B, than B needs to recover the full value of A's deposits. Otherwise B will also face liquidity problems and this can be transmitted to C and then possibly to D. The chances are therefore high that the whole system might break down. In the second case all financial institutions are connected with each other and the deposits are by assumption split amongst them equally. If A faces the same problems like in the first case, then now B, C and D share the losses from A equally. Therefore the chance that B faces liquidity problems is much lower.

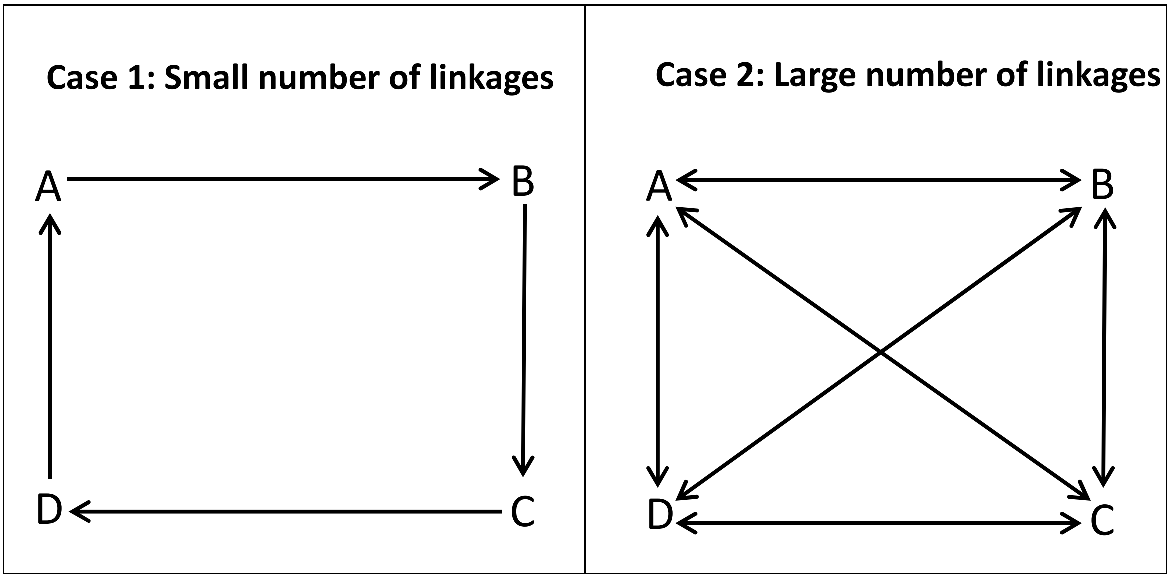

Figure 2.1: Resilience of a banking system due to number of linkages, own graphic

All in all the banking system in case 2 is less fragile and less susceptible to shocks. This result is supported by Nier et al. (2007) who has modeled a more complex network of banks and showed that the financial systems' ability to absorb shocks improves if connectivity between the banks increases.

Another important aspect is capital adequacy of each financial institution. If bank B would have enough capital resources and a strong balance sheet to cushion the withdrawals of deposits by A then there would be no significant transmission of the shock to the other banks and the system would not melt down. That is one reason why regulators emphasise on the capital endowments of each financial institution.

(IV) Interaction between financial institutions (FIs) and financial markets (FMs)

Financial institutions invest their funds most often in several markets and different asset classes. The transmission of a shock from one country to another country could be through the FI-FM channel. There are two possible scenarios: The first is from the financial institution to the financial markets. For example a bank which has an important role in country j, but faces a shock in another country i. This shock can cause a reduction of the availability of credit or liquidity problems in the financial market of country j. In the second scenario the shock in country i affects its financial market and causes losses for the bank in country i. Due to its losses the bank might be forced to reduce its loan portfolio in country j and in this way the shock will be transmitted.

Most of the literature about contagion focuses its attention on the Asian countries and the Emerging Markets.[2] But there is also a study by Kuusk, Paas and Viikmaa (2011) who tested for contagion from the US crisis in 2008 to the Baltic States. Their results are mixed rather than giving a clear answer, and mainly depend on the exact method they were using.

Horta, Mendes and Vieira (2008) did a similar study and tested for contagion effects of the US crisis to several developed countries. One of their results is that the German economy seems to be more resilient to contagion from the US than all other industrial countries in their survey. Their paper also shows that Canada and Japan are more vulnerable to the US crisis, but this might be also the case because of its geographical proximity and larger bilateral trade flows.

[2] For example Goldfajn and Baig (1999) or Calvo (1999).

# 3 Investor behaviour

According to the efficient market hypothesis stated by Fama (1970) asset prices should purely reflect fundamentals. The changes in asset prices therefore are simply the reaction to news about future cash-flows, the outlook of future earnings and certain discount factors, but they are not dependent on some extrinsic influences of the investors. In the strongest definition of the efficient market hypothesis new information about these factors should be even incorporated immediately. In this chapter we are analysing the behaviour of investors and we will demonstrate that in some cases the financial markets can not be considered as efficient. This is also the root for the occurrence of contagion by its definition of transmitting a shock from one country or market to another country or market without fundamental reasons underlying.

## 3.1 Noise traders and arbitrageurs

Let us consider the following simplification that we have two different traders in the capital markets. The first group consists of uninformed traders who are chasing the trend in their trading or investment decisions. Because these participants pick up some noise like market sentiment and rumours they are also called noise traders. On the other hand we have a group of informed persons who can falsify the information about the markets and who evaluate the assets according to its underlying fundamentals. If the current price of an asset is lower than its fundamental value they would buy the asset until the market price equals its reasonable value. If the current price of an asset is higher than its fundamental value they would sell the asset, or if they are not the owner of the security they would short sell it. The second group exploits arbitrage opportunities and they are therefore called arbitrageurs. If the efficient market hypothesis would be valid in all circumstances than there would be no arbitrage opportunity available because all asset prices would always reflect their fundamental value.

According to Shleifer (2000) noise trader risk plays an important role in the idea that arbitrageurs can not always bring asset prices back to its fundamental values and therefore the market is sometimes not efficient. If the noise traders' beliefs become more extreme in the short run, so that the asset price develops further and further away from its fundamental value then an arbitrageur who is betting against them is facing the risk of extended losses in the short run. Being aware of this assumption, arbitrageurs as a group are not able to exploit every arbitrage situation as indirectly stated in the efficient market hypothesis. The fact that arbitrageurs often have short time horizons, because their performance is usually evaluated quarterly or yearly, supports the argument that their willingness to bet against the uninformed noise traders is limited. Furthermore arbitrageurs often fulfil their trades with borrowed money. Therefore they have to pay interest on that money and also face the risk of early liquidation, so they might go bankrupt before the asset price is back to its true value. Shleifer (2000) also mentions the problem that even with infinite time horizon arbitrage is limited in cases that securities or indexes do not have perfect substitutes. That is why it might be easier for arbitrageurs to bet against one security instead of betting against the whole market.

Furthermore Shleifer (2000) illustrates a situation in which arbitrageurs lose their possible stabilization powers and even worse they become a factor of destabilizing security prices, especially in the presence of positive feedback traders. This investment strategy is characterized by buying an asset if the price goes up and selling it when the price goes down. Consider a case in which an arbitrageur receives novel good news about a company which is not already incorporated in the asset price. If he exploits this situation in buying the stock then he also motivates positive feedback traders to also buy the stock and therefore even drive the price above the fundamental value of the underlying asset. Buying in anticipation of further buying by uninformed traders can therefore produce a self-feeding bubble. The evolution of bubbles as well as its historical relevance will be further discussed in the context of herding behaviour in the next paragraph.

## 3.2 Herding behaviour

Following Bikhchandani and Sharma (2001) there are three reasons why investors imitate other investors in their investment decisions. Firstly, others may have more information about the return of a certain investment and might unveil this information with their action. Secondly fund managers who simply follow the herd will not perform worse than the market and this often reflects there bonus scheme because it is not their absolute performance but their relative performance which will be assessed at the end of the year. And thirdly, many individuals seem to have a preference for conformity.

Herding behaviour can be seen as individually rational, as for example the collection of information is not costless, but if it is combined to group behaviour it can have negative effects and might reflect irrationality. This can also be demonstrated with the famous restaurant example of Shiller (2000). He considers a few couples who want to go out to eat dinner and have the choice between two restaurants which are both empty and next to each other. The first couple will make their decision completely random, so they might toss a coin or roll a dice. For the second couple one of the restaurants will then not be empty, but they can recognize that someone else decided to eat in one of the restaurants. Therefore they make the conclusion that couple one might have a good reason for their decision and will follow them. If every other couple also follows them for the same reason, than it might be possible that at the end of the day one restaurant is crowded while the other is still empty. But the people might not eat in the better restaurant as couple one's decision was completely random and not based on solid information.

The same behaviour can be recognized in the creation of bubbles. Bagehot (1872) describes it as follows: „owners of savings […] rush into anything that promises speciously, and when they find that these specious investments can be disposed at a high profit, they rush into them more and more. The first taste is for high interest, but that taste soon becomes secondary. There is a second appetite for large gains to be made by selling the principal which is to yield the interest. So long as such sales can be effected the mania continues". Probably the first and still one of the most famous bubbles is the Dutch Tulip mania from the 1630s. Due to mosaic viruses some tulips looked more beautiful in the eyes of connoisseurs and therefore they were willing to pay higher prices. This was the initial good news which stands at the beginning of every bubble and leads to substantial profits for a few investors. According to Kindleberger (1978) the next step in the development of a bubble is the increase of the supply of physical assets and claims to them. In the Tulip mania smart investors invented speculative contracts whereby one could profit from the increasing prices of the special tulips. Even the ordinary people could so far realize that they can increase their wealth with trading tulips. Then more and more people followed the first investors. This led to further price ascents and the bubble grew and grew. But as the underlying asset was just a tulip, at a certain point the price declined and more and more people realized that their speculative contracts might not pay out. In the same way the bubble was formed by herding behaviour, it also got destroyed as most people simply followed the action of other investors and sold their contracts. The same mechanics can be observed in other bubbles like the South Sea Bubble in the beginning of the 18th century or the US railway boom in the 1870s. As argued earlier herding behaviour can be seen as rational behaviour for individuals but it can end up in devastating results. The willingness to invest in an obviously over-valuated asset, but the hope for further profits is what can be best described as herding mentality.

Stock market contagion can therefore follow a stock market boom like in the 1920s in the US and might be an adverse result of a bubble. But even without the existence of a bubble contagion can be caused by herding behaviour. Goldfajn and Baig (1999) demonstrated that after the devaluation of the Thai Baht some investors lost confidence also in other Asian countries and therefore reduced their exposure and started to speculative on a devaluation of the currencies of the countries under focus. This action was imitated by more and more investors without asking about the fundamentals and so the crisis in the Thai market spread to Malaysia, Korea, Indonesia and other countries which had no clear linkages to Thailand. Therefore herding behaviour can explain contagion by mirroring the establishment of a bubble. After a shock investors tend to sell their assets while imitating those who are the first to take action and hence show that their information might be correct. But if a bubble is identified at its early stage, then investors can even earn abnormal profits by exploiting the existence of herding behaviour.

## 3.3 Investor anomalies

There are also more investor anomalies which are interesting to study and may also play a role in the explanation of contagion and the transmission of financial crises. Kahnemann and Tversky (1979) where one of the first researchers who did lab and classroom experiments to observe the decision-making process of human subjects under uncertainty. As a result they developed their famous prospect theory. Nowadays more and more experiments are carried out with the outcome that the efficient market hypothesis might be proven to be wrong. As the field of behavioural finance is still quite young there is a lot of room for future research. In the following we want to highlight just a few more investor anomalies.

(I) Overconfidence

DeBondt and Thaler (1994) point out that one of the most robust findings in the psychology of judgment is that people tend to be overconfident. This is not limited to the financial market and investment decisions. Svenson (1981) showed in his study that 90 per cent of

Sweden's automobile drivers considered themselves as being above the average driver. Slovic (1973) shows in his example that bookmakers became more confident in their decision of the race performance of different horses if they got more information. But on the other hand the accuracy of their forecasts has not increased at all. Similar results are offered by Handzic (2001) and Davis et al. (1994) who both demonstrate that additional information only leads to more confidence, but not to more accurate results.

(II) Investor mood

There is a lot of current research done do tackle the question if the decision making process of investors is truly rational or if they are influenced by emotions and feelings. Saunders (1993) figures out that cloudy weather had a negative relationship on equity prices at the New York stock market. This result is also supported by a follow-up study by Hirshleifer and Shumway (2003) who tested the relationship between cloud cover and the returns of equities of 26 international markets. The influence of the weather on the mood of humans is widely accepted in psychology. Howarth and Hoffman (1984) as well as many other psychologists show that the hours of sunshine per day increase optimism and general mood. So there is a good reason to think that the weather also affects the investors' behaviour. Like the weather there might be more extrinsic factors which influence the investment decision. Kamstra et al. (2000) mentions the reaction of the interruption of the sleeping pattern. There might be even more factors such as the occurrence of new moon who affect the humans biorhythm and therefore probably also his trading and investment decision.

(III) Mental accounting

According to Shefrin and Statman (2000) people sometimes tend to put their assets into different mental accounts and therefore treat them differently instead of considering the whole portfolio when making choices. One feature of the mental accounting is that investors become more risky when they made gains by an investment. Therefore the gains are sometimes considered as a lottery ticket and they are more willing to gamble with this part of their portfolio. Massa and Simonov (2003) have proven this behavioural bias for private accounts in Sweden. They found out that the gains of previous years were used as "house money", so investors became less risk averse to this money.

All in all we can show that there are plausible arguments why full investor rationality should not be taken for granted. The stated anomalies lead to non-optimal investment decisions because a higher level of risk would be taken and the investors are extrinsic influenced. Supporters of the efficient market hypothesis would argue that these “wrong” investment decisions only happen on an individual basis and that these biases cancel each other out on the market level. But as we demonstrated earlier arbitrage is limited and so the mispricings can not fully be revised. Therefore all of these investment anomalies might play a little role in the transmission of a financial crisis. As investors are still human beings they are also influenced by their environmental surrounding and personal condition which can additionally explain why crises can transmit even without fundamental reasons.

# 4 Testing for stock market contagion

In chapter 4 we conduct two different testing methods for stock market contagion from the US crisis in 2008 to Italy, Germany and France. As most of the tests for contagion in the literature concentrate on Emerging Markets, with our selected countries we can check if contagion from the US stock market crash also spilled over to the three biggest economies in Europe. Our examined tests shall give the reader an idea of how to detect contagion. First we used the approach by Forbes and Rigobon (2002) and tested if the correlation between the two markets increased after the outbreak of the crisis in the US. The second approach is contributed to Baur (2003) and tests for volatility contagion. There exist a lot more possibilities how to identify contagion. Just to name two more examples, Yang and Lim (2004) argue that one might detect contagion by examining the Granger causality test. Billio, Duca and Pelizzon (2005) have another approach. They use Markov switching models to detect non-linearities in the financial markets produced by a break due to contagion. It would be very interesting for future research to find out even more possibilities and to cover them also in greater detail. But because of some time constraints and the extent of the work, we only concentrate in this paper on the two methods mentioned in the beginning and we just test for stock market contagion as one specific transmission channel.

## 4.1 Data

In order to test for correlation changes and volatility contagion we used the following data. We calculated the daily continuously compounded returns of the stock indices of Germany (DAX), France (CAC), Italy (MIB) and the United States (S&P 500)[3]. These four indices stand for the biggest firms by market capitalization in each single market and can therefore be seen as a good representative of the respective economy. Our starting point for the observations is March 3rd 2008. The end date is March 9th 2009, so the total number of observations is T=259. Our total time span can be divided into a tranquil period from March 3rd 2008 until September 15th 2008 and a crisis period following the day after the bankruptcy of Lehman Brothers as it marks the starting point of the financial crisis, lasting until March 9th 2009. As we deal with different time zones we use the close values for the three European

[3] The data was collected at yahoo.finance under http://finance.yahoo.com/intlindices?e=europe. We calculate the continuously compounded return by the following formula: ror = $\ln(P_{t-1})-\ln(P_t)$.

indices and the opening prices for the S&P 500. All our indices are denominated in Euro.[4] One big advantage of using stock market returns calculated from their respective indices is that it is easily accessible data and available on a daily basis. Table A.1 in the Appendix provides the descriptive statistics for the stock market returns of the four selected countries.

## 4.2 Methodology and testing results

### 4.2.1 Correlation contagion

Some authors like Forbes and Rigobon (2002) or King and Wadhwani (1990) argue that we can detect contagion by a significant increase of the correlation between two or more markets. A higher co-movement between two or more markets in the crisis period compared to a stable period would be seen as a transmission of a shock. This test is quite intuitive and forms the basis of the testing for contagion since the 1990s. The method is straightforward and simple to examine. Therefore it can be used as a good and quick method to test for contagion. In our paper we estimated the correlation coefficient between two stock markets. Our simple model for the test of a contagion effect from the US as the originator of the crisis to another market can then be written as:

$$\mathrm{Y}_{it} = \alpha + \beta * X_t + u_t$$

Where $\alpha$ is a non-zero intercept, $u_t$ is the error term and $\beta$ our correlation coefficient that is of high interest for us. $Y_{it}$ represents the Italian, the French or respectively the German stock market. To check if the correlation coefficient increases, we run a simple regression by OLS (ordinary least squares) for the tranquil period as well as for the crisis period. Afterwards we can compare our estimated values of $\beta$ for each period. As provided in table 4.1 below, the correlation coefficient for the tranquil period between the US and Italy is 0.33, between US and France -0.08 and between US and Germany -0.02. In the crisis period our correlation coefficient increased for Italy to 0.48 and for France to 0.06, but it decreased for Germany to -0.17. Our estimates are only statistically significant for Italy in both periods and for Germany in the crisis period.

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[4] The historical US-Dollar – Euro exchange rates are for example available at the website of the European central bank: http://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=120.EXR.D.USD.EUR.SP00.A.

These coefficients show us that the Italian stock market is surprisingly much higher correlated with the US market, compared to the French and the German market in the respective time periods. In fact, the German stock market even has a slightly negative correlation with the US both in the tranquil and in the crisis period. For Italy and France the correlation coefficient increased after the shock in the US, but only for Italy this increased co-movement is significant. If we follow the Forbes and Rigobon (2002) approach, this would be seen as a sign of contagion from the US to the Italian stock market.

**Table 4.1:** Correlation coefficients between the US and Italy, France and Germany

| | **Italy** | **France** | **Germany** |
|---|---|---|---|
| **Tranquil period** | 0.332576* | -0.083983 | -0.019595 |
| **Crisis period** | 0.480605* | 0.061943 | -0.176766* |

The statistically significant values (at 5% level of significance) are marked with an asterisk.

### 4.2.2 Volatility Contagion

Baur (2003) points out that in periods of crises the volatility of financial time series often increases considerably. Higher uncertainty about the future might play an important role in this case. Below we plotted the continuously compounded rate of returns for Italy, France and Germany. We can see that there is an increase of the volatility for all three markets in the last quarter of 2008. But for all three time series we have a stationary process around a non-zero equilibrium.

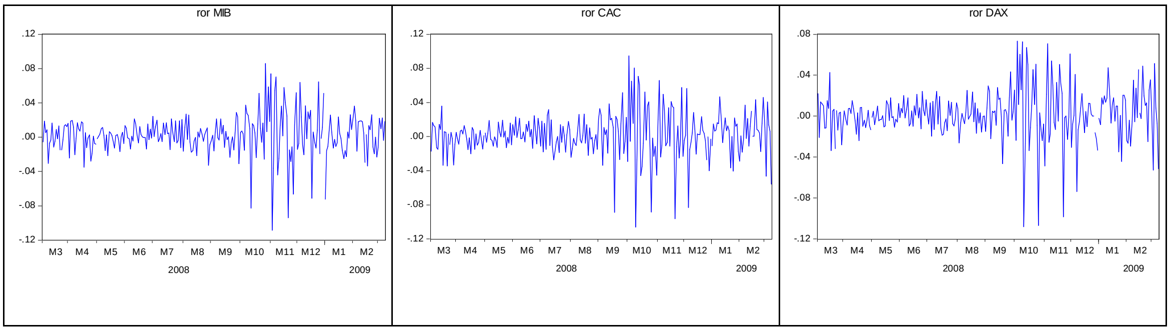


Figure 4.1: Continuously compounded rate of returns for Italy (MIB), France (CAC) and Germany (DAX).

As we found out that the volatility of our observed time series is not fully constant over time, it might be a better approach to test for contagion effects by using the method of volatility contagion and therefore set up the following framework:

$$Y_t = u_t = z_t * \sqrt{h_t}$$

$$\mathrm{h_t} = a_0 + b_0 * u_{t-1}^2 + c_0 * h_{t-1} + d_1 * X_{t-1}^2 + d_2 * X_{t-1}^2 dummy_{crisis_{t-1}}$$

The first equation expresses the affected market $Y_t$. Therefore $z_t$ being a normally distributed random variable and $h_t$ being the conditional variance of the affected market. In the GARCH (1,1)-model we added two extra regressors. According to Baur (2003) $d_1$ captures the volatility spillover that is commonly observed and $d_2$ reveals any departure from the normal volatility spillover during the crisis period. Our dummy variable is equal to 1 for observations in the crisis period and 0 otherwise. Because of the fact that our $d_2$ can take on negative values we have to use EGARCH (exponential GARCH). Our second equation from the model above therefore changes to the following one:

$$\mathrm{h_t} = \exp\left\{\begin{matrix}\alpha + \theta z_{t-1} + \gamma\left(|z_{t-1}| - E(|z_{t-1}|)\right) + \delta \log(h_{t-1}) + d_1 * X_{t-1}^2 \\ + d_2 * X_{t-1}^2 dummy_{crisis_{t-1}}\end{matrix}\right\}$$

The table below shows us the estimated coefficients for volatility contagion. We tested the null hypothesis of no volatility contagion $H_0$:$d_2 \leq 0$ against $H_1$:$d_2 > 0$. Only for Italy we can find a positive and significant value for $d_2$. For France and Germany $d_2$ is negative and not significant. But all our residuals are normally distributed. So we can find a proof of volatility contagion from the US to Italy, but not to France and Germany.

**Table 4.2:** Coefficients for volatility contagion

| Country | Italy | France | Germany |
|---|---|---|---|
| **α** | -0.943925* | 0.001647 | -0.094757 |
| **θ** | -0.063501 | 0.02471 | -0.03394 |
| **γ** | 0.216295* | 0.182539* | 0.223497* |
| **δ** | 0.881631* | 1.001128* | 0.98375* |
| **d1** | -112.6034 | 73.12572 | 4.718865 |
| **d2** | 211.4962* | -94.8838 | -11.28467 |

The statistically significant values (at 5% level of significance) are marked with an asterisk.

### 4.2.3 Summary of our testing results

Because of the complexity of the whole concept of contagion it is quite difficult to draw really clear conclusions from our different testing methods. We can emphasise that the correlation coefficient between the US and Italy increased significantly in the crisis period and therefore might be seen as a proof of contagion. This result is also affirmed if we test for volatility contagion. For Germany we can validate the results found out by Horta, Mendes and Vieira (2008) in their study, that there is no evidence for contagion from the US to the German market. A possible explanation might be that the German economy is very strong and highly globalized, so that even a shock in the US might not affect it with full strength or at least not immediately. That time lag effect sounds quite reasonable as the correlation coefficient between the US and Germany even decreased in the crisis period. An increase of our timespan might deliver other results and also the problem of different time zones might have biased our findings.

As mentioned earlier our purpose of testing for stock market contagion was to provide the reader with an example of how to detect and measure contagion. While the focus of this thesis is more on the theoretical explanation of contagion, the reader can find a large extend of testing methods for contagion as well as empirical results in the literature.

# 5 Implications for portfolio and risk management

In this chapter we are going to discuss some further implications for investors and regulators how to tackle the problem of contagion and the assessment of systemic crises. We demonstrate that international portfolio diversification can contribute to transmit shocks and therefore be a factor for contagion effects. One of the major tools to assess the interconnectedness between financial agents are network analyses. From our point of view they can play an important role to prevent contagion, especially if we improve their abilities to exactly forecast shock propagation and run realistic simulations. The new regulation rules which are summed up by the term Basel III can further help to make the banking system more resilient to systemic shocks. And they definitely show that the supervisors are aware of the importance of contagion effects with its serious ramifications for the whole economy as well as their willingness to contain the triggers of financial crises. Because the banking system is just one possible channel that can transmit a crisis, improving banks' supervision and regulation is just one out of many necessary steps in solving the problem of contagion.

## 5.1 Portfolio Diversification

In general investors are well advised to invest their money not only in one stock, but set up a portfolio of different stocks. The reason for this diversification is due to the fact that they can eliminate part of the risk. Therefore the variance of a portfolio $\sigma_P^2$, which is a widely accepted indicator for its risk, is expressed by the following formula which can be found in Elton et al. (2011):

$$\sigma_P^2 = \frac{1}{N}\,\bar{\sigma}_j^2 + \frac{N-1}{N}\,\bar{\sigma}_{jk}$$

If the number of assets N goes to infinity we can get rid of the first part of the right side of the equation which stands for the added up idiosyncratic risk of each stock. Concludingly the risk of the portfolio is then only expressed by the systematic risk or market risk. By investing in more and more assets investors can eliminate the idiosyncratic risk of bad outcomes by one company. Consequently they can also avoid the cumulative risk of industries by investing in different sectors. To go even one step further investors can also add foreign assets to their portfolio. Elton et al. (2011) exhibit that international diversification can further lower the risk of the portfolio. They demonstrate in their example that the risk reduction is through the lower correlation among international markets compared to the intra-country portfolios. Additionally the variance and the expected return for each country's securities play a key role in the decision about how much to invest in the foreign assets and how much in the domestic market. Because of international diversification the investors face some exchange rate risk if they are investing in foreign markets with a different currency. But firstly they can hedge the exchange rate risk by buying futures. And secondly Black (1989) points out that some of the exchange rate risk can even increase expected returns. This extra return might be simply a compensation for taking part of the risk. From the point of view of the individual investor international diversification can improve the optimal portfolio, because it lowers the risk of the portfolio and can even increase its return.

On the other hand there might be the negative side effect that international diversification on an aggregated level can lead to contagion, especially when investors' portfolios are leveraged. Schinasi and Smith (1999) argue in their paper that the rebalancing of an international diversified portfolio can be sufficient to explain contagion. They describe the scenario in which a shock to one asset's return distribution also leads to a reduction of other risky positions. This effect is a consequence of strict obedience with general portfolio management rules. We briefly discuss two of these rules. The first is the expected return benchmarking rule. The portfolio manager chooses the least risky portfolio under the constraint of a fixed expected return. The second rule is the volatility benchmarking rule and is similar to the first one. Here the manager settles a certain level of risk and chooses the portfolio with the highest expected return. Both rules define one single point on the efficient set and highlight the optimal portfolio which the investor should choose. Consider now a shock which occurs in country i and therefore makes the assets more risky. This volatility event leads to an increase of the variance of the chosen portfolio and makes the basket of risky assets more risky and less desirable to hold. In order of the above stated portfolio management rules the investor needs to rebalance the portfolio which can be done by selling the risky assets. If the investor believes that the shock in country i also increases the variance of the assets in another country j than he or she will be also willing to sell part of these assets. On an aggregated level this action can lead to contagion. Another possible way of contagion through portfolio diversification happens in the case of a capital event. Assume that our investor faces losses of a certain amount of capital in the portfolio. Schinasi and Smith (1999, p. 13) state that in the case: "[if] the portfolio is leveraged, then the optimal amount invested in risky assets at time t is less than the […] value of the portfolio prior to rebalancing. Thus, there are net sales of risky assets during period t." So due to leverage, investors are forced to withdraw capital from other higher-risk markets when losses are encountered in one market. Because many institutional investors like banks or hedge funds finance their activities with borrowed funds, the selling of many risky assets at the same time can lead to contagion effects. Margin calls might even boost this effect, but following Schinasi and Smith (1999) it is sufficient to explain the occurrence of contagion with simple portfolio management rules. International diversification might therefore be very fruitful to help investors in reducing their portfolio risk and possibly also increase their returns. But as explained above it can have adverse effects that it can cause contagion on the macro level.

## 5.2 Network analyses

In order to prevent to get hit by contagion investors could observe the linkages between countries, financial institutions as well as financial markets. Of course there might be some problems to get all the important data, but to a certain extent banks or other financial players should have the resources to portray the connections between market participants. Because the simple collection of more and more data is not necessarily useful, the real obstacle then is to filter out the important linkages and its crunch points.

If a crisis in one country or market happens or if a single financial institution faces financial distress than our financial agent could immediately check and maybe also reduce its exposure to its infected counterpart. We are aware of the fact, that the reduction of the exposure done by other FIs simultaneously can lead to herding behaviour what we have described in 3.2, and therefore even trigger or boost a crisis. But there are two aspects while this strategy can still be seen as a desirable approach. Firstly if our financial institution is one of the first to react, than the losses from reducing the exposure are smaller than for those participants who waited too long and just followed the herd. This first mover advantage can therefore make significant differences. The second argument follows the logic of the market forces. If a company or in this case a bank faces losses and has a weak balance sheet than this simply means that it is worse than its competitors. Analogously to other markets the customers have lower preferences for the "losing" company and therefore it should not survive in the market. But because of the interconnection between the financial institutions the regulators have to make sure that each single FI fulfils some specific criteria to cushion the disappearance of its trading partners. Otherwise a failure of one bank or hedge fund can trigger a systematic crisis among all financial institutions as the collapse of Lehman Brothers in September 2008 did.

Network analyses and the installation of an early warning system might therefore not only be fruitful for the financial institutions but also for the supervisory authorities. Minoiu and Reyes (2011) analysed in a recent study the geographical patterns in the global banking network and its changes in the period of 1978 to 2009 by using network techniques. They have used locational statistics provided by the Bank of International Settlements (BIS). The residence of each bank is the basis to which country it belongs. Their bilateral data on cross-border bank lending captures 184 countries. 15 countries in the sample act as lenders (BIS reporting countries) and 169 as borrowers (non-BIS reporting countries). Minoiu and Reyes (2011) describe the lenders as the core and the borrowers as the periphery. Each country represents a node in the network. The links indicate the banking flows between the countries. The compiled network displays country centrality as well as network density. Figure A.1 in the appendix shows us an increase of inter-country lending in 2007 compared to 1980. Also more links exist in 2007 which is an indicator of higher globalized and interconnected financial markets. Minoiu and Reyes (2011) also examined how the global banking network changed after shocks like the 1987 stock market crash, the Scandinavian banking crisis in 1991/92 or the bankruptcy of Lehman Brothers in 2008. Their observation is that in times of financial stress many links die and the network clustering diminishes. Banking and debt crises therefore led to reduced borrower access to capital markets worldwide. This can be illustrated by the reduction in the number of links and the amount of flows. All in all their conclusion about the global banking network is that it is relatively unstable. But nevertheless these network graphs can show important coherencies in the international financial system and are therefore useful for decision-makers in financial institutions as well as for the regulators.

We see two main challenges how these network analyses can even improve to help better understanding the reactions of the global financial system to shocks. Firstly the network graphics are static and therefore just show the relationships between the lenders and borrowers at a certain point in time. Of course one can construct network graphs on a quarterly, monthly or even daily basis (if the data would be available) and then compare the outcomes. But it would be more fruitful to run simulations and directly see the changes in the network in animated pictures. The ultimate goal of these simulations would then be to even forecast the new network structure after a shock occurs. But this is extremely difficult as we simply do not know what happens if one link breaks off and so it is hard to estimate exact results. Therefore further research is needed also in other disciplines like mathematics and econometrics. The second problem we face is that our data exists on an aggregated basis. To improve our results we would need more detailed information about the interconnectedness between each single bank and its counterparts. Cerutti, Claessens and McGuire (2012, p. 8) point out that also differences in the organizational structure of the firms and their legal status have to be taken into account. They further support our argumentation by stating that "available data only allow calculations at the level of whole banking systems, rather than at the level of individual banks". But of course this would increase the data collection and makes our analyses even more complex. However further developments in the information technology (IT) and the willingness for better supervisory of the financial markets could help us to successfully overcome this hurdle.

## 5.3 Basel III

The Basel Committee on Banking Supervision (2010) has made some important proposals to strengthen the global banking sector's ability to absorb financial and economic shocks. Their suggestions are summarized by the term Basel III and are more or less improvements of the earlier regulation process. In the following we are going to briefly highlight four aspects which can enhance the chances to prevent systemic crises and contagion effects.

(I) Raising the quality, consistency and transparency of the capital base

Banks need to have strong capital buffers to preserve their ability to absorb losses on a going concern basis and to sustain periods of economic downturns. Basel III therefore suggests to increase the Tier 1 capital base from 4% of risk-weighted assets to 6%. Additionally only shares and retained earnings are part of Tier 1 capital base, but hybrid capital is no longer included. Tier 2 capital instruments will be simplified and Tier 3 will be abolished. To improve consistency an international harmonization of what can be regarded as common equity will be examined. Furthermore the disclosure of detailed information about banks' capital will help to better assess and compare the quality of capital.

(II) Strengthening the risk coverage of the capital framework

Major on- and off-balance sheet risks need to be captured to make correct risk assessments. Basel III attempts to improve the risk coverage by strengthening the capital requirements for counterparty credit risk exposures which emerge from derivatives, repos and securities financing activities. This approach can therefore help to curb one of the key destabilising factors of the financial crisis in 2008. Furthermore this approach aims to shift bilateral OTC (over the counter) derivative contracts to multilateral clearing through central counterparties and exchanges.

(III) Introduction of a leverage ratio

One of the most important goals of Basel III is to introduce a leverage ratio as a supplementary measure to the Basel II related risk-based framework. High levels of leverage were one of the severe problems during the past financial crisis. As market pressure forced the banks to deleverage in a manner that put downward pressure on asset prices and therefore expanded the loop between losses, declines in bank capital and contraction in credit supply. The introduction of a leverage ratio is believed to help in avoiding such a deleveraging process.

(IV) Introduction of a global minimum liquidity standard

Another feature of the 2008 global financial crisis was that liquidity of the banking sector quickly evaporated and illiquidity became a common threat to many financial institutions. This stressed situation was solved by worldwide actions of the central banks. To prevent a repeating scenario Basel III promotes the introduction of a 30-day liquidity coverage ratio, so that banks have sufficient high-quality liquid assets to withstand short-term liquidity shocks. Additionally a longer-term structural ratio shall be implemented to address liquidity mismatches and give banks incentives to use more stable sources for their funding activities.

To sum it up it can be said that all suggestions of the Basel Committee attempt to improve banks supervision and risk management. But as Blundell-Wignall and Atkinson (2010) point out there are still some weaknesses in the Basel III proposals. One of their main arguments is that while regulation on the banking system will be unequivocally improved, financial promises might shift to the more or less unregulated shadow banking system.

Therefore the question arises how much hedge funds and other shadow-banking entities shall be regulated in similar ways like banks under Basel III. Another problem remains if regulation and supervisory is nationally limited. But all in all we are optimistic that the Basel III approach can help to make the banking system more resilient to crises and transmission of shocks.

# 6 Conclusions

This paper is theoretically motivated by the new academic field of behavioural finance. If we would follow the efficient market hypothesis contagion and bubbles would not occur. Therefore it is helpful to understand the main concepts of investor behaviour. As Shleifer (2000) clearly has proven in his work there are some limitations (like noise trader risk, no perfect substitutions and leveraging) for arbitrageurs to exploit mispricings and that is why they can not bring asset prices back to its fundamental values in all circumstances. We also showed that herding behaviour can play an essential role in the development of a bubble and mirror-inverted in the transmission of shocks. Even if investors follow others on a rational basis, as a group they can end up in devastating results. We further pointed out more investor anomalies like overconfidence, investor mood and mental accounting. These might be special cases of wrong investment decisions, but they lead us to pose the following questions: What exactly drives the decision-making process of investors? Can they be recognized as rational? Or does irrationality play a more important role than assumed in the classical finance theory? As Kahnemann and Tversky (1979) were one of the first who did lab and classroom experiments to observe the decision-making process of human subjects under uncertainty, more research at this area can be very worthwhile and might deliver new insights.

The early detection of contagion can help investors to adjust their investment strategies and improve the performance of their portfolios. Therefore it is necessary to know some methods to test for contagion. In our work we demonstrated how to test for stock market contagion as one possible transmission channel. The first method checked for an increased correlation between two markets, while the second method tested for a transmission of volatility contagion. More sophisticated models and a bigger selection of markets could be used in future research. As most of the testing methods are backward-orientated, in our point of view network analyses will play a substantial role in detecting contagion or systemic crisis even before they appear. But the main problem is that it is hard to estimate how shocks will transform a network and how to exactly forecast the changes in the linkages between countries, financial institutions or on a micro level between each market participant.

We believe that this paper can be seen as a good introduction for portfolio and risk managers who have to deal with the aspect of contagion. But also the supervisors need to be aware of the problem and have to find suitable answers to this financial phenomenon. We briefly highlighted some proposals of the Basel Committee on Banking Supervision (2010) in the last chapter. In the future it is very important that these suggestions will be perfected and implemented worldwide. But at least three questions remain open. Shall also the shadow-banking system be more regulated? Can better information about counterparties prevent or in an undesired manner precipitate financial crises? And how effective will improved supervision be in limiting international financial contagion?

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# Appendix

Table A.1: Descriptive statistics of the rate of returns

| | United States (S&P 500) | Italy (MIB) | France (CAC 40) | Germany (DAX) |
|---|---|---|---|---|
| **Mean** | 0.001945 | 0.002547 | 0.002173 | 0.002096 |
| **Median** | 0.000048 | 0.002831 | 0.002257 | 0.001667 |
| **Max.** | 0.091150 | 0.085991 | 0.094715 | 0.073355 |
| **Min.** | -0.101394 | -0.108742 | -0.105946 | -0.107975 |
| **Std. Dev.** | 0.024966 | 0.023671 | 0.025765 | 0.024449 |
| **Skewness** | 0.104782 | -0.511775 | -0.399508 | -0.569788 |
| **Kurtosis** | 6.364065 | 7.267287 | 6.367114 | 7.135083 |

The table shows the descriptive statistics of the continuously compounded rate of returns for the US (S&P 500), Italy (MIB), France (CAC 40) and Germany (DAX), calculated by EViews 7.

**Eviews Outputs**

E.1: Correlation contagion

*Italy*

Dependent Variable: ROR_MIB
Method: Least Squares
Date: 03/30/12 Time: 11:48
Sample: 3/03/2008 9/15/2008
Included observations: 138

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 0.001115 | 0.001028 | 1.085515 | 0.2796 |
| X | 0.332576 | 0.081226 | 4.094452 | 0.0001 |

| | | | |
|---|---|---|---|
| R-squared | 0.109741 | Mean dependent var | 0.001314 |
| Adjusted R-squared | 0.103195 | S.D. dependent var | 0.012732 |
| S.E. of regression | 0.012058 | Akaike info criterion | -5.983863 |
| Sum squared resid | 0.019772 | Schwarz criterion | -5.941439 |
| Log likelihood | 414.8865 | Hannan-Quinn criter. | -5.966622 |
| F-statistic | 16.76454 | Durbin-Watson stat | 2.214346 |
| Prob(F-statistic) | 0.000072 | | |

OLS regression to estimate the correlation coefficient between the US and Italian stock market in the tranquil period. The calculations were performed by EViews 7.

Dependent Variable: ROR_MIB
Method: Least Squares
Date: 03/30/12 Time: 11:54
Sample: 9/16/2008 3/09/2009
Included observations: 121

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 0.002280 | 0.002513 | 0.907084 | 0.3662 |
| X | 0.480605 | 0.073958 | 6.498322 | 0.0000 |

| | | | |
|---|---|---|---|
| R-squared | 0.261916 | Mean dependent var | 0.003953 |
| Adjusted R-squared | 0.255713 | S.D. dependent var | 0.031873 |
| S.E. of regression | 0.027498 | Akaike info criterion | -4.333043 |
| Sum squared resid | 0.089978 | Schwarz criterion | -4.286832 |
| Log likelihood | 264.1491 | Hannan-Quinn criter. | -4.314275 |
| F-statistic | 42.22819 | Durbin-Watson stat | 2.405415 |
| Prob(F-statistic) | 0.000000 | | |

OLS regression to estimate the correlation coefficient between the US and Italian stock market in the crisis period. The calculations were performed by EViews 7.

*France*

Dependent Variable: ROR_CAC
Method: Least Squares
Date: 03/30/12 Time: 14:34
Sample: 3/03/2008 9/15/2008
Included observations: 138

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 0.001181 | 0.001259 | 0.937978 | 0.3499 |
| X | -0.083983 | 0.099557 | -0.843565 | 0.4004 |

| | | | |
|---|---|---|---|
| R-squared | 0.005205 | Mean dependent var | 0.001131 |
| Adjusted R-squared | -0.002110 | S.D. dependent var | 0.014763 |
| S.E. of regression | 0.014779 | Akaike info criterion | -5.576875 |
| Sum squared resid | 0.029704 | Schwarz criterion | -5.534451 |
| Log likelihood | 386.8044 | Hannan-Quinn criter. | -5.559635 |
| F-statistic | 0.711601 | Durbin-Watson stat | 2.175130 |
| Prob(F-statistic) | 0.400394 | | |

OLS regression to estimate the correlation coefficient between the US and French stock market in the tranquil period. The calculations were performed by EViews 7.

Dependent Variable: ROR_CAC
Method: Least Squares
Date: 03/30/12 Time: 14:28
Sample: 9/16/2008 3/09/2009
Included observations: 121

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 0.003145 | 0.003141 | 1.001184 | 0.3188 |
| X | 0.061943 | 0.092439 | 0.670095 | 0.5041 |

| | | | |
|---|---|---|---|
| R-squared | 0.003759 | Mean dependent var | 0.003360 |
| Adjusted R-squared | -0.004613 | S.D. dependent var | 0.034290 |
| S.E. of regression | 0.034369 | Akaike info criterion | -3.886949 |
| Sum squared resid | 0.140564 | Schwarz criterion | -3.840738 |
| Log likelihood | 237.1604 | Hannan-Quinn criter. | -3.868181 |
| F-statistic | 0.449027 | Durbin-Watson stat | 2.135613 |
| Prob(F-statistic) | 0.504096 | | |

OLS regression to estimate the correlation coefficient between the US and French stock market in the crisis period. The calculations were performed by EViews 7.

*Germany*

Dependent Variable: ROR_DAX
Method: Least Squares
Date: 03/30/12 Time: 14:56
Sample: 3/03/2008 9/15/2008
Included observations: 138

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 0.000843 | 0.001122 | 0.751287 | 0.4538 |
| X | -0.019595 | 0.088660 | -0.221011 | 0.8254 |

| | | | |
|---|---|---|---|
| R-squared | 0.000359 | Mean dependent var | 0.000831 |
| Adjusted R-squared | -0.006991 | S.D. dependent var | 0.013115 |
| S.E. of regression | 0.013161 | Akaike info criterion | -5.808726 |
| Sum squared resid | 0.023557 | Schwarz criterion | -5.766302 |
| Log likelihood | 402.8021 | Hannan-Quinn criter. | -5.791486 |
| F-statistic | 0.048846 | Durbin-Watson stat | 2.275187 |
| Prob(F-statistic) | 0.825416 | | |

OLS regression to estimate the correlation coefficient between the US and German stock market in the tranquil period. The calculations were performed by EViews 7.

Dependent Variable: ROR_DAX
Method: Least Squares
Date: 03/30/12 Time: 14:58
Sample: 9/16/2008 3/09/2009
Included observations: 121

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 0.004155 | 0.002972 | 1.398090 | 0.1647 |
| X | -0.176766 | 0.087472 | -2.020838 | 0.0455 |

| | | | |
|---|---|---|---|
| R-squared | 0.033179 | Mean dependent var | 0.003540 |

| | | | |
|---|---|---|---|
| Adjusted R-squared | 0.025054 | S.D. dependent var | 0.032937 |
| S.E. of regression | 0.032522 | Akaike info criterion | -3.997419 |
| Sum squared resid | 0.125863 | Schwarz criterion | -3.951207 |
| Log likelihood | 243.8438 | Hannan-Quinn criter. | -3.978650 |
| F-statistic | 4.083787 | Durbin-Watson stat | 1.939904 |
| Prob(F-statistic) | 0.045541 | | |

OLS regression to estimate the correlation coefficient between the US and German stock market in the crisis period. The calculations were performed by EViews 7.

## E.2: Volatility contagion

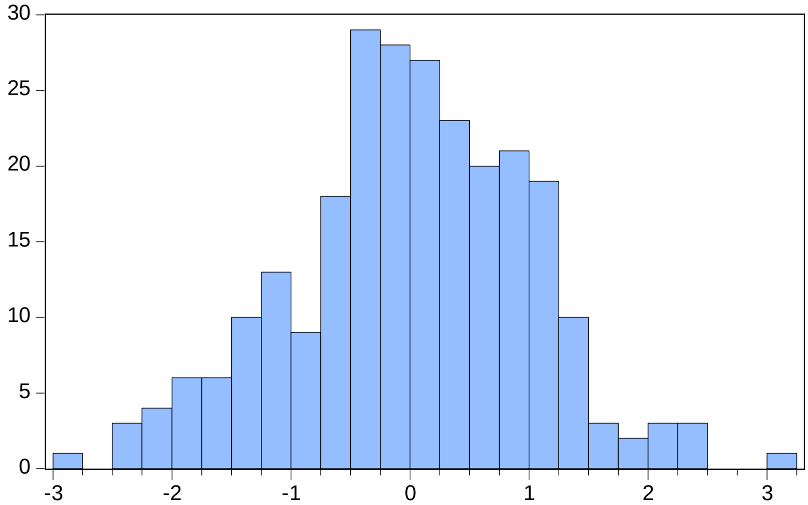
### *Italy*

Dependent Variable: ROR_MIB
Method: ML - ARCH (Marquardt) - Normal distribution
Date: 04/25/12 Time: 11:14
Sample: 3/03/2008 3/09/2009
Included observations: 259
Convergence achieved after 26 iterations
Presample variance: backcast (parameter = 0.7)
LOG(GARCH) = C(2) + C(3)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(4)*RESID(-1)/@SQRT(GARCH(-1)) + C(5)*LOG(GARCH(-1)) + C(6)*X^2 + C(7)*X^2*DUMMY

| Variable | Coefficient | Std. Error | z-Statistic | Prob. |
|---|---|---|---|---|
| C | 0.002219 | 0.000990 | 2.240173 | 0.0251 |
| | | Variance Equation | | |
| C(2) | -0.943925 | 0.249113 | -3.789139 | 0.0002 |
| C(3) | -0.063501 | 0.093513 | -0.679057 | 0.4971 |
| C(4) | 0.216295 | 0.043375 | 4.986609 | 0.0000 |
| C(5) | 0.881631 | 0.031076 | 28.37044 | 0.0000 |
| C(6) | -112.6034 | 105.0140 | -1.072270 | 0.2836 |
| C(7) | 211.4962 | 99.27668 | 2.130371 | 0.0331 |

| | | | |
|---|---|---|---|
| R-squared | -0.000193 | Mean dependent var | 0.002547 |
| Adjusted R-squared | -0.000193 | S.D. dependent var | 0.023671 |
| S.E. of regression | 0.023674 | Akaike info criterion | -5.150301 |
| Sum squared resid | 0.144594 | Schwarz criterion | -5.054171 |
| Log likelihood | 673.9640 | Hannan-Quinn criter. | -5.111651 |
| Durbin-Watson stat | 2.037452 | | |

We used EGARCH to test for volatility contagion from the US to the Italian stock market. The calculations were performed by EViews 7.




Series: Standardized Residuals
Sample 3/03/2008 3/09/2009
Observations 259

| | |
|---|---|
| Mean | 0.006966 |
| Median | 0.045025 |
| Maximum | 3.030460 |
| Minimum | -2.925929 |
| Std. Dev. | 1.002105 |
| Skewness | -0.134101 |
| Kurtosis | 3.095873 |
| Jarque-Bera | 0.875458 |
| Probability | 0.645501 |

To check if the residuals are normally distributed we used the Jarque-Bera normality test, where $H_0$: Normal distribution vs. $H_1$:Non-normal distribution. The Jarque-Bera test statistic is 0.875458. Since the p-value of 0.6455 is much greater than the 5%-significance level we can not reject the null hypothesis, so our residuals are normally distributed.

*France*

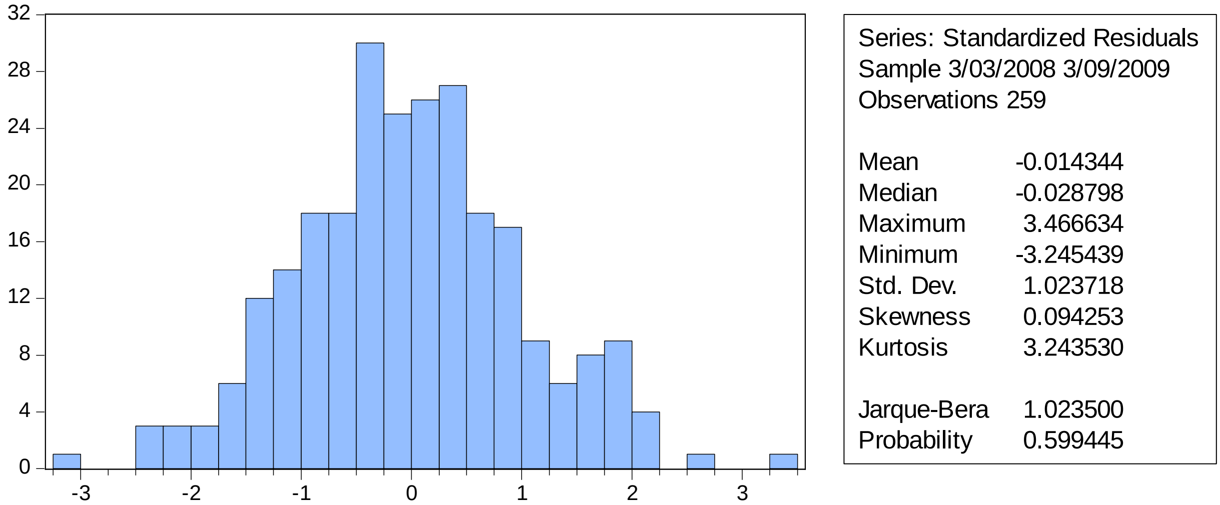
Dependent Variable: ROR_CAC
Method: ML - ARCH (Marquardt) - Normal distribution
Date: 04/25/12 Time: 11:16
Sample: 3/03/2008 3/09/2009
Included observations: 259
Failure to improve Likelihood after 12 iterations
Presample variance: backcast (parameter = 0.7)
LOG(GARCH) = C(2) + C(3)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(4)
*RESID(-1)/@SQRT(GARCH(-1)) + C(5)*LOG(GARCH(-1)) + C(6)*X^2 +
C(7)*X^2*DUMMY

| Variable | Coefficient | Std. Error | z-Statistic | Prob. |
|---|---|---|---|---|
| C | 0.002793 | 0.000438 | 6.377693 | 0.0000 |
| | | Variance Equation | | |
| C(2) | 0.001647 | 0.078820 | 0.020898 | 0.9833 |
| C(3) | 0.024710 | 0.051453 | 0.480250 | 0.6310 |
| C(4) | 0.182539 | 0.051967 | 3.512579 | 0.0004 |
| C(5) | 1.001128 | 0.011170 | 89.62603 | 0.0000 |
| C(6) | 73.12572 | 115.3010 | 0.634216 | 0.5259 |
| C(7) | -94.88380 | 108.2958 | -0.876154 | 0.3809 |

| | | | |
|---|---|---|---|
| R-squared | -0.000581 | Mean dependent var | 0.002173 |
| Adjusted R-squared | -0.000581 | S.D. dependent var | 0.025765 |
| S.E. of regression | 0.025773 | Akaike info criterion | -4.899494 |
| Sum squared resid | 0.171373 | Schwarz criterion | -4.803363 |
| Log likelihood | 641.4844 | Hannan-Quinn criter. | -4.860844 |

| | |
|---|---|
| Durbin-Watson stat | 2.156421 |

We used EGARCH to test for volatility contagion from the US to the French stock market. The calculations were performed by EViews 7.




To check if the residuals are normally distributed we used the Jarque-Bera normality test, where $H_0$: Normal distribution vs. $H_1$:Non-normal distribution. The Jarque-Bera test statistic is 1.0235. Since the p-value of 0.599445 is much greater than the 5%-significance level we can not reject the null hypothesis, so our residuals are normally distributed.

*Germany*

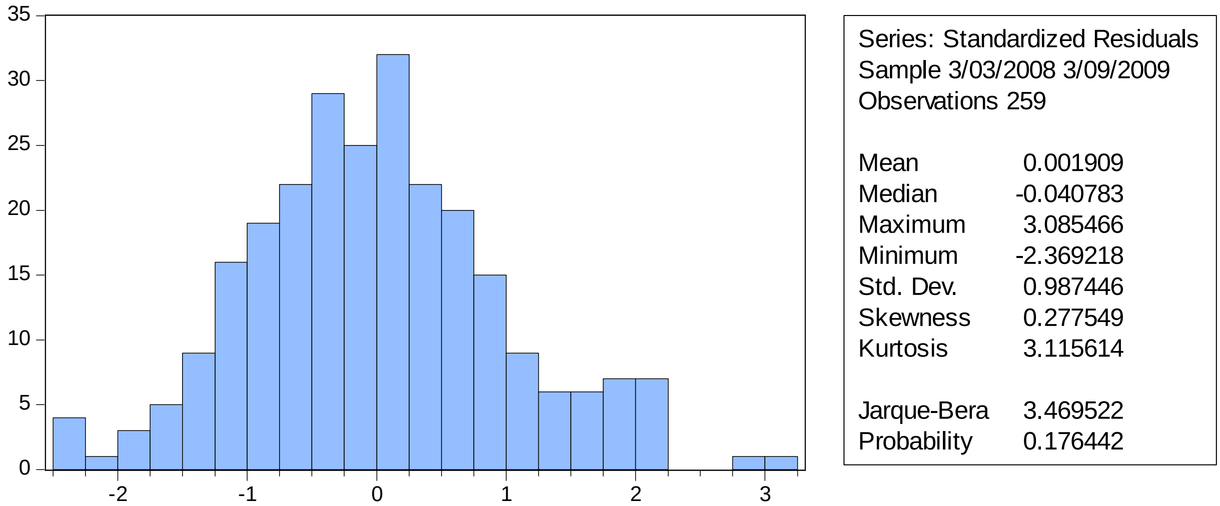
Dependent Variable: ROR_DAX
Method: ML - ARCH (Marquardt) - Normal distribution
Date: 04/25/12 Time: 11:17
Sample: 3/03/2008 3/09/2009
Included observations: 259
Convergence achieved after 11 iterations
Presample variance: backcast (parameter = 0.7)
LOG(GARCH) = C(2) + C(3)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(4)
*RESID(-1)/@SQRT(GARCH(-1)) + C(5)*LOG(GARCH(-1)) + C(6)*X^2 +
C(7)*X^2*DUMMY

| Variable | Coefficient | Std. Error | z-Statistic | Prob. |
|---|---|---|---|---|
| C | 0.002422 | 0.000948 | 2.554575 | 0.0106 |
| | | Variance Equation | | |
| C(2) | -0.094757 | 0.129475 | -0.731858 | 0.4643 |
| C(3) | -0.033940 | 0.061566 | -0.551289 | 0.5814 |
| C(4) | 0.223497 | 0.050570 | 4.419520 | 0.0000 |
| C(5) | 0.983750 | 0.016276 | 60.44354 | 0.0000 |

| | | | | |
|---|---|---|---|---|
| C(6) | 4.718865 | 86.23204 | 0.054723 | 0.9564 |
| C(7) | -11.28467 | 77.20733 | -0.146161 | 0.8838 |

| | | | |
|---|---|---|---|
| R-squared | -0.000178 | Mean dependent var | 0.002096 |
| Adjusted R-squared | -0.000178 | S.D. dependent var | 0.024449 |
| S.E. of regression | 0.024451 | Akaike info criterion | -5.037831 |
| Sum squared resid | 0.154248 | Schwarz criterion | -4.941701 |
| Log likelihood | 659.3992 | Hannan-Quinn criter. | -4.999181 |
| Durbin-Watson stat | 2.058446 | | |

We used EGARCH to test for volatility contagion from the US to the Italian stock market. The calculations were performed by EViews 7.




To check if the residuals are normally distributed we used the Jarque-Bera normality test, where $H_0$: Normal distribution vs. $H_1$:Non-normal distribution. The Jarque-Bera test statistic is 3.469522. Since the p-value of 0.176442 is much greater than the 5%-significance level we can not reject the null hypothesis, so our residuals are normally distributed.

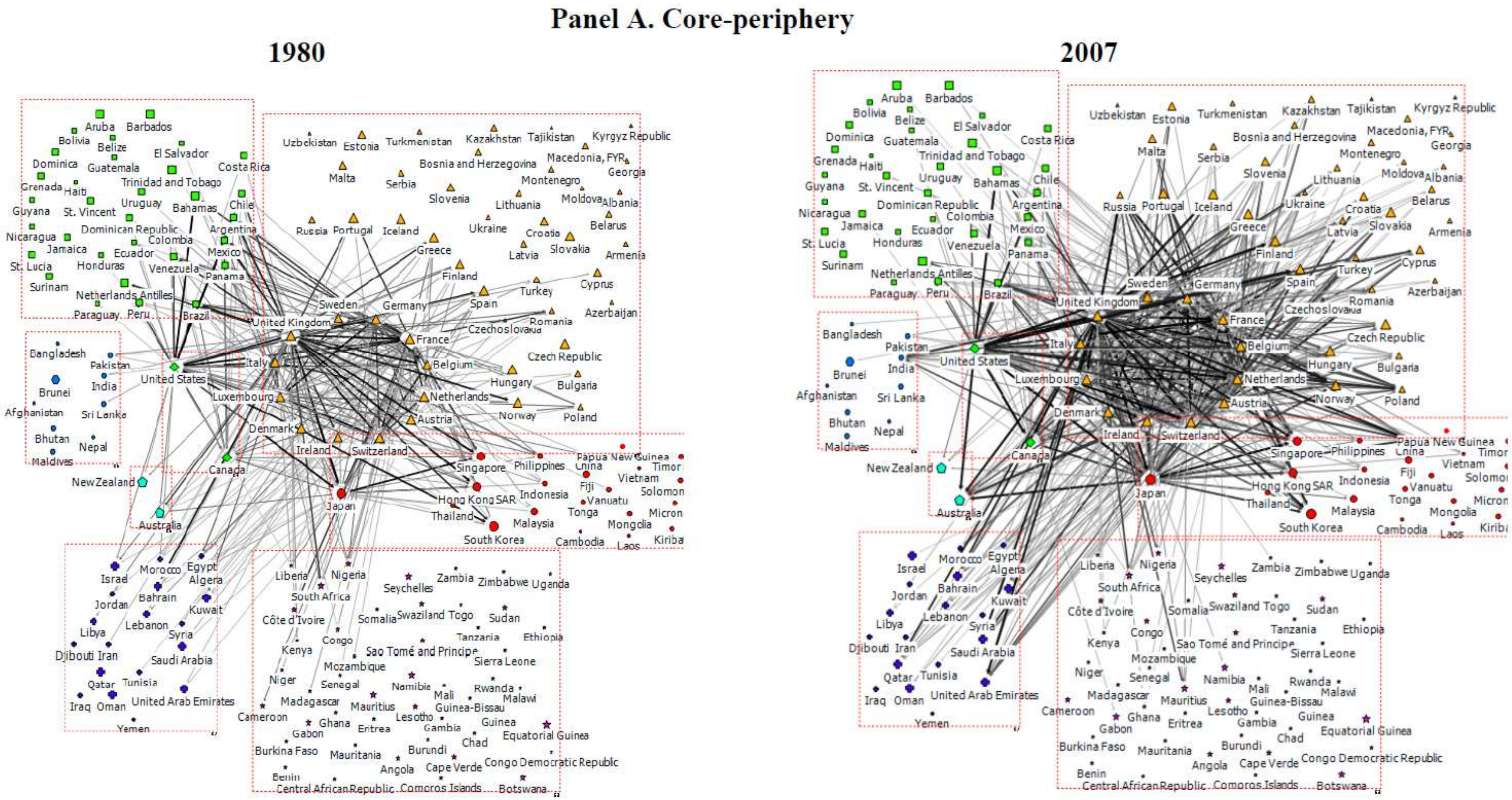



Figure A.1: Network view of cross-border banking in 1980 and in 2007. Each node represents one country. The links between the countries illustrate cross-border bank loans. Thicker and darker links indicate larger flows. (Source: Minoiu and Reyes, 2010).