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Systemic Risk in European Banking: Evidence from Bivariate GARCH Models

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Michael Schröder and Martin Schüler

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Zentrum für Europäische
Wirtschaftsforschung GmbH

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Non-Technical Summary

This paper attempts to assess the Europe-wide systemic risk in banking. Systemic risk is one of the main reason why banks are regulated and supervised. The failure of a specific bank may trigger a chain reaction of bank failures and generate negative externalities for the whole banking system. In addition, systemic financial events may induce undesirable negative real effects, such as substantial reductions in output and employment. In Europe banking regulation and in particular supervision is organised at a national level. However, increased systemic risk at the European level may call for a reform of the European supervisory framework. A bank failure in one country could potentially trigger further failures not only in the same country but also in other countries. The current nation-based system may then incorporate the danger that a national banking supervisor would possibly undervalue or even disregard such a cross-border contagion effect. Thus, a single European supervisor or at least strong co-ordination among national supervisors could be needed. In order to discuss a future institutional structure for the supervision of banks in the EU it is of crucial importance to know about the actual threat of systemic risk in European banking. This paper attempts to contribute toward this direction.

As a measure of systemic risk we use the conditional correlations between pairs of national bank stock indices of the EU countries. The correlations are estimated using bivariate GARCH-models which consider the influence of the national stock market index and a short-term interest rate as explanatory factors. The correlations measure the linear relationships between the residuals of the GARCH-models and as these residuals mainly reflect bank specific factors they are suitable to quantify the systemic risk. We employ three tests to assess the development of Europe-wide systemic risk. First, we test if the hypothesis of a constant correlation is false. Second, we test for structural breaks after the completion of the internal banking market in the EU. Here, we identify two possible dates on which structural breaks could have occurred: the time after the implementation of the second banking directive and after the introduction of the Euro. And third, we test the hypothesis of a gradual increase of the cross-border correlations. We apply these three approaches to monthly data from 1980 on and to weekly data from 1990 on.

Our main finding is that many conditional correlations exhibit significant upward changes over time either as parallel shifts at the two specified dates or as linear time trends. We interpret these results as evidence of an ongoing integration process in the European banking business which leads to growing similarities in the international economic factors that drive the profits of the banks. As a consequence of a more similar business behaviour this is evidence for an increase in systemic risk in the European banking market.

Systemic Risk in European Banking – Evidence from Bivariate GARCH Models

Michael Schröder* **and Martin Schüler****

Centre for European Economic Research (ZEW), Mannheim

March 2003

Abstract

This paper attempts to assess the Europe-wide systemic risk in banking. We employ a bivariate GARCH model to estimate conditional correlations between European bank stock indices. These correlations are used as an indication for the interdependencies amongst the banking business in Europe and hence for the systemic risk potential. We employ several tests to assess the development of systemic risk: a non-parametric test of constancy of the correlation, a test of parallel shifts in the correlation at pre-specified events, and a test for a linear time trend in the correlations. The results show that many of the conditional correlations exhibit an upward move in the last years. This is an indication that the economic factors determining the European banking business have become more similar and that the systemic risk potential has increased.

JEL-Classification: G21, F34, G15

Keywords: *systemic risk, banking, contagion, Europe, bivariate GARCH*

* *Centre for European Economic research; P.O. Box 103443, D-68034 Mannheim, Germany, Phone: +49/621/1235-140, Fax: +49/621/1235-223,* E-mail: schroeder@zew.de.

** *Centre for European Economic research; P.O. Box 103443, D-68034 Mannheim, Germany, Phone: +49/621/1235-148, Fax: +49/621/1235-223,* E-mail: schueler@zew.de. *The author is also affiliated to Otto Beisheim Graduate School of Management WHU Koblenz.*

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1 Motivation

Systemic risk is one of the main reason why banks are regulated and supervised. The failure of a specific bank may trigger a chain reaction of bank failures and generate negative externalities for the whole banking system. In addition, systemic financial events may induce undesirable negative real effects, such as substantial reductions in output and employment.

In Europe banking regulation and in particular supervision is organised at a national level. However, increased systemic risk at the European level may call for a reform of the European supervisory framework. Integration of financial markets in Europe has increased rapidly not just since the introduction of the Euro. This development may have increased interdependencies among financial institutions of different countries which in turn may have led to a rise in the potential of cross-border contagion, i.e. systemic risk at a European level. If this is true a bank failure in one country could potentially trigger further failures not only in the same country but also in other countries. The current nation-based system may then incorporate the danger that a national banking supervisor would possibly undervalue or even disregard such a cross-border contagion effect. Thus, a single European supervisor or at least strong co-ordination among national supervisors could be needed.[1] Just recently, the discussion of the appropriate institutional structures and mechanisms in the European Union (EU) has intensified. The discussion resulted in a proposal by the Economic and Financial Committee (EFC) to the Council of the EU that will probably lay the basis for a future supervisory structure in the EU.[2]

In order to discuss a future institutional structure for the supervision of banks in the EU it is of crucial importance to know about the actual threat of systemic risk in European banking. This paper attempts to contribute toward this direction. We employ a bivariate GARCH model to estimate correlations between European bank stock indices. These correlations are used as an indication for the interdependencies among European banks and hence for the systemic risk potential. We employ three tests to assess the development of Europe-wide systemic risk. First, we test if the hypothesis of a constant correlation is false. Second, we test for structural breaks after the completion of the internal banking market in the EU. Here, we identify two possible dates on

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[1] The question that arises is whether the potential of systemic risk may be even world-wide and not just Europe-wide. The analysis in this paper is motivated from banking supervision that – at least in the short and medium run – will not be organised at a world-wide level. Thus, we merely analyse the potential of systemic risk at the European level and do not ask whether there may be also contagion between European and non-European banks.

[2] For a discussion of this proposal see, e.g., Schüler (2003).

which structural breaks could have occurred: the time after the implementation of the second banking directive and after the introduction of the Euro. And third, we test the hypothesis of a gradual increase of the cross-border correlations.

The paper is organised as follows. Section 2 defines systemic risk and gives a brief review of the empirical literature. Section 3 presents the methodology and data employed. The empirical results are given in section 4. Finally, section 5 concludes.

2 Systemic Risk in the Banking Market

2.1 The Concept of Systemic Risk

In general the banking or the financial sector is viewed as more vulnerable to contagion than other industries since banks are viewed as more susceptible to failures (Kaufman 1995, 1996, Goodhart et al., 1998, de Bandt and Hartmann, 2000). In this sense, banks are special for several reasons: One reasons lies in the structure of the banks. Banks are vulnerable to runs due to fractional reserve banking, i.e. in the case of high withdrawals the banks may not be able to fulfil deposit obligations. Furthermore, banks are highly leveraged, i.e. they have a low capital-to-assets ratio. Thus there is only little room for losses. In addition, they exhibit low cash-to-assets ratios which may require the sale of earning assets to meet deposit obligations. Furthermore banks are highly interconnected through direct exposures in the interbank money market, the large-value payment and security settlement systems. These characteristics of the international banking business give reasons for concerns about systemic risk across countries.

There exists, however, no unique definition of systemic risk in the literature. Loosely speaking, systemic risk means “the risk or probability of breakdowns in an entire system, as opposed to breakdowns in individual parts or components” (Kaufman and Scott, 2000: 1). Systemic risk can occur in banking as well as in other parts of the financial sector, e.g. in payment and settlement systems or in securities markets – in financial markets in general. Furthermore, there is consensus on the existence of different channels through which systemic risk can occur in banking. Instead of giving a comprehensive definition of systemic risk these different channels are discussed in order to explain the concept of systemic risk in banking.[3]

[3] The definitions for systemic risk given so far all refer to one or more parts of this whole concept of systemic risk. For a comprehensive definition of systemic risk see de Bandt and Hartmann (2000).

There are two ways in which systemic risk can occur in the banking market (Staub, 1999). First, a macro shock can simultaneously have adverse effects on several banks. Such a macro shock can either be a cyclical downturn or other aggregate shocks like interest rate or exchange rate shocks or a stock market crash.

Second, systemic risk can occur as a result of contagion in the banking market, i.e. an initial shock causes one bank to fail which subsequently leads to the failure of other banks ("micro channel"). Such contagion in banking can work through two channels (de Bandt and Hartmann, 2000): the exposure channel and the information channel. The former results from real exposures in the interbank market and/or in payment systems. Thus, insolvency problems of one bank can trigger a chain reaction leading to other bank failures. This channel refers to the so called "domino effect". The information channel, in contrast, refers to ways through which bad news from one bank lead to the conclusion in the market that other banks are also in trouble. This will lead to adjustments of contracts with other partners or – on the depositor level – to contagious withdrawals (bank runs). A central concept of this channel is that depositors and also other counterparties have only imperfect information about (a) the type of shocks hitting a bank, i.e. whether it is idiosyncratic or systemic and (b) the real exposures to other banks.

In this paper the focus is on the micro channel of systemic risk. Thus, in the context of this paper a macroeconomic shock that causes several banks to fail is not regarded as systemic risk. This view is in line with the definitions of systemic risk given, for example, by Kaufman (1995)[4] or the Bank for International Settlements (BIS). Furthermore, it should be stressed that systemic risk can be viewed as an immanent threat to the international banking business that is not confined to only a crisis situation. Thus, in our definition systemic risk increases when the economic factors that drive the banking business become more similar across countries.

2.2 Review of the Literature

There is a wide theoretical literature on systemic risk starting from the classical bank run models following Diamond and Dybvig (1983) and extensions of these

[4] Kaufman (1995: 47) defines systemic or contagion risk as "the probability that cumulative losses will occur from an event that sets in motion a series of successive losses along a chain of institutions or markets comprising a system."

models of single banks' fragility to models of multiple bank systems, leading to the modern bank contagion literature.[5]

Also, there are empirical studies on systemic risk and contagion in the banking sector that utilise several different approaches. The predominant part of these studies examine specific bank failures of the past either by looking at intertemporal correlations of bank failures or by doing event studies.[6] Since today – i.e. in times of deposit insurance's and lenders of last resort – bank runs and accumulated bank failures do not actually occur in industrial countries such methods can not be applied in order to empirically examine systemic risk. Also the use of historical data – for example from the free banking era in the United States – is not appropriate when assessing the actual threat of systemic risk and contagion in banking. Hence, an indicator for the potential of systemic risk is needed.

Focusing exclusively on the potential threat stemming from interbank lending, i.e. on the exposure channel of systemic risk one approach is to directly examine exposures in the interbank market and simulate contagious effects following the hypothetical failure of one bank. There are some studies for the US that use this approach utilising data, for example, from the Federal Reserve's large-value transfer system, Fedwire, or the Clearinghouse Interbank Payments System (CHIPS) (Kaufman, 1994, Humphrey, 1986, Furfine, 1999). For Europe, Michael (1998), reports some exposures from London interbank markets, Angelini et al. (1996) from the Italian netting system, and Sheldon and Maurer (1998) base their simulations on accounting data drawn from banks that operate in Switzerland. All of these studies report a relatively small threat to financial market stability from the failure of one bank. Unfortunately, for whole Europe data on interbank lending is only available on an aggregate level which does not allow for statements concerning contagion risk between individual banks.

In contrast to former studies our study attempts to assess the threat of systemic risk in an international context.[7] In particular, the aim is to measure changes in the systemic risk in the European banking market. For this purpose, we employ a bivariate GARCH model with constant correlation to estimate the conditional correlation between pairs of bank stock indices for the European countries.

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[5] For a good survey on the theoretical as well as the empirical literature on systemic risk see de Bandt and Hartmann (2000).

[6] See, for example, Aharony and Swary (1983), Swary (1986), Schoenmaker (1996), Slovin et al. (1999), Bessler and Nohel (2000), Akhigbe and Madura (2001).

[7] Of course there is the financial crisis literature that looks at cross-border contagion (see, e.g., Dornbusch et al., 2000). But their focus is primarily on currency or debt crisis.

2.3 Correlations of Bank Stock Returns as a Measure of Systemic Risk

De Nicolo and Kwast (2002) argue that estimation of the systemic risk potential may be achieved using a measure of the interdependencies of financial institutions. For an economic shock to become systemic a negative externality must exist, i.e. a negative shock at a single bank must be highly likely to have contagious effects on other banks. Only if the banks are interdependent in some way such an externality exists – i.e. there is the threat of systemic risk. Such interdependencies can be either direct, i.e. through direct exposures or indirect, i.e. they arise from correlated exposures to non-financial sectors and financial markets.

De Nicolo and Kwast (2002) measure total interdependencies by the correlations of stock returns of large banking organisations. Since stock prices reflect market participants' collective evaluation of a firms prospects in the future they should also include the impact of the firms interdependencies with other institutions.[8] Consequently one can assume that an observed increase in correlations amongst bank stock returns signals an increase in the systemic risk potential. No change in correlations or a decrease would therefore lead to the conclusion that the potential of systemic risk has not increased or has declined.

In this paper we do not use individual bank stock returns but rather national stock indices for the banking sector that represent the prospects of the banking industry in a country. We estimate correlations between pairs of excess bank stock index returns of European countries using a bivariate GARCH model.

Certainly, in an international context we have to consider a few more things. Estimating correlations between pairs of bank stock indices without controlling for common factors could result in incorrect conclusions with respect to interdependencies and, hence, the systemic risk potential. An increase in correlations may result merely from an increase in the comovement between the underlying common factors which has nothing to do with the development of systemic risk.

The empirical literature on the explanatory factors of bank stock returns has shown that the inclusion of an interest rate factor adds substantial explanatory power to the single-factor market model.[9] The interest rate variable is important

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[8] A quite similar consideration was already made by Pozdena (1991) who regressed the stock returns of various individual banks on each other in each period in order to get evidence for contagious effects.

[9] See, e.g., Stone (1974), Flannery and James (1984a,b), Aharony et al. (1986), Sweeney and Warga (1986), Yourougou (1990), Benink and Wolff (2000).

for the valuation of stocks of financial institutions because the accounting returns and costs of financial institutions are directly related to changes in interest rates.[10] The concrete interest rate sensitivity depends on the individual characteristics of the bank's asset and liability positions.

As a consequence, we include two common factors in the return equations of the bivariate GARCH model: the excess return of the national stock market index and a short-term interest rate. By excluding the influence of these two identified factors we analyse only that part of the excess bank stock index returns which is explained by the risk exposure to bank specific factors. The international correlations of these factors, for example, comprise the exposure to other banks (e.g. due to inter-bank lending) or the interdependencies to other banks via third companies. In short, these (unidentified) factors should comprise the potential for systemic risk. We measure the correlation of these bank specific factors and apply different tests for changes in the correlation. In our approach a change in the correlation is equivalent to a change in the systemic risk between the banking sectors of two countries.

3 Methodology and Data

The aim of our study is to measure changes in the systemic risk in the European banking industry. Our main method to estimate systemic risk is the bivariate GARCH model with constant correlation. This gives us an estimate of the conditional correlation between each pair of bank stock indices for the European countries.

The bivariate GARCH model consists of five equations: the first two equations define the excess returns of the bank stock indices (r_{B1} and r_{B2}) and the following two equations the time-varying variances. The last equation is used to estimate the constant correlation *corr*.

(1)
$$
\begin{aligned}
r_{B1}(t) &= a_1 + b_1 \cdot r_{M1}(t) + c_1 \cdot is_1(t) + \delta_1 \cdot r_{B1}(t-1) + \varepsilon_1(t) \\
r_{B2}(t) &= a_2 + b_2 \cdot r_{M2}(t) + c_2 \cdot is_2(t) + \delta_2 \cdot r_{B2}(t-1) + \varepsilon_2(t)
\end{aligned}
$$

The residuals $\varepsilon_i(t)$ are assumed to follow a bivariate distribution with variance-covariance matrix $\Phi(t)$:

[10] An additional important argument in favour of the inclusion of the interest rate variable is that within EMU the convergence – and after the introduction of the Euro the equality – of money market rates would lead to an increase in the correlations of unadjusted stock returns.

$$\Phi(t) = \begin{pmatrix} \sigma^2_{B1}(t) & \sigma_{B1,B2}(t) \\ \sigma_{B1,B2}(t) & \sigma^2_{B2}(t) \end{pmatrix}$$

The variances ($\sigma^2_{B1}(t)$, $\sigma^2_{B2}(t)$) follow a GARCH (1,1)-process[11] and the covariances $\sigma_{B1,B2}(t)$ are simply the product of the correlation and the two time-varying variances.

(2)
$$\begin{aligned} \sigma^2_{B1}(t) &= \alpha_1 + \beta_1 \cdot \sigma^2_{B1}(t-1) + \gamma_1 \cdot \varepsilon^2_1(t-1) \\ \sigma^2_{B2}(t) &= \alpha_2 + \beta_2 \cdot \sigma^2_{B2}(t-1) + \gamma_2 \cdot \varepsilon^2_2(t-1) \end{aligned}$$

(3a) $\sigma_{B1,B2}(t) = corr \cdot \sigma_{B1}(t) \cdot \sigma_{B2}(t)$

In (1) the excess returns of the bank stock indices depend on the excess returns of the national stock market index (r_M) and a short-term interest rate (*is*). In addition, the use of the bank index of period (*t-1*) captures a first-order autocorrelation. Thus, the residuals (ε) measure those part of the bank stock returns which are not explained by the risk exposures to the total market and short-term interest rates. As pointed out above, the inclusion of these two factors is crucial for our analysis. A higher correlation between bank stock returns that is explained by stronger comovements between the national stock indices does not tell us anything about systemic risk but is only another measure of the market-wide comovements on a sectoral level. The short-term interest rates are an important factor in the return equations as the bank profit is usually interest rate sensitive. A higher correlation amongst interest rates can therefore lead to higher correlations amongst bank stock returns. This is particularly important for an analysis of the EU banking industry as our data sample includes the convergence process towards the monetary union. Thus, a neglect of the short-term interest rates would result in an increase in the correlation of the bank stock indices which were only due to the interest rate convergence.

The residuals measure mainly those parts of the return series that are caused by specific influences on the banking sectors in Europe. Changes in the conditional correlation *corr* can therefore be interpreted as changes in the cross-border risk of the banking industry.

Equation (3a) estimates the average correlation for the whole sample. The results of this equation can be used to test the assumption of the constancy of *corr*. We apply the non-parametric information matrix (*IM*) test of Bera and

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[11] Experiments with higher order GARCH-processes showed that in our applications only the GARCH (1,1)-parameters were significantly different from zero.

Kim (2002) to get first insights into the stability of the correlations. Bera and Kim develop two test statistics, IM_C and IM_3. The second test statistic is equal to the third of three parts of IM_C. Both tests do not purely investigate the constancy of the correlation but are also affected by deviations from normality. As IM_3 is less influenced by deviations from the normal distribution than IM_C it is recommended by Bera and Kim if one is mainly interested in testing the constancy of the correlation.

The basic versions of the two tests of Bera and Kim assume that the standardised residuals $(\varepsilon_i(t)/\sigma_{Bi}(t))$ follow a standard normal distribution. As in our applications the standardised residuals exhibit excess kurtosis we apply the so called studentised version IM_{3S} which is robust against deviations from normality.

More important for our analysis are parametric tests of structural breaks and changes in the correlation. In equation (3b) we include in addition to (3a) two dummy variables (*du1*, *du2*):

(3b) $$\sigma_{B1,B2}(t) = [corr1 + corr2 \cdot du1(t) + corr3 \cdot du2(t)] \cdot \sigma_{B1}(t) \cdot \sigma_{B2}(t)$$

The first dummy variable estimates a structural break after the liberalisation of the market for banking services (2nd EU banking directive) in 1993. To allow for an adjustment period we test for a structural break at the beginning of 1994. Thus *du1* is zero until December 1993 and one afterwards. The second dummy variable tests for a break after the start of the European Monetary Union, *du2* is therefore zero until December 1998 and one from January 1999 on. Thus, the parameter *corr1* estimates the correlation from the beginning of the data sample until December 1993. If *corr2* and *corr3* are significant these parameters indicate parallel shifts of the correlation in the periods January 1994 until December 1998 and January 1999 until the end of the sample.

Both events – the second EU banking directive and the introduction of the euro – could have increased the correlation amongst bank stock returns as a consequence of stronger interconnections of the European banking business. To be more concrete, the 2nd EU banking directive should have increased the international activities of European banks in other European countries. This should make the risk and return characteristics of European banks more similar across countries and as a result should drive correlations upwards. The same could be true after the launch of the EMU as the common currency reduces the transaction costs of cross-border banking business.

In addition, we test the hypothesis of a gradual increase of the cross-border correlations between the banking sectors. In equation (3c) a linear time trend (*t*) is included that accounts for these changes in the correlation of the bank stock indices:

(3c) $\sigma_{B1,B2}(t) = [corr4 + corr5 \cdot t] \cdot \sigma_{B1}(t) \cdot \sigma_{B2}(t)$

Whereas equation (3b) is used to investigate the effects of two distinct events on the correlations, equation (3c) is based on the assumption that the correlations change gradually over time following a linear trend. As the banking business in Europe has a tendency to increase the cross-border business we expect a positive sign of *corr5* in equation (3c). For the estimation the trend *t* has been centred. Thus, the estimate of *corr4* gives the correlation in the middle of the sample period where *t* is equal to zero.

All estimations have been conducted using Maximum Likelihood (ML) under the assumption that the residuals $\varepsilon_i(t)$ follow a bivariate normal distribution. But this assumption is in fact not true because in most cases the standardised residuals exhibit leptokurtosis. Thus, the application of the bivariate normal distribution leads to a so called Quasi- or Pseudo-ML estimation.[12] The standard errors of the parameters are in addition corrected for (still remaining) heteroskedasticity and autocorrelation using the approach of Newey and West (1987).

The Data

We include 13 European countries in the analysis, namely Germany (DE), Belgium (BE), Denmark (DK), Spain (ES), Finland (FI), France (FR), Ireland (IE), Italy (IT), The Netherlands (NL), Austria (AU), Portugal (PT), Sweden (SE) and the United Kingdom (UK). Due to lack of data we dropped Greece and Luxembourg from the sample of the 15 EU countries. Thus, there result 78 pairs of countries, i.e. 78 bivariate GARCH estimations. We estimate the above specified GARCH models using weekly and monthly data. The weekly data are only available since 1990 on a consistent basis. Thus, we estimate the GARCH-

[12] According to Weiss (1986) this leads to a consistent estimation of the parameters if the equations for the (conditional) means and variances are specified correctly. But as this estimator is inefficient in case of non-normal standardised residuals some authors choose a distribution that takes leptokurtosis explicitly into account. E.g. Hafner (2001) applies the standardised multivariate t-distribution. However, when a distribution different from the normal distribution is used and this distribution is not the true distribution then the estimates are in most cases not consistent (see Newey and Steigerwald, 1997 and, particularly for the case of an incorrectly assumed t-distribution, Gonzalez-Rivera and Racine, 1995). Therefore, we prefer to apply the (conditional) normal distribution.

models also using monthly data which are available since 1980. This is advantageous particularly with regard to the test of structural break in 1994.[13]

All data are taken from the Thomson Financial Datastream database. For a list of the abbreviations see the data appendix. All indices are total return indices in local currency. Excess returns of the bank stock indices (r_{B1} and r_{B2}) are then calculated as the logarithmic differences between two values of the return index (RI) minus the weekly or monthly based short-term interest rate (is): $r_B(t) = \log[RI(t)] - \log[RI(t-1)] - is(t-1)$.

For the monthly regressions we use the values of the Datastream bank stock indices at the beginning of each month.[14] As market indices we use the MSCI national monthly gross indices in local currency for calculating the excess returns of the national stock market indices (r_M). Here we take the end-of-the-month value as the respective value for the following month. As the interest rate (is) we use the money market rate from the IMF's International Financial Statistics (line 60b). Here we take the 15th of the month values as the values for the following month.

For the weekly regressions we use weekly average data. We use again the same Datastream bank stock indices as for the monthly regressions. For the short-term interest rate we use a 3-month inter-bank lending rate and for the national stock market excess return we use the main stock market index of the respective national stock exchange. For the abbreviations see the data appendix.

4 Empirical Results

In tables 1 and 2, we present a summary of the results of the weekly and monthly bivariate GARCH estimations. Each table is subdivided into three sections that present a summary of the results of, first, the tests of correlation constancy (based on equation (3a)), second, the test for structural breaks (equation (3b)), and third, the test for a linear trend in the correlations (equation (3c)). The results are summarised in terms of significance of the parameters.

- insert tables 1 and 2 about here -

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[13] Note that for Italy and Portugal the weekly interest rate series are too short to allow for structural break tests in 1994. As a consequence, we conduct these tests only for 55 pairs of countries.

[14] Using bank stock indices would cause a problem if there were major changes in the composition of the indices, e.g. due to mergers and acquisitions. Although we do not know the developments in the composition of the indices, this should not be a problem, since most mergers and acquisitions involved domestic banks and, in particular, smaller institutions (ECB Annual Report 2000, p.123).

For a detailed presentation of all GARCH estimations see tables A1 and A2 in the appendix where parameter estimates with associated p-values are reported for all 78 pairs of countries.

Testing Conditional Correlation Constancy

First of all, we apply the Bera and Kim (2002)-test to investigate potential changes in the conditional correlation *corr* of equation (3a). The Bera-Kim-test is a non-parametric test with the null hypothesis of a constant correlation against an unspecific alternative. Under the null hypothesis the test statistic IM_{3S} of Bera and Kim asymptotically follows a chi-square distribution with one degree of freedom. Tables A1 and A2 display the implicit significance level of the test statistics (= implicit type-I error probabilities) for the 78 pairs of countries. In the cases where this value is below 0.01/0.05/0.10 we can reject the null at the respective significance level and conclude that the conditional correlation is not constant. The tables A1 and A2 in the appendix present the conditional correlations *corr* with associated p-values. The first section of tables 1 and 2 summarise these results in terms of significance of the parameters. In these two tables we take the 0.10 significance level as the relevant one.[15]

In the weekly regressions, we can reject the null of constancy of the conditional correlations in only 7 of the 78 cases (= ca. 9%). Using monthly data which start 10 years earlier, the Bera and Kim test statistic rejects the null hypothesis in 24 out of the 78 cases (= ca. 31%). Whereas in the shorter period from 1990 on the test indicates that correlations between bank stock indices of European countries have been predominantly stable, the results for the longer period indicate a non-constancy in more than a quarter of the analysed number of correlations.

For our analysis, i.e. the question whether bank stock indices exhibit a higher positive correlation, the Bera-Kim test is only of minor importance. A rejection of the null hypothesis does not tell us in which direction the correlations changed. Thus, the structural break tests and the estimation of a trend in the correlations can give us more information about the changes in the correlations. In addition, these two parametric tests could also be more precise. The Bera-Kim test is a non-parametric test against an unspecific alternative hypothesis. Thus, the power of the Bera-Kim test against specific alternatives (parallel shifts, time trend) might be relatively low. As a consequence, the Bera-Kim test can only be regarded as a first step in our analysis and the parametric tests are more important for the questions under consideration.

[15] Note however, that a lot of coefficients are significant at the 0.05 or even 0.01 significance level.

Testing for Structural Breaks in Correlations

By estimating equation (3b) we test for structural breaks after the completion of the EU banking market in the time after the 2nd Banking Directive in 1993, and after the introduction of the euro in 1999. In tables A1 and A2 in the appendix, we present the estimated parameters *corr1*, *corr2* and *corr3* with associated p-values for all 78 pairs of countries. If *corr2* and *corr3* are significant these parameters indicate parallel shifts of the correlation in the periods Jan. 1994 – Dez. 1998 or Jan. 1999 – end of the sample. In addition, a Wald-test statistic is computed that tests for joint significance of *corr2* and *corr3*. Under the null hypothesis (*corr2=corr3=0*) this Wald statistic is asymptotically chi-squared distributed with two degrees of freedom. The second section of tables 1 and 2 give a summary of the results in terms of significance of the parameters.

In the weekly regressions, we find *corr2* to be positively significant (at the 10% level) in 15 of 55 possible combinations (= 27.3%). In only one case *corr2* is negatively significant. *Corr3* is significantly positive in 11 cases and significantly negative in 3 cases. According to the Wald test, they are in 20 regressions jointly significantly different from zero (= 36.4%). In the majority of these cases (= 85%) the Wald test coincides either with a significantly positive t-test of *corr2* and/or *corr3* or with not significant but positive estimates of *corr2* and *corr3.*

In the monthly estimations, we obtain in 23 of the 78 cases (= 29.5%) a significantly positive and in no single case a significantly negative estimate of *corr2*. *Corr3* is in 10 regressions significantly positive and in two significantly negative. In 33 cases they are jointly significant (= 42.3%). Only in one of these 33 cases gives the significant Wald test statistics an indication of a decrease in the correlation.

Overall, the results of these parametric tests of structural breaks show that the completion of the single EU banking market and the introduction of the euro have increased the correlations between European bank stock index returns. According to our approach the reason for this has been stronger interdependencies between the banking industries of the European countries. This gives evidence that these two events have increased the potential for systemic risk in European banking.

Testing for a Trend in Correlations

By including a time trend in the correlation equation (3c) we are testing whether the correlations change gradually over time. Tables A1 and A2 in the appendix show the estimates of the parameters *corr4* and *corr5* with associated p-values for the 78 pairs of countries. If *corr5* is significantly positive this indicates a gradual increase of the correlation which we interpret as an increase in the interdependencies between banking markets and, hence, an increase in the systemic risk potential. The third section of tables 1 and 2 summarises these results in terms of significance of the parameters.

In the weekly regressions, we find the linear time trend in the correlation equation to be significantly positive in 30 of the 78 pairs of countries (= 38.5%). In 32 cases it is positive, although not significantly. It is significantly negative not once, and in 16 pairs negative, but not significantly. The results from the monthly regressions are quite similar. In 29 cases (= 37.2%) the correlation increases significantly over time. In no single regression is the linear trend significantly negative.

The results of this test indicate that correlations between bank stock index returns of European countries have increased significantly over the last 10 and 20 years. In addition to the results of the test for structural breaks, this gives further evidence that the systemic risk potential in the EU banking market has increased over time.

Comparison of the Non-Parametric and the Parametric Tests

There is the question whether results of the three tests in individual pairs of countries contradict each other. Looking in more detail on the results of the different tests (tables A1 and A2 in the appendix) we can identify three different cases:

Firstly, there is the case where the results from the different tests correspond to each other. This means that for one pair of country the Bera and Kim-test rejects the null hypothesis of constancy of correlation and we find significant shifts and/or a significant gradual increase in correlation (case 1a). In case 1b we classify those cases in which the Bera-Kim-test cannot reject the constancy of correlation and we find neither shifts nor a gradual increase in correlations.

Case 2 comprise those cases where the Bera-Kim test is significant and both parametric tests are not significant. Such a result may be explained by a change in correlations that is neither characterised by a shift nor by a linear trend. An example might be a sinus-type change in the correlations with a constant unconditional mean and large fluctuations of the correlations around this mean.

Finally, there is case 3 where the Bera-Kim test does not reject constancy of correlations, however, the parametric tests indicate a shift and/or a gradual increase in correlation. This can be explained by the fact that the parametric tests specify the development of correlations more exactly and, thus, have more power than the non-parametric Bera and Kim-test.

Table 3 summarises the findings with respect to these three cases.

- insert table 3 about here -

In the weekly regressions there are 38 pairs of countries where the results of the Bera and Kim-test correspond to the parametric tests. In 5 regressions the hypothesis of constancy can be rejected and there is a significant shift and/or a significant gradual increase in the correlation (case 1a). In 33 regressions neither is the Bera and Kim-statistic nor the structural breaks nor the time trend significant (case 1b). Thus, in about 49% the test results are qualitatively equal indicating altogether either a change in the correlation or a constant correlation. Case 2, i.e. none of the two parametric tests is significant but the Bera-Kim test is, applies to only 2 regressions and is therefore negligible. In 38 pairs of countries we find case 3, i.e. significant shifts and/or a significant trend and no rejection of constancy of correlation. Thus, in approximately 49% of all cases the parametric tests indicate a structural change but the Bera-Kim test does not. Concerning this case we assume that the parametric tests are more reliable and conclude that a structural change actually occurred.

The comparison of the three tests for the monthly regressions shows the following. Here we have 16 regressions where the Bera-Kim test rejects the hypothesis of a constant correlation and there is a significant shift and/or trend in correlations (case 1a). The higher number of pairs of countries in the monthly compared to the weekly regressions to which case 1a applies is not surprising: in the monthly regressions the sample is 10 years longer and thus the probability of structural changes is also higher. Case 1b occurs 26 times. Therefore, in about 54% the non-parametric and parametric tests find the same qualitative result. In 8 regressions we have case 2, i.e. the Bera and Kim-statistic is significant and there is neither a significant shift nor a significant gradual increase in correlation. This applies to ca. 10% of all pairs of countries. In these cases the correlation has not been constant but the changes are neither equal to a parallel shift nor to a linear trend. Case 3 applies to 28 of pairs of countries (= ca. 36%).

The majority of the results (= ca. 90%) can be classified into cases 1a,b and 3. There are only a few regressions where case 2 applies, i.e. where the non-parametric test indicates a change in correlation and neither of the two parametric tests indicates such a change. Although, case 2 does not necessarily constitute a contradiction, it is rather inconvenient and more difficult to explain. In sum, most of the results of the three tests are consistent with each other.

To sum up, the results of the parametric tests indicate that correlations between bank stock index returns of European countries have increased over the last 20 years. In only very few cases we have found a significantly negative change. For example, in 38% of all estimations the time trends in the weekly and monthly regressions are significantly positive and none are significantly negative. In addition to the tests of parallel shifts in the correlations at two pre-specified events this gives evidence of an overall increase in the correlations between European bank stocks. We take this as an evidence that interdependencies between the European banking industries have become stronger and, hence, the systemic risk potential in the EU banking market has increased.

5 Conclusions

Has the systemic risk amongst European banking sectors increased over time? This is the major question we want to answer with this study. The integration process in the European Union and particularly the development of the single market and the introduction of the euro are directed towards an increase in the international business of European industrial companies and banks. An unintended negative consequence of this integration process might be a rise in the systemic risk in the European banking business.

As a measure of systemic risk we use the conditional correlations between pairs of national bank stock indices of the EU countries. The correlations are estimated using bivariate GARCH-models which consider the influence of the national stock market index and a short-term interest rate as explanatory factors. The correlations measure the linear relationships between the residuals of the GARCH-models and as these residuals mainly reflect bank specific factors they are suitable to quantify the systemic risk.

We test for changes in the systemic risk by applying three different approaches. First, we use the Bera and Kim (2002)-test to get an impression of possible structural breaks. As the Bera-Kim test does not give us information about the direction of changes in the correlation and has probably low power against specific alternative hypotheses we mainly use the results of the following two parametric approaches: (1) test for parallel shifts in the correlations at two specific events: after the 2nd EU banking directive and after the introduction of the euro, (2) test for a linear time trend in the correlations.

We apply these three approaches to monthly data from 1980 on and to weekly data from 1990 on. Our main finding is that many conditional correlations exhibit significant upward changes over time either as parallel shifts at the two specified dates or as linear time trends. Overall, the correlations between European bank stock indices have risen significantly in the last years.

We interpret these results as evidence of an ongoing integration process in the European banking business which leads to growing similarities in the international economic factors that drive the profits of the banks. As a consequence of a more similar business behaviour this is evidence for an increase in systemic risk in the European banking market.

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Tables

Table 1 – Summary of the results of the weekly bivariate GARCH estimations

	significant positive	*positive, but insignificant*	*significant negative*	*negative, but insignificant*
	Testing conditional correlation constancy (equation 3a)			
corr (conditional correlation)	66	10	0	2
Bera-Kim test[1]	7	71		
	Testing for structural breaks in correlations[2] (equation 3b)			
corr1	8	29	2	16
corr2 (structural break in 1994)	15	29	1	10
corr3 (structural break in 1999)	11	25	3	16
Wald test[3]	20	35		
	Testing for a trend in correlations (equation 3c)			
corr4	63	11	0	4
corr5 (linear trend)	30	32	0	16

Note that 0.10 is taken as the relevant significance level, although a lot of the statistics and coefficients are significant at the 0.05 or even 0.01 level.

[1] The Bera-Kim test does test for the constancy of the correlation, irrespective of the direction.

[2] Note that for Italy and Portugal interest rate series are too short to allow for structural break tests. As a consequence, we conduct these test only for 55 pairs of countries.

[3] Since the Wald statistic is always positive there is no differentiation between positive and negative changes.

Table 2 – Summary of the results of the monthly bivariate GARCH estimations

	significant positive	*positive, but insignificant*	*significant negative*	*negative, but insignificant*
	Testing conditional correlation constancy (equation 3a)			
corr (conditional correlation)	64	12	0	2
Bera-Kim test[1]	24	54		
	Testing for structural breaks in correlations (equation 3b)			
corr1	17	37	3	21
corr2 (structural break in 1994)	23	44	0	11
corr3 (structural break in 1999)	10	37	2	29
Wald test[2]	33	45		
	Testing for a trend in correlations (equation 3c)			
corr4	54	22	0	2
corr5 (linear trend)	29	40	0	9

Note that 0.10 is taken as the relevant significance level, although a lot of the statistics and coefficients are significant at the 0.05 or even 0.01 level.

[1] The Bera-Kim test does test for the constancy of the correlation, irrespective of the direction.

[2] Note that for Italy and Portugal interest rate series are too short to allow for structural break tests. As a consequence, we conduct these test only for 55 pairs of countries.

[3] Since the Wald statistic is always positive there is no differentiation between positive and negative changes.

Table 3 – Comparison of the non-parametric and the parametric tests

Cases	*Weekly regressions*	*Monthly regressions*
1a: Bera and Kim significant, shifts and/or trend significant	5	16
1b: Bera and Kim not significant, shifts and trend not significant	33	26
2: Bera and Kim significant, shifts and trend not significant	2	8
3: Bera and Kim not significant, shifts and/or trend significant	38	28
Sum	78	78

Appendix

Table A1 – Results of the weekly bivariate GARCH model estimations

		Testing conditional correlation constancy (equation 3a)		*Testing for structural breaks in correlations (equation 3b)*				*Testing for a trend in correlations (equation 3c)*	
	Country combination	*corr (conditional correlation)*	*Bera-Kim test*	*corr1*	*corr2 (structural break in 1994)*	*corr3 (structural break in 1999)*	*Wald test statistic*	*corr4*	*corr5 (linear trend)*
1	DE-BE	0.1451***	0.715	0.0972	0.0525	0.0820	1.4351	0.1531***	0.021
		(0.000)		(0.198)	(0.574)	(0.414)	(0.4879)	(0.000)	(0.375)
2	DE-DK	0.0953**	0.937	0.0292	0.0357	0.0367	0.3217	0.0624	0.0114
		(0.023)		(0.735)	(0.743)	(0.735)	(0.851)	(0.157)	(0.658)
3	DE-ES	0.2022***	0.907	0.2127*	-0.0885	0.1492*	3.1372	0.1850***	0.0386
		(0.000)		(0.051)	(0.477)	(0.077)	(0.208)	(0.000)	(0.167)
4	DE-FI	0.1090***	0.496	0.2323***	-0.1492	0.0001	2.8038	0.1279***	-0.0276
		(0.009)		(0.002)	(0.117)	(0.999)	(0.246)	(0.004)	(0.247)
5	DE-FR	0.3371***	0.000***	0.1396	0.1382	0.1283	6.3234**	0.2797***	0.0486**
		(0.000)		(0.105)	(0.171)	(0.111)	(0.042)	(0.000)	(0.029)
6	DE-IE	0.0822**	0.395	0.0744	-0.0467	0.1145	1.5228	0.0755*	0.0018
		(0.040)		(0.424)	(0.677)	(0.217)	(0.467)	(0.070)	(0.942)
7	DE-IT	0.2421***	0.470					0.2276***	0.0874***
		(0.000)						(0.000)	(0.005)
8	DE-NL	0.2462***	0.711	0.2673***	-0.1041	0.1630*	3.7512	0.2455***	0.0047
		(0.000)		(0.001)	(0.306)	(0.057)	(0.153)	(0.000)	(0.837)
9	DE-AT	0.1431***	0.402	-0.0143	0.1240	0.0869	3.1718	0.1073**	0.0528**
		(0.000)		(0.898)	(0.344)	(0.321)	(0.205)	(0.021)	(0.025)
10	DE-PT	0.1241***	0.115					0.1037**	0.0687
		(0.010)						(0.037)	(0.219)

11	DE-SE	0.1983***	0.995	-0.0625	0.1807	0.2234**	12.249***	0.1579***	0.0803***
		(0.000)		(0.465)	(0.119)	(0.033)	(0.002)	(0.000)	(0.004)
12	DE-UK	0.0949**	1.000	-0.0228	0.1625	-0.0323	2.4229	0.0780*	0.0239
		(0.019)		(0.793)	(0.129)	(0.721)	(0.298)	(0.078)	(0.254)
13	BE-DK	0.0766*	0.350	0.1358**	-0.1649*	0.1615	4.1703	0.0691*	-0.0082
		(0.053)		(0.017)	(0.057)	(0.109)	(0.124)	(0.081)	(0.671)
14	BE-ES	0.0874**	0.414	0.0808	-0.0290	0.1012	1.1390	0.0905**	0.0211
		(0.034)		(0.492)	(0.828)	(0.287)	(0.566)	(0.043)	(0.499)
15	BE-FI	0.0300	0.662	0.0219	-0.0228	0.0028	0.0668	0.0092	-0.0116
		(0.485)		(0.748)	(0.806)	(0.982)	(0.967)	(0.834)	(0.628)
16	BE-FR	0.1021**	0.345	-0.0482	0.0963	0.2174**	8.3777**	0.0783*	0.0591***
		(0.018)		(0.561)	(0.355)	(0.028)	(0.015)	(0.061)	(0.008)
17	BE-IE	0.0025	0.821	-0.0845	0.0984	0.1222	4.5606	-0.0013	0.0459**
		(0.952)		(0.228)	(0.339)	(0.243)	(0.102)	(0.975)	(0.019)
18	BE-IT	0.0935**	0.763					0.0920*	0.0419
		(0.049)						(0.054)	(0.245)
19	BE-NL	0.2634***	0.029**	0.0910	0.0682	0.3091***	23.0257	0.2307***	0.0852***
		(0.000)		(0.176)	(0.417)	(0.000)	(0.000)	(0.000)	(0.000)
20	BE-AT	0.1007**	0.954	0.1175	-0.0079	-0.0400	0.2086	0.0999**	-0.0119
		(0.019)		(0.190)	(0.946)	(0.705)	(0.901)	(0.025)	(0.630)
21	BE-PT	0.0901	0.845					0.0924*	0.0192
		(0.103)						(0.092)	(0.714)
22	BE-SE	0.0044	0.568	-0.0799	0.0550	0.1351	2.1452	0.0101	0.0613*
		(0.926)		(0.394)	(0.651)	(0.284)	(0.342)	(0.837)	(0.053)
23	BE-UK	0.0423	0.773	-0.0851	0.2026**	-0.0077	5.0986*	0.0426	0.0301
		(0.301)		(0.221)	(0.032)	(0.942)	(0.078)	(0.307)	(0.186)
24	DK-ES	0.1102**	0.823	0.0196	0.0939	0.0512	1.1416	0.1112**	0.0262
		(0.011)		(0.870)	(0.488)	(0.594)	(0.565)	(0.017)	(0.392)

25	DK-FI	0.1158***	0.358	0.0041	0.1626*	-0.0241	3.1884	0.1039**	0.0450**
		(0.002)		(0.953)	(0.091)	(0.830)	(0.203)	(0.013)	(0.039)
26	DK-FR	0.1292***	0.130	-0.0408	0.1197	0.1136	4.7614	0.0815**	0.0433**
		(0.000)		(0.586)	(0.213)	(0.217)	(0.092)	(0.038)	(0.033)
27	DK-IE	0.0792**	0.740	0.0693	0.1086	-0.127	2.2302	0.0983	-0.0064
		(0.043)		(0.433)	(0.328)	(0.153)	(0.328)	(0.018)	(0.767)
28	DK-IT	0.1475***	0.581					0.1273**	-0.0180
		(0.001)						(0.011)	(0.590)
29	DK-NL	0.1214***	0.918	-0.0247	0.1760	0.0066	3.3225	0.1079**	0.0177
		(0.003)		(0.7736)	(0.116)	(0.944)	(0.190)	(0.014)	(0.409)
30	DK-AT	-0.0184	0.267	-0.0775	0.0128	0.1158	1.2229	-0.0288	0.0346
		(0.705)		(0.502)	(0.921)	(0.3188)	(0.543)	(0.583)	(0.259)
31	DK-PT	0.0264	0.781					0.0108	0.0478
		(0.628)						(0.849)	(0.436)
32	DK-SE	0.2039***	0.310	0.0327	0.1836*	0.1345	8.9382**	0.2163***	0.0799***
		(0.000)		(0.634)	(0.062)	(0.216)	(0.011)	(0.000)	(0.001)
33	DK-UK	0.1219***	0.966	0.0034	0.1545	0.0234	3.1935	0.1122***	0.0393*
		(0.002)		(0.966)	(0.148)	(0.819)	(0.203)	(0.006)	(0.071)
34	ES-FI	0.0744*	0.919	0.0391	0.0621	-0.0250	0.2542	0.0824*	0.0392
		(0.099)		(0.712)	(0.618)	(0.822)	(0.881)	(0.078)	(0.196)
35	ES-FR	0.2454***	0.075*	0.0926	0.1426	0.1217	4.7249*	0.2394***	0.0728**
		(0.000)		(0.379)	(0.240)	(0.170)	(0.094)	(0.000)	(0.011)
36	ES-IE	0.1268***	0.671	0.1296***	0.0792*	-0.1459**	37.7688***	0.1384***	-0.0171
		(0.002)		(0.001)	(0.064)	(0.011)	(0.000)	(0.001)	(0.520)
37	ES-IT	0.3663***	0.267					0.3393***	0.1018***
		(0.000)						(0.000)	(0.000)
38	ES-NL	0.1494***	0.146	0.1741	-0.1567	0.2332***	7.4207**	0.1164***	0.0550**
		(0.000)		(0.133)	(0.268)	(0.006)	(0.024)	(0.005)	(0.030)

39	ES-AT	0.0028	0.128	-0.2976***	0.3695***	0.0154	13.2440***	-0.0168	0.0758***
		(0.9450)		0.001	(0.001)	(0.873)	(0.001)	(0.686)	(0.004)
40	ES-PT	0.2177***	0.207					0.2519***	-0.0351
		(0.000)						(0.000)	(0.446)
41	ES-SE	0.2184***	0.205	0.1169	0.1239	0.0141	1.2337	0.2166***	0.0477*
		(0.000)		(0.268)	(0.320)	(0.876)	(0.540)	(0.000)	(0.091)
42	ES-UK	0.2090***	0.856	-0.0163	0.1532	0.1952*	7.4710**	0.1786***	0.0730**
		(0.000)		(0.890)	(0.290)	(0.063)	(0.024)	(0.000)	(0.016)
43	FI-FR	0.0977**	0.662	-0.1097	0.2649***	-0.0108	8.8152**	0.0677*	0.0504**
		(0.017)		(0.131)	(0.005)	(0.913)	(0.012)	(0.098)	(0.019)
44	FI-IE	0.1780***	0.965	0.0794	0.1871**	-0.1835*	6.1703**	0.1650***	-0.0003
		(0.000)		(0.274)	(0.035)	(0.050)	(0.046)	(0.000)	(0.988)
45	FI-IT	0.1289***	0.842					0.1420***	0.0540*
		(0.009)						(0.006)	(0.099)
46	FI-NL	0.0979**	0.692	0.0734	0.0203	0.0325	0.2540	0.0950**	0.0144
		(0.016)		(0.375)	(0.847)	(0.739)	(0.881)	(0.023)	(0.512)
47	FI-AT	-0.0238	0.521	0.0085	-0.0189	-0.0476	0.2987	-0.0261	-0.0007
		(0.572)		(0.916)	(0.852)	(0.672)	(0.861)	(0.582)	(0.978)
48	FI-PT	0.1330***	0.402					0.1364**	0.0462
		(0.005)						(0.016)	(0.290)
49	FI-SE	0.2640***	0.708	0.0932	0.1163	0.2671***	18.2069***	0.2863***	0.0860***
		(0.000)		(0.409)	(0.368)	(0.000)	(0.000)	(0.000)	(0.000)
50	FI-UK	0.1273***	0.740	-0.0066	0.2156**	-0.0376	4.9741*	0.1288***	0.0342
		(0.003)		(0.928)	(0.035)	(0.735)	(0.083)	(0.005)	(0.135)
51	FR-IE	0.1783***	0.080*	0.0400	0.2005**	-0.0788	4.1660	0.1627***	0.0113
		(0.000)		(0.594)	(0.041)	(0.356)	(0.125)	(0.000)	(0.548)

52	FR-IT	0.2626***	0.034					0.2082***	0.0966***
		(0.000)						(0.000)	(0.001)
53	FR-NL	0.2393***	0.076	0.1595**	0.0370	0.1706**	7.5665**	0.2175***	0.0603***
		(0.000)		(0.043)	(0.722)	(0.034)	(0.023)	(0.000)	(0.004)
54	FR-AT	0.0922**	0.504	0.0111	0.1467	-0.0787	1.5480	0.0885*	0.0304
		(0.027)		(0.916)	(0.239)	(0.445)	(0.461)	(0.064)	(0.266)
55	FR-PT	0.1531***	0.274					0.0970*	-0.0166
		(0.002)						(0.088)	(0.753)
56	FR-SE	0.2157***	0.473	0.0009	0.2227*	0.0864	5.1645*	0.2175***	0.0511
		(0.000)		(0.993)	(0.057)	(0.435)	(0.076)	(0.000)	(0.121)
57	FR-UK	0.1534***	0.210	0.0880	0.0935	-0.0041	0.8951	0.1460***	0.0120
		(0.000)		(0.290)	(0.381)	(0.965)	(0.639)	(0.001)	(0.602)
58	IE-IT	0.1750***	0.017**					0.1325***	-0.0049
		(0.000)						(0.004)	(0.876)
59	IE-NL	0.1292***	0.852	-0.0469	0.2500**	-0.0810	5.5084*	0.1092**	0.0182
		(0.001)		(0.570)	(0.020)	(0.371)	(0.064)	(0.014)	(0.365)
60	IE-AT	0.0324	0.850	-0.0813	0.0991	0.1077	2.4194	0.0253	0.0579**
		(0.466)		(0.466)	(0.454)	(0.304)	(0.298)	(0.592)	(0.042)
61	IE-PT	0.0797	0.453					0.0717	0.0528
		(0.162)						(0.219)	(0.286)
62	IE-SE	0.2271***	0.290	0.0325	0.2970**	-0.0158	7.0029**	0.2520***	0.0311
		(0.000)		(0.733)	(0.012)	(0.863)	(0.030)	(0.000)	(0.241)
63	IE-UK	0.2089***	0.593	0.2031***	0.1793**	-0.3049***	11.9138***	0.2068***	-0.0236
		(0.000)		(0.001)	(0.028)	(0.001)	(0.003)	(0.000)	(0.190)
64	IT-NL	0.1666***	0.184					0.1248**	0.0813**
		(0.000)						(0.011)	(0.015)

65	IT-AT	0.1186***	0.075*					0.1386***	-0.0079
		(0.008)						(0.003)	(0.781)
66	IT-PT	0.1717***	0.562					0.1485***	0.0292
		(0.000)						(0.007)	(0.540)
67	IT-SE	0.1825***	0.794					0.2718***	0.1794***
		(0.000)						(0.000)	(0.000)
68	IT-UK	0.1596***	0.590					0.1178**	0.0780**
		(0.000)						(0.026)	(0.025)
69	NL-AT	0.1067**	0.376	0.0447	0.0621	-0.0055	0.2532	0.0957**	-0.0030
		(0.011)		(0.681)	(0.625)	(0.954)	(0.881)	(0.023)	(0.908)
70	NL-PT	0.1214***	0.132					0.0920	-0.0392
		(0.003)						(0.109)	(0.452)
71	NL-SE	0.1643***	0.644	0.0377	0.1636	0.0477	2.1761	0.1750***	0.0431
		(0.001)		(0.749)	(0.233)	(0.668)	(0.337)	(0.000)	(0.198)
72	NL-UK	0.1731***	0.538	0.0659	0.1839*	-0.0611	3.1105	0.1692***	0.0213
		(0.000)		(0.412)	(0.078)	(0.532)	(0.211)	(0.000)	(0.327)
73	AT-PT	0.0920*	0.865					0.1160**	0.0035
		(0.099)						(0.046)	(0.953)
74	AT-SE	0.1033***	0.097*	-0.1303***	0.1945***	0.1538**	17.0152***	0.0940***	0.1047***
		(0.006)		(0.001)	(0.000)	(0.026)	(0.000)	(0.009)	(0.000)
75	AT-UK	0.0632*	0.146	-0.0547	0.0726	0.1171	3.9241	0.0362	0.0493**
		(0.068)		(0.525)	(0.5311)	(0.220)	(0.141)	(0.385)	(0.027)
76	PT-SE	0.2221***	0.797					0.1963***	0.0788***
		(0.000)						(0.000)	(0.000)

77	PT-UK	0.0516	0.335					0.0578	0.0259
		(0.289)						(0.237)	(0.509)
78	SE-UK	0.1312***	0.446	0.1900*	-0.1165	0.1753*	3.632	0.1523***	0.0267
		(0.003)		(0.022)	(0.292)	(0.060)	(0.163)	(0.001)	(0.304)

*Note: P-values in parentheses; ***, **, * indicates 0.01, 0.05, 0.10 significance level. For the Bera and Kim-test the implicit significance levels of the test statistic are given. Germany (DE), Belgium (BE), Denmark (DK), Spain (ES), Finland (FI), France (FR), Ireland (IE), Italy (IT), The Netherlands (NL), Austria (AU), Portugal (PT), Sweden (SE) and the United Kingdom (UK).*

Table A2 – Results of the monthly bivariate GARCH model estimations

		Testing conditional correlation constancy (equation 3a)		*Testing for structural breaks in correlations (equation 3b)*				*Testing for a trend in correlations (equation 3c)*	
	Country combination	*corr (conditional correlation)*	*Bera-Kim test*	*corr1*	*corr2 (structural break in 1994)*	*corr3 (structural break in 1999)*	*Wald test statistic*	*corr4*	*corr5 (linear trend)*
1	DE-BE	0.2213***	0.188	0.1758*	0.0001	0.0001	0.0000	0.2035**	0.0108
		(0.001)		(0.091)	(0.999)	(0.999)	(1.000)	(0.011)	(0.907)
2	DE-DK	0.1746**	0.005***	0.1190	-0.0266	0.1352	0.5449	0.1439	0.0320
		(0.039)		(0.289)	(0.909)	(0.562)	(0.761)	(0.102)	(0.751)
3	DE-ES	0.4123***	0.076*	0.1745	0.1016	0.3645***	12.8009**	0.3165***	0.2650
		(0.000)		(0.343)	(0.626)	(0.002)	(0.002)	(0.000)	(0.104)
4	DE-FI	0.2560***	0.381	0.1043	0.2171	-0.0941	1.0984	0.1898*	0.1366
		(0.001)		(0.451)	(0.302)	(0.679)	(0.577)	(0.052)	(0.454)
5	DE-FR	0.3655***	0.001***	-0.0109	0.5048***	0.0911	12.1276***	0.1917**	0.2201
		(0.000)		(0.940)	(0.004)	(0.521)	(0.002)	(0.046)	(0.196)
6	DE-IE	0.2782***	0.063*	0.0263	0.4786**	-0.1894	5.1694*	0.2773***	0.0734
		(0.000)		(0.868)	(0.023)	(0.306)	(0.075)	(0.003)	(0.657)
7	DE-IT	0.2459***	0.056*	0.1078	0.2045	0.0278	3.7090	0.2091***	0.2816***
		(0.000)		(0.204)	(0.121)	(0.883)	(0.157)	(0.001)	(0.000)
8	DE-NL	0.3283***	0.000***	0.3902***	0.0637	-0.1824	0.7238	0.3887***	0.0134
		(0.000)		(0.000)	(0.515)	(0.471)	(0.696)	(0.000)	(0.837)
9	DE-AT	0.0583	0.619	0.1053	-0.1179	0.1961	0.6058	0.0240	0.1616
		(0.527)		(0.568)	(0.604)	(0.470)	(0.739)	(0.817)	(0.428)
10	DE-PT	0.3023***	0.061*	-0.1456	0.4686*	0.1116	3.3901	0.1431	0.4961*
		(0.000)		(0.573)	(0.087)	(0.561)	(0.184)	(0.179)	(0.059)
11	DE-SE	0.1913**	0.480	0.0761	-0.0862	0.4250*	3.7612	0.1730**	0.0384
		(0.012)		(0.510)	(0.660)	(0.061)	(0.152)	(0.036)	(0.774)

12	DE-UK	0.3563***	0.000***	0.1974**	0.1601	0.2570*	9.3978***	0.2964***	0.1832**
		(0.000)		(0.031)	(0.263)	(0.080)	(0.009)	(0.000)	(0.017)
13	BE-DK	0.1979***	0.973	0.0441	0.3354**	-0.0094	5.1355*	0.2137***	0.1294
		(0.002)		(0.673)	(0.050)	(0.962)	(0.077)	(0.009)	(0.177)
14	BE-ES	0.3955***	0.168	0.4055***	0.0032	-0.0503	0.1120	0.4294***	-0.1387
		(0.000)		(0.000)	(0.981)	(0.748)	(0.946)	(0.000)	(0.188)
15	BE-FI	0.1907**	0.838	-0.0139	0.3097	0.0337	2.8668	0.1345	0.2646
		(0.021)		(0.933)	(0.143)	(0.870)	(0.239)	(0.198)	(0.161)
16	BE-FR	0.2527***	0.012**	0.2812**	0.0017	-0.0001	0.0001	0.2561***	0.0000
		(0.000)		(0.036)	(0.992)	(1.000)	(1.000)	(0.002)	(0.999)
17	BE-IE	0.2391***	0.325	-0.2400*	0.7424***	-0.1544	14.1830***	0.0767	0.3949*
		(0.000)		(0.094)	(0.000)	(0.430)	(0.001)	(0.447)	(0.057)
18	BE-IT	0.1866***	0.031**	0.1251	0.0008	0.0001	3.1226	0.1756**	0.2024***
		(0.003)		(0.188)	(0.997)	(1.000)	(1.000)	(0.011)	(0.006)
19	BE-NL	0.1605**	0.074*	0.1198	0.0031	0.0015	0.0006	0.1307	0.1187
		(0.038)		(0.199)	(0.987)	(0.995)	(1.000)	(0.103)	(0.191)
20	BE-AT	0.1340	0.582	-0.1061	0.3800	0.0354	3.5774	0.1003	-0.0000
		(0.132)		(0.576)	(0.115)	(0.889)	(0.167)	(0.334)	(0.999)
21	BE-PT	0.1637**	0.113	-0.1002	0.1781	0.3172	3.1110	0.0730	0.4656**
		(0.040)		(0.648)	(0.500)	(0.225)	(0.211)	(0.467)	(0.041)
22	BE-SE	0.1326**	0.350	-0.0898	0.3758**	0.1639	10.5210***	0.0883	0.3110***
		(0.040)		(0.462)	(0.022)	(0.343)	(0.005)	(0.290)	(0.002)
23	BE-UK	0.2676***	0.292	0.1065	0.2058	0.1573	7.4663**	0.2203***	0.1625**
		(0.000)		(0.312)	(0.183)	(0.262)	(0.024)	(0.003)	(0.026)
24	DK-ES	0.2408***	0.686	0.2426*	0.0962	-0.1241	0.3990	0.2625***	0.0274
		(0.000)		(0.078)	(0.628)	(0.564)	(0.819)	(0.004)	(0.865)

25	DK-FI	0.3355***	0.477	0.2572*	0.0333	0.0999	0.3918	0.3451***	-0.0000
		(0.000)		(0.095)	(0.859)	(0.620)	(0.822)	(0.000)	(0.999)
26	DK-FR	0.1143	0.966	-0.0164	0.2277	-0.0109	1.3733	0.1509*	0.0001
		(0.156)		(0.915)	(0.314)	(0.962)	(0.503)	(0.099)	(0.999)
27	DK-IE	0.3635***	0.385	0.0084	0.4249	0.2184	7.3967**	0.3534***	0.3817**
		(0.000)		(0.972)	(0.119)	(0.162)	(0.025)	(0.001)	(0.042)
28	DK-IT	0.0810	0.778	-0.0742	0.4853***	-0.0752	12.4780***	0.0715	0.2789***
		(0.227)		(0.423)	(0.003)	(0.717)	(0.002)	(0.342)	(0.000)
29	DK-NL	0.1486**	0.552	0.1878**	-0.0207	-0.1547	0.4751	0.1759**	-0.0760
		(0.039)		(0.040)	(0.900)	(0.561)	(0.789)	(0.016)	(0.417)
30	DK-AT	0.1105	0.646	0.1890	-0.1767	0.1422	0.7982	0.1058	0.0000
		(0.158)		(0.260)	(0.416)	(0.483)	(0.671)	(0.390)	(0.999)
31	DK-PT	0.1402	0.779	0.2514	-0.3349	0.3996	2.4588	0.1122	0.0000
		(0.112)		(0.138)	(0.200)	(0.136)	(0.292)	(0.215)	(0.999)
32	DK-SE	0.3371***	0.143	0.1441	0.3239**	0.1043	11.5948***	0.2631***	0.3004***
		(0.000)		(0.125)	(0.037)	(0.443)	(0.003)	(0.000)	(0.000)
33	DK-UK	0.1649**	0.787	-0.0664	0.4079**	0.0964	10.3743***	0.1520**	0.1774**
		(0.011)		(0.542)	(0.031)	(0.583)	(0.006)	(0.030)	(0.044)
34	ES-FI	0.3214***	0.632	0.2654*	0.0484	0.0594	0.2765	0.2751***	0.1926
		(0.000)		(0.085)	(0.822)	(0.761)	(0.871)	(0.002)	(0.304)
35	ES-FR	0.3819***	0.027**	0.1914	0.3451*	-0.0065	3.2882	0.4478***	0.0000
		(0.000)		(0.211)	(0.086)	(0.968)	(0.193)	(0.000)	(0.999)
36	ES-IE	0.2944***	0.169	0.0196	0.5485**	-0.3195**	6.7795**	0.2333*	0.1469
		(0.000)		(0.939)	(0.043)	(0.047)	(0.034)	(0.056)	(0.449)
37	ES-IT	0.3742***	0.404	0.1823	0.2221	0.2894**	12.2570***	0.4020***	0.0000
		(0.000)		(0.221)	(0.211)	(0.023)	(0.002)	(0.000)	(0.999)

38	ES-NL	0.2181**	0.590	0.2183	0.2254	-0.0814	1.2470	0.2485**	0.0000
		(0.019)		(0.161)	(0.264)	(0.719)	(0.536)	(0.019)	(0.999)
39	ES-AT	0.1031	0.187	-0.2725*	0.5884***	-0.1074	10.5498***	0.0115	0.3719**
		(0.209)		(0.076)	(0.001)	(0.601)	(0.005)	(0.899)	(0.027)
40	ES-PT	0.3313***	0.007***	0.1874	0.2710	-0.1421	1.5042	0.3271***	0.0965
		(0.000)		(0.381)	(0.258)	(0.455)	(0.471)	(0.000)	(0.591)
41	ES-SE	0.4349***	0.992	0.3089**	0.2040	-0.0151	1.8325	0.3943***	0.1425
		(0.000)		(0.014)	(0.206)	(0.923)	(0.400)	(0.000)	(0.333)
42	ES-UK	0.4380***	0.090*	-0.0327	0.5335***	0.1248	13.6814***	0.2830***	0.4889***
		(0.000)		(0.841)	(0.004)	(0.289)	(0.001)	(0.001)	(0.000)
43	FI-FR	0.3016***	0.134	0.0778	0.1225	0.2576	5.2598*	0.1547**	0.5026***
		(0.000)		(0.609)	(0.542)	(0.119)	(0.072)	(0.033)	(0.002)
44	FI-IE	0.3439***	0.549	0.2025	0.3183	-0.2515	3.9383	0.3335***	0.0195
		(0.000)		(0.290)	(0.102)	(0.155)	(0.140)	(0.000)	(0.907)
45	FI-IT	0.1994**	0.974	0.0702	0.1146	0.1765	1.5696	0.2200***	0.0000
		(0.014)		(0.694)	(0.598)	(0.379)	(0.456)	(0.008)	(0.999)
46	FI-NL	0.2251**	0.473	0.2227*	0.0155	-0.0537	0.0344	0.2262**	-0.0173
		(0.014)		(0.088)	(0.939)	(0.854)	(0.983)	(0.027)	(0.923)
47	FI-AT	-0.0085	0.781	-0.1394	0.1157	0.2336	2.4826	-0.0184	0.3037*
		(0.926)		(0.431)	(0.668)	(0.351)	(0.289)	(0.852)	(0.086)
48	FI-PT	0.1593*	0.647	-0.2045	0.4093*	0.2294	8.2981**	0.889	0.0000
		(0.074)		(0.182)	(0.078)	(0.330)	(0.016)	(0.343)	(0.999)
49	FI-SE	0.4821***	0.705	0.4797***	0.0414	0.0928	0.8726	0.5207***	0.1202
		(0.000)		(0.000)	(0.812)	(0.551)	(0.646)	(0.000)	(0.428)
50	FI-UK	0.2568***	0.858	-0.0578	0.3264	0.1355	4.6676*	0.1144	0.4794**
		(0.003)		(0.749)	(0.202)	(0.514)	(0.097)	(0.271)	(0.015)

51	FR-IE	0.3882***	0.288	0.2288	0.3156	-0.1389	2.2125	0.4394***	-0.0406
		(0.000)		(0.196)	(0.148)	(0.442)	(0.331)	(0.000)	(0.776)
52	FR-IT	0.3010***	0.053*	0.0094	0.3618**	0.1317	8.1277**	0.2409***	0.3284**
		(0.000)		(0.944)	(0.049)	(0.406)	(0.017)	(0.002)	(0.010)
53	FR-NL	0.1688**	0.051*	0.0033	0.2305	-0.0288	1.5933	0.1079	0.2414
		(0.030)		(0.978)	(0.251)	(0.920)	(0.451)	(0.215)	(0.113)
54	FR-AT	0.2004***	0.114	0.1632	-0.0092	0.1647	0.6325	0.1323	0.1584
		(0.007)		(0.259)	(0.963)	(0.459)	(0.729)	(0.123)	(0.288)
55	FR-PT	0.3465***	0.044**	0.3758**	-0.1233	0.2504	2.1449	0.2536**	0.2874
		(0.000)		(0.047)	(0.613)	(0.154)	(0.342)	(0.017)	(0.250)
56	FR-SE	0.2522***	0.277	0.0056	0.3225*	0.2954**	9.5911***	0.1757**	0.4763***
		(0.001)		(0.973)	(0.092)	(0.046)	(0.008)	(0.030)	(0.003)
57	FR-UK	0.3426***	0.040**	0.3824***	-0.1442	0.3706**	5.9612*	0.3277***	0.1538
		(0.000)		(0.001)	(0.412)	(0.020)	(0.051)	(0.000)	(0.296)
58	IE-IT	0.2396***	0.080*	0.0876	0.2794	-0.0280	2.0097	0.2631***	-0.0092
		(0.001)		(0.546)	(0.188)	(0.899)	(0.366)	(0.001)	(0.952)
59	IE-NL	0.3050***	0.089*	0.1898	0.2271	-0.4236*	3.9782	0.2542**	-0.0530
		(0.001)		(0.303)	(0.274)	(0.054)	(0.137)	(0.019)	(0.756)
60	IE-AT	-0.0359	0.328	-0.1315	0.2520	-0.1379	1.2795	-0.0349	0.0001
		(0.679)		(0.419)	(0.259)	(0.592)	(0.527)	(0.697)	(0.999)
61	IE-PT	0.1321	0.435	-0.2788*	0.3039	0.2258	6.2548**	0.0955	0.0000
		(0.108)		(0.077)	(0.210)	(0.350)	(0.044)	(0.417)	(0.999)
62	IE-SE	0.3573***	0.395	-0.0192	0.5299***	0.1050	10.9282***	0.2849***	0.4674***
		(0.000)		(0.896)	(0.007)	(0.503)	(0.004)	(0.001)	(0.003)
63	IE-UK	0.4371***	0.330	0.3996***	0.1273	-0.0737	0.5860	0.4574***	0.0607
		(0.000)		(0.005)	(0.461)	(0.596)	(0.746)	(0.000)	(0.571)

64	IT-NL	0.0834	0.267	0.0474	0.3922***	0.1147	11.9615***	0.2077***	0.2405***
		(0.225)		(0.585)	(0.004)	(0.527)	(0.003)	(0.001)	(0.004)
65	IT-AT	0.2376***	0.303	0.1671	0.2872	-0.2533	2.5436	0.2466***	0.0499
		(0.002)		(0.243)	(0.134)	(0.258)	(0.280)	(0.004)	(0.737)
66	IT-PT	0.3319***	0.001***	0.0313	0.3612	0.0571	2.5116	0.2610***	0.4880**
		(0.000)		(0.891)	(0.157)	(0.760)	(0.285)	(0.007)	(0.018)
67	IT-SE	0.1978***	0.788	-0.0473	0.2762*	0.3905**	17.4326***	0.1196*	0.4098***
		(0.007)		(0.635)	(0.072)	(0.022)	(0.000)	(0.075)	(0.000)
68	IT-UK	0.2569***	0.001***	0.0864	0.2895*	0.3214**	22.7112***	0.2560	0.2134***
		(0.000)		(0.414)	(0.063)	(0.019)	(0.000)	(0.000)	(0.010)
69	NL-AT	0.1825**	0.239	0.2252	-0.0669	0.4671**	6.0632**	0.2595***	0.0410
		(0.028)		(0.232)	(0.785)	(0.024)	(0.048)	(0.005)	(0.857)
70	NL-PT	0.2010**	0.049**	-0.2480	0.6719***	-0.1781	11.5879***	0.2197*	0.4750*
		(0.020)		(0.175)	(0.001)	(0.508)	(0.003)	(0.054)	(0.054)
71	NL-SE	0.2117***	0.716	0.1505	0.2332	-0.2239	1.9828	0.1515*	0.0001
		(0.008)		(0.143)	(0.163)	(0.456)	(0.371)	(0.057)	(0.999)
72	NL-UK	0.3534	0.219	0.2310**	0.2391*	-0.0258	3.3528	0.3034***	0.1295
		(0.000)		(0.016)	(0.092)	(0.891)	(0.187)	(0.000)	(0.103)
73	AT-PT	0.1815**	0.261	0.4184***	-0.0394	-0.2934	1.6019	0.2946***	-0.0967
		(0.031)		(0.008)	(0.844)	(0.258)	(0.449)	(0.003)	(0.667)
74	AT-SE	0.0957	0.725	-0.0939	0.3987	-0.0901	2.5697	0.0442	0.3893*
		(0.299)		(0.630)	(0.109)	(0.714)	(0.277)	(0.661)	(0.081)
75	AT-UK	0.1258	0.252	-0.1672	0.1039	0.4245*	5.1022*	0.1015	0.0000
		(0.128)		(0.251)	(0.573)	(0.068)	(0.078)	(0.231)	(0.999)
76	PT-SE	0.2954***	0.989	-0.0940	0.4393	0.2989	10.2523***	0.2390**	0.7126***
		(0.002)		(0.665)	(0.116)	(0.109)	(0.006)	(0.014)	(0.001)

77	PT-UK	0.2411***	0.011**	-0.2681	0.6283***	0.0253	8.4120**	0.1004	0.6819***
		(0.001)		(0.161)	(0.006)	(0.868)	(0.015)	(0.227)	(0.000)
78	SE-UK	0.2143***	0.344	0.1099	0.1649	0.2322	6.8282**	0.2001***	0.2045**
		(0.002)		(0.281)	(0.360)	(0.206)	(0.033)	(0.007)	(0.036)

*Note: P-values in parentheses; ***, **, * indicates 0.01, 0.05, 0.10 significance level. For the Bera and Kim-test the implicit significance levels of the test statistic are given. Germany (DE), Belgium (BE), Denmark (DK), Spain (ES), Finland (FI), France (FR), Ireland (IE), Italy (IT), The Netherlands (NL), Austria (AU), Portugal (PT), Sweden (SE) and the United Kingdom (UK).*

Data Appendix

Country	*National bank stock indices*	*Market indexes**	*Short-term interest rates**
Germany	BANKSBD(RI)	DAXIDXI	FIBOR3M
Belgium	BANKSBG(RI)	BGBEL20	BIBOR3M
Denmark	BANKSDK(RI)	DKKFXIN	CIBOR3M
Spain	BANKSES(RI)	IBEX35I	ESMIB3M
Finland	BANKSFN(RI)	HEX25IN	FNIBF3M
France	BANKSFR(RI)	FCAC40C	PIBOR3M
Ireland	BANKSIR(RI)	TOTMKIT	EIRED3M
Italy	BANKSIT(RI)	ISEGNRL	ITIBK3M
The Netherlands	BANKSNL(RI)	AMSTEOE	AIBOR3M
Austria	BANKSOE(RI)	ATXINDX	ASVIB3M
Portugal	BANKSPT(RI)	POPSIGN	BBPTE3M
Sweden	BANKSSD(RI)	SWEDOMX	SIBOR3M
United Kingdom	BANKSUK(RI)	FTSE100	LDNIB3M

The table displays Abbreviations for the respective series drawn from Thomson Financial Datastream.
** For weekly regressions only.*