New Measures for Systemic Banks

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Abstract

This paper contributes to the literature on systemic risk measures for the banking sector by proposing a set of measures to identify the banks that are systemically relevant. In our framework a bank is said to be systemically relevant if its stock returns are related to the stock returns of the whole market, especially when bank returns are negative. In particular, the systemic relevance of a bank is determined as the non-neutrality of the market returns with respect to the returns of the bank in terms of i) correlation, ii) mean, iii) variance, iv) Value-at-Risk (VaR), and v) extreme (tail) distributions. Using publicly available stock market returns, we identify several financial institutions that should be deemed as systemically relevant. Moreover, using Italian banks as a case study, we also show that in some circumstances it seems that systemically relevant banks are better identified during normal times than during crisis periods.

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1 Introduction

The 2007–08 financial crisis highlighted the importance of having reliable measures of systemic risk for macro-prudential purposes. Usually, systemic risk is defined as the risk associated with one or more relevant financial institutions (or markets) being under severe stress. This definition, however, does not clarify: i) what a *relevant* financial institution (or market) is, and ii) how a situation of *stress* is defined. Because of the lack at the international level of a unique definition of systemic risk and because of the multiple facets in which systemic risk can materialize, international financial institutions (as the International Monetary Fund, the European Central Bank and the Bank for International Settlements) use a wide range of indicators to monitor one or more particular aspects of systemic risk. Indeed, according to Lo (2009), monitoring systemic risk requires a variety of measures that capture seven broad characteristics of the entire financial system: leverage, liquidity, correlation, concentration, sensitivities, implicit guarantees, and connectedness. Moreover, once a particular definition of systemic risk is chosen and a related measure is implemented for the whole financial system, it still remains the necessity for financial sector supervisors to determine which financial institution is systemically relevant, i.e. which individual bank generates systemic risk.

This paper aims at contributing to the recent literature on systemic risk measures for the banking sector (see, among others, Adrian and Brunnermeier, 2010; Tarashev et al., 2009, 2010; Huang et al., 2009, 2010) by proposing a set of measures to identify systemically relevant banks. In particular, a bank is said to be systemically relevant if its stock returns are related to the stock returns of the whole market, especially when the bank's returns are negative. Thus, the aim of this paper is to measure the dependence between the stock returns of a broad market index and individual banks in order to identify the banks that are mostly connected with the market, if any. In this regard, we build on Patton (2009) that defines five different measures of neutrality to market risk for hedge funds. Systemic relevance for banks is thus evaluated by examining the neutrality of market stock returns with respect to the stock returns of individual financial institutions in terms of i) correlation, ii) mean, iii) variance, iv) Value-at-Risk (VaR), and v) extreme (tail) distributions. The systemic relevance assessed according to this methodology, which is based on several measures of co-movement for stock returns, has the major advantage to circumvent the problem of relying on a single specific definition or measure of systemic risk for the whole financial system.

We apply this methodology to two samples of banks, the first includes the major European banks while the second focusses on the main Italian banks. Several systemically relevant institutions emerge from our tests, although the results can vary depending on which neutrality test is used. Moreover, from our results it also appears that in some cases it is more appropriate to identify systemic institutions in "normal" periods, rather than in a crisis period. This happens when the crisis that hits a country is mainly due to external factors, so that the statistical tests involving national banks tend to lose their explanatory power.

The remainder of the paper is organized as follows. Section 2 reviews the literature related with our approach. Section 3 outlines the methodology and presents the various measures of dependence. Section 4 shows some preliminary results, and Section 5 concludes. The Appendix presents the details about a bootstrap methodology used in the paper.

2 Related literature

Because of the importance that monitoring systemic risk for financial stability purposes has acquired since the onset of the financial crisis, several papers have recently proposed different definitions and measures for systemic risk.

Huang et al. (2009, 2010) define systemic risk as the simultaneous default of several large financial institutions and propose to measure it as the price of an hypothetical insurance contract that would protect against large default losses (i.e. losses that exceed a minimum share of total liabilities) in the banking sector in the coming 12 weeks. By using market data information on CDS spreads and equity prices, Huang et al. (2009, 2010) estimate both the risk neutral probability of defaults (PDs) of individuals banks and the correlations among asset returns one quarter ahead. Once these two key portfolio credit risk parameters are estimated, Monte Carlo simulations are used to compute what is called the "distress insurance premium". Huang et al. (2009, 2010) also disentangle the total systemic risk into the sum of marginal risk contributions. In particular, the marginal contribution of a particular bank to the distress insurance premium is identified as the expected loss arising from the default of that bank, conditional on a large loss for the whole banking sector.

Adrian and Brunnermeier (2010) define the CoVaR of an institution as the VaR of the financial system conditional on that institution being under distress (i.e. the return of the institution is at its VaR level). They propose to measure the marginal contribution of an institution to the overall systemic risk through the delta CoVaR (ΔCoVar), defined as the difference between the CoVaR conditional on the distress of a particular financial institution and the CoVar conditional on the median state of that institution.

Finally, Tarashev et al. (2009, 2010) take another approach. They do not focus on defining and measuring the systemic risk but instead propose two alternative procedures for attributing the total systemic risk among the individual financial institutions. The methodologies they suggest can be used independently of how systemic risk is defined and measured (for instance, using VaR or expected shortfall methodologies). The two procedures, based on the Shapley value methodology, disentangle the same magnitude of systemic risk in different ways. A first procedure measures the contribution of each bank to a given level of global systemic risk and it is therefore better suited for macro-prudential purposes. The other measure calculates the expected share of an institution in the overall cost of systemic events (taking such events as given), and it is more appropriate for deriving actuarially fair premia for insurance against losses in case of systemic events.

Our paper differentiate from these recent studies in several ways. First, we do not propose either a definition or a specific measure of systemic risk for the whole financial system (as in Huang et al., 2009, 2010) and, second, we do not adopt a top-down approach that gauges systemic relevance by allocating system-wide risk to individual institutions (as in Tarashev et al., 2009, 2010). We aim at assessing the systemic importance of a financial institution by directly focusing on the relationship it has with the whole market through the use of several indicators. In this regard, we distinguish from Adrian and Brunnermeier (2010) which rely on a single specific measure only.

3 Methodology

We adopt the idea that a financial institution is deemed to be considered systemically relevant whenever its financial conditions can have an impact on the whole economic system. In order to implement this concept, we use equity returns for both individual banks and broad-based indices as proxies for the conditions of the banks and the overall economy, respectively.

The extent to which a financial institution is related to the whole economy is measured using five concepts of dependence between the returns of individual institutions and those of the market. These measures have been proposed by Patton (2009) to test whether hedge funds are market neutral; they are used to appraise the relationships between the returns of an individual institution and the returns of the whole market in terms of neutrality with respect to i) correlation, ii) mean, iii) variance, iv) VaR and v) tail risk. As in Patton (2009), in order to construct confidence intervals for each neutrality test, we rely on a block bootstrap procedure that is able to deal with the econometric issues related to sample size, serial correlation, volatility clustering and non-normality of financial returns. In particular, since all these empirical issues make the calculation of the exact distribution of our estimators not feasible, the bootstrap procedure, that resamples the original data set with replacement, is used to calculate several bootstrap replications of the estimators and the corresponding distributions, which are then used to construct the confidence intervals and to make statistical inference (see the Appendix for details on the bootstrap methodology).

Correlation neutrality

The first indicator which is used to analyze the relationship between the returns of the whole market and those of the individual financial institutions is the standard linear correlation (or Pearson correlation). In particular, the linear correlation between the stock returns of each bank and the market index is first calculated and then the bootstrap procedure is used to verify the statistical significance of the results obtained in the first step. In addition to testing for the presence of a statistically significant correlation (being either positive or negative) we also test specifically for the presence of positive correlation, which is what one would expect for a systemically relevant institution.

Although the correlation is an admittedly simple measure, it nonetheless provides a first clue of the relationship between individual banks and the whole economy. First of all, the correlation provides a sufficient statistic for the degree of dependence between the whole market and individual institutions as long as the joint distribution of the returns is multivariate normal. Moreover, Patro et al. (2010) find that daily stock return correlation, regardless of its measure (parametric Pearson correlation or non-parametric Kendall and Spearman correlations), is a simple, robust, forward-looking and timely systemic risk indicator, since it captures the trend as well as the fluctuations in the levels of systemic risk in the economy in the United States.

Mean neutrality

A second way to assess the connection between individual bank returns and market returns is in terms of mean neutrality. Mean neutrality is defined as the independence of the expected returns of the market from the returns of individual banks or, formally,

$$\mathbb{E}[r_{mt}|r_{it}] = \mathbb{E}[r_{mt}], \quad \forall t, \tag{1}$$

where r_{mt} and r_{it} are the returns at time t of the market and bank i, respectively. Equation (1) means that the expected returns of the market are not influenced by the returns of bank i. It is worth noting that this concept of mean neutrality nests also the standard correlation and beta neutrality, in the sense that the latter two approaches can be tested by looking at the statistical significance of the regression coefficient of a simple linear regression of the market returns on the returns of an individual bank. Mean neutrality not only requires that there is no linear relationship between market and bank returns but also that there is no nonlinear relationship. Equation (1) can be tested by assuming a specific functional form for the conditional expected market returns $\mathbb{E}[r_{mt}|r_{it}] = \gamma_i(r_{it})$ and verifying that $\gamma_i(r_{it})$ in $r_{mt} = \gamma_i(r_{it}) + \epsilon_{it}$ is constant. As in Patton (2009), we specify the conditional mean function as a third-order polynomial to account for both the linear and the non-linear relationships between the returns of a given financial institution and the market and test for the presence of mean neutrality using a Wald test on β_1, β_2, and β_3 of the following equation:

$$r_{mt} = \beta_0 + \beta_1 r_{it} + \beta_2 r_{it}^2 + \beta_3 r_{it}^3 + \epsilon_{mt}. \tag{2}$$

When the null hypothesis of the Wald test (i.e. that β_1, β_2, and β_3 are all equal to zero) cannot be rejected, the hypothesis that bank i is not systemically relevant cannot also be rejected, as the returns of bank i appear, on average, to have no relationship with the returns of the whole market. On the contrary, a lack of mean neutrality for the market with respect to bank i can be interpreted as the returns of bank i having a connection with market returns. However, this property by itself is not sufficient for saying that one should be worried for the negative returns of that bank, as the relationship between market and bank returns could also be negative, in principle. For this reason, we also test for "mean neutrality on the downside", which is defined as the expected market returns being neutral or negatively related to the returns of the individual institution when the latter are negative:

$$\frac{\partial \mathbb{E}[r_{mt}|r_{it}]}{\partial r_{it}} \leq 0, \quad \text{for } r_{it} \leq 0. \tag{3}$$

The definition of market neutrality on the downside only focusses on the case in which bank returns are negative. When the null hypothesis of mean neutrality on the downside for the market with respect to bank i cannot be rejected, one should take bank i as not systemically relevant, as the more negative its returns are the more positive, or less negative, its contribution to overall market returns is. Following Patton (2009), we test for the average value of the derivative in Equation (3) across all non-positive values of r_{it}, or

$$H_0 : \mathbb{E}\left[\frac{\partial \mathbb{E}[r_{mt}|r_{it}]}{\partial r_{it}}\middle| r_{it} \leq 0\right] \leq 0. \tag{4}$$

Using a third-order polynomial for $\mathbb{E}[r_{mt}|r_{it}]$ in Equation (4) and plugging in the parameter estimates gives

$$\mathbb{E}\left[\frac{\partial \hat{\mathbb{E}}[r_{mt}|r_{it}]}{\partial r_{it}}\middle| r_{it} \leq 0\right] = \hat{\beta}_1 + 2\hat{\beta}_2\mathbb{E}[r_{it}|r_{it} \leq 0] + 3\hat{\beta}_3\mathbb{E}[r_{it}^2|r_{it} \leq 0], \tag{5}$$

so that the null hypothesis of Equation (4) can be tested by looking at the confidence interval of the first derivative of the conditional mean function evaluated at the point $\left(\hat{\mathbb{E}}[r_{it}|r_{it} \leq 0], \hat{\mathbb{E}}[r_{it}^2|r_{it} \leq 0]\right)$. Also in this case, we rely on the bootstrap procedure to construct the empirical distribution of the test statistic.

Variance neutrality

Another type of neutrality useful to identify financial institutions that can be considered as systemically relevant is related to the riskiness of the market, which should be connected with the institution's returns. In particular, for non-systemically relevant banks it can be expected that the risk of the market index is not related to the returns of the individual institutions. The riskiness of the market can be measured in several ways, for instance through the variance, the Value-at-Risk, or extreme tail probabilities. In the following tests we also control for mean non-neutrality before testing variance, VaR and tail neutrality. Actually, a failure to control for mean non-neutrality generally leads to the presence of apparent variance non-neutrality, even if the variance of the market is truly neutral to the institution returns (see Patton, 2009).

In particular, the variance neutrality, controlling for mean non-neutrality, is defined as

$$\mathbb{V}\text{ar}\left[r_{mt} - \mu_m(r_{it})|r_{it}\right] = \mathbb{V}\text{ar}\left[r_{mt} - \mu_m(r_{it})\right]. \tag{6}$$

Equation (6) is the formal representation of the statement that the variance of the market is not related to the returns of bank i.

The control for violations of mean neutrality is done by estimating the conditional variance of the error term of Equation (2) and using a conditional variance function with an ARCHX(1) effect

$$\sigma_{mt}^2 = \alpha_0 + \alpha_1 r_{it}^2 + \alpha_2 \epsilon_{mt-1}^2. \tag{7}$$

Equation (7) can be used to test for the presence of variance neutrality by applying a Wald test on α_1. Indeed, when the null hypothesis of the Wald test (i.e. that α_1 is equal to zero) cannot be rejected, the hypothesis that bank i is not systemically relevant cannot also be rejected. In that case, the returns of bank i appear to have no relationship with the variance of the whole market.

Using the block bootstrap methodology we test also for variance neutrality "on the downside". The null hypothesis of this test is that the expected volatility of the market is neutral or related positively to the institution's returns when the institution's returns are negative. In other words, a financial institutions cannot be considered as systemically relevant if the volatility of the market decreases when it is doing poorly, or

$$H_0 : \mathbb{E}\left[\frac{\partial \sigma_{mt}^2(r_{it})}{\partial r_{it}} \Big| r_{it} \leq 0\right] \geq 0. \tag{8}$$

Following the same idea as for the test of mean neutrality on the downside, one has

$$\mathbb{E}\left[\frac{\partial \sigma_{mt}^2(r_{it})}{\partial r_{it}} \Big| r_{it} \leq 0\right] = 2\hat{\alpha}_1 \mathbb{E}[r_{it}|r_{it} \leq 0], \tag{9}$$

so that the null hypothesis of Equation (8) can be tested by looking at the confidence interval of the first derivative of the conditional variance function evaluated at the point $\hat{\mathbb{E}}[r_{it}|r_{it} \leq 0]$.

VaR neutrality

A second risk-related neutrality concept is the Value-at-Risk (VaR) neutrality, which means that the VaR of the market is neutral to the institution's returns. As before, violations of mean neutrality or variance neutrality generally lead to violations of VaR neutrality. We therefore consider the VaR of the standardized returns:

$$\text{VaR}\left(\frac{r_{mt} - \mu_m(r_{it})}{\sigma_m(r_{it})} \Big| r_{it}\right) = \text{VaR}\left(\frac{r_{mt} - \mu_m(r_{it})}{\sigma_m(r_{it})}\right). \tag{10}$$

Since the quantile estimation provides a nonparametric approach to VaR calculation, we use a quantile regression to (Wald) test the influence of the institution's returns on a quantile of the market standardized returns distribution

$$\text{quantile}\left(\frac{r_{mt} - \mu_m(r_{it})}{\sigma_m(r_{it})}\right) = \beta_0 + \beta_1 r_{it} + \beta_2 r_{it}^2 + \beta_3 r_{it}^3 + \epsilon_{mt}. \tag{11}$$

When the null hypothesis of the Wald test (i.e. that β_1, β_2, and β_3 are all equal to zero) cannot be rejected, the hypothesis that bank i is not systemically relevant cannot also be rejected. In that case, the returns of bank i appear to have no relationship with the market risk, as measured by its VaR.

Similarly to the previous neutrality concepts, we also test Equation (11) for VaR neutrality "on the downside", which corresponds to the idea that the expected quantile of the standardized market returns are neutral or related negatively to the institution's returns when the latter are negative:

$$H_0 : \mathbb{E}\left[\left. \frac{\partial \text{quantile}\left(\frac{r_{mt}-\mu_m(r_{it})}{\sigma_m(r_{it})}\right)}{\partial r_{it}} \right| r_{it} \leq 0 \right] \leq 0. \quad (12)$$

Since the VaR is defined as a loss and has a negative sign, the more it increases when the institution's returns are negative the less significant is the loss of the market. A financial institution that fulfill this type of restricted VaR neutrality is therefore not systemic.

Similarly to the previous neutrality tests on the downside we have

$$\mathbb{E}\left[\left. \frac{\partial \text{quantile}\left(\frac{r_{mt}-\mu_m(r_{it})}{\sigma_m(r_{it})}\right)}{\partial r_{it}} \right| r_{it} \leq 0 \right] = \hat{\beta}_1 + 2\hat{\beta}_2 \mathbb{E}[r_{it}|r_{it} \leq 0] + 3\hat{\beta}_3 \mathbb{E}[r_{it}^2|r_{it} \leq 0], \quad (13)$$

so that the null hypothesis of Equation (12) can be tested by looking at the confidence interval of the first derivative of the conditional VaR function evaluated at the point $\big(\hat{\mathbb{E}}[r_{it}|r_{it} \leq 0], \hat{\mathbb{E}}[r_{it}^2|r_{it} \leq 0]\big)$.

Tail risk neutrality

Finally, neutrality during extreme events, or tail neutrality, can be defined as an extension of the VaR neutrality to the extreme quantile. Tail neutrality is verified when the probability of extreme negative returns on the market is not related to the fact that extreme negative returns on a financial institution are observed:

$$\mathbb{P}\left[r_{mt} \leq q | r_{it} \leq q\right] = \mathbb{P}\left[r_{mt} \leq q\right] \quad (14)$$

This type of neutrality presents similarities with the CoVaR notion proposed by Adrian and Brunnermeier (2010). As a measure of tail dependence we use the extremal correlation estimator of Quintos (2004), that allows for GARCH(1,1) process in the data:

$$\hat{\psi}(2) = \frac{\hat{\alpha}_{12}^{-1}(2) - \hat{\alpha}_1^{-1}(2)\hat{\alpha}_2^{-1}(2)}{\hat{\sigma}^*_{\varepsilon_{1+}}(2)\hat{\sigma}^*_{\varepsilon_{2+}}(2)} \quad (15)$$

where

$$
\begin{aligned}
\hat{\alpha}_{12}^{-1}(2) &= \frac{1}{L}\sum_{t=1}^{T} \varepsilon_{1t+}^{*}(2)\varepsilon_{2t+}^{*}(2) \\
\hat{\alpha}_{i}^{-1}(2) &= \frac{1}{L}\sum_{t=1}^{T} \varepsilon_{1t+}^{*}(2), \quad i = 1,2 \\
\sigma_{\varepsilon_{i+}}^{\hat{2}*}(2) &= \frac{1}{L}\sum_{t=1}^{T} \varepsilon_{1t+}^{2*}(2) - \left[\frac{1}{L}\sum_{t=1}^{T} \varepsilon_{1t+}^{*}(2)\right]^2, \quad i = 1,2 \\
\varepsilon_{it+}^{*}(2) &= \log\left(\frac{\hat{\sigma}_{it}^2}{\hat{\sigma}_{i(T-m_i)}^2}\right) 1_{(\varepsilon_{it}>1)}
\end{aligned}
\tag{16}
$$

and $L = \sum_{t=1}^{T} 1_{(\varepsilon_{1t}>1, \varepsilon_{2t}>1)}$ is the number of joint exceedances.

The extremal correlation estimator ψ is explicitly written in terms of the tail index, which determines the shape of the tail. In Equation (15), $\hat{\alpha}_{12}^{-1}(2)$ is an Hill estimator (or shape parameter for the tail): the smaller the α, the slower the rate of decay and the thicker the tail of the distribution.

Similarly to the case of correlation neutrality, we first calculate the extremal correlation estimator between the stock returns of each bank and the market index and then use the bootstrap procedure to calculate a large number of bootstrap replications of the estimator. From the probability distribution of the replications we then construct confidence intervals to test for the presence of correlation in the lower tail. We also test for the presence of positive correlation in the lower tail, i.e. the sign of lower tail correlation that applies to systemic financial institutions.

4 Results

In order to empirically assess the systemic importance of financial institutions, we run the previous five neutrality tests on two groups of banks. The first group contains twelve European large and complex financial institutions (LCFIs) and the second group has twelve Italian banks of different size. The two largest Italian banks are included in both groups. The systemic relevance of each bank is evaluated with respect to both the Datastream non-financial and financial sector indices. For the LCFIs we use Datastream indices referring to the European Union while for Italian banks we use Datastream indices referring to the Italian market. We utilize weekly stock returns from December 2001 until January 2011. The sample period is also divided into two subsamples, to take account of the pre-crisis period (December 2001–June 2007) and crisis period (July 2007–January 2011).

We identify the banks that are not related with the market as those financial institutions for which the neutrality tests cannot be rejected at 10% significance level (highlighted in bold in the tables). These banks are certainly not systematically relevant. The banks for which the null hypotheses are rejected have instead significant statistical relationships with the market. These relationships, however, could be due to either their systematic relevance or some underlying common factor. Strictly speaking, our tests permit to separate the banks that are not systemically relevant from those that are potentially systemically relevant. In this light, our approach is conservative, meaning that all banks that are connected to the market are deemed to be systematically relevant. Moreover, we believe that more accurate results can be attained by running several tests, as we do.

Tables 1 and 2 examine the relationship between European LCFIs and the European non-financial sector index (as a proxy of the real economy) during the pre-crisis and the crisis period, respectively. The European non-financial sector index is positively correlated with all the European banks in the sample. Similarly, the mean neutrality hypothesis for the European non-financial sector index is rejected with respect to each bank. These results imply that all the banks included in the sample are deemed to be considered as systemically relevant according to the first two tests, for both the pre-crisis and crisis periods. On the contrary, the variance of the non-financial sector index is neutral to individual bank returns, as shown by the high p-values. The overall variance neutrality of the European non-financial sector does not hold for three banks (Deutsche Bank, HSBC, and UBS) during the crisis period, since the test of neutrality can be rejected at 10% significance level in those cases. These three banks have had a more relevant connection with the overall volatility of the non-financial sector index than the other banks of the sample, and can be considered systemically relevant in this respect. When focusing on the variance neutrality given that individual bank returns are negative (variance neutrality on the downside), it turns out that stock returns for all banks are significantly related to the volatility of the European non-financial sector index.

The results presented in tables 1 and 2 also show that the hypothesis of neutrality of the VaR test can be rejected with respect to several banks at a low level of significance during both the pre-crisis and the crisis period. This test has been conducted on standardized returns of the non-financial sector to control for the mean and the variance non-neutrality. Focusing instead on the restricted version of the VaR neutrality test on the downside, almost all banks present high p-values. These results imply that generally there is no statistical significant relationship between the negative returns of the banks and the VaR of the non-financial sector index. One exception is HSBC, whose negative returns are significantly connected with the VAR of the European non-financial sector during the pre-crisis period. Therefore, it cannot be ruled out that this institution is a systemic one. For comparison reasons, we have also run the VaR neutrality test on the normal (i.e., non-standardized) returns of the non-financial sector index and we found that avoiding to control for mean and variance neutrality lead to all the banks to be significantly connected with the VaR of the index.[1] Finally, according to the tail neutrality test, the European non-financial sector index presents a low positive extremal correlation

[1] More detailed results are available from the authors on request.

with several banks. In particular, during the pre-crisis period the index has recorded an unambiguous positive correlation in the lower tail with Barclays, which therefore could be considered as systematically relevant.

Similarly, Tables 3 and 4 analyze the relationships between Italian banks and the corresponding non-financial sector index in the two sub-periods. Our results show that during the pre-crisis period only Banca Popolare di Sondrio can be excluded from being a systemic relevant institution according to the mean neutrality test. However, its stock returns showed a significant degree of connection with the riskiness of the market as measured by the variance and the VaR. The VaR of the Italian non-financial sector index was also significantly related with the negative returns of several other banks (Credito Valtellinese, Credito Bergamasco, Banca Popolare di Milano, Credito Emiliano, Mediobanca, and Banca Monte dei Paschi di Siena) from December 2001 to June 2007. Rather surprising, during the crisis period there is no statistical evidence that the negative returns of the banks have been related with the VaR of the index. In this respect, no Italian bank can be deemed to be systemically relevant. This result is probably due to the fact that Italian banks were not the drivers of the crisis, and that other external factors had stronger impact on the Italian non-financial firms. Our findings suggest that for some countries it would be probably more useful to discriminate between systemic and non-systemic institutions using data from "normal" periods instead of "exceptional" times, when several external factors may impact on the economy.

We also replicate the same estimations for the financial sector index. Tables 5 and 6 indicate that during the pre-crisis period only the negative returns of HSBC have been related with the VaR of the European financial sector index. Moreover, according to the tail neutrality test, almost all banks included in the sample present a positive extreme correlation with the financial sector index during both the pre-crisis and the crisis period. Likewise, from Tables 7 and 8 it comes out that the negative returns of Unicredit, Credito Valtellinese, and Banca Popolare di Sondrio have been connected with the VaR of the Italian financial sector index during the pre-crisis period. Several Italian banks have also recorded a positive extreme correlation with the corresponding financial sector index during the two sub-periods that are examined.

5 Conclusion

The 2007–08 financial crisis emphasized the importance for policymakers to monitor financial stability not only with the traditional firm-level approach, but also using a system-wide macro-prudential approach.

In this paper we propose several tests of neutrality to spot systemically important financial institutions. Following the methodology of Patton (2009) we analyze the dependence between market returns and individual institutions' returns. Our results are helpful to shed light on the fact that individual institutions are related to the market in several ways, by affecting either its expected returns or its riskiness (measured by the variance, the VaR, and the tail extreme correlation). Several banks that are potentially systemically relevant emerge from this paper, depending on the specific neutrality test. For instance, during the pre-crisis period HSBC could be considered systemically relevant as its negative stock returns have been connected with the VaR of the European non-financial sector index. At the same time, Barclays' stock returns recorded a significant positive correlation in the lower tail with the index, so that this bank could also be considered systemically relevant. During the crisis period, instead, the overall returns of Deutsche Bank, HSBC, and UBS have all been strongly related with the variance of the market. Our results for Italian banks also suggest that it could be more appropriate to identify systemic institutions in "normal" periods, rather than during a crisis period.

Possible future work may include the enlargement of the sample, by considering also a focus on the main German and French banks. Moreover, one could also analyze the determinants of the dependence between banks and general indices by relating the several measures of neutrality to the individual characteristics of the banks such as size, leverage, and capitalization.

Appendix: Block bootstrap methodology

To test the neutrality of the market with respect to individual financial institutions, this paper uses several measures (correlation, mean neutrality, variance neutrality, VaR neutrality, extremal correlation) of which the probability distribution of the estimators is unknown due to several empirical features of the data (small sample size, serial correlation, volatility clustering and non-normality of financial returns). The bootstrap methodology is a procedure that resamples the original data set with replacement. From the bootstrap samples one can therefore calculate bootstrap replications of the parameter of interest and obtain its probability distribution with the related critical values for the tests. Since we are interested in testing the dependence between two time series of returns, we resort to the "block" bootstrap methodology.

The procedure works as follows:

1. Start by "wrapping" the data $X_1, X_2, \ldots, X_T$ around a circle.
2. Calculate the block size for the circular bootstrap. We use the algorithm of Politis and White (2004) to the market returns, the squared market returns, the bank returns, the squared bank returns and the product of the market returns and the bank returns; we then select the largest of these lengths to use as the block length for that bank.
3. The starting points of the blocks are randomly drawn; they are the same for the 2 variables (r_m, r_i).
4. From the starting points we attach the block size.
5. Cut the bootstrap sample at T observations (the number of observations of the 2 variables).

In particular, the block lengths selected ranges from 23 to 25 during the pre-crisis period, and from 10 to 18 during the crisis period. All the tests have been conducted based on 100 replications. Finally, to set the confidence intervals for the standard correlation measure and the extremal correlation estimator we have constructed two types of intervals: the percentile interval and the bias-corrected and accelerated interval.

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Tables

Table 1 – Impact of European banks on European non financial sector index: pre-crisis period[a]

European banks	Correlation neutrality		Mean neutrality		Variance neutrality		VaR neutrality[b]		Tail risk neutrality[c]	
	$\rho = 0$	$\rho \leq 0$	global	downside	global	downside	global	downside	$\psi = 0$	$\psi \leq 0$
BNP Paribas	No	No	0.00	0.00	**0.79**	0.00	**0.92**	**0.18**	No/Yes	No/Yes
Societe Generale	No	No	0.00	0.00	**0.90**	0.00	0.00	**0.13**	**Yes**	No/Yes
Deutsche Bank	No	No	0.00	0.00	**0.58**	0.00	**0.61**	**0.28**	**Yes**	**Yes**
ING Groep	No	No	0.00	0.00	**0.93**	0.00	0.04	**0.28**	**Yes**	**Yes**
Banco Santander	No	No	0.00	0.00	**0.96**	0.00	0.00	**0.30**	No/Yes	No/Yes
HSBC Hdg.	No	No	0.00	0.00	**0.73**	0.00	0.00	0.05	No/Yes	No/Yes
Barclays	No	No	0.00	0.00	**0.46**	0.00	0.00	**0.19**	No	No
Royal Bank of Sctl. Gp.	No	No	0.00	0.01	**0.88**	0.00	0.00	**0.32**	No/Yes	No/Yes
UBS	No	No	0.00	0.00	**0.58**	0.00	**0.71**	**0.54**	**Yes**	No/Yes
Credit Suisse Group	No	No	0.00	0.00	**0.71**	0.00	**0.44**	**0.16**	**Yes**	**Yes**
Unicredit	No	No	0.00	0.00	**0.35**	0.00	**0.17**	**0.15**	No/Yes	No/Yes
Intesa Sanpaolo	No	No	0.00	0.00	**0.51**	0.00	**0.22**	**0.19**	**Yes**	**Yes**

[a] Pre-crisis period: December 2001-June 2007. In bold are highlighted the p-values for which the neutrality tests cannot be rejected at 10% significance level. [b] VaR neutrality calculated on standardized returns. [c] Tail neutrality tests according two types of confidence intervals: the percentile interval and the bias-corrected and accelerated interval.

Table 2 – Impact of European banks on European non financial sector index: crisis period[a]

European banks	Correlation neutrality		Mean neutrality		Variance neutrality		VaR neutrality[b]		Tail risk neutrality[c]	
	$\rho = 0$	$\rho \leq 0$	global	downside	global	downside	global	downside	$\psi = 0$	$\psi \leq 0$
BNP Paribas	No	No	0.00	0.00	**1.00**	0.00	**0.88**	**0.78**	**Yes**	**Yes**
Societe Generale	No	No	0.00	0.00	**0.55**	0.00	**0.15**	**0.54**	**Yes**	**Yes**
Deutsche Bank	No	No	0.00	0.00	0.05	0.00	0.00	**0.77**	No/Yes	No/Yes
ING Groep	No	No	0.00	0.00	**0.19**	0.00	**0.83**	**0.83**	**Yes**	No/Yes
Banco Santander	No	No	0.00	0.00	**0.40**	0.00	**0.61**	**0.97**	No/Yes	No/Yes
HSBC hdg.	No	No	0.00	0.00	0.06	0.00	0.02	**0.88**	**Yes**	No/Yes
Barclays	No	No	0.00	0.00	**0.43**	0.00	0.10	**0.45**	**Yes**	**Yes**
Royal Bank of Sctl. Gp.	No	No	0.00	0.00	**0.15**	0.00	**0.99**	**0.66**	**Yes**	**Yes**
UBS	No	No	0.00	0.00	0.10	0.00	0.00	**0.36**	No/Yes	No/Yes
Credit Suisse Group	No	No	0.00	0.00	**0.16**	0.00	0.00	**0.87**	No/Yes	No/Yes
Unicredit	No	No	0.00	0.00	**0.33**	0.00	**0.69**	**0.76**	**Yes**	**Yes**
Intesa Sanpaolo	No	No	0.00	0.00	**0.14**	0.00	**0.28**	**0.83**	No/Yes	No/Yes

[a] Crisis period: July 2007-January 2011. In bold are highlighted the p-values for which the neutrality tests cannot be rejected at 10% significance level. [b] VaR neutrality calculated on standardized returns. [c] Tail neutrality tests according two types of confidence intervals: the percentile interval and the bias-corrected and accelerated interval.

Table 3 – Impact of Italian banks on Italian non financial sector index: pre-crisis period[a]

Italian banks	Correlation neutrality		Mean neutrality		Variance neutrality		VaR neutrality[b]		Tail risk neutrality[c]	
	$\rho = 0$	$\rho \leq 0$	global	downside	global	downside	global	downside	$\psi = 0$	$\psi \leq 0$
Unicredit	No	No	0.00	0.00	**0.23**	0.00	0.02	**0.11**	Yes/No	Yes/No
Intesa Sanpaolo	No	No	0.00	0.00	**0.54**	0.00	**0.34**	**0.19**	**Yes**	Yes/No
Banca Monte dei Paschi	No	No	0.00	0.00	**0.38**	0.00	0.05	0.09	**Yes**	No
Banca Pop. di Milano	No	No	0.00	0.00	0.04	0.00	**0.13**	0.06	**Yes**	Yes/No
Banca Pop. di Sondrio	**Yes**	No	**0.26**	**0.14**	**0.87**	0.00	0.07	0.04	**Yes**	**Yes**
Banca Pop. dell'Emilia R.	No	No	0.01	0.01	**1.00**	0.00	**0.76**	**0.29**	**Yes**	**Yes**
Banco Popolare	No	No	0.00	0.00	**0.15**	0.00	**0.20**	**0.13**	**Yes**	**Yes**
Banca Pop. di Spoleto	No	No	0.00	0.00	**0.95**	0.00	**0.42**	**0.18**	**Yes**	**Yes**
Mediobanca	No	No	0.00	0.00	**0.25**	0.00	0.00	0.08	**Yes**	Yes/No
Credito Emiliano	No	No	0.00	0.00	**0.46**	0.00	**0.15**	0.07	Yes/No	No
Credito Valtellinese	No	No	0.00	0.00	**0.85**	0.00	0.00	0.00	**Yes**	**Yes**
Credito Bergamasco	No	No	0.00	0.01	**1.00**	0.00	0.00	0.03	**Yes**	**Yes**

[a] Pre-crisis period: December 2001-June 2007. In bold are highlighted the p-values for which the neutrality tests cannot be rejected at 10% significance level. [b] VaR neutrality calculated on standardized returns. [c] Tail neutrality tests according two types of confidence intervals: the percentile interval and the bias-corrected and accelerated interval.

Table 4 – Impact of Italian banks on Italian non financial sector index: crisis period[a]

Italian banks	Correlation neutrality		Mean neutrality		Variance neutrality		VaR neutrality[b]		Tail risk neutrality[c]	
	$\rho = 0$	$\rho \leq 0$	global	downside	global	downside	global	downside	$\psi = 0$	$\psi \leq 0$
Unicredit	No	No	0.00	0.00	**0.43**	0.00	**0.92**	**0.69**	**Yes**	**Yes**
Intesa Sanpaolo	No	No	0.00	0.00	**0.39**	0.00	**0.36**	**0.78**	No/Yes	No/Yes
Banca Monte dei Paschi	No	No	0.00	0.00	**0.27**	0.00	**0.63**	**0.95**	No	No
Banca Pop. di Milano	No	No	0.00	0.00	**1.00**	0.00	**0.28**	**0.58**	No/Yes	No/Yes
Banca Pop. di Sondrio	No	No	0.00	0.00	**0.44**	0.00	**0.55**	**0.41**	**Yes**	**Yes**
Banca Pop. dell'Emilia R.	No	No	0.00	0.00	**1.00**	0.00	0.09	**0.46**	**Yes**	**Yes**
Banco Popolare	No	No	0.00	0.00	0.03	0.00	**0.63**	**0.87**	**Yes**	**Yes**
Banca Pop. di Spoleto	No	No	0.00	0.00	**0.46**	0.00	**0.41**	**0.58**	**Yes**	**Yes**
Mediobanca	No	No	0.00	0.00	**1.00**	0.00	0.00	**0.62**	**Yes**	**Yes**
Credito Emiliano	No	No	0.00	0.00	**0.95**	0.00	0.10	**0.55**	**Yes**	No/Yes
Credito Valtellinese	No	No	0.00	0.00	**0.31**	0.00	**0.11**	**0.67**	**Yes**	No/Yes
Credito Bergamasco	No	No	0.00	0.00	**0.15**	0.00	0.00	**0.21**	No/Yes	No/Yes

[a] Crisis period: July 2007-January 2011. In bold are highlighted the p-values for which the neutrality tests cannot be rejected at 10% significance level. [b] VaR neutrality calculated on standardized returns. [c] Tail neutrality tests according two types of confidence intervals: the percentile interval and the bias-corrected and accelerated interval.

Table 5 – Impact of European banks on European financial sector index: pre-crisis period[a]

European banks	Correlation neutrality		Mean neutrality		Variance neutrality		VaR neutrality[b]		Tail risk neutrality[c]	
	$\rho = 0$	$\rho \leq 0$	global	downside	global	downside	global	downside	$\psi = 0$	$\psi \leq 0$
BNP Paribas	No	No	0.00	0.00	**0.74**	0.00	**0.90**	**0.23**	No	No
Societe Generale	No	No	0.00	0.00	**0.94**	0.00	**0.63**	**0.23**	No	No
Deutsche Bank	No	No	0.00	0.00	**0.42**	0.00	0.07	**0.18**	**Yes**	Yes/No
ING Groep	No	No	0.00	0.00	**0.77**	0.00	**0.84**	**0.34**	No	No
Banco Santander	No	No	0.00	0.00	**0.50**	0.00	0.10	**0.50**	No	No
HSBC Hdg.	No	No	0.00	0.00	**0.32**	0.00	0.00	0.00	No	No
Barclays	No	No	0.00	0.00	**0.40**	0.00	0.01	**0.49**	No	No
Royal Bank of Sctl. Gp.	No	No	0.00	0.00	**0.74**	0.00	**0.91**	**0.75**	No	No
UBS	No	No	0.00	0.00	**0.19**	0.00	**0.87**	**0.53**	Yes/No	No
Credit Suisse Group	No	No	0.00	0.00	**0.51**	0.00	**0.55**	**0.65**	Yes/No	Yes/No
Unicredit	No	No	0.00	0.00	**0.37**	0.00	**0.72**	**0.13**	No	No
Intesa Sanpaolo	No	No	0.00	0.00	**0.42**	0.00	**0.26**	**0.31**	**Yes**	**Yes**

[a] Pre-crisis period: December 2001-June 2007. In bold are highlighted the p-values for which the neutrality tests cannot be rejected at 10% significance level. [b] VaR neutrality calculated on standardized returns. [c] Tail neutrality tests according two types of confidence intervals: the percentile interval and the bias-corrected and accelerated interval.

Table 6 – Impact of European banks on European financial sector index: crisis period[a]

European banks	Correlation neutrality		Mean neutrality		Variance neutrality		VaR neutrality[b]		Tail risk neutrality[c]	
	$\rho = 0$	$\rho \leq 0$	global	downside	global	downside	global	downside	$\psi = 0$	$\psi \leq 0$
BNP Paribas	No	No	0.00	0.00	**0.24**	0.00	**0.16**	**0.49**	**Yes**	**Yes**
Societe Generale	No	No	0.00	0.00	**0.21**	0.00	0.00	**0.12**	**Yes**	No
Deutsche Bank	No	No	0.00	0.00	0.02	0.00	0.00	**0.67**	No/Yes	No
ING Groep	No	No	0.00	0.00	**0.22**	0.00	**0.26**	**0.95**	No	No
Banco Santander	No	No	0.00	0.00	**1.00**	0.00	0.00	**0.52**	No/Yes	No/Yes
HSBC Hdg.	No	No	0.00	0.00	0.04	0.00	**0.92**	**0.55**	No/Yes	No/Yes
Barclays	No	No	0.00	0.00	**0.18**	0.00	0.00	**0.45**	No	No
Royal Bank of Sctl. Gp.	No	No	0.00	0.00	0.04	0.00	0.04	**0.90**	Yes/No	No
UBS	No	No	0.00	0.00	**0.18**	0.00	0.00	**0.42**	No/Yes	No/Yes
Credit Suisse Group	No	No	0.00	0.00	0.04	0.00	0.00	**0.86**	No	No
Unicredit	No	No	0.00	0.00	**0.18**	0.00	**0.98**	**0.63**	No	No
Intesa Sanpaolo	No	No	0.00	0.00	**0.12**	0.00	0.00	**0.36**	No/Yes	No/Yes

[a] Crisis period: July 2007-January 2011. In bold are highlighted the p-values for which the neutrality tests cannot be rejected at 10% significance level. [b] VaR neutrality calculated on standardized returns. [c] Tail neutrality tests according two types of confidence intervals: the percentile interval and the bias-corrected and accelerated interval.

Table 7 – Impact of Italian banks on Italian financial sector index: pre-crisis period[a]

Italian banks	Correlation neutrality		Mean neutrality		Variance neutrality		VaR neutrality[b]		Tail risk neutrality[c]	
	$\rho = 0$	$\rho \leq 0$	global	downside	global	downside	global	downside	$\psi = 0$	$\psi \leq 0$
Unicredit	No	No	0.00	0.00	**0.54**	0.00	0.00	0.03	No	No
Intesa Sanpaolo	No	No	0.00	0.00	**0.66**	0.00	**0.30**	**0.13**	Yes/No	Yes/No
Banca Monte dei Paschi	No	No	0.00	0.00	**0.23**	0.00	**0.32**	**0.20**	Yes/No	No
Banca Pop. di Milano	No	No	0.00	0.00	**0.30**	0.00	0.00	**0.24**	Yes/No	Yes/No
Banca Pop. di Sondrio	No	No	0.00	0.00	**1.00**	0.00	**0.52**	0.08	**Yes**	**Yes**
Banca Pop. dell'Emilia R.	No	No	0.00	0.00	**1.00**	0.00	**0.54**	**0.16**	**Yes**	Yes/No
Banco Popolare	No	No	0.00	0.00	**0.11**	0.00	**0.72**	**0.47**	Yes/No	No
Banca Pop. di Spoleto	No	No	0.00	0.00	**0.99**	0.00	**0.21**	**0.19**	**Yes**	Yes/No
Mediobanca	No	No	0.00	0.00	**0.35**	0.00	0.00	**0.31**	No	No
Credito Emiliano	No	No	0.00	0.00	**0.64**	0.00	**0.96**	**0.47**	Yes/No	Yes/No
Credito Valtellinese	No	No	0.00	0.00	**0.99**	0.00	0.00	0.03	**Yes**	**Yes**
Credito Bergamasco	No	No	0.00	0.06	**0.96**	0.00	0.04	**0.16**	**Yes**	**Yes**

[a] Pre-crisis period: December 2001-June 2007. In bold are highlighted the p-values for which the neutrality tests cannot be rejected at 10% significance level. [b] VaR neutrality calculated on standardized returns. [c] Tail neutrality tests according two types of confidence intervals: the percentile interval and the bias-corrected and accelerated interval.

Table 8 – Impact of Italian banks on Italian financial sector index: crisis period[a]

Italian banks	Correlation neutrality		Mean neutrality		Variance neutrality		VaR neutrality[b]		Tail risk neutrality[c]	
	$\rho = 0$	$\rho \leq 0$	global	downside	global	downside	global	downside	$\psi = 0$	$\psi \leq 0$
Unicredit	No	No	0.00	0.00	**0.32**	0.00	**0.65**	**0.70**	No	No
Intesa Sanpaolo	No	No	0.00	0.00	**0.26**	0.00	**0.34**	**0.97**	No	No
Banca Monte dei Paschi	No	No	0.00	0.00	0.05	0.00	0.00	**0.99**	No/Yes	No/Yes
Banca Pop. di Milano	No	No	0.00	0.00	**0.45**	0.00	**0.50**	**0.56**	No/Yes	No
Banca Pop. di Sondrio	No	No	0.00	0.00	**0.15**	0.00	**0.78**	**0.43**	No/Yes	No/Yes
Banca Pop. dell'Emilia R.	No	No	0.00	0.00	0.04	0.00	**0.60**	**0.61**	**Yes**	**Yes**
Banco Popolare	No	No	0.00	0.00	0.04	0.00	**0.70**	**0.87**	**Yes**	No/Yes
Banca Pop. di Spoleto	No	No	0.00	0.00	**0.29**	0.00	**0.44**	**0.77**	**Yes**	**Yes**
Mediobanca	No	No	0.00	0.00	0.10	0.00	0.03	**0.51**	**Yes**	**Yes**
Credito Emiliano	No	No	0.00	0.00	**0.38**	0.00	**0.69**	**0.39**	No/Yes	No/Yes
Credito Valtellinese	No	No	0.00	0.00	**0.13**	0.00	**0.22**	**0.47**	**Yes**	No/Yes
Credito Bergamasco	No	No	0.00	0.00	**0.16**	0.00	0.01	**0.11**	No/Yes	No/Yes

[a] Crisis period: July 2007-January 2011. In bold are highlighted the p-values for which the neutrality tests cannot be rejected at 10% significance level. [b] VaR neutrality calculated on standardized returns. [c] Tail neutrality tests according two types of confidence intervals: the percentile interval and the bias-corrected and accelerated interval.