# TURBULENCE AND SYSTEMIC RISK IN THE EUROPEAN UNION FINANCIAL SYSTEM

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**Abstract**

The purpose of this paper is to analyze the performance of the Absorption Ratio (AR), defined as the fraction of the total variance of a set of asset returns explained or "absorbed" by a fixed number of eigenvectors, as a leading indicator of turbulence in the European Union financial markets over the period January 2000 – July 2015. Using an event study methodology centered around financial turbulence episodes, identified with a method based on the Mahalanobis distance, we find that shifts in AR of more than one standard deviation consistently predict crisis episodes in the sample about 20 trading days before they happen, at the aggregate EU level as well as at individual level for most countries in the sample. We offer an interpretation of the ratio as a measure of systemic risk and financial fragility, and suggest its inclusion in the regulatory toolkit of systemic risk measures, to be relied on in combination with other indicators as a signal for the activation of certain macro-prudential policy instruments.

**Keywords:** financial fragility, systemic risk, financial turbulence, contagion, principal components, subprime mortgage crisis, Eurozone debt crisis

**JEL Classification:** C53, G01, G12, G15, G17

## 1. Introduction

Before the start of the financial crisis of 2007-2009, the literature on systemic risk had focused on contagion and "financial fragility". De Bandt and Hartman (2000) provide an early review. Following the financial crisis, the interest in defining, measuring and monitoring systemic risk has surged. Research projects aimed at systematizing the literature on systemic risk and at developing new systemic risk measures and models have received generous funding by public institutions in developed countries. The most prominent result of this trend is the study published by Bisias, Flood, Lo and

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Valavanis (2012)[1], which surveys in a comprehensive fashion systemic risk analytics developed in recent years. The authors survey 31 quantitative measures of systemic risk in the economics and finance literature. They classify the measures under six categories: (1) macroeconomic, including costly asset-price boom/bust cycles, property-price, equity-price, and credit-gap indicators, macro-prudential regulation; (2) granular foundations and network measures, including the default intensity model, network analysis and systemic financial linkages, simulating a credit scenario, simulating a credit-and-funding-shock scenario, granger-causality networks, bank funding risk and shock transmission, mark-to-market accounting and liquidity pricing; (3) forward looking risk measures, including contingent claims analysis, Mahalanobis distance, the option iPoD, multivariate density estimators, simulating the housing sector, consumer credit and principal components analysis; (4) stress-test measures, including GDP stress tests, lessons from the SCAP, a 10-by-10-by-10 approach; (5) cross-sectional measures, including CoVaR, distressed insurance premium, Co-Risk, marginal and systemic expected shortfall; and (6) measures of illiquidity and insolvency, including risk topography, the leverage cycle, noise as information for illiquidity, crowded trades in currency funds, equity market illiquidity, serial correlation and illiquidity in hedge funds returns, broader hedge-fund based systemic risk measures.

In the survey, two measures stand out as simple, practical and easy to implement: the Mahalanobis distance, used to identify episodes of financial turbulence, and the Principal Components Analysis, used to capture the extent to which markets are unified or tightly coupled, and thus fragile.

In this paper we estimate a measure of financial turbulence in the European Union financial system based on the Mahalanobis distance and map its performance to a timeline of events that unfolded during the most recent three global crisis episodes: the subprime mortgage crisis originating in the United States, the Eurozone debt crisis and the Russia-Ukraine conflict. Moreover, we explore the prediction ability of another indicator, based on principal

[1] *This study is the first working paper published by the Office of Financial Research, operating under the U.S. Department of the Treasury. The Office has been established under the Dodd Frank Act, enacted by the U.S. Congress in July 2010.*

components analysis, to signal the approach of such crisis episodes or, in other words, to act as a leading indicator of financial turmoil.

The paper is structured as follows: in Section 2 we survey the literature on systemic risk, financial fragility and contagion; Section 3 presents descriptive statistics of the data; in Section 4 we explain the methodology for constructing the financial turbulence and the systemic risk measures; Section 5 discusses the results of the empirical analysis; and Section 6 concludes.

## 2. Literature review

The literature on systemic risk is related to that on contagion and financial fragility. In this section, we explore this literature by classifying the most relevant studies according to their focus on either developing indicators of market stress and financial turbulence, or directly measuring financial fragility.

### Financial Turbulence

Chow, Jaquier, Lowrey and Kritzman (1999) proposed a measure of financial turbulence originally developed by Mahalanobis (1927). Their methodology addresses the instability of risk parameters in a portfolio allocation setting. The insight of this study is to identify multivariate outliers and use them to estimate a new covariance matrix. The authors claim that their method provides a better representation of a portfolio's riskiness during periods of market turbulence. However, their approach is suitable for portfolio allocation and does not concentrate on specifically identifying periods of market turbulence.

Kritzman and Li (2010) extend the research of Chow et al (1999) by investigating the empirical properties of financial turbulence and by demonstrating the application of this methodology to the stress testing of portfolios, to the construction of turbulence-resistant portfolios, and show how to scale exposure to risk to improve performance.

Financial turbulence has been modeled in the literature using other methodologies as well.

One problem that has been studied extensively is the asymmetry of correlations conditioned on upside and downside market conditions.

Ang and Chen (2002) find that correlations between domestic equity portfolios and the aggregate market are greater in downside markets than in upside markets. They develop a statistic to measure asymmetries in correlations which can be used to assess the extent of correlation asymmetry in the data relative to any particular model. The authors examine several empirical models to establish if they can account for the correlation asymmetries in the data and find that the popular CAPM-based and GARCH-M models can produce asymmetric correlations, but of the wrong sign. They observe that regime-switching models perform best in explaining the amount of correlation asymmetry reflected in the data, but still leave a significant amount of correlation asymmetry unexplained.

Financial turbulence has also been studied using variants of the Generalized Autoregressive Conditional Heteroskedasticity model developed by Bollerslev (1986).

The seminal paper of Bollerselv (1986) introduces a generalization of the Autoregressive Conditional Heteroskedastic (ARCH) process to allow for past conditional variances in the current conditional variance equation. GARCH-type models based on various distributional assumptions have been developed and applied to the study of risk management problems, including the coupling of asset volatilities during periods of financial stress. Multivariate GARCH models have been developed to assess the behavior of correlations.

Markov regime-switching models are another class of models that are suitable for the study of turbulence in international financial markets.

Ang and Bekaert (2002) introduce regime-switching into a dynamic international asset allocation setting. They find evidence of the presence of a high volatility-high correlation regime which tends to coincide with a down-market. They reach the following three conclusions that are robust across all models used: (1) the existence of a high volatility regime does not cancel the benefits of international diversification; (2) the costs of ignoring regime switching are small for moderate levels of risk aversion; (3) the inter-temporal hedging demands under regime switches are economically negligible and statistically insignificant.

Mixture models, such as jump diffusions, have been used for the same purpose by researchers of international asset pricing.

Das and Uppal (2004) start from the observation that returns on international equities are characterized by jumps occurring at the same time across countries, leading to return distributions that are fat-tailed and negatively skewed. They develop a model that captures this stylized fact and show how an investor would choose an optimal portfolio when returns have these features. Their main result is that systemic risk reduces only slightly the gains from international diversification implied in standard portfolio models.

**Financial Fragility and Systemic Risk**

Billio, Getmansky, Lo and Pelizzon (2010) show that correlations increase during market crashes. They propose several econometric measures of connectedness based on principal components analysis and Granger-causality networks, and apply them to the monthly returns of hedge funds, banks, broker/dealers, and insurance companies. Their findings suggest that these sectors have become highly interrelated, likely increasing the level of systemic risk in the finance and insurance industries. Their econometric techniques rely on principal components analysis and Granger-causality networks. They also claim that risk management practices based on Value-at-Risk may increase aggregate fluctuations if they are widely adopted.

Kritzman, Lowry, and Van Royen (2001) argue that the perception of risk as fully represented by the distribution of terminal wealth, together with the assumption of a single regime, leads to overconfidence. They apply a methodology to measure risk based on quiet or turbulent regimes that shows the extent to which the traditional measurement of risk understates exposure to loss. The forecasting procedure introduced in this article allows the assessment of the relative likelihood of quiet and turbulent regimes and provides a method to use this information to structure portfolios that are regime-sensitive.

Hyde, Bredin, and Nguyen (2007) study the correlation dynamics in equity markets of 13 Asia-Pacific countries, Europe and US using the asymmetric dynamic conditional correlation model introduced by Cappiello, Engle, and Sheppard (2006). They find that stocks exhibit asymmetries in conditional correlations in addition to conditional volatility. The authors claim that this feature is more prominent in more integrated markets. The findings support the hypothesis of increasing global market integration.

Cappiello, Engle, and Sheppard (2006) find strong evidence of asymmetries in conditional covariance of both equity and bond returns. They develop an asymmetric Dynamic Conditional Correlation model and show that it outperforms similar models that rely on the symmetry assumption. One of the interesting conclusion of their findings is that international diversification might not bring the benefits it is expected to during periods of global markets unrest.

They are also able to identify the “flight to quality phenomenon”, where investors move capital from equities to less risky assets.

Ferreira and Gama (2004) show that the diversification effect is present for global industry returns. They propose a volatility decomposition method that is applied in an international setting in order to analyze the behavior of volatility in developed stock markets. The results suggest that the power of international diversification to reduce risk has not been eroded by the globalization process and claim that industry diversification has become relatively more efficient than geographic diversification. However, their data sample ends in 2001. More recent studies discussed above have shown that international diversification is less efficient during global markets turmoil and prolonged downturns.

Kritzman, Li, Page and Rigobon (2010) apply principal components analysis to several broad markets and estimate the fraction of the total market variance explained by a finite number of factors on a rolling basis throughout history, which they call the absorption ratio. They also introduce a standardized measure of shifts in the absorption ratio, and analyze how these shifts relate to changes in asset prices and financial turbulence. They show that stock returns are much lower, on average, following spikes in the absorption ratio than they are in the wake of significant declines in the absorption ratio. They also demonstrate that the absorption ratio has been a leading indicator for the housing bubble in the United States, and also that the time series of the absorption ratio closely track the evolution of other measures of financial contagion.

Berger and Pukthuanthong (2012) argue that the probability of a worldwide financial crash is at its peak during periods when many countries are exposed to the world market factor. They develop a risk measure defined as the average loading on the world factor across countries at a point in time and link this measure to systemic risk. The systemic risk indicator introduced in this paper is similar to that proposed by Kritzman et al (2010).

Kinlaw, Kritzman, Turkington (2012) use the absorption ratio defined by Kritzman et al (2010) to develop an algorithm for measuring systemic importance of financial institutions. The algorithm captures an asset’s riskiness and connectivity to other risky assets during periods of high systemic risk. Their findings suggest that entities associated with finance, energy and technology are the most systemically important. They also provide a ranking of global financial institutions based on their vulnerability to failure and connectivity to other risky entities.

Benoit, Colletaz, Hurlin, Perignon (2013) propose a theoretical and empirical comparison of the most popular systemic risk measures. They derive the systemic risk measures in a common framework and show that they can be expressed as linear transformations of firms' market risk. They also show how the systemic risk measures can be used to rank global financial institutions according to their systemic importance. The conclusions of this study suggest that systemic risk is multi-faceted and that no single systemic risk measure can be used to capture its multiple facets.

We extend the methodology proposed by Kritzman and Li (2010) by identifying turbulence periods that have been observed between January 2000 and July 2015 in European stock markets, and calculate the time series of the absorption ratio defined Kritzman, Page, Li, and Rigobon (2010) in order to show that it is a leading indicator of periods of financial turmoil in this region, both at the aggregate level and for individual countries.

## 3. Data

The data used to calculate the financial turbulence indicator and the time series of the absorption ratio has been sourced from Thomson Reuters Datastream. The data includes the Datastream country equity indices for 26 countries in the European Union, as well as the Datastream industry equity indices for each country, for as many as 9 industries: Oil and Gas, Basic Materials, Industrials, Consumer Services, Healthcare, Telecommunications, Utilities, Financials, Technology. The levels of the index series have be transformed to log-returns before any calculation was performed. The sample period is January 1, 2000 to July 31, 2015. Descriptive statistics of the country equity index returns are given in Table 1.

**Table 1**

**Descriptive statistics of Datastream equity indices returns**

| | Mean | Std. dev. | Max. | Min. | Skewness | Kurtosis |
|---|---|---|---|---|---|---|
| Austria | 0.02% | 1.17% | 9.69% | -8.10% | -0.42 | 11.13 |
| Belgium | 0.03% | 1.17% | 8.24% | -8.13% | -0.13 | 8.77 |
| Cyprus | -0.08% | 1.79% | 12.90% | -11.84% | -0.10 | 7.39 |
| Estonia | 0.04% | 1.41% | 9.62% | -9.18% | -0.02 | 8.06 |

| | Mean | Std. dev. | Max. | Min. | Skewness | Kurtosis |
|---|---|---|---|---|---|---|
| Finland | 0.00% | 1.91% | 15.35% | -18.24% | -0.39 | 11.11 |
| France | 0.02% | 1.32% | 9.94% | -8.41% | -0.05 | 7.69 |
| Germany | 0.01% | 1.27% | 16.06% | -7.79% | 0.24 | 13.07 |
| Greece | -0.05% | 1.85% | 12.47% | -15.61% | -0.11 | 9.22 |
| Ireland | 0.02% | 1.36% | 9.13% | -13.34% | -0.58 | 10.20 |
| Italy | 0.01% | 1.36% | 10.51% | -8.61% | -0.16 | 7.72 |
| Lithuania | 0.03% | 1.06% | 12.73% | -11.62% | -0.19 | 19.06 |
| Luxemburg | 0.02% | 1.07% | 10.14% | -6.81% | -0.09 | 9.29 |
| Malta | 0.02% | 0.79% | 7.30% | -6.34% | 0.27 | 12.67 |
| Netherlands | 0.01% | 1.31% | 9.32% | -9.20% | -0.25 | 9.09 |
| Portugal | 0.00% | 1.11% | 9.52% | -10.54% | -0.26 | 10.43 |
| Slovakia | 0.02% | 0.89% | 8.14% | -18.02% | -3.00 | 85.38 |
| Slovenia | 0.02% | 0.94% | 8.17% | -8.33% | -0.49 | 12.75 |
| Spain | 0.02% | 1.34% | 11.77% | -8.47% | 0.04 | 7.59 |
| Bulgaria | 0.05% | 1.75% | 29.10% | -31.20% | -1.49 | 70.46 |
| Croatia | 0.02% | 1.16% | 11.76% | -8.89% | 0.23 | 19.43 |
| Cz. Rep. | 0.05% | 1.45% | 17.32% | -14.55% | -0.19 | 16.66 |
| Hungary | 0.01% | 1.78% | 15.38% | -18.68% | -0.13 | 11.11 |
| Poland | 0.02% | 1.63% | 10.37% | -10.34% | -0.24 | 6.66 |
| Romania | 0.04% | 1.90% | 12.30% | -13.33% | -0.53 | 9.86 |
| Sweden | 0.02% | 1.71% | 11.38% | -8.86% | 0.00 | 6.53 |
| UK | 0.01% | 1.26% | 9.02% | -8.91% | -0.16 | 9.04 |

*Source: Thomson Reuters Datastream, author's calculations*

## 4. Methodology

### 4.1. Principal Components Analysis

Principal Components Analysis (PCA) has many applications to risk and finance problems. A technical overview of the method is given in Jolliffe (2002). There are several studies using PCA in the context of measuring systemic risk, including Kritzman, Li, Page and Rigobon (2010) and Billio, Getmansky, Lo, and Pelizzon (2010).

Given a covariance matrix of asset returns estimated over a particular period, the first eigenvector is a linear combination of asset weights that explains the greatest percentage of the asset's total variance. The second eigenvector is orthogonal to the first and constructed in the same manner. That is, it is the eigenvector that explains most of what is left of the assets total variance. The third, fourth and subsequent eigenvectors are determined using the same procedure until all the variance is explained[2]. In practice, however, we need not concern ourselves with explaining all of the variance. The first few eigenvectors often suffice.

In some cases, it is useful to find an economic interpretation of the first few eigenvectors. It may be the case that they are closely correlated with meaningful economic variables, when these variables are certain to affect a particular set of assets. In other cases, the eigenvectors may reflect the combined influence of several factors, making it difficult to interpret from an economic point of view.

Kritzman et al. (2010) introduce a measure of systemic risk which they title the Absorbtion Ratio (AR). The ratio is defined as the fraction of the total variance of a set of asset returns explained or "absorbed" by a fixed number of eigenvectors. The economic interpretation of the AR rests on the fact that the ratio shows whether markets are unified. When they are, negative shocks propagate more easily and more broadly then when markets are decoupled.

**4.2. Construction of the Absorption Ratio**

**Definition**

The construction of the Absorption Ratio relies on the covariance matrix of a set of asset returns. Given *N* assets and the *N x N* covariance matrix, the AR is defined as:

$$AR = \frac{\sum_{i=1}^{n} \sigma_{E_i}^2}{\sum_{j=1}^{n} \sigma_{a_j}^2}$$

where

$n$ = number of eigenvectors used in calculating AR

$\sigma_{E_i}^2$ = variance of eigenvector *i*

$\sigma_{a_j}^2$ = variance of asset *j*

There is a link between the level of the absorption ratio and systemic risk. When the AR is at high levels, sources of risk are more

[2] The number of eigenvectors will not exceed the number of assets in the sample.

unified. The authors note that high systemic risk is not necessarily an indication of unavoidable asset depreciation or financial turbulence. Instead, higher systemic risk represents a higher degree of fragility in financial markets. It is important to note that, even though the AR measure is based only on stock market data, it has behaved in the past as a leading indicator for the housing bust preceding the subprime mortgage crisis in the United States of America, as well as for other crises of the past decade, as shown in Kritzman et al. (2010).

The authors also propose a technical indicator of AR movements, named the AR shift, which they claim to be a leading indicator of severe downturns in asset prices. The indicator is based on the difference between short-term and long-term moving average of the AR time series, standardized by the long-term standard deviation.

$$\Delta AR = \frac{AR_{15-Day} - AR_{1-Year}}{\sigma_{AR_{1-Year}}}$$

where

$\Delta AR$ = standardized AR shift

$\overline{AR}_{15-Day}$ = 15-day moving average of AR

$\overline{AR}_{1-Year}$ = 1-year moving average of AR

$\sigma_{AR_{1-Year}}$ = standard deviation of the 1-year AR

**4.3. Financial Turbulence Indicator**

Kritzman and Li (2010) define “financial turbulence” as a condition in which asset prices, given their time series history, display uncharacteristic behavior, including extreme price movements, decoupling of correlated assets, and convergences of uncorrelated assets. They employ the Mahalanobis distance (Merton, 1937) to measure the statistical peculiarity of a set of asset returns given their history.

Mahalanobis distance for a sample of *n* assets is defined as:

$$d_t = (\mathbf{y_t} - \mathbf{m})' \mathbf{\Sigma}^{-1} (\mathbf{y_t} - \mathbf{m})$$

$d_t$ = turbulence at time *t*

$\mathbf{y}_t$ = (n x 1) vector of asset returns

$\mathbf{m}$ = (n x 1) sample average vector of asset returns

$\boldsymbol{\Sigma}$ = (n x n) sample covariance matrix of asset returns

We use the above definition to generate the daily time series of $d_t$ and define "turbulent" periods the days for which $d_t$ is above its 90$^{th}$ percentile. The Mahalanobis distance has applications in stress testing asset portfolios. Kritzman and Li (2010) propose the calculation of VaR based only on turbulent periods instead of the full sample. They claim that the turbulence-adjusted VaR better reflects asset correlations and returns during a turbulent states and is therefore a more realistic estimate of possible losses arising from a systemic event.

## 5. Results

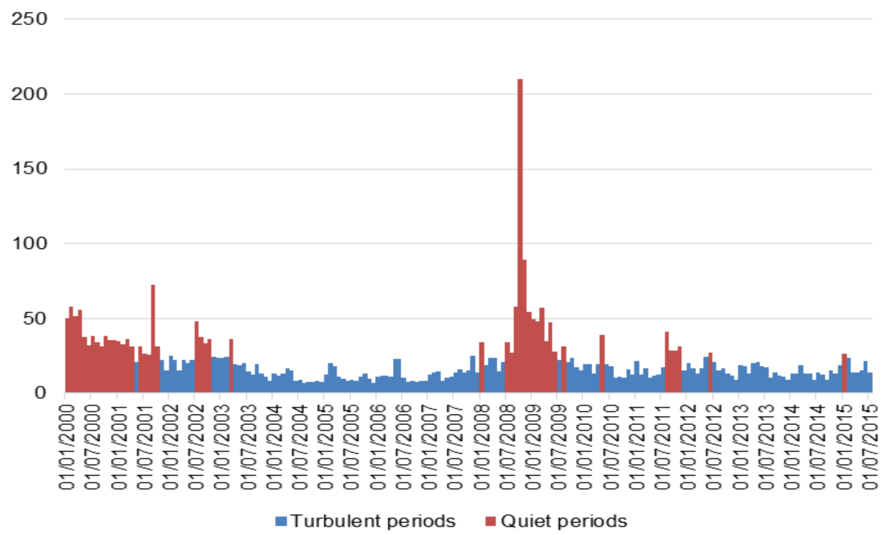
### 5.1. Turbulence

The measurement of financial turbulence using the Mahalanobis distance proposed by Kritzman and Li (2010) is appealing in its simplicity and, as we will see below, a useful measure for determining periods of unrest in financial markets. We compute the time series of this indicator and illustrate its evolution through time in Figure 1. In Tables 2a, 2b and 2c we summarize the most significant events that took place during what have been named the US subprime mortgage crisis, the Eurozone debt crisis and the Russia-Ukraine conflict. These globally significant crises have triggered responses in stock prices across the EU and prompted unprecedented government intervention, which had an impact on movements in asset prices and may have had direct consequences in creating financial fragility, thus increasing systemic risks.

Given the series of financial turbulence in Figure 1, we may pinpoint the events that have had the most serious impact, leading to spillovers or financial contagion. It is interesting to observe that the turbulent periods shown in Figure 1 in red correspond, by construction, to the top 10 percent increases in the financial turbulence indicator. Their connection to actual economic, political or market events will be determined qualitatively, using information in Table 2a, 2b and 2c. Another aspect that is worth mentioning refers to the intuition behind selecting the 10 percent threshold. In their article, Kritzman and Li (2010) denote quiet periods as those falling within 75 percent of the distribution, and therefore choose a 25 percent threshold. However, using the same value would have generated a larger sample of “turbulent” periods. We chose to concentrate only on the most severe of the spikes in the turbulence indicator in order to capture the usefulness as a leading indicator of the Absorption Ratio, which will be discussed in the next section, as the first two sections are linked.

**Figure 1**

**Turbulence indicator**




Periods of turbulence calculated at 90% threshold are shown on the figure in red.
*Source: author’s calculations*

The 10 percent most turbulent periods identified using the Mahalanobis distance are June, 2000 to October, 2001, July, 2002 to October, 2002, March, 2003, January, 2008, July, 2008 to August, 2009, May, 2010, August, 2011 to November, 2011, June, 2012 and January 2015.

In Table 2a we summarize the events that span the subprime mortgage crisis. *Post factum*, it is obvious that the crisis in the United States started in February 2007. The subsequent events have had a profound negative impact on stock prices in the United States. The turbulence indicator, which is based only on data for European stock markets, does not seem to react strongly at the beginning of the crises in the United States. Spillovers are contained until January 2008, when we record the first sharp increase in the value of the indicator. Until that point, the relevant events take place in the United States. The run on the UK bank Northern Rock, which took place on September 14, 2007, preceded by the increase of LIBOR to a seven-year high, generated a spike in the series, but not large enough to count September 2007 as one of the most turbulent 10 percent of months in the sample.

The actual start of financial turbulence in Europe seems to be in July 2008, which corresponds to the announcement by the Nationwide Building Society, Britain's fourth-biggest mortgage lender, that UK house prices declined the most in almost two decades in July and consumer confidence fell to record low. This is immediately followed by the decision of UBS AG, the largest Swiss bank, to separate its investment banking and wealth management units after mounting subprime writedowns prompt rich clients to withdraw funds for the first time in eight years. The Lehman Brothers Holdings Inc collapse happens in September 2008, followed at the end of the month by a bailout of Forits, the largest Belgian financial-services firm, by Belgium, the Netherlands and Luxembourg governments. September also sees the rescue of Dexia SA in Ireland, the acquisition of Fortis by BNP Paribas SA, together with significant policy interventions in the US to prop up the financial system. October 2008 is thus the month where the financial turbulence index reaches its peak.

**Table 2a**

**Timeline of events during the US subprime crisis**

| | |
|---|---|
| Feb. 27, 2007 | Freddie Mac announces that it will no longer buy subprime loans |
| Apr. 2, 2007 | Subprime mortgage lender New Century Financial files for bankruptcy-court protection |
| Jul. 31, 2007 | Investment bank Bear Sterns liquidates two hedge funds that invested in subprime mortgage backed securities |
| Aug.6, 2007 | American Home Mortgage Investment files for bankruptcy protection |
| Jul 19, 2007 | Federal Reserve Chairman Ben Bernanke informs the US Senate of expected $100 billion in losses associated with subprime mortgage products |

| | |
|---|---|
| Aug 9, 2007 | BNP Paribas SA announces that it is unable to fairly value the holdings of three investment funds and halts all withdrawals |
| Aug 22, 2007 | Countrywide Financial Corp., the largest US mortgage lender, sells $2 billion preferred stock to Bank of American |
| Sept 7, 2007 | The 3m LIBOR rises to seven-year high |
| Sept. 14, 2007 | Northern Rock Plc. announces that Bank of England agreed to provide emergency funds to ease severe liquidity freeze following bank run |
| Oct. 9, 2007 | US stock markets bounce back after Federal Reserve alleviates fears that the economy is heading into recession |
| Oct. 30, 2007 | Merrill Lynch & Co. fires chairman and chief executive officer after reporting $2.24 billion loss |
| Nov. 4, 2007 | Citigroup increases its estimate of losses for mortgage-related writedowns |
| Jan. 11, 2008 | Bank of America agrees to buy Countrywide for $4 billion |
| Mar. 14, 2008 | Bear Sterns Cos. receives emergency funding from the US Federal Reserve and JPMorgan Chase & Co. following run on the bank |
| Mar. 16, 2008 | JPMorgan Chase agrees to buy Bear Sterns |
| Apr. 1, 2008 | Lehman Brothers Holding Inc. raises $4 billion from a stock sell |
| Apr. 9, 2008 | Washington Mutual Inc. rejects offer from JPMorgan chase before announcing it received $7 billion capital infusion |
| May 31, 2008 | Acquisition by JPMorgan of Bear Sterns is complete |
| Jul. 11, 2008 | Run by depositors on IndyMac Bancorp Inc prompts federal regulators to seize control |
| Jul. 31, 2008 | UK's fourth-biggest mortgage lenders, Nationwide Building Society announces that home prices dropped the most in two decades and consumer confidence fell to record low |
| Aug. 12, 2008 | Switzerland's UBS AG announces plans to separate investment banking and wealth management units |
| Aug. 31, 2008 | Commerzbank AG agrees to buy Allianz SE's Dresdner Bank for 9.8 billion euros |
| Sep. 7, 2008 | US government seizes control of Fannie Mae and Freddie Mac, the largest US mortgage-finance companies |
| Sep. 15, 2008 | Lehman Brothers Holding Inc. files for bankruptcy and Bank of America agrees to acquire Merrill Lync for about $50 billion. |
| Sep. 16, 2008 | American International Group Inc. receives $85 billion loan from the Fed and the government takes over the company |
| Sep. 18, 2008 | Lloyds TSB Group Plc agrees to buy HBOS Plc, Britain's largest mortgage lender, for 10.4 billion pounds |

| | |
|---|---|
| Sep. 21, 2008 | Goldman Sachs and Morgan Stanley are approved by the Fed to become commercial banks |
| Sep. 23, 2008 | Goldman Sachs raises $7.5 billion from Berkshire Hathaway Inc. and public investors |
| Sep. 26, 2008 | Washington Mutual is seized by government regulators while its branches and assets are sold to JPMorgan Chase |
| Sep. 27, 2008 | Washington Mutual files for bankruptcy protection. |
| Sep. 28, 2008 | The largest Belgian financial-services firm, Fortis, receives 11.2 billion euro from Belgium, the Netherlands and Luxembourg |
| Sep. 29, 2008 | Citigroup agrees to acquire the banking operations of Wachovia Corp. for about $2.16 billion. The House of Representatives rejects $700 billion plan to rescue US financial system |
| Sep. 30, 2008 | Dexia SA receives 6.4 billion euro state-backed rescue, while Ireland pledges to guarantee the bank’s deposits and debts for two years |
| Oct. 1, 2008 | US Senate approves revised version of rescue plan |
| Oct. 3, 2008 | The House of Representatives passes the revised version of the rescue plan |
| Oct. 5, 2008 | BNP Paribas SA, would take control of Fortis’s units in Belgium and Luxembourg after government rescue had failed |
| Oct. 6, 2008 | German government and the country’s banks and insurers agree on a 50 billion euro rescue package for commercial property lender Hypo Real Estate Holding AG after earlier bailout fails |
| Oct. 12, 2008 | European leaders agree to guarantee bank borrowing and use government money to prevent the failure of big lenders |

*Source: compiled by the author from various media sources, including Bloomberg.com and usatoday.com*

The most turbulent period in recent history ended in August 2009. A new spike in financial turbulence was recorded in May 2010. It is interesting to note that the Eurozone debt crisis had already started in October 2009, with the appointment of George Papandreou as Greek Prime Minister. The events that followed revealed the dire situation of Greek finances and prompted the rating agencies to downgrade Greek sovereign debt to below investment grade already in December 2009. At the time, however, the probability of the crisis that would ensue was deemed low by market participants. The first reaction came in May 2010, when the Greek government reached a deal with the IMF and Eurozone leaders for a 110 billion euro bailout package. The next phase of the crisis, accompanied by increased financial fragility, came in August 2011, when Italian government bond yields surpassed the 6 percent threshold. Even the remote possibility of an Italian default was enough to generate concerns among market participants about the sustainability of sovereign debt of Eurozone member states, especially of the periphery countries. The turmoil ended in December 2011, with the extension of a substantial loan facility by the European Central Bank to 500 European banks. Another episode of turmoil was in June 2012, when a Greek exit from the Eurozone first became a real possibility. The last turbulence period in our sample was recorded in January 2010 and corresponds to the decision of the Swiss National Bank to abandon the Swiss franc peg to the Euro, followed by the introduction of the quantitative easing program by the European Central Bank.

**Table 2b**

**Timeline of events during the Eurozone Debt Crisis**

| | |
|---|---|
| Oct. 2009 | Leader of the Greek party PASOK, George Papandreou, is sworn in as prime minister |
| Nov. 2009 | Papandreou's administration brings to light misleading accounting by preceding Greek government. Corrected figures show a budget deficit of 12.7 percent of GDP |
| Dec. 2009 | Rating agencies Fitch and Standard & Poor's downgrade Greece's credit rating to below investment-grade status |
| Feb. 2010 | Greek government announces austerity plan to reduce deficit by ten percent by 2012.<br>Spanish Prime Minister announces austerity plan that would increase retirement age from 65 to 67. |
| Mar. 2010 | Leaders of the Eurozone and the IMF agree on deal to provide financial support for Greece. |
| Apr. 2010 | Greek budget deficit reaches 13.6 percent, Standard & Poor's downgrades Greek government bonds to junk |
| May 2010 | Greek government, the IMF and Eurozone leaders agree to 110 billion euro three-year bailout package for Greece.<br>EU and IMF create 750 billion euro emergency fund |
| Sep. 2010 | Ireland's central bank announces that the cost of bailing out Anglo Irish Bank could amount to 34.3 billion euro, raising Ireland's budget deficit to 32 percent of GDP. |
| Nov. 2010 | 85 billion euro rescue package is approved for Ireland |
| Feb. 2011 | European finance ministers announce the creation of European Stability Mechanism (ESM), a permanent 500 billion euro fund to be used as last |

| | |
|---|---|
| | resort for Eurozone economies |
| Mar. 2011 | Fitch and Standard & Poor's cut ratings of Portuguese sovereign debt |
| May 2011 | European leaders approve 78 billion euro bailout package for Portugal in exchange for commitment to austerity program |
| Jun. 2011 | Standard & Poors downgrades Greece's sovereign rating to CCC |
| Jul. 2011 | European leaders extend additional rescue package to Greece amounting to 109 billion euro and restructure Greek loans with more generous terms. |
| Aug. 2011 | Interest rates on 10-year Italian government bonds top 6 percent |
| Sep. 2011 | The Swiss National Bank devalues the franc and pegs its value to that of the euro |
| Oct. 2011 | Greek parliament approves new austerity measures. Eurozone leaders discuss bond swap that would cut the value of Greek debt in half. Papandreou calls for a referendum on latest EU bailout plan. |
| Dec. 2011 | European Central Bank extends 489 billion euro in loans to more than 500 European banks to prevent credit freeze. |
| Feb. 2012 | Moody's cuts the debt ratings of six European countries, including Italy, Portugal and Spain, and downgrades economic outlook on France and the United Kingdom.<br>About 800 European banks use ECB's second long-term refinancing operation, which injects an additional 530 billion euro into the banking system. |
| Mar. 2012 | 25 EU countries sign a new pact on fiscal discipline. The UK and the Czech Republic opt out entirely.<br>Eurozone leaders announce the expansion of the EFSF and ESM giving them access to a combined 800 billion euro in funding. |
| May 2012 | Market analysis begin to discuss a Greek exit from the Eurozone. |
| Sep. 2012 | Germany's Federal Constitutional Court authorizes the ratification of the European Stability Mechanism. |
| Mar. 2013 | Cyprus negotiates 10 billion euro bailout agreement with international lenders. Bank of Cyprus customers lose 47.5 percent of deposits that are over 100,000 euro. |
| Jun. 2014 | The ECB cuts its deposit rate to -0.1 percent in an effort to increase lending |
| Jan. 2015 | Switzerland abandons its three-year peg to the euro<br>ECB Governor Mario Draghi announces the creation of a 1.1 trillion euro quantitative easing program to boost euro-zone growth. |

| | |
|---|---|
| Jun. 2015 | Greece defaults on IMF payment |
| Jul. 2015 | Even though Greek voters back Prime Minister Alexis Tsipras by rejecting the latest bailout terms in a referendum, Greece finally agrees to most bailout conditions by the end of the month, thus averting Grexit. |

*Source: compiled by the author from various media sources, including Britannica.com*

The Russia-Ukraine conflict, which was significant at a political level, has not been a trigger of increased systemic risk and financial fragility in European Union Member countries. Throughout 2013 and 2014, the financial turbulence indicator remained at low levels. The effects of the conflict were felt more in the fluctuations of exchange rates of non-Eurozone member states. This fact is consistent with the interpretation that regulatory and policy measures implemented before the start of the conflict, such as the creation of the European Stability Mechanism or the pledge by the European Central Bank governor Mario Draghi to "do whatever it takes" to preserve the Euro have been effective in mitigating systemic risk and increasing the resilience of the financial system.

**Table 2c**

**Timeline of Ukraine crisis**

| | |
|---|---|
| Dec. 1, 2013 | Ukrainian police break up student protest camp in Kiev's Independence Square over president Viktor Yanukovich's failure to sign trade deal with EU |
| Feb. 20, 2014 | Police and protesters clash in Kiev |
| Feb. 22, 2014 | Ukraine's president flees Kiev |
| Feb. 27, 2014 | Government buildings are seized up in Simferopol, the capital of Ukraine's Crimea peninsula |
| Mar. 18, 2014 | Russia's president Vladimir Putin signs a law incorporating Crimea into Russia |
| Apr. 7, 2014 | Protesters seize government buildings in Kharkiv, Donetsk and Luhansk in Eastern Ukraine. |
| May 25, 2014 | Petro Poroshenko is elected president of Ukraine |
| Jun. 27, 2014 | EU signs trade deal with Ukraine |
| Jul.17, 2014 | Malaysia Airlines Flight MH17 is shot down in Eastern Ukraine |
| Jul. 31, 2014 | EU agrees to economic sanctions, restricting access of Russian banks and oil companies to Western financing |

| | |
|---|---|
| Sep. 5, 2014 | Peace deal signed in Belarus over conflict in Eastern Ukraine |
| Jan. 31, 2015 | Peace talks collapse in Minsk |

*Source: compiled by the author from various media sources, including telegraph.co.uk*

The analysis of the three crisis episodes outlined above has shown that the financial turbulence indicator is a reliable measure of systemic risk. We will use this indicator to check the ability of the Absorption Ratio to pinpoint future downturns and thus act as a leading indicator.

**5.2. Absorption Ratio**

**Absorption Ratio at the aggregate EU level**

Figure 2 shows the time series of the absorption ratio (AR) estimated from the returns of EU markets equity indices based on 500 day overlapping windows, along with the level of the Datastream aggregate equity index of EU markets from December 2001 to July 2015. The results of the analysis are similar to those obtained by Kritzman et al. (2010) for the US market. There is a clear inverse relationship between the AR and the level of the index. Moreover, the AR ratio reached its peak after June 2008, although it had been trending upwards since June 2006. As mentioned in section 5.1., the AR ratio estimated for Europe should lag behind the AR ratio estimated for the United States because the spillovers from US to the EU during the subprime mortgage crisis happened over a period of a few months. However, the EU AR ratio should display a characteristic pattern around the Eurozone debt crisis, which has been felt more severely in Europe than in the United States. Another interesting observation from this chart is the drop of the AR ratio to its lowest level in the sample from December 2012 to December 2014, which points to a reduction in systemic risk during this period marked by relative calmness after fears of a sovereign default in Europe had subsided. The subsequent rise of the ratio from December 2014 to the end of the sample, in July 2015, exposes the increased fragility of the European financial system. The causes of this increase may relate to the recent development in sovereign debt markets and the uncertainty surrounding the Greek agreement for an extension of the bailout package. As we will show in the next sections, the AR ratio can be viewed as a leading indicator of financial turmoil. For this reason, supervisory authorities and regulators entrusted with monitoring systemic risk should be on the lookout for events that may trigger a new crisis episode.

**Figure 2**

**Absorption ratio and European stock prices**

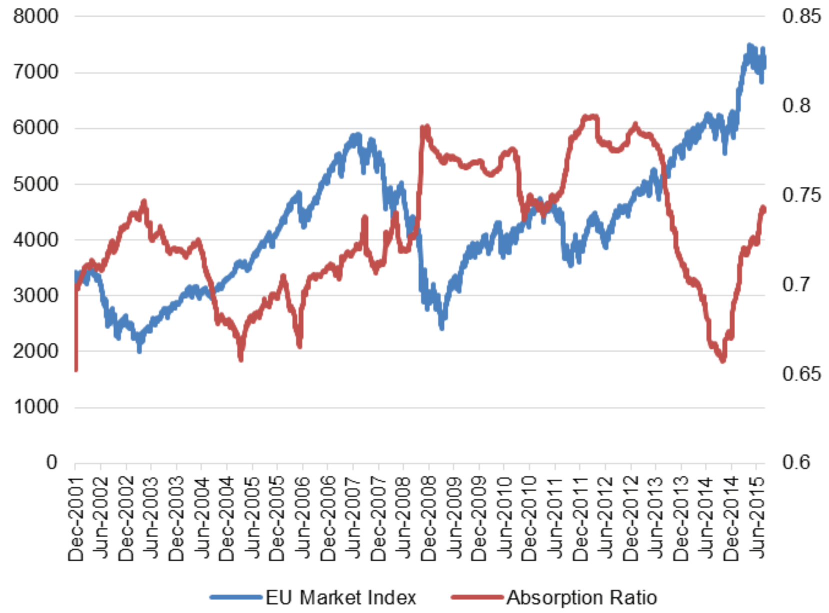



Figure shows absorption ratio based on equity index returns of EU countries and the aggregate value-weighted EU market index. *Source: author's calculations*

The AR shift has been defined in Section 4.2. To calculate the AR shift, we first compute the moving average of the absorption ratio over 15 days and subtract it from the moving average of the absorption over one year. We then divide the difference by the standard deviation of the one-year absorption ratio. Similar to Kritzman et al (2010), we analyze how the aggregate EU stock market performs following a one standard deviation move of the AR ratio, as measured by the AR shift. That is, we identify the periods when the absolute value of the AR shift, computed over rolling windows of one year, first surpasses the value of 1, and then look at the behavior of the aggregate EU markets index returns over a 1-day, 1-week or 1-month horizon. If the AR is indeed a leading indicator of crisis episodes, we would expect returns to be on average negative following an increase of the AR shift (to more than 1) and positive otherwise (to below -1). Table 2 shows that this behavior is indeed present at all horizons when the AR shift increases suddenly. In the case when the AR shift decreases below -1, the expected behavior is only present at 1-day and 1-week horizons. Because this analysis is not rigorous from a statistical point of view, it is useful to also study the AR as a leading indicator in a different context.

**Absorption Ratio as a leading indicator**

**Table 2**

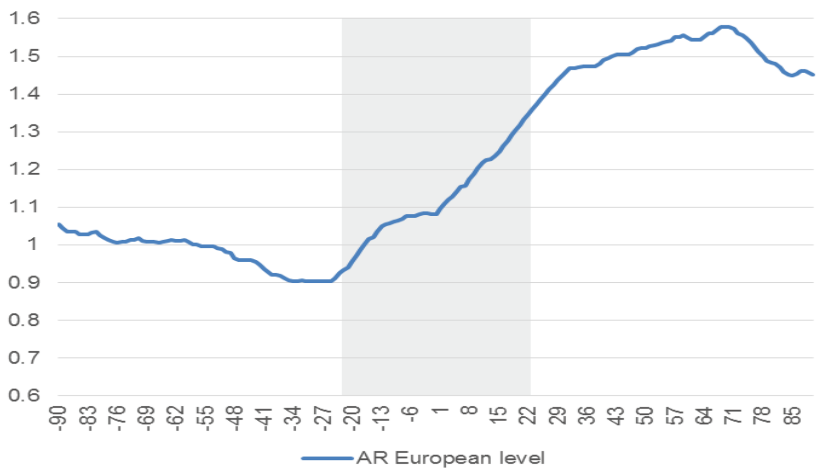
**EU equity index return after extreme movements in AR**

| | 1 Sigma Increase | 1 Sigma Decrease | Difference |
|---|---|---|---|
| 1-day | -0.24% | 1.58% | 11.91% |
| 1-week | -0.08% | 0.61% | 4.41% |
| 1-month | -0.03% | -0.08% | 0.33% |

We can study the ability of the AR ratio to act as a leading indicator by first identifying the turbulent periods as described in Section 5.1. In order to measure the link between systemic risk and financial turbulence, we synchronize all the turbulent events identified previously and observe changes in the 15-day absorption ratio relative to one-year absorption ratio estimated from country index returns. Figure 3 is a summary of this event study. Prior to turbulent events in the stock markets (the start of the event is at 0 in the Figure), the median of the AR shift starts to increase beginning around 20 days in advance of the event, and then starts falling after around 80 days. In terms of trends, the results for the European markets are similar to those presented by Kritzman et al. (2010) for the United States. However, they find that the AR shift signals trouble beginning about 40 days before the turbulent event.

**Figure 3**

**Median absorption ratio around turbulent periods**




*Source: author's calculations*

**Analysis of the Absorption Ratio at individual country level**

The previous subsection analyzed the performance of the absorption ratio calculated based on the returns of EU countries stock market indices. The results show that the AR is a potential leading indicator of financial crises. We study next the behavior of the absorption ratio calculated for each EU country out of its industry equity returns. In Figure 4a we plot the absorption ratio for all countries in the sample (conditional on data availability). In order to make the results comparable, we first normalize the series by dividing the difference between AR recorded for each country in a period and the minimum of the country's full sample to the range (difference of maximum and minimum) over the full sample period. Since the level of the AR is less important than its variation, this procedure offers a better picture of the ability of the indicator to signal crisis episodes. We observe that for most of the countries represented in Figure 4a, the AR started to change color already in Q2 2008. However, it appears that over the next quarters, the AR remained at higher levels for most countries compared to its historical performance. The pattern is markedly different from that of the financial turbulence indicator presented in Figure 1.

**Figure 4a**

**Heatmap of normalized absorption ratios calculated for each country out of industry equity indices**

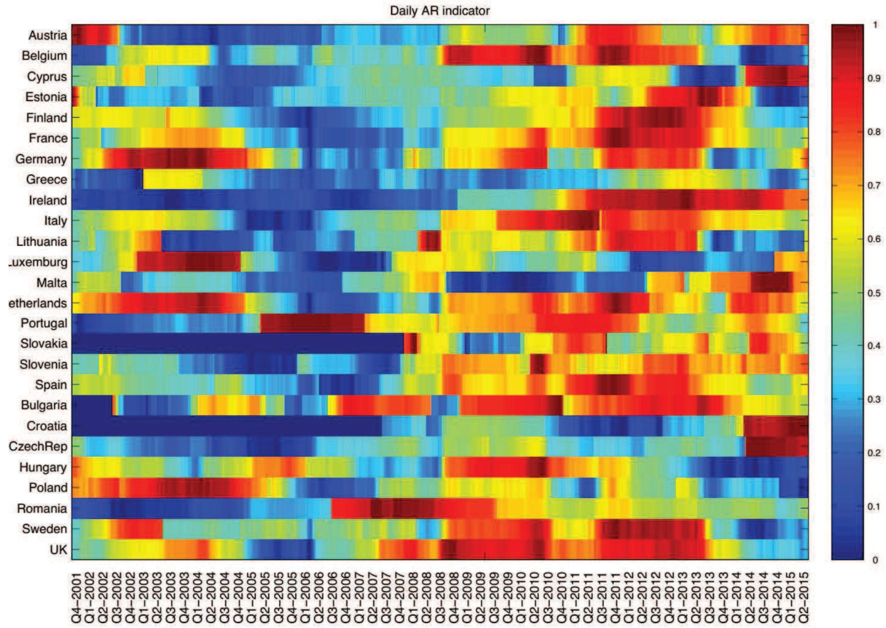



Figure shows normalized absorption ratios calculated over the period Dec. 2001 – Junl. 2015 for all countries in the sample, based on Datastream industry equity indices described in Table 1. *Source: author's calculations*

Figure 4b shows the evolution in time of the AR shift for all the countries in the sample. The AR shift displays a more interesting pattern and appears to be a leading indicator of all the crises episodes. The pattern of the AR shift is consistent with that of the turbulence indicator. By disaggregating the data, we can assess the impact of significant events on different countries. We can see, for instance, that Eurozone countries have experienced increased systemic risk and financial fragility, while countries relying on their own currencies have been somewhat protected. Developed countries such as Austria, Belgium, France, Germany, Greece, Ireland, Italy, Luxemburg, the Netherlands, Portugal, Spain and the UK have recorded higher levels of the AR shift between 2010 and 2012, during the Eurozone debt crisis, then countries like Croatia, the Czech Republic, Hungary, Poland, and Romania. Also worth mentioning, Austria, Cyprus, Luxemburg, Malta, Portugal, Slovakia, Bulgaria and

Croatia appear to record higher levels of financial fragility starting with the beginning of 2014.

**Figure 4b**

**Heatmap of AR shift calculated for each country out of industry equity indices**

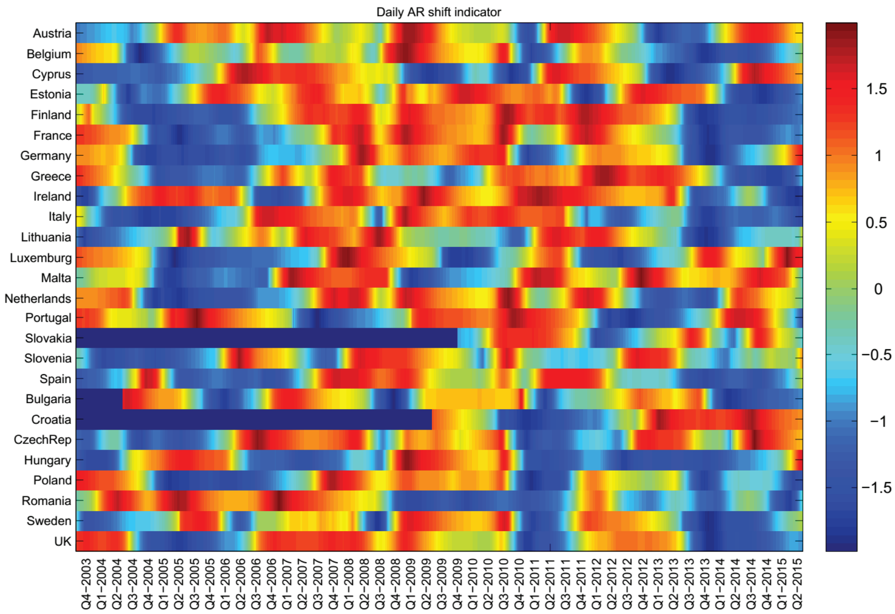



Figure shows AR shift calculated over the period Dec. 2001 – Junl. 2015 for all countries in the sample, based on Datastream industry equity indices described in Table 1. *Source: author's calculations*

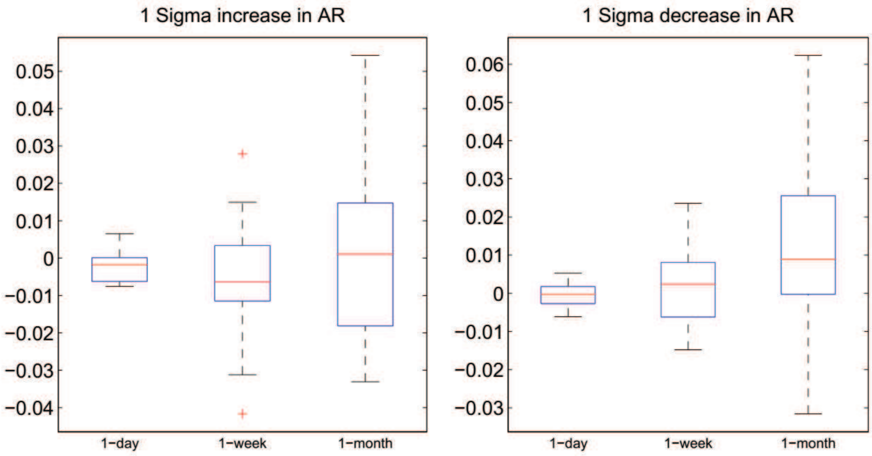
In the previous subsection, we studied the pattern of the AR ratio estimated for each country in the sample based on the returns of its industry equity indices. In this section, we analyze the performance of the AR ratio as a leading indicator by applying the same method as in the aggregate case. We use the same turbulent periods that have been identified using the Mahalanobis distance with a 90 percent threshold. The financial turbulence indicator captures turmoil at the European level. It shows when stock prices in the European Union behaved in an uncharacteristic fashion, including extreme price movements, decoupling of correlated assets and convergence of uncorrelated assets (Kritzman and Li, 2010). We ask in this subsection how individual countries experienced the EU-wide turbulence. Is the AR computed from industry index returns, expressed in local currency, still a leading indicator for individual countries in the sample, or is this property only present at the aggregate level?

In Table 3 we show the mean returns at 1-day, 1-week and 1-month horizons of the individual country equity index, following changes of more than one standard deviation in the difference between the 15-day moving average AR ratio and the 1-year moving average AR ratio. On average, following an increase in the AR ratio, index returns have been negative at all horizons and following a decrease in the AR ratio index returns have been positive. In the cases of Estonia, Finland, Ireland, Lithuania, Slovenia and Spain, the behavior has been consistent with the hypothesis that the AR is a leading indicator of financial crises. In the case of France, Greece, Malta, the Netherland, Croatia and the UK, the index returns have been negative at all horizons following a one-sigma increase in the AR. However, a decrease in the AR has not led in this countries to an average increase in returns at all horizons.

Figure 5 provides a better picture of the results in Table 3. We show in this picture the boxplots of returns following one-sigma increases and decreases of the AR ratio. We observe that the cross-country distributions of returns are positively skewed in the case of an increase and negatively skewed in the case of a decrease. The variance of the cross-country returns also grows as we move from the 1-day horizon to the 1-month horizon, which is to be expected. But the distribution shows clearly, in our view, that the absorption ratio has predictive power even at individual country level. The variation could be explained by the fact that some countries are more resilient than others to global or Europe-wide shocks. In other words, the build-up of systemic risks in these countries is less noticeable during crisis episodes because their financial systems are more resilient. We also mention here the arbitrary nature of choosing return horizons. To account for this fact, we study in the next subsection the behavior of the AR shift around turbulent periods for all countries in the sample.

**Figure 5**

**Boxplots of returns following significant increases in AR**




The figure illustrates the results in Table x, showing the distribution of country index returns at different horizons (1 day, 1 week and 1 month) following an increase (left) or decrease (right) in the AR of more than one standard deviation, as measured by the AR shift. *Source: author's calculations*

**Table 3**

**Country stock market index reaction after 1 standard deviation increase or decrease in the absorption ratio**

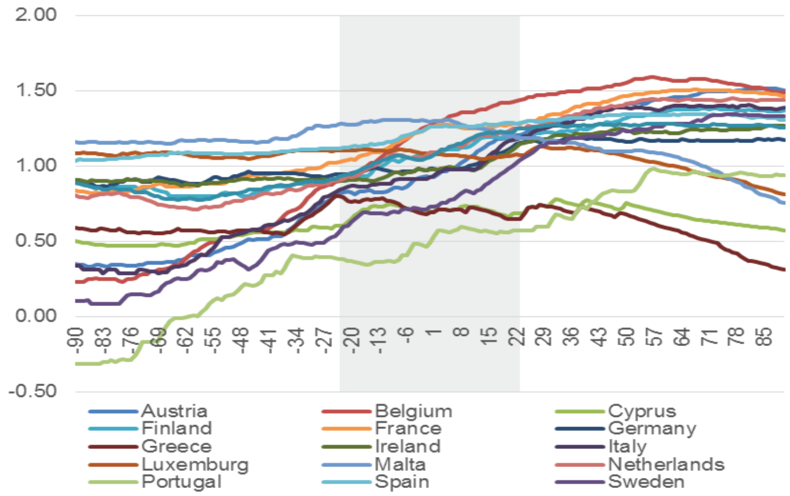
| | 1 Standard Deviation Increase | | | 1 Standard Deviation Decrease | | |
|---|---|---|---|---|---|---|
| | 1-day | 1-week | 1-month | 1-day | 1-week | 1-month |
| Austria | -0,2% | 0,2% | 0,7% | 0,0% | 0,2% | 0,5% |
| Belgium | 0,0% | -4,2% | 3,1% | -0,5% | 0,0% | 0,5% |
| Cyprus | 0,6% | 0,3% | 0,7% | -0,3% | -0,2% | 1,1% |
| Estonia | -0,3% | -1,3% | -3,1% | 0,4% | 2,2% | 4,6% |
| Finland | -0,2% | -1,1% | -1,7% | 0,4% | 1,6% | 3,5% |
| France | -0,8% | -3,1% | -2,6% | -0,3% | -0,8% | 1,4% |
| Germany | -0,5% | -0,9% | 1,9% | -0,1% | 0,1% | 2,4% |
| Greece | -0,2% | -1,6% | -1,5% | -0,6% | -1,5% | -2,5% |
| Ireland | -0,3% | -1,6% | -2,2% | 0,5% | 1,2% | 1,0% |
| Italy | -0,6% | -1,0% | 2,0% | 0,0% | 0,7% | 0,5% |
| Lithuania | -0,6% | -1,0% | -1,7% | 0,1% | 0,6% | 4,5% |

| | | | | | | |
|---|---|---|---|---|---|---|
| Luxemburg | 0,0% | -0,5% | 0,6% | -0,1% | 0,9% | 2,6% |
| Malta | -0,7% | -1,0% | -3,3% | -0,2% | -0,4% | 0,0% |
| Netherlands | -0,5% | -0,6% | -1,2% | 0,2% | -0,6% | 0,6% |
| Portugal | 0,0% | 0,4% | 1,5% | 0,1% | 2,4% | 2,7% |
| Slovakia | 0,1% | 1,5% | 0,3% | -0,2% | -0,1% | -1,1% |
| Slovenia | -0,2% | -0,7% | -3,1% | 0,3% | 0,5% | 0,5% |
| Spain | -0,7% | -1,9% | -1,8% | 0,2% | 0,8% | 3,0% |
| Bulgaria | -0,1% | -0,1% | 3,5% | 0,1% | 0,3% | -3,2% |
| Croatia | -0,7% | -1,1% | -2,8% | 0,2% | 0,3% | -1,4% |
| Czech Republic | 0,1% | 0,5% | 0,7% | 0,0% | -1,0% | 2,2% |
| Hungary | -0,7% | 0,3% | 1,4% | -0,3% | -0,7% | -1,2% |
| Poland | 0,6% | 1,0% | -0,5% | -0,6% | -1,5% | 1,3% |
| Romania | 0,2% | 1,0% | 1,7% | -0,1% | 0,5% | 6,2% |
| Sweden | 0,1% | 2,8% | 5,4% | 0,4% | 1,5% | 0,8% |
| UK | -0,1% | -0,2% | -0,1% | -0,6% | -1,1% | -2,1% |
| **Average** | **-0,2%** | **-0,5%** | **-0,1%** | **0,0%** | **0,2%** | **1,1%** |

Figure 5a and 5b illustrate the pattern of the AR shift around turbulent periods identified based on the financial turbulence indicator for developed countries and emerging countries, respectively. The pattern is similar to that observed in Figure 3 and confirms the hypothesis that the AR is indeed a leading indicator of turbulence episodes. Only in the case of Spain (Figure 5a) and Slovenia (Figure 5b) the evolution of the AR shift starting 90 days before the turbulence period and ending 90 days after is more or less flat, and thus unconvincing in the role of a leading indicator. For all other countries, the AR behaves in the expected manner. It is most informative for countries like Belgium, Sweden, Portugal, Cyprus and the UK, in the developed markets group, and Hungary, the Czech Republic, and Poland in the emerging markets group.

**Figure 5a**

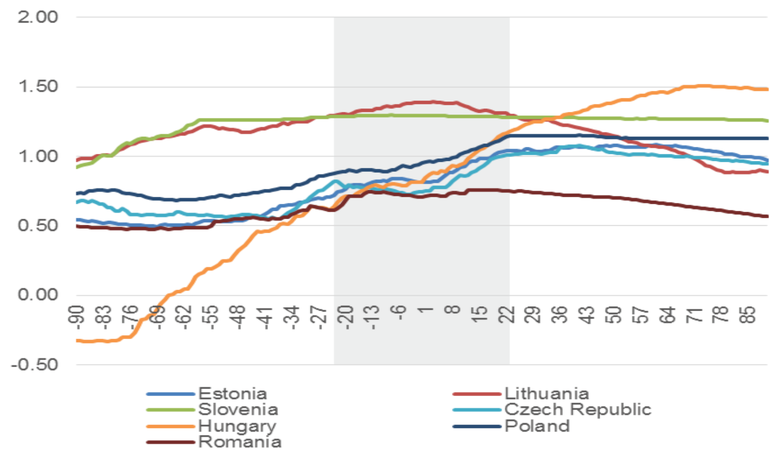
**Median absorption ratio around turbulent periods of equity indices of countries with developed capital markets in the sample**




*Source: author's calculations*

**Figure 5b**

**Median absorption ratio around turbulent periods of equity indices of countries with emerging capital markets in the sample**




*Source: author's calculation*

## 6. Conclusions

In this paper we have studied a measure of systemic risk called the absorption ratio (Kritzman et al, 2010). The absorption ratio is equal to the fraction of a set of asset's total variance explained by a finite number of eigenvectors. A high absorption ratio implies that financial markets are tightly coupled. When this phenomenon is observed, markets are also more fragile, as it becomes easier for shocks to propagate quickly and broadly. A low absorption ratio implies that markets are less compact, and thus the financial system is more resilient.

Consistent with the findings of Kritzman et al. (2010), we find that most significant stock market declines in EU countries have been preceded by spikes in the absorption ratio. We contribute to the literature on systemic risk and financial fragility by studying this indicator in the context of European capital markets. By disaggregating the data, we have shown that even in countries with less developed capital markets, the absorption ratio might have predictive power and could be used as a leading indicator of crisis episodes. We have demonstrated this ability of the AR by employing an event study of changes in the AR around turbulence episodes, as identified using a financial turbulence indicator based on the Mahalanobis distance. However, we are cautious to interpret these results in the absence of more rigorous statistical analysis.

Further research should aim at developing statistical methods for testing the AR ratio as a leading indicator, compare the performance of this indicator to other indicators of financial fragility, explore the correlations between the AR ratio and other empirical measures of systemic risk, and apply the method to different types of financial data, such as exchange rates movements, yields of government and corporate bonds, or CDS spreads.

Given its promising features, the AR ratio could be used in practice, alongside other measures of systemic risk, to improve asset portfolio performance, as well as to signal the need for policy action in the form of activation of macro-prudential instruments.

**Acknowledgement**

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