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## Did the Basel Process of Capital Regulation Enhance the Resiliency of European Banks?

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# Did the Basel Process of Capital Regulation Enhance the Resiliency of European Banks?

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1 August 2016<sup>‡</sup>

## Abstract

This paper analyses the evolution of measures of the safety and soundness of the European banking sector during the various stages of the Basel process of capital regulation. With the help of SRISK and Delta CoVaR we trace systemic risk and measures of systematic risk as the Basel process unfolds. We observe that, though systematic risk for European banks has been moderately decreasing over the last three decades, exposure to systemic risk has heightened considerably especially for the largest systemic banks. While the Basel process has succeeded in containing systemic risk for smaller banks, it has been less successful for the largest institutions. By exploiting the option of self-regulation embodied in the choice of internal models, the latter effectively seem to have increased their exposure to systemic risk as reflected in increasing SRISK. Hence, the sub-prime crisis found especially the largest and more systemic banks ill-prepared and lacking resiliency. This condition has even aggravated during the European sovereign crisis. Banking Union has not (yet) brought about a significant increase in the safety and soundness of the European banking system.

## 1 Introduction

The rules of regulating bank capital as developed by the Basel Committee of Banking Supervision were intended to increase the safety and soundness of banking systems while maintaining a level playing field in an increasingly globalized

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banking industry <sup>1</sup> Did these rules achieve their goals? How did they affect the conduct of banks in European banking markets, where they were actually implemented?

After almost thirty years of capital reform it is high time for an evidence-based evaluation of the economic consequences of the massive regulatory interventions since the adoption of the first Basel Capital Accord in 1988 (Basel I). From an economic point of view this seems even more relevant, since the Basel Process was set into motion without at a time of basically well functioning global banking markets, and without reference to any form of market failure that required correction (see Goodhart 2011) <sup>2</sup>. Subsequently elements of self-regulation were introduced into the regulatory framework, initially to reward banks for implementing modern risk-management techniques in order to model market risks (market risk amendment under Basel I) and later most importantly for modelling credit risk (Basel II). The evaluation of Basel II is complicated by the fact that the implementation period (2006) was immediately succeeded and in fact over-shadowed by the Great Financial Crisis and the subsequent repair operations now known as Basel III starting in November 2008.

This paper attempts a first evaluation of the Basel process of Capital Regulation. In particular we track down the evolution of the resilience of European banks right from its implementation date. By employing two recently developed new measures of systemic risk we trace the evolution of these risk measures. If resiliency was enhanced we would expect a long-run decline in the trajectories of these measures, reflecting an overall enhancement in the safety and soundness of European banking systems. We find differently.

The novel risk measures that we employ are currently widely discussed in academia and readily available in the public domain: SRISK has been developed by Brownless and Engle (2015) and Delta CoVaR by Adrian and Brunnermeier (2011). While SRISK can be viewed as an aggregate measure of banks' *exposures* to systemic risk, Delta CoVaR is an aggregate measure of banks' *contribution* to aggregate risk. While SRISK is a measure of resiliency of a bank, Delta Covar measures the risk of contagion originating in a particular bank.<sup>3</sup>

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<sup>1</sup>In its 1988 Report the Basel Committee on Banking Supervision explicitly states: "Two fundamental objectives lie at the heart of the Committee's work on regulatory convergence. These are, firstly, that the new framework should serve to strengthen the soundness and stability of the international banking system; and secondly that the framework should be in [sic!] fair and have a high degree of consistency in its application to banks in different countries with a view to diminishing an existing source of competitive inequality among international banks." (BIS, 1988)

<sup>2</sup>This is not saying that there was no issue of banking crises. Thus the implementation of Basel I coincides with the end of the S&L-crisis in the United States, which, however, according to general current perception is related to risk insensitive deposit insurance pricing. The argument that under-capitalized banks might be tempted to engage in risk taking has never been officially made by the Basel Committee.

<sup>3</sup>We present more precise formal definitions below in subsequent chapters.

While the SRISK measure is made publicly available for 100 European banks from 2000 onwards by Robert Engle’s V-Lab,<sup>4</sup> we reconstruct the measure back to the early 1980s in order to trace its evolution all the way from the early days of the Basel Committee.

Our central finding is that in contrast to the ambitions of the Basel process we cannot find a general reduction in the aggregate measures of systemic risk. Delta CoVar essentially remains constant across time while SRISK is increasing in various stages that correlate with the introduction of internal models for market risk (Basel I, 1996) and again for credit risk (Basel II, 2006). Interestingly we also identify heterogeneous effects across banking groups. The build up in aggregate systemic risk SRISK is primarily driven by the highest quintile of large and systemic banks. If there are beneficial effects of capital regulation it occurs at the level of smaller banks in small economic magnitudes.

It is even more unsettling, that according to the SRISK measure both the recent innovations of Basel III as well as the regulatory attempts of the European Union and the European Central Bank to strengthen the banking systems within the European Banking Union did not result in a significant decline in the aggregate SRISK measure. The individual SRISK of the most systemic institutions remains at levels considerably elevated relative to levels prior to the Great Financial Crisis of 2007-8.

In retrospect our results may not come as a big surprise. Academics have always been critical of the Basel process of Capital Regulation already at the time of inception of the various regulations. Hellwig (1995) was worried about correlations between market and credit risk not being properly addressed by Basel I regulation<sup>5</sup>. Danielson, Embrechts, Goodhart, Keating, Münnich, Renault and Shin (2001) raised serious concerns about the endogeneity of risks not being addressed at all within the Basel II framework, suggesting that Basel II might unintentionally and paradoxically even reduce safety and soundness of the banking system.<sup>6</sup>

In the cross-section of (European) banks we also attempt to identify the main drivers of systemic risk. As such we run panel regressions that allow us to control for macroeconomic factors as well as bank-specific balance sheet items. In addition we control for the implementation dates of important amendments of the Basel process of capital regulation. In particular, the implementation of

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<sup>4</sup><http://vlab.stern.nyu.edu/welcome/risk/>.

<sup>5</sup>On a Panel Discussion on Capital Requirements for Market Risks Based on Inhouse Models in 1995 Hellwig (1996) suggests “that ten years later there may well be another panel, this one devoted to problems of quality assessment for inhouse models of credit risk and that a key question is what will happen to banks and banking systems in the ten intervening years”. History has replaced that panel with a true field experiment in the 2007-8 crisis. So this paper can also be viewed as a response to Hellwig’s (1996) request for an evidence-based evaluation of the internal model based approach to market risk.

<sup>6</sup>On the problem of neglecting the endogeneity of systemic risk see also Hellwig (2010).

credit risk models along Basel II regulation has a strong impact on individual bank systemic risk exposures (SRISK). We find an interesting non-linear effect. In quantile regressions we find that the negative effect of internal credit risk models is strongest for the largest and most risky banks, while it is small and almost negligible for the lower quintiles. While the market risk amendment in 1996 did increase resiliency across the distributions of banks its effect remains largely statistically insignificant.

Overall we verify that the ECB was successful in identifying the most systemic banks when it took over supervisory responsibilities within the newly established European Banking Union in 2014. However, the systemic risk of those banks did not decline significantly after various stages of re-capitalisation and after entry into the Banking Union.

Finally, we also discover spillovers in systemic risk from the banking sector especially to the insurance sector starting 1996 with the Market Risk Amendment of the Basel Accord, and increasing in size and relevance thereafter.

With hindsight we know that European banks were not well prepared for the Great Financial Crisis 2007-8. Capital buffers of large European banks were threatened to be wiped out even before the collapse of Lehman Brother. In the case of UBS, they proved to be as low as 1.4% capital to asset ratios, while Deutsche Bank survived barely with a similarly low level of capitalization. Also in larger systematic analyses Demirguc-Kunt, Detragiache, Merrouche (2013) and Beltratti, Stulz (2012) find that better capitalized banks were more resilient and fared much better during that crisis. Accordingly, it has been claimed (e.g. Gehrig, 2013a and 2013b) that the lack of capital, and hence resiliency, did result as an unintended consequence of the political process that did subsidize “optimizing” capital charges for individual banks and, ironically, so-called systemic banks in particular.

While the academic literature has focused on methodology and on developing new systemic risk measures, few studies exist about the market reactions to Basel driven regulation in the banking industry. One important study is Wagster (1996) who has linked the Basel process to the competitiveness of banks across countries. In particular he identified market reactions at various stages of the discussion about Basel I reforms. He shows that the Basel process can be viewed as a bargaining process between national regulators; many agreements by Japanese authorities, in particular concerning the regulatory treatment of hidden reserves, were elicited by concessions to the Japanese banking sector that were capitalized in market prices and can be measured accordingly. To the best of our knowledge our work is the first systematic evaluation of the effect of the Basel process of capital regulation on the safety and soundness of banking systems.

Finally, concerning internal credit risk models we confirm and extend the re-

sults of Behn, Haselmann and Vig (2014) about the limitations of model-based regulation. Also they find negative effects of internal models for credit risk on the resiliency of German banks. We verify negative effects also for European banks and additionally we establish an important non-linearity of this effect across the SRISK-spectrum of banks.

The paper will proceed as follow: Section 2 briefly describes the Basel process. Section 3 introduces the data and the methodology used in the empirical analysis. Section 4 presents the main descriptive results, while Section 5 interprets the main multivariate results. Finally, Section 6 concludes summarizing the unintended consequences of the Basel process.

## 2 The Basel process

The Basel process of capital regulation was initiated in late 1974. The first meeting of Basel Committee on Banking Regulations and Supervisory Practices took place in February 1975. After a long period of consultations<sup>7</sup> the first Basel Capital Accord (Basel I) was approved by the G10 governors in December 1987 and publicly announced in July 1988. The Accord was formally implemented in December 1992.

The Accord had already been amended in 1991, to reform the treatment of loan loss reserves, and later repeatedly in 1995 and 1996. The most important amendment was the introduction of internal models under supervisory review as an alternative to statutory rules in January 1996 as part of the market risk amendment (Basel Committee of Banking Supervision, 1996). This amendment essentially provided a choice between a self-regulatory regime under supervisory review and statutory regulation. It provided incentives to improve in-house risk management models, which were highly deficient in the 1990s even in multinational banks (see Wuffli, 1995). However, the amendment also implicitly provided incentives to employ internal models as an instrument to reduce regulatory burdens and capital charges, and, hence, to reduce resiliency (see Hellwig, 1995).

Proposals for a new capital accord were triggered by the initiation of a consultation process on a Revised Capital Framework in June 1999. This became the basis of the three-pillar framework of Basel II, which formally culminated in June 2006 in the agreement on Basel II: "International convergence of capital measurement and capital standards: a revised framework for comprehensive supervision".

Basel II was adopted in most countries with the notable exception of the U.S.

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<sup>7</sup>See Goodhart (2011) for details on the early years of the Basel Committee.

However, the impact of its implementation could not be properly assessed<sup>8</sup> since already in 2007 the subprime crises developed into a worldwide crisis and depression. Hence, already in September 2008, the Basel Committee was forced to reconsider its regulatory framework with its guidelines on Principles for Sound Liquidity Risk Management and Supervision triggering the discussion on reforming Basel II, a process now commonly referred to as Basel III.

### 3 Sample and Methodology

In order to assess the implementation of the Basel principles, we propose an empirical investigation on a sample of European financial institutions from 1987 to 2015. The sample includes the listed institutions covered by Compustat Global and belonging to sector groups 4010 (banks), 4020 (diversified institutions), 4030 (insurance companies) and 4040 (real estate companies). To reduce survivorship bias, we include active as well as non-active institutions. We estimate systemic risk for 451 institutions from the Euro-area, Switzerland, and the United Kingdom, for whom we have at least 10 years of balance sheet data.

We use daily stock prices and market capitalization as well as quarterly fundamental data, such as book value of equity, assets and debt. As quarterly data on European institutions go back till 1996, we complete the information back to 1987 with annual balance sheet data. We use the MSCI Europe index as the broad market return, and the yield on German federal bonds, as the risk free rate (from Datastream). Moreover, we use market stress indicator, such as CISS, from Hollo, Kremer and Lo Duca (2012), and information on credit risk internal models from SNL and Bundesbank.

The empirical analysis proceeds in three steps. We estimate systemic risk according to the SRISK measure proposed by Brownless and Engel (2015) and the Delta CoVaR developed by Adrian and Brunnermeier (2011). We then investigate the main drivers of the SRISK measure, using information on bank-level cost of equity and fundamental information on total assets, investments, and non-performing loans, and market-level characteristics.

We conclude on the impact of the Basel regulation considering both bank-level use of IRBA models from 2006, and country-level milestone dates that have affected the business models of the banks in our sample: the introduction of market risk internal models in January 1996, the agreement on Basel II reached in June 2006, and the publication of Basel III guidelines in September 2008.

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<sup>8</sup>Given the length of the consultancy process for Basel II, it is quite likely that the process did affect bank business models already well before the official implementation. Moreover, the self-regulatory pillar allowing internal models was available to officially and fully compliantly drive bank business models since 1996.

### 3.1 SRISK and Co-VaR measures

We use two measures of systemic risk that would capture the contribution to aggregate risk of an institution in distress (Delta CoVaR) and the exposure in a distress market (SRISK).

Building on the theoretical work of Acharya, Pederson, Philippon and Richardson (2010), the SRISK measure developed by Brownlee and Engel (2015) exploits market information to value expected capital shortfall, and, hence, the cost of recapitalizing a bank at any point in time. SRISK is a good measure of the exposure of an individual bank to systemic risk since it attempts to measure the (temporary) amount of capital a supervisor would have to inject to keep the bank running in an orderly way in case of a major disturbance. This systemic risk measure considers the combined effect of three components: sensitivity of the bank returns to aggregate shocks, leverage and size of the bank, and weakness of the financial system as a whole. Given these ingredients, a firm is considered systemically risky if it is likely to face a proportionally relevant capital shortfall when the financial sector is weak.

Adapting this methodology, we estimate (i) an asymmetric GJR GARCH model (Glosten, Jaganathan and Runkle, 1993) of the returns volatility of each institution and of the market equity index, (ii) a DCC correlation model (Engel, 2002) for the correlation between the institution return and the market index, and (iii) the performance of the bank, and the capital shortfall in case of extreme financial downturns.

We assume a bivariate daily time series model of the equity returns of institution  $i$ , dependent on a value-weighted market index  $m$ :

$$\begin{aligned} r_{m,t} &= \sigma_{m,t} \varepsilon_{m,t} \\ r_{i,t} &= \sigma_{i,t} (\rho_{i,t} \varepsilon_{m,t} + \sqrt{1 - \rho_{i,t}^2} \xi_{i,t}) \end{aligned}$$

where the volatilities are asymmetric GJR GARCH processes and correlations are Dynamic Conditional correlations. We use the MSCI Europe index for the market returns as a more representative benchmark for our sample of European banks.

The measures of performance and systemic risk are evaluated in the event of an extreme aggregate shock. We identify extreme downturns by falls in the daily market index higher than its 95% VaR. The expected daily loss of the bank returns, in this case, is the Marginal Expected Shortfall (MES):

$$MES_{it}(c) = E_{t-1}(r_{it} | r_{mt} < c = q_{5\%}) \quad (1)$$

The higher the bank's MES, the higher is its exposure to the risk of the financial system.



We estimate both the performance of the bank in such extreme events and the capital shortfall. The Long-Run Marginal Expected Shortfall (LRMES) is the expected loss in equity value of bank  $i$ , if the market were to fall by more than the above threshold within the next six months. As Acharya, Engel and Richardson (2012), we approximate it without simulation using the daily MES:<sup>9</sup>

$$LRMES = 1 - e^{(-18 * MES)} \quad (2)$$

Finally, given the above conditional expected equity losses, the current equity market value and the outstanding book value of debt, we determine the expected capital shortfall a bank would experience in case of distress. SRISK is defined as such capital shortfall in the event of an aggregate crisis:

$$\begin{aligned} SRISK_{i,t} &= E_{t-1}[Capital\ shortfall_i | Crisis] \\ &= E_{t-1}[k(Debt + Equity) - Equity | Crisis] \\ &= E_{t-1}[k(Debt_{i,t}) + (1 - k)(1 - LRMES_{i,t})Equity_{i,t} | Crisis] \end{aligned} \quad (3)$$

where:  $k$  is the prudential capital ratio, that we assume 8%.

We define the optimal capital for the institution, when  $SRISK = 0$ :

$$Equity_{i,t} \geq \frac{kDebt_{i,t}}{(1 - k)(1 - LRMES_{i,t})} \quad (4)$$

that corresponds to an optimal capital ratio of:

$$k_{i,t} = \frac{Equity_{i,t} * (1 - LRMES_{i,t})}{Debt_{i,t} + Equity_{i,t} * (1 - LRMES_{i,t})} \quad (5)$$

Once the individual  $SRISK_{i,t}$  are estimated per each bank, the relative exposure of firm  $i$  to the aggregate SRISK of the financial sector is:

$$SRISK\%_{i,t} = \frac{SRISK_{i,t}}{\sum_{j \in J} SRISK_{j,t}}, \text{ where } J = \text{firms with } SRISK > 0 \quad (6)$$

It represents the percentage aggregate capital shortfall that would be experienced by this firm in the event of a crisis, and it allows to identify the most systemic institutions in the sector.

Besides the estimation of the SRISK and its components, we also estimate the Delta CoVaR developed by Adrian and Brunnermeier (2011). It corresponds to the VaR of market returns conditional on a critical event on the returns of a bank  $i$ . The marginal contribution of bank  $i$  to the overall systemic risk,  $\Delta CoVaR$ , is the difference between the CoVaR in distress and the CoVaR in a median state.<sup>10</sup>

<sup>9</sup>The approximation represents the equity value loss over a six-month period conditional on a market fall by more than 40% within the next six months.

<sup>10</sup>See Benoit et al. (2013) for a comparison of the two measures.

This measure starts from the estimation of an aggregate extreme loss in terms of Value-at-Risk, as the maximum loss of the market return within the  $\alpha\%$ -confidence interval, conditionally on some event  $C(r_{it})$  observed for bank  $i$ :

$$Pr(r_{mt} \leq CoVaR_t^{m|C(r_{it})}) = \alpha \quad (7)$$

Using a quantile regression approach, we identify this distress event of firm  $i$  as a loss equal to its  $(1 - \alpha)\%$  VaR:  $r_{it} = VaR_{it}(\alpha)$ .

The systemic risk of the bank  $i$  is then defined as the difference between the CoVaR of the financial system conditional on firm  $i$  being in distress and the CoVaR of the financial system conditional on firm  $i$  being in its median state:

$$\Delta CoVaR_{it}(\alpha) = CoVaR_t^{m|r_{it}=(VaR_{it}(\alpha))} - CoVaR_t^{m|r_{it}=Median(r_{it})} \quad (8)$$

### 3.2 Drivers of Systemic Risk

Historically prudential regulation of banks has focused on individual bank risk and micro-prudential regulation, neglecting the correlated systemic effects of several institutions in distress and in needs of recapitalization at the same time.<sup>11</sup> Therefore, it is of great interest to understand the potentially divergent effects of the Basel measures on individual bank risk (microprudential risk) and aggregate systemic risk (macroprudential risk), and how the the market prices systemic risk (Hellwig, 2009).

We focus on a subsample of 48 banks for which we have SNL data on the implementation of IRBA after Basel II.

The analysis proceeds in three steps: we perform panel regressions, a VAR model, and quantile regressions on the SRISK measure. First, we perform panel regressions with firm and year fixed effects in two different specifications: weekly and quarterly. In a weekly model, we regress the  $SRISK_{it}$  on Basel dummies to capt the impact of banking regulation, and on the bank's systematic risk (Beta with the market), or the bank's contribution to systemic risk (Delta CoVaR). We control for market characteristics  $X_{kq-1}$  that would proxy for market investment opportunities (European market return, country policy rate, market stress proxied by the CISS measure of Hollo et al., 2012):

$$SRISK_{it} = \alpha + \gamma_0 Beta_{it} + \sum_k \gamma_k X_{kt} + \lambda_1 BIAmend + \lambda_2 BII + \lambda_3 IRBA_{it} + \lambda_4 BIII + \mu_i + \tau + \varepsilon_{it} \quad (9)$$

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<sup>11</sup>Only under Basel III capital surcharges for systemically important financial institutions (SIFI) are introduced.

Alternatively, we regress the SRISK on Basel dummies, systematic risk or contribution to systemic risk, controlling for lagged quarterly bank characteristics  $Z_{kq-1}$  (total assets, non-performing loans, total loans, other investment in security assets, other investments in fixed income assets, market capitalization and leverage), and market stress. In order to address issues of mixed frequencies, we aggregate the daily measures (SRISK, Beta, Delta CoVaR, and market capitalization) to their quarterly median, and perform the following regression:

$$SRISK_{iq} = \alpha + \gamma_0 Beta_{iq} + \sum_k \gamma_k Z_{kq-1} + \lambda_1 BIAmend + \lambda_2 BII + \lambda_3 IRBA_{iq} + \lambda_4 BIII + \mu_i + \tau + \varepsilon_{iq} \quad (10)$$

Concerning the specific Basel dummy variables, we perform our analysis considering three important milestones of the process in the time span of our sample: the introduction of Market Risk internal models (January 1996), the agreement on Basel II (July 2006), and the guidelines of Basel III (September 2008). We therefore include three dummy variables identifying these subperiods: (i) Basel I and statutory regulation, (ii) Basel I and self-regulatory regime by use of internal models, (iii) Basel II and self-regulatory regime, and (iv) Basel III.

Moreover, we consider bank-level information on the usage of Internal Rating Based Models for credit risk after Basel II. Per bank-quarter, we introduce a categorical variable equal to 1 for standardized models as Basel II regulation, and 2 for the implementation of IRBA models.

As measures of cost of equity, we consider (i) the time-varying beta between the bank asset returns and the market index, and (ii) the cost of equity measured by means of a CAPM model. The time-varying beta is estimated from the previous GJR-DCC GARCH model. The Cost of Equity is the CAPM return required by the market given the estimated dynamic beta and the risk premium of the market portfolio:

$$CostEquity_{it} = R_{ft} + \widehat{beta}_{it} * (R_{mt} - R_{ft}) \quad (11)$$

We use the daily annualized yield on German Bonds as a proxy for the risk-free rate for the European banks. We use the MSCI Europe return compounded over the previous year as benchmark market return.

We use the CISS measure as an indicator of the systemic stress that the European financial market as a whole experiences through time (Hollo, Kremer and Lo Duca, 2012). It consists in a weighted index of the instability in five different market segments: financial intermediaries, money markets, equities and bonds markets, and foreign exchange markets.<sup>12</sup>

We proceed estimating possible lag-lead effects between exposure to systemic risk (SRISK), systematic risk (Beta), contribution to systemic risk (Delta

<sup>12</sup>The measure is publicly available from the ECB databank from 1999. We thank Manfred Kremer for sharing the CISS estimated from 1987.

CoVaR), market capitalization with a VAR approach.

Finally, we use quantile regressions approach to address potentially differential effects across the main quantiles of the distribution of the SRISK. We use the same specifications above, including year effects and estimating clustered standard errors (Parente and Santos Silva, 2016).

In the following section, we present the empirical results. A first part consists in a descriptive analysis of the time evolution of the systemic measures, in conjunction with measures of systematic risk. A second part consists in a multivariate analysis of the drivers of the SRISK, at the light of the cost of equity and Basel regulation.

## 4 Results

### 4.1 Evolution of Measures of Systemic and Systematic Risk from 1987-2015

Arguably, the Basel process of capital regulation was intended to increase the stability and safety of the banking industry.<sup>13</sup> Accordingly, we might expect to see a decrease in the riskiness of bank business models after the formal implementation of the various stages of the Basel process. This should ideally be reflected in lower risk premia and, hence, lower funding costs such as lower costs of bank equity. Moreover, one would expect that an improvement in stability and safety of the banking sector would also be reflected in a reduction in the exposure of banks to systemic risk. So what do the data tell us about the evolution of these measures for (almost) the past three decades?

Indeed, it turns out that market-based measures of the cost of bank equity did decrease significantly on average (Figure 1).<sup>14</sup> The trend, however, is not pervasive across countries and we do not observe particularly different time trends (Figure 2). This decrease did happen across most of the advanced economies such as Germany and Great Britain, consistent with previous literature on the G-10 countries and the US in particular (Baker and Wurgler, 2015, Maccario et al. 2002). We observe the exceptions of France and Italy, which more closely follow Japan in this respect, as reported by King (2009).

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<sup>13</sup>Gehrig (1995) suggests that harmonization of regulation and creating a level playing field was another goal of the Basel Committee.

<sup>14</sup>We follow the Federal Reserve System (Barnes and Lopez, 2006) and the BIS (King, 2009) in measuring costs of bank equity on the basis of a CAPM-model. Moreover, again following King (2009) we provide a moving-average presentation of the daily cost of capital, which is notoriously volatile. Unlike King (2009) we provide confidence intervals to allow an assessment of statistical significance.

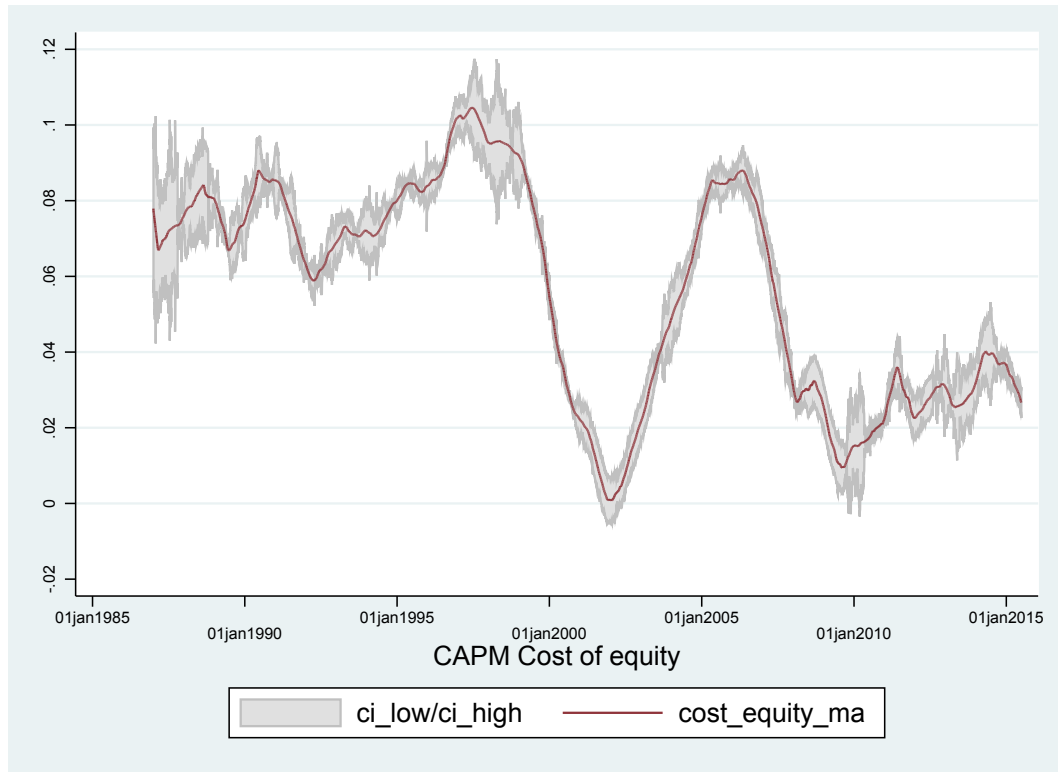


Figure 1: Evolution of measures of cost of bank equity. The Figure presents the evolution of the daily cost of equity across time, from January 1987 to 2015. The cost of equity is the return required by the market applying a CAPM model with the time-varying beta and the annual risk premium required on the market return, as Equation 11:  $CostEquity_{it} = R_{ft} + \widehat{\beta}_{it} * (R_{mt} - R_{ft})$ . We use the yield on German Bund as risk-free rate, and the MSCI Europe index compounded over the previous year as market return. The time-varying beta is estimated by a GJR DCC Garch model.

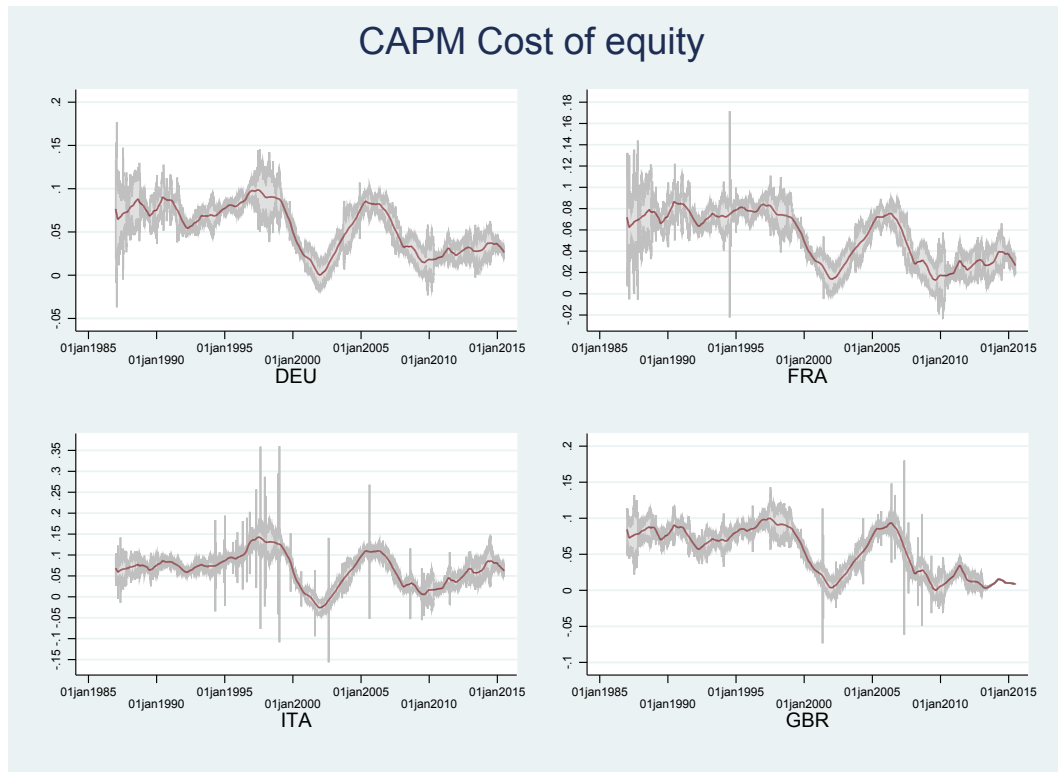


Figure 2: Cross-country variation of cost of bank equity. The Figure presents the evolution of the daily cost of equity by different country, across time, from January 1987 to 2015. We report Germany (DEU), France (FRA), Italy (ITA) and United Kingdom (GBR). The cost of equity is the return required by the market applying a CAPM model with the time-varying beta and the annual risk premium required on the market return, as Equation 11.

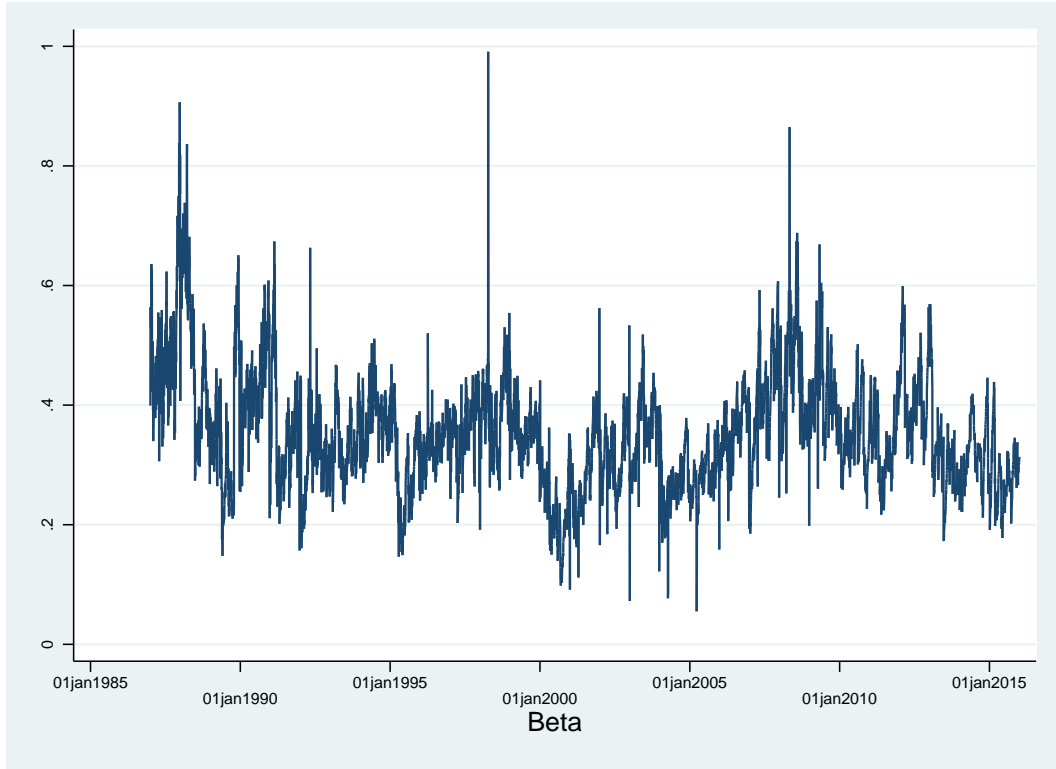


Figure 3: Evolution of measures of systematic risk. The Figure presents the evolution of the daily beta across time, from January 1987 to 2015. It represents the sensitivity of the bank equity returns to the MSCI Europe index returns. It is estimated by a GJR DCC Garch model.

While permanently declining long-term interest rates contributed to a decline in cost of bank equity, most of the decrease actually is driven by an average decline in systematic risk measured by the beta. However, we also observe significant country variation (Figures 3 and 4). Hence systematic risk appears as being in long-term decline. This finding implies increasingly more favorable funding conditions for banks and lower costs of issuing bank equity.<sup>15</sup> It is also worth noting that this long-run evidence runs counter to the perception of contemporary observers in the early phase of the Basel process. The ubiquitous sense of increasing risk in banking due to narrower intermediation margins caused by deregulation and intensified competition (e.g. Gehrig, 1995, 1996) is not reflected in average risk premia across European banks in subsequent decades.

How does this evidence of lower risk premia and systematic risk in the bank-

<sup>15</sup>This finding is in line with Barnes and Lopez (2006) and King (2009) who also find downward trending cost of bank capital except for the case of Japan.

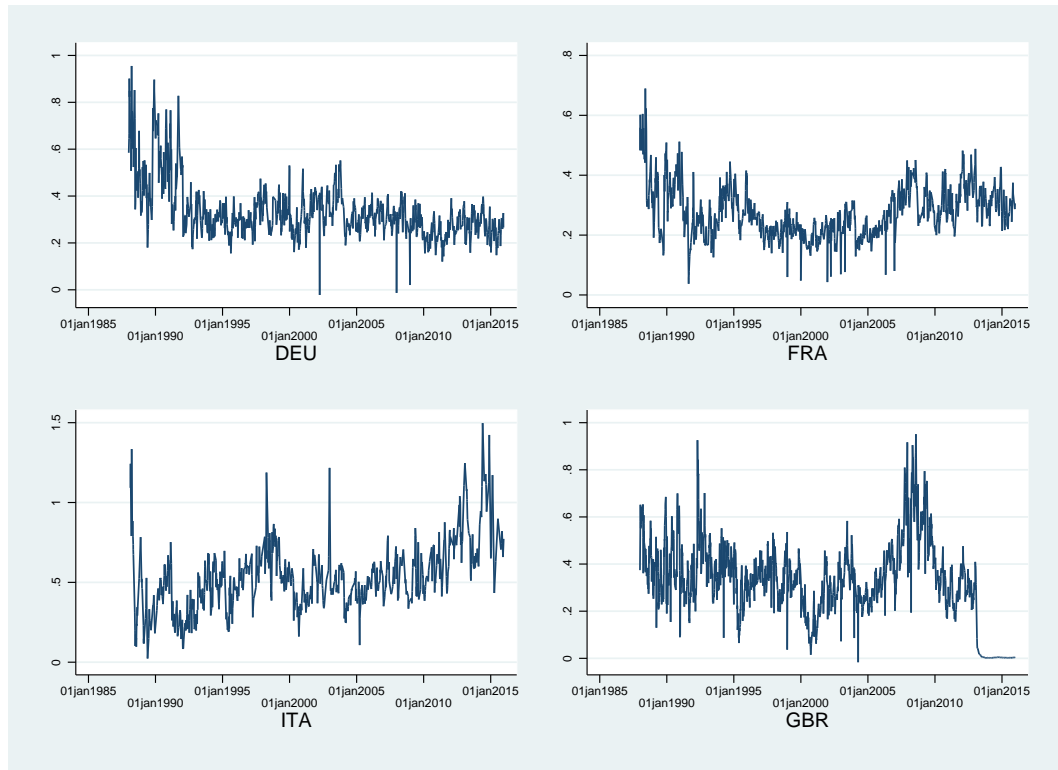


Figure 4: Cross-country variation of systematic risk. The Figure presents the evolution of the daily beta by different country, across time, from January 1987 to 2015. We report Germany (DEU), France (FRA), Italy (ITA) and United Kingdom (GBR). It represents the sensitivity of the bank equity returns to the MSCI Europe index returns. It is estimated by a GJR DCC Garch model.



ing industry relate to measures of systemic risk? Has the safety and stability of the banking system been enhanced by the Basel process at large? Are there segments in the banking system where resilience has actually declined?

To address these questions we employ two standard measures of systemic risk, the Delta CoVaR measure of Adrian and Brunnermeier (2011) as a measure of an institution’s contribution to systemic risk and the SRISK measure of Brownlees and Engle (2015) as a market-based measure of an institution’s exposure to systemic risk.

The Delta CoVaR measure first peaks in the late 1980’s at the end of the S&L crisis. After the Basel accord of 1988 the Delta CoVaR measure is in decline until 1996, from which on it remains heightened until about 2005 (Figure 5). This period roughly corresponds with the period after the introduction of the market risk amendment of Basel I until the end of the consultancy process of Basel II. This period also covers the dot-com bubble, which apparently did not affect contagion risk of European financial institutions. The next huge increase in Delta CoVaR coincides with the European sovereign crisis in 2009-10.

Surprisingly, while figuring significantly the subprime crisis does not figure prominently according to the Delta CoVaR measure. There is a single peak around Lehman failure in September 2008 but Delta CoVaR remains below pre-crisis levels. To the effect that the subprime crisis has been characterized by a drying-up of liquidity it appears remarkable that contagion risk has not shot up dramatically during the 2007-8 period.

The SRISK measure exhibits a markedly different pattern (Figure 6). In fact, we present two versions: i) in the first version we aggregate over shortfalls and surpluses of individual banks and ii) in the second version we only aggregate positive shortfalls. While the first version does implicitly allow for inter-industry netting of bank capital, the second version measures the total amount of re-capitalization needed for a given capitalization standard. Thus, the net measure is a measure of the shortfall from a societal level after potential redistribution of bank capital, while the latter measure is an indicator of overall industry stress.

Overall, both measures exhibit an increasing trend suggesting a growing reduction in resilience. Both SRISK measures are quite low around the dot-com bubble, which may just be a reflection of the bubble per se.<sup>16</sup> The measure shoots up when the bubble bursts, but remains elevated prior to the subprime crisis. During the Great Recession it shoots up again after the Lehman failure, but subsequently, and in contrast to Delta CoVaR, remains at almost identically high levels during the European sovereign crisis. On the positive side though,

<sup>16</sup>Since SRISK is a market-based risk measure it underestimates true exposure to systemic risk in periods of overpricing (bubbles) and it overestimates true exposure to systemic risk in periods of underpricing. In this sense SRISK is not a useful early warning indicator.

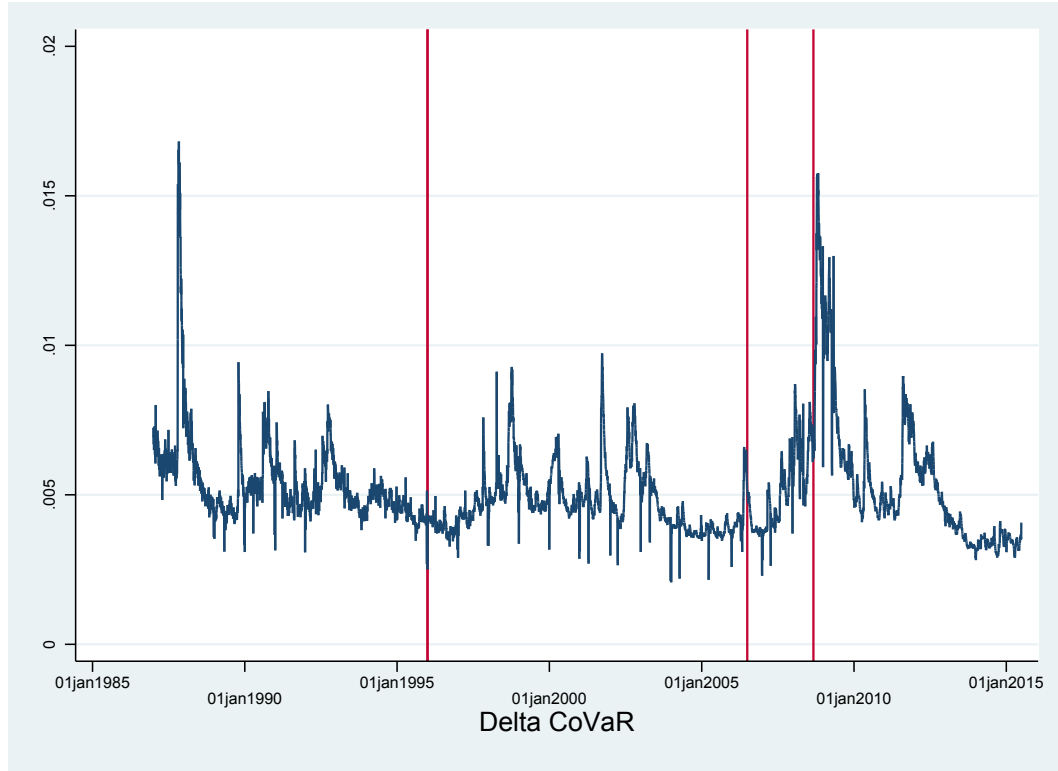


Figure 5: Evolution of systemic risk - Delta CoVaR. The Figure reports the evolution of the daily estimated Delta CoVaR in Equation 8, estimated with quantile regressions.

the Basel III measures seem to be effective in preventing a further rise in SRISK, albeit at a rather high level well above that observed in the 1990s.

By visual inspection of the first SRISK measure three major level changes in aggregate SRISK catch the eye: i) the early stage from 1988-2001, ii) the period from 2002-2009 and the iii) sovereign crisis stage from 2009 onwards. Again the liquidity crisis of 2007-8 does not exhibit dramatic effects on SRISK.

While SRISK clearly indicates a sharp build-up of exposure to systemic risk, also Delta CoVaR does not provide any evidence of a reduction in the contribution to systemic risk, and, hence, an increase in resiliency in the banking system. According to these measures, the Basel process does not seem to have achieved the goal of increasing the stability and safety of the banking system relative to the pre-Basel era, at least for the European countries.

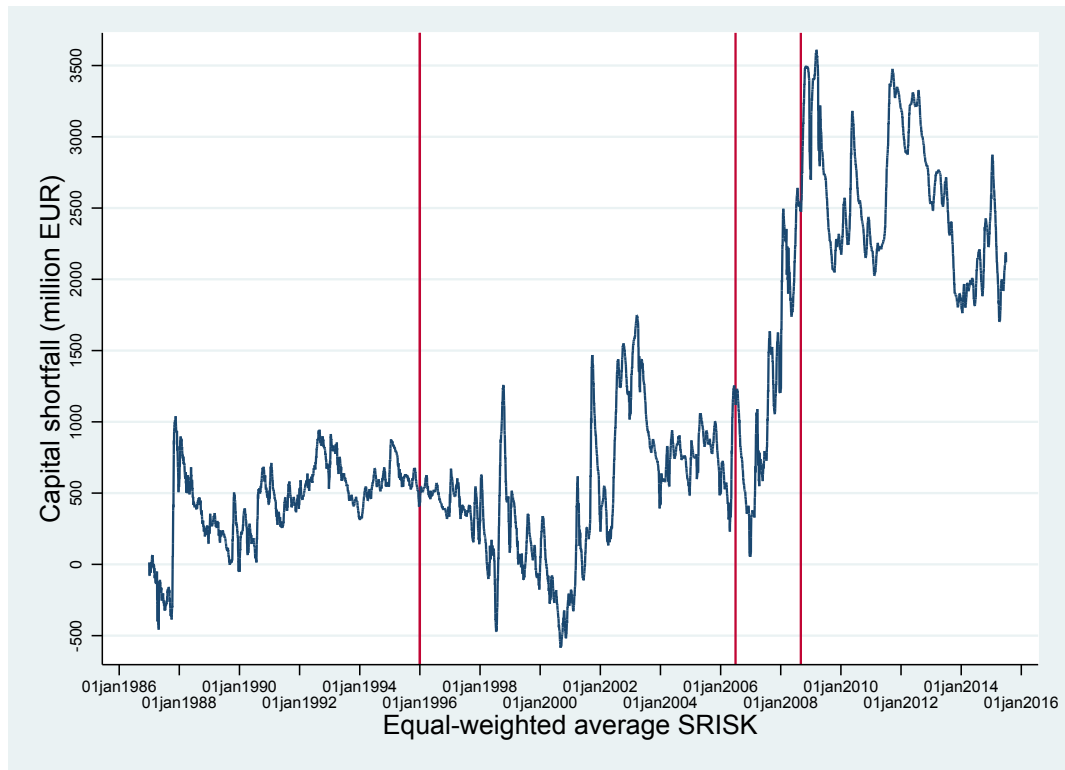


Figure 6: Evolution of systemic risk - SRISK. The Figure reports the evolution of the daily estimated SRISK in Equation 3. The SRISK is estimated by MLE using a GJR-DCC Garch model.

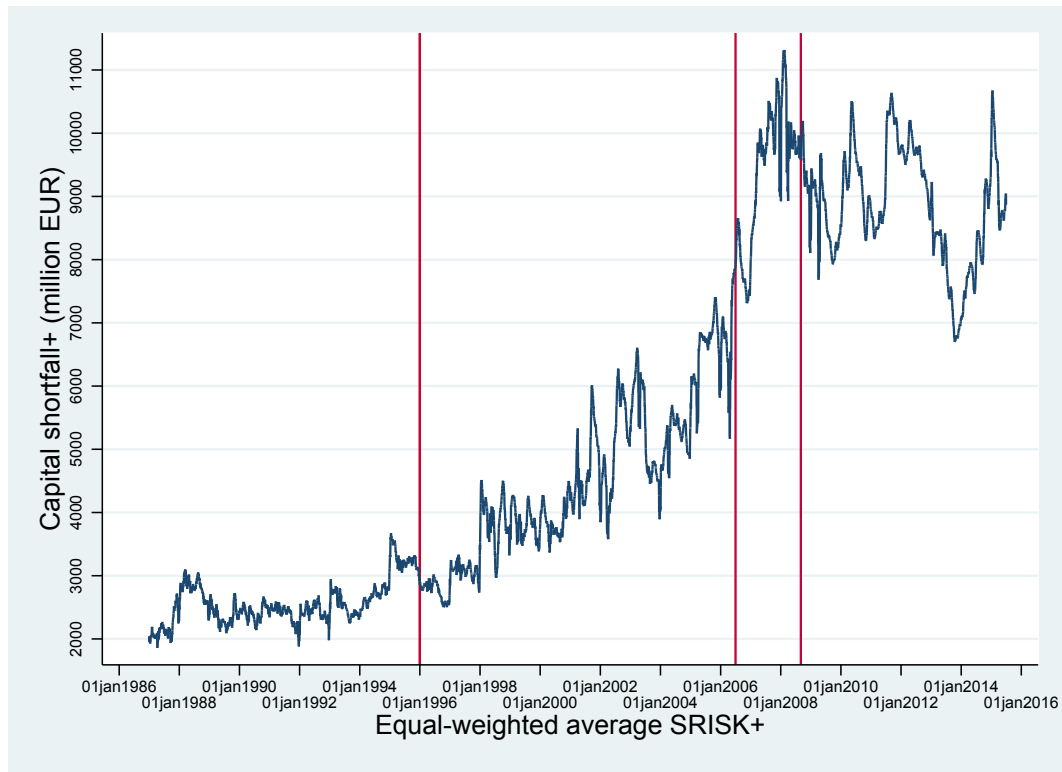


Figure 7: Evolution of systemic risk - SRISK. The Figure reports the evolution of the daily estimated SRISK (Equation 3) in case of capital need (positive SRISK). The SRISK is estimated by MLE using a GJR-DCC Garch model.

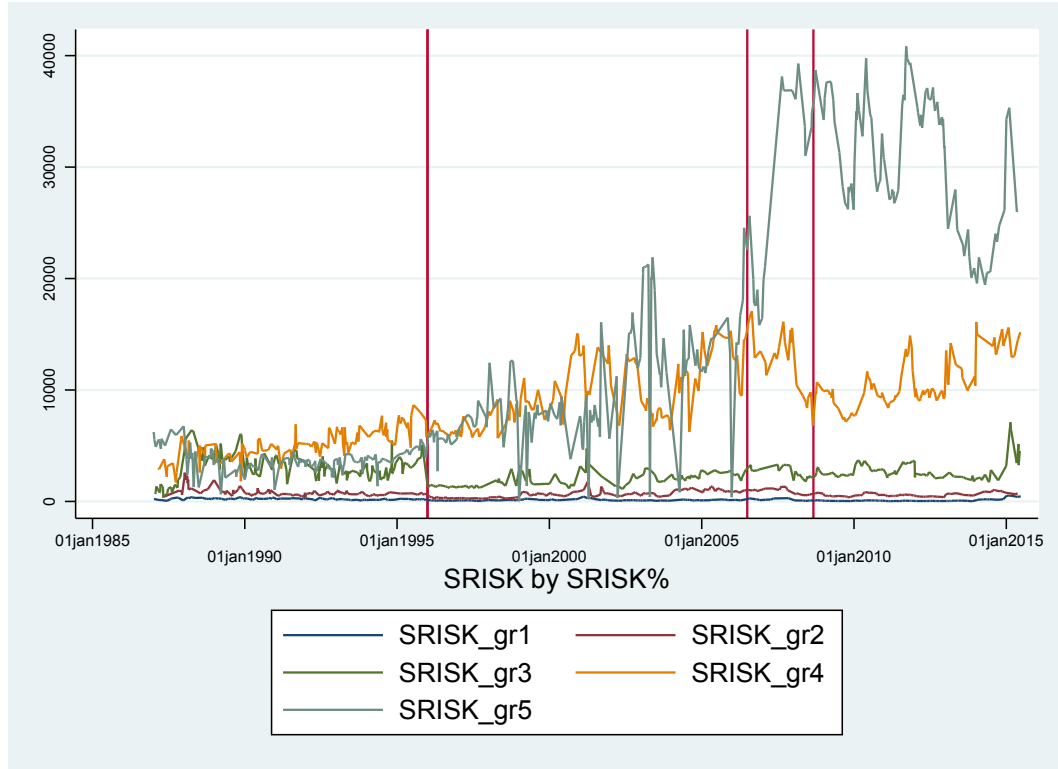


Figure 8: Quantile effects and non-linearities. The Figure reports the evolution of the daily estimated SRISK (Equation 3), distinguishing for the five quintiles of SRISK%, as in Equation 6. The top quintile (gr5) correspond to the group of banks with the highest level of positive SRISK, while the bottom quintile (gr1) correspond to the group of banks with the lowest level of capital shortfall.

## 4.2 Evolution across banks and sectors

These results lead to a final question. Can we say anything about the sources of the build-up of systemic risk? We first check whether the build-up has been uniform across the banking system or whether it is related to particular institutions or business models.

When looking into quintiles of the SRISK measure it turns out that it is the upper two quintiles that massively build up SRISK, while in the case of CoVaR, banks seem to be more uniformly affected. Accordingly, important non-linearities show up in the case of SRISK (Figures 8 and 9).

It turns out that it is mainly the large banks that contribute to SRISK. Moreover, it is also the banks that are now supervised directly by the ECB within the new Banking Union regime officially in place since November 2014 (Figure 10). We can see that SRISK has increased across all quintiles and also

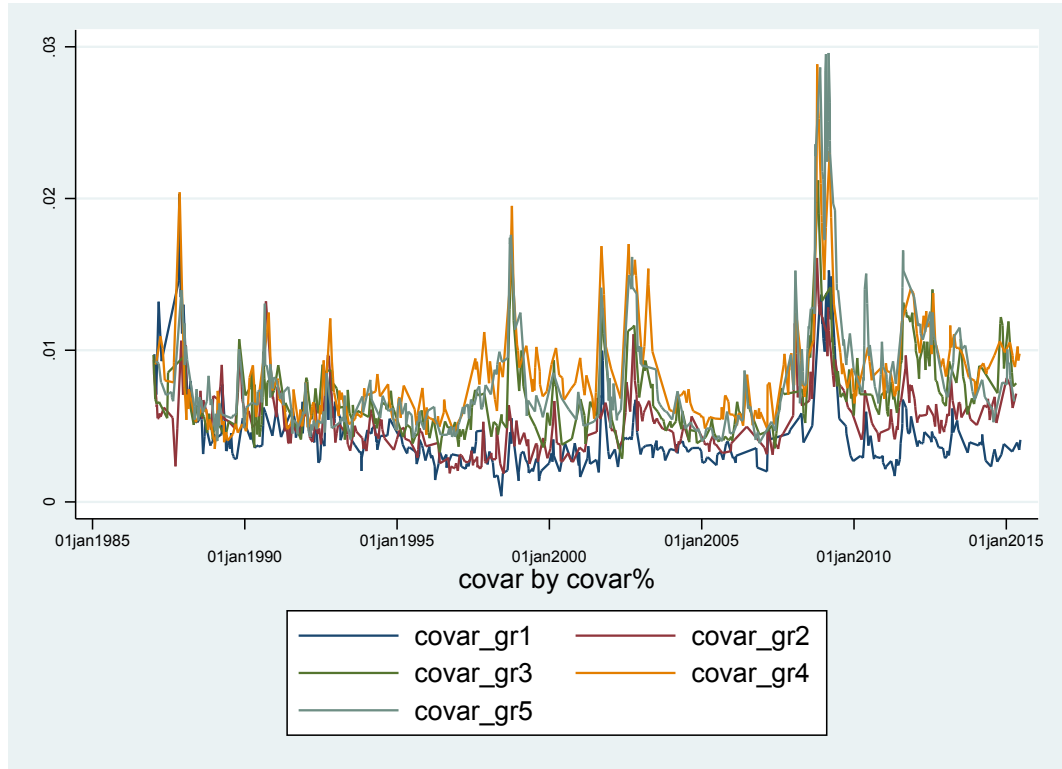


Figure 9: Quantile effects and non-linearities. The Figure reports the evolution of the daily estimated Delta CoVaR (Equation 8), distinguishing for the five quintiles of SRISK%, as in Equation 6. The top quintile (gr5) correspond to the group of banks with the highest level of CoVaR, while the bottom quintile (gr1) correspond to the group of banks with the lowest level.

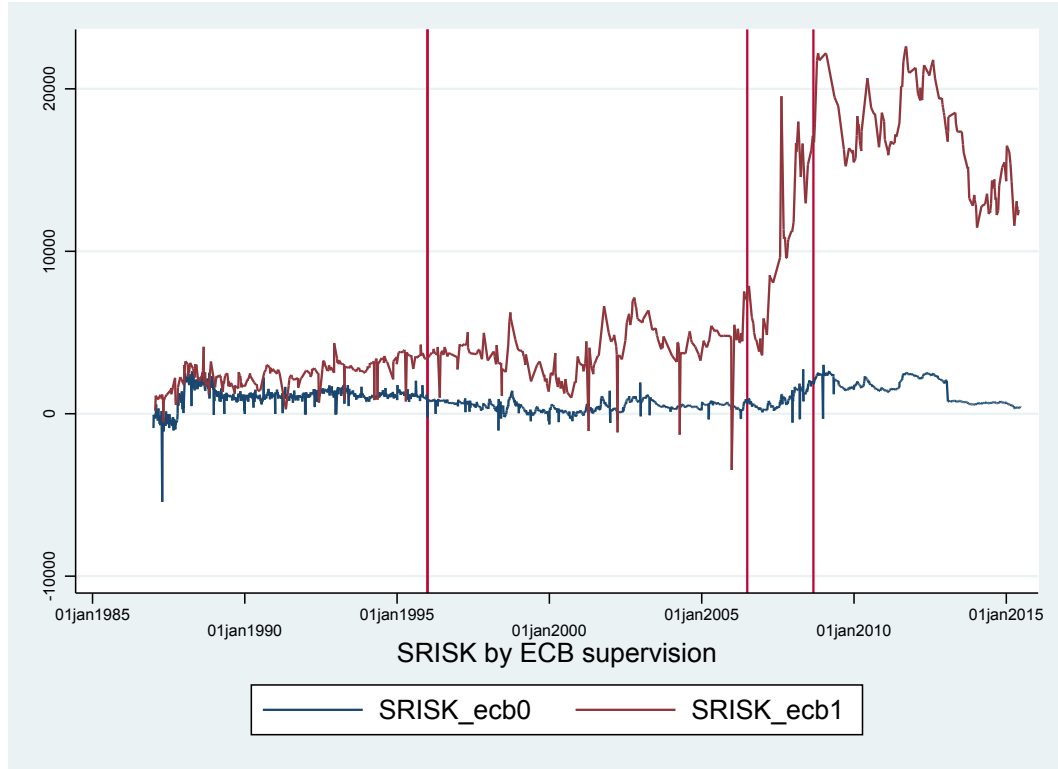


Figure 10: ECB Supervision. The Figure reports the evolution of the daily estimated SRISK (Equation 3), distinguishing for ECB supervision. The first group (ecb0) correspond to the group of banks that were not part of the Stress Test performed by ECB in 2014, while the second group (ecb1) correspond to the group of banks that were part of the ECB Stress Test in 2014 and their supervision has been taken over by ECB.

for banks not supervised directly by ECB, reconfirming an overall increase in systemic risk according to that measure. However, the banks chosen by the ECB are the ones that have distinguished themselves in building up a massive contribution to the systemic risk after 2008.

Let us now take a system's perspective on the whole financial system by differentiating according to banks (1), diversified financials (2), insurance companies (3) and real estate companies (4).

Figure 11 and Figure 12 establish that there is significant variation in the time trend of Beta for the different sectors. It is particularly the diversified financials and the insurance sector that saw a decline in beta, while the banking sector per se experiences a rise in beta after the financial crisis.

Interestingly Figure 13 demonstrates that the risk of contribution to systemic risk, i.e. contagion risk, has been largest in the insurance sector. Also

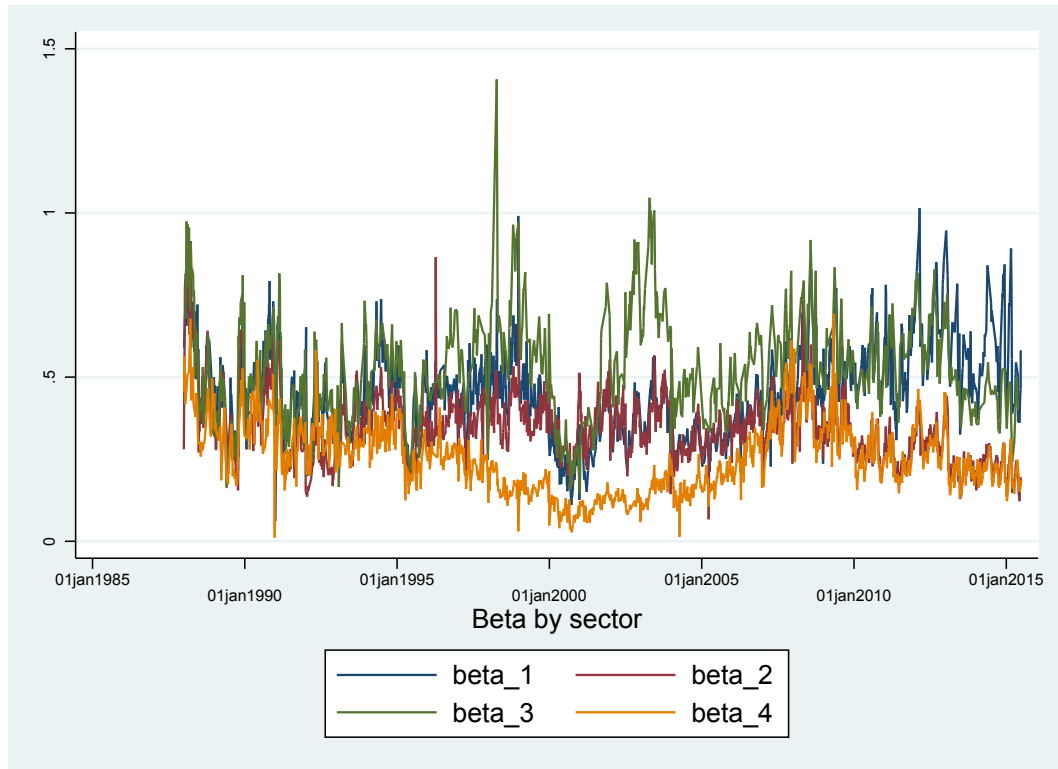


Figure 11: Evolution of measures of systematic risk. The Figure presents the evolution of the daily beta across time, from January 1987 to 2015. It represents the sensitivity of the bank equity returns to the MSCI Europe index returns. It is estimated by a GJR DCC Garch model. We report banks (1), diversified financials (2), insurance companies (3) and real estates (4).



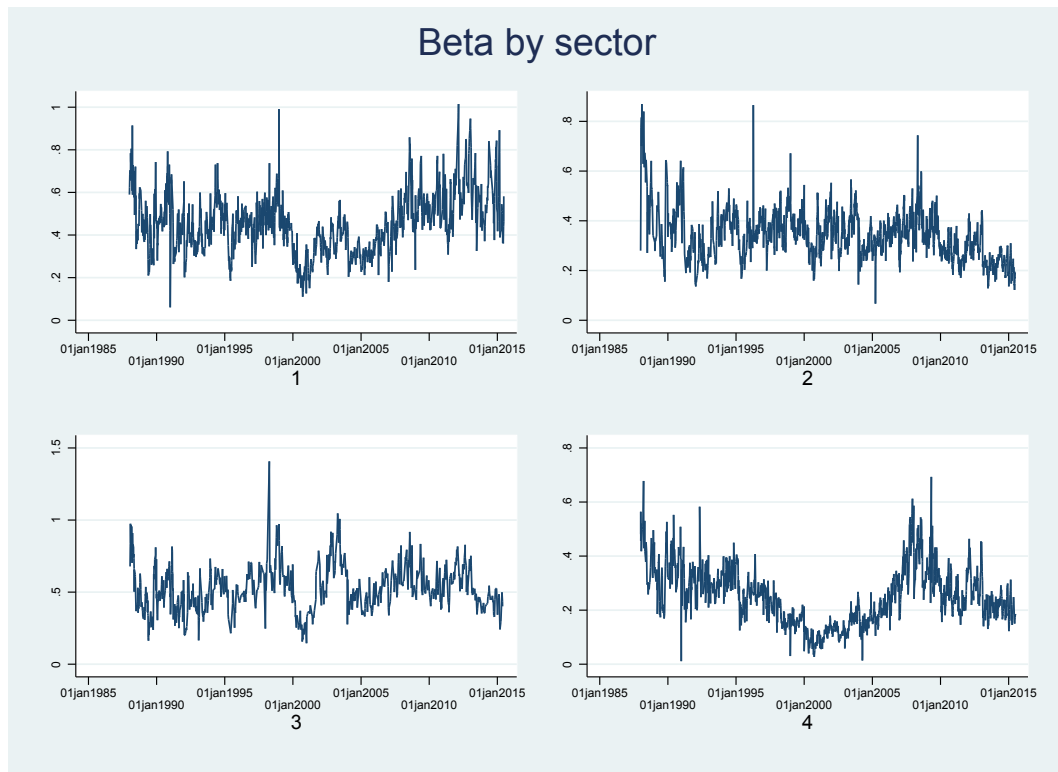


Figure 12: Cross-sector variation of systematic risk. The Figure presents the evolution of the daily beta by different country, across time, from January 1987 to 2015. We report banks (1), diversified financials (2), insurance companies (3) and real estates (4). It represents the sensitivity of the bank equity returns to the MSCI Europe index returns. It is estimated by a GJR DCC Garch model.

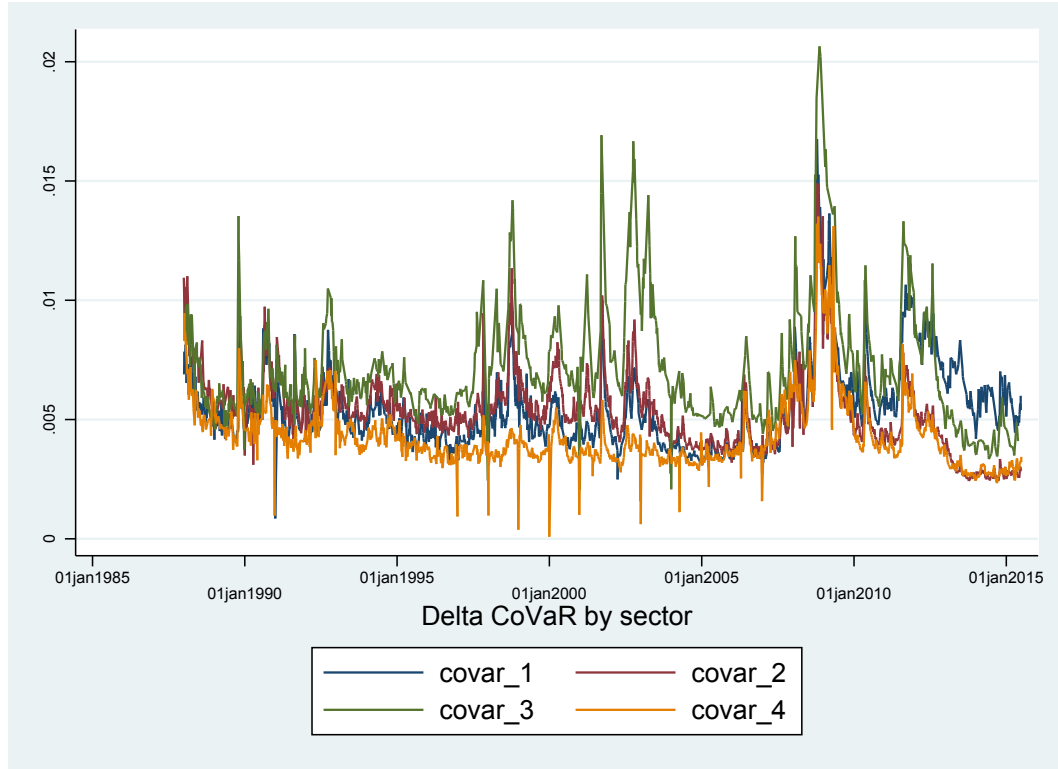


Figure 13: Evolution of systemic risk - Delta CoVaR. The Figure reports the evolution of the daily estimated Delta CoVaR in Equation 8. We report banks (1), diversified financials (2), insurance companies (3) and real estates (4).

Delta CoVaR for the insurance sector follows Delta CoVaR in the banking sector with a small lag. Moreover, Delta CoVaR has been rising between 2002-2005 and again in the European sovereign crisis in 2009-2010. The real estate sector exhibits significant contagion risk only during the European sovereign crisis. Overall, however, Delta CoVaR measures are quite generally highly correlated across sectors.

The most striking differences across intermediary groups can be witnessed in the exposure to systemic risk as demonstrated in Figure 15. SRISK has considerably increased both for banks, around 2001 and again after 2009, and for insurance companies especially after 2002. Moreover, exposure to systemic risk is still increasing in the case of the insurance sector.

To summarize: according to the SRISK measure, the exposure to systemic risk has increased considerably after the implementation of the Basel accord. This finding may seem surprising, since it suggests that the Basel process of

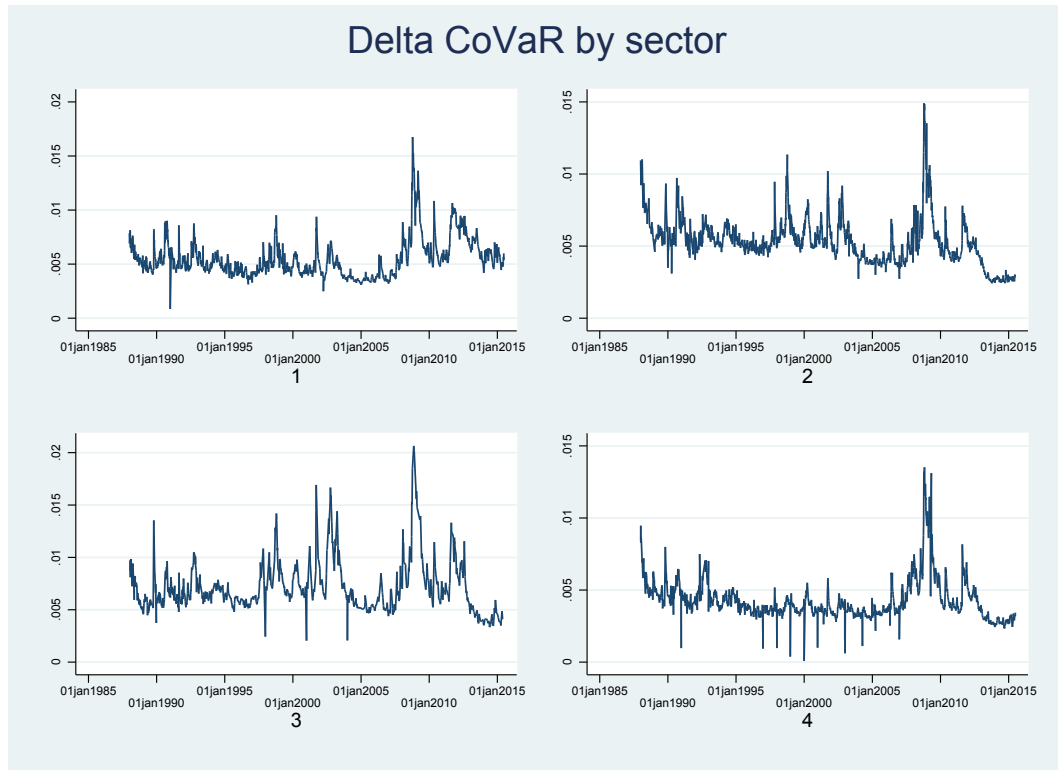


Figure 14: Evolution of systemic risk - Delta CoVaR. The Figure reports the evolution of the daily estimated Delta CoVaR in Equation 8. We report banks (1), diversified financials (2), insurance companies (3) and real estates (4).

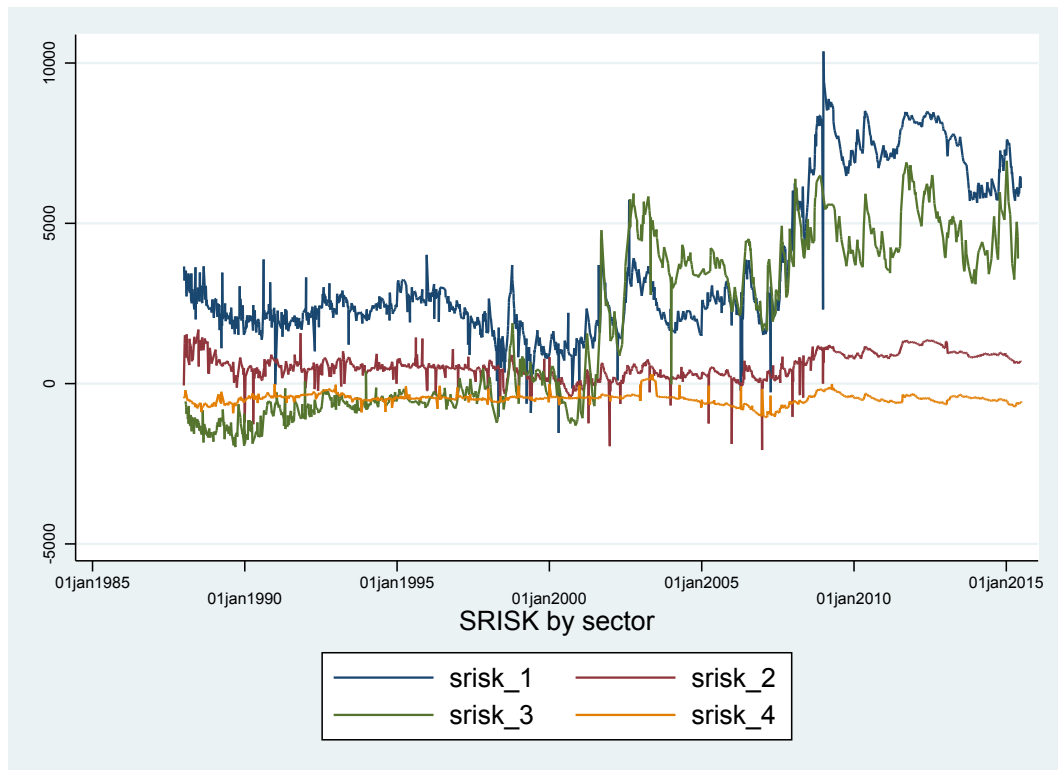


Figure 15: Evolution of systemic risk - SRISK. The Figure reports the evolution of the daily estimated SRISK in Equation 3. The SRISK is estimated by MLE using a GJR-DCC Garch model. We report banks (1), diversified financials (2), insurance companies (3) and real estates (4).

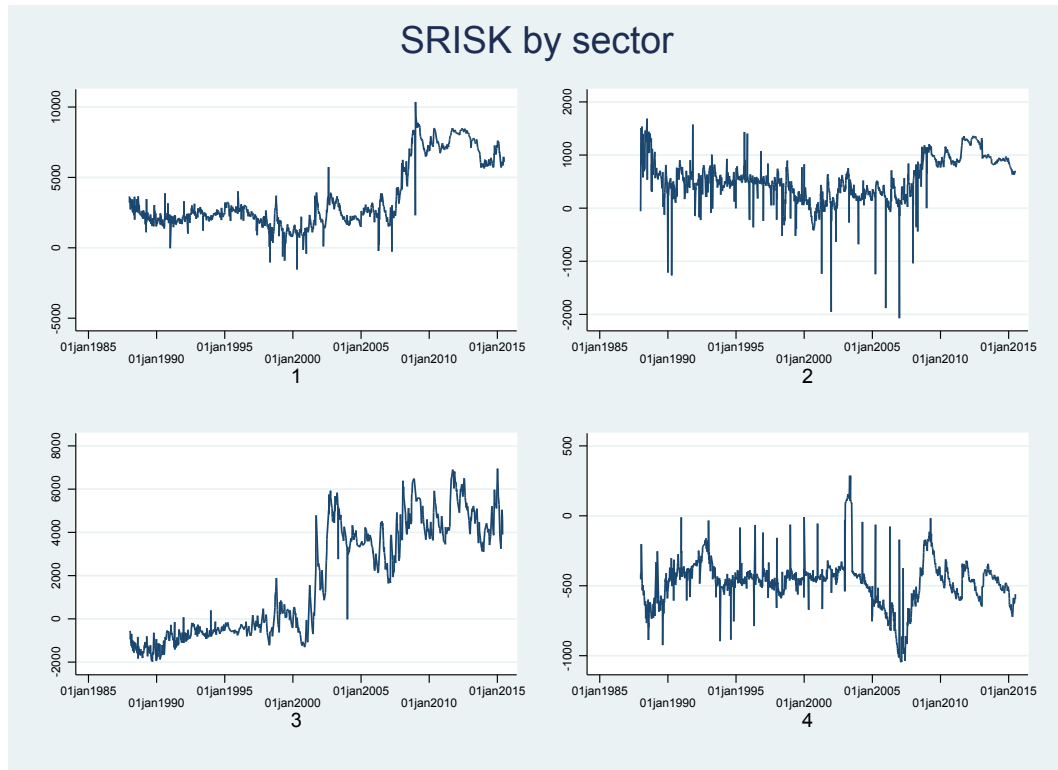


Figure 16: Evolution of systemic risk - SRISK. The Figure reports the evolution of the daily estimated SRISK in Equation 3. The SRISK is estimated by MLE using a GJR-DCC Garch model. We report banks (1), diversified financials (2), insurance companies (3) and real estates (4).

capital regulation has failed to achieve its stated goals of increasing the safety and stability of the banking system. This conclusion is less strict by employing Delta CoVaR as a measure of contributing to systemic risk. However, also Delta CoVaR certainly does not suggest a general reduction of contagion risk during the various stages of the Basel process of capital regulation.

### 4.3 Drivers of Systemic Risk

While the bivariate analysis reveals a systematic and permanent increase in the SRISK measure, it does provide only limited information about the potential drivers of these developments, such as size and some balance sheet items. To analyze the causes of the increase in systemic risk a fully fledged multivariate analysis is required. We regress the estimated SRISK on different cost of equity measures, as well as lagged balance sheet items, including fixed effects and year dummies.

Table 1 shows that SRISK is positively affected by the composite indicator of systemic stress in the overall system. Moreover, it reveals size of the total assets has a strong determinant in all specifications. Therefore, controlling for total assets, we observe that SRISK is contained by investments in loans and, by construction, by the market capitalization of the bank. Non-performing assets are positively related, but unexpectedly are not significant in mean. Systematic risk, as measured by beta and return on equity (ROE), are also significant drivers of SRISK. Counter-intuitively, the cost of bank equity, on the other hand, has a strongly moderating effect on systemic risk. Evidently, it is the low-cost banks that impose the largest contribution to SRISK.

Interestingly, the market risk internal models dummy is positive, suggesting that the market risk amendment of January 1996 has indeed not reduced systemic risk. However, the estimate is lacking significance in one of the specifications, and implies only weak support in another. Moreover, the Basel II dummy (July 2006) has contrasting results across specifications, showing only a weak contribution in reducing systemic risk. These reforms were steered towards improving capital and liquidity positions on banks' balance sheets. The Basel III dummy is instead positive and highly significant in two of the specifications, showing an enhancement of systemic risk and, thus, a reduction in resiliency.

Surprisingly, cost of equity has a moderating effect on SRISK. This contemporaneous effect could, however, result from endogeneity. Well capitalized banks will enjoy lower cost of bank equity and for that reason exhibit lower SRISK.

We then look more carefully at the relation between SRISK and the cost of equity. The VAR-analysis with lags up to four weeks and the Granger causality tests (Tables 2 and 3) reveal that the cost of equity is one of the main drivers

Table 1: Drivers of SRISK

	(1)	(2)	(3)
Beta	1,459*** (311.9)		
ROE		2.347 (2.645)	
Cost of Equity			-2,077** (909.5)
CISS	1,550*** (323.9)	1,717*** (370.9)	754.9*** (276.7)
Tot.Assets	0.0688*** (0.00849)	0.0684*** (0.00916)	0.0686*** (0.00865)
NPA	0.135 (0.135)	0.141 (0.147)	0.147 (0.142)
Equity Securities	-0.0297 (0.0289)	-0.0496 (0.0401)	-0.0317 (0.0304)
Fixed Income Securities	-0.00536 (0.00588)	-0.00683 (0.00890)	-0.00315 (0.00611)
Mark.Cap	-0.569*** (0.0750)	-0.537*** (0.0778)	-0.561*** (0.0788)
Leverage	0.646** (0.252)	-0.344 (0.227)	-0.356 (0.233)
Market Risk Amendment	-175.2 (505.1)	1,041 (654.4)	1,001 (610.1)
Basel 2	-39.07 (34.99)	48.12 (36.09)	80.34** (37.21)
Basel 3	43.04 (126.7)	-74.41 (142.8)	-130.1 (130.8)
Constant	-1,217** (483.6)	-944.9* (499.2)	-700.3* (392.3)
Observations	16,746	13,532	16,745
R-squared	0.825	0.824	0.823
Number of id	400	383	400

Clustered standard errors in parentheses

\*\*\* p&lt;0.01, \*\* p&lt;0.05, \* p&lt;0.1

<sup>a</sup> This table reports the results from the panel regressions of SRISK with fixed effects and year dummies for the individual banks. We regress the SRISK measure on CISS, indicator of systemic stress in the European system (Hollo et al, 2012), cost of equity measures, such as Beta (model 1), CAPM cost of equity (model 3) and ROE (model 2), an internal model dummy from January 1996 and two Basel dummies, Basel II from June 2006 to September 2008, and Basel III from September 2008. The Beta is estimated from a GJR-DCC Garch model between the bank stock returns and the MSCI Europe index. The CAPM cost of equity is the return required by the market applying the time-varying beta to the annual risk premium required on the market return, as Equation 11:  $CostEquity_{it} = R_{ft} + \widehat{beta}_{it} * (R_{mt} - R_{ft})$ . We use the yield on German Bund as risk-free rate. Moreover, we include drivers as total assets, non-performing assets, other investment in equity securities, market capitalization and leverage quantiles.

of SRISK, but not the reverse. Moreover, market capitalization does not significantly affect any of the other measures, else than CISS. By construction the CISS measure does pick systemic risk ex-post, and, in fact it is affected by all our other measures.

While the results on the policy variables seem somewhat inconclusive they could be driven by the non-linearities that we have observed earlier in the discussion of the SRISK measure.

In order to control for potential non-linearities in SRISK, we also present quantile regressions in Table 4. And indeed the quantile regressions contribute to resolving the puzzle on the mean estimations. It turns out that both regulatory instruments, the market risk amendment of Basel I (January 1996) and the implementation of Basel II (July 2006) significantly contributed to reduce systemic risk for the lower quartile, while they contributed gradually less in the upper quartiles.<sup>17</sup> The introduction of modelling market risk internally has effectively increased the contribution to systemic risk in the upper quartile. Basel III moreover is strongly positively increasing SRISK of the bigger systemic contributors. If we combine the overall contribution of Basel II and Basel III dummies, we observe a significant increase of exposure to systemic risk after Basel II, especially for the major banks (by unreported results).

While internal models for measuring market risk contributed to increase resiliency in the safer segment they have contributed to a sizeable build-up of systemic risk precisely in the systemically relevant segment. Hence, after 20 years of evidence, it turns out that Hellwig's (1995) concerns proved right, while Wuffli's (1995) optimism was unfounded. With hindsight, we witness that it was the smaller banks that reduced their systemic risk contribution while the large banks (mis-)used the options offered by the use of internal models to effectively enlarge their systemic risk exposure and reduce their resiliency. Clearly this effect appears as an unintended consequence of the 1996 amendment.

#### 4.4 SRISK and Internal Models of Credit Risk based on Microdata

Overall, so far our results suggest that the January 1996 amendment on market risk had ambiguous effects in reducing systemic risk. While the shift towards internal models apparently was successful in containing systemic risk for small banks, larger banks in the upper SRISK-quartile tended to benefit less, or even exploit market risk internal models to effectively increase their SRISK positions.

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<sup>17</sup>We only report the broad dummy here, since we are still in the process of collecting bank specific implementation dates - more specifically dates for regulatory approval of the respective models - for the Basel I and the Basel II dummies. Preliminary results with the incomplete data set greatly increase the significance of our exogenous variables.



Table 2: VAR results

	(1) SRISK	(2) CISS	(3) Beta	(4) cost_eq	(5) mv
L.SRISK	1.022*** (0.0317)	2.49e-05*** (5.48e-06)	2.53e-06 (6.12e-06)	-1.17e-06 (2.04e-06)	-0.0185 (0.0167)
L2.SRISK	-0.00553 (0.0451)	-1.14e-05 (7.78e-06)	-3.94e-06 (8.69e-06)	-1.34e-06 (2.90e-06)	0.0149 (0.0238)
L3.SRISK	-0.0349 (0.0450)	-1.51e-05* (7.77e-06)	3.69e-06 (8.67e-06)	6.36e-06** (2.89e-06)	-0.000218 (0.0237)
L4.SRISK	-0.00922 (0.0316)	3.16e-06 (5.46e-06)	1.21e-06 (6.10e-06)	-3.74e-06* (2.03e-06)	-0.000669 (0.0167)
L.CISS	114.4 (159.4)	0.628*** (0.0275)	-0.00943 (0.0307)	-0.00733 (0.0103)	-141.8* (84.08)
L2.CISS	-222.6 (186.0)	0.108*** (0.0321)	-0.00759 (0.0358)	-0.000882 (0.0120)	-20.30 (98.08)
L3.CISS	211.3 (185.2)	0.125*** (0.0320)	0.0610* (0.0357)	-0.0285** (0.0119)	193.3** (97.67)
L4.CISS	24.38 (159.2)	0.107*** (0.0275)	-0.0493 (0.0307)	0.0262** (0.0102)	-28.33 (83.93)
L.Beta	411.0*** (146.0)	0.0452* (0.0252)	0.951*** (0.0281)	-0.0220** (0.00939)	76.78 (76.98)
L2.Beta	-409.2** (203.8)	-0.0650* (0.0352)	-0.106*** (0.0393)	0.0184 (0.0131)	-58.11 (107.5)
L3.Beta	-67.61 (203.8)	-0.0480 (0.0352)	0.0954** (0.0393)	0.0130 (0.0131)	66.83 (107.5)
L4.Beta	51.14 (143.0)	0.0630** (0.0247)	-0.0363 (0.0276)	-0.0107 (0.00920)	-131.4* (75.42)
L.cost_eq	-1,360*** (448.0)	-0.327*** (0.0774)	0.0745 (0.0864)	1.078*** (0.0288)	-88.31 (236.3)
L2.cost_eq	1,755*** (650.1)	0.370*** (0.112)	-0.341*** (0.125)	-0.112*** (0.0418)	-146.3 (342.8)
L3.cost_eq	-626.4 (652.1)	-0.0938 (0.113)	0.100 (0.126)	0.0689 (0.0420)	184.9 (343.9)
L4.cost_eq	335.4 (450.2)	0.0445 (0.0777)	0.149* (0.0868)	-0.0665** (0.0290)	42.02 (237.4)
L.mv	-0.120** (0.0596)	-4.58e-05*** (1.03e-05)	-1.67e-05 (1.15e-05)	6.40e-06* (3.84e-06)	1.096*** (0.0315)
L2.mv	0.0818 (0.0890)	2.34e-05 (1.54e-05)	2.18e-05 (1.72e-05)	-4.31e-06 (5.72e-06)	-0.0699 (0.0469)
L3.mv	0.0791 (0.0891)	1.43e-05 (1.54e-05)	-2.42e-05 (1.72e-05)	-7.58e-06 (5.74e-06)	-0.0470 (0.0470)
L4.mv	-0.0397 (0.0596)	1.00e-05 (1.03e-05)	1.86e-05 (1.15e-05)	5.08e-06 (3.83e-06)	0.0138 (0.0314)
Constant	9.137 (28.10)	0.000260 (0.00485)	0.0338*** (0.00542)	0.00436** (0.00181)	40.54*** (14.82)
Observations	1,447	1,447	1,447	1,447	1,447

Robust standard errors in parentheses

\*\*\* p&lt;0.01, \*\* p&lt;0.05, \* p&lt;0.1

<sup>a</sup> This table reports the results from the VAR(4) regressions of weekly average SRISK, weekly CISS of systemic stress, market capitalization, and the weekly average cost of equity measures, such as the time-varying Beta from the GJR-DCC Garch model between the bank stock returns and the MSCI Europe index, the CAPM cost of equity as the return required by the market applying the time-varying beta to the annual risk premium required on the market return. We also include market capitalization as one of the main components of the SRISK measure.

Table 3: Granger causality test

Equation	Excluded	chi2	df	pvalue
SRISK	CISS	6.8474	4	0.1442
	Beta	9.2071	4	0.0561
	Cost of equity	12.0403	4	0.0171
	Mark.Cap	5.1748	4	0.2698
	all	32.0944	16	0.0097
CISS	SRISK	27.1135	4	0.0000
	Beta	12.7527	4	0.0125
	Cost of equity	18.5260	4	0.0010
	Mark.Cap	33.0954	4	0.0000
	all	100.1145	16	0.0000
Beta	SRISK	6.4255	4	0.1695
	CISS	3.8728	4	0.4235
	Cost of equity	14.4944	4	0.0059
	Mark.Cap	5.0332	4	0.2839
	all	42.1543	16	0.0004
Cost of equity	SRISK	5.4548	4	0.2437
	CISS	17.0217	4	0.0019
	Beta	7.4761	4	0.1128
	Mark.Cap	6.2956	4	0.1781
	all	34.7249	16	0.0043
Mark.Cap	SRISK	2.3677	4	0.6685
	CISS	6.2781	4	0.1793
	Beta	6.2356	4	0.1822
	Cost of equity	1.2323	4	0.8728
	all	18.9754	16	0.2699

<sup>a</sup> This table reports the Granger causality test results from the VAR(4) regressions of weekly average SRISK, weekly CISS of systemic stress, market capitalization, and the weekly average cost of equity measures, such as the time-varying Beta from the GJR-DCC Garch model between the bank stock returns and the MSCI Europe index, the CAPM cost of equity as the return required by the market applying the time-varying beta to the annual risk premium required on the market return. We also include market capitalization as one of the main components of the SRISK measure.

Table 4: Quantiles Regressions

	(1) Q.25	(2) Q.50	(3) Q.75
Beta	108.6*** (13.66)	76.34*** (10.34)	36.62*** (10.80)
CISS	103.5*** (16.00)	86.89*** (12.29)	63.96*** (12.12)
Tot.Assets	0.0791*** (0.000728)	0.0822*** (0.000308)	0.0854*** (0.00289)
NPA	0.00915*** (0.00233)	-0.00651* (0.00368)	-0.0200 (0.0544)
Equity Securities	0.0247*** (0.00308)	0.0314*** (0.00148)	0.0313 (0.0388)
Fixed Income Securities	-0.00359*** (0.00106)	-0.0112*** (0.000448)	-0.0178*** (0.00375)
Mark.Cap.	-0.803*** (0.0237)	-0.752*** (0.00624)	-0.671*** (0.00620)
Leverage	0.0745*** (0.0172)	0.0497*** (0.00726)	0.0333*** (0.00854)
Market Risk Amendment	-20.52* (12.06)	4.101 (10.53)	20.61* (10.95)
Basel 2	-13.80*** (4.711)	-5.467 (3.598)	-1.539 (1.761)
Basel 3	-24.86*** (6.388)	-13.79** (5.918)	12.76 (10.24)
Constant	-61.38*** (13.02)	-49.68*** (11.89)	-43.31*** (11.94)
Year effects	yes	yes	yes
Observations	16,746	16,746	16,746

Clustered standard errors in parentheses

\*\*\* p&lt;0.01, \*\* p&lt;0.05, \* p&lt;0.1

<sup>a</sup> This table reports the results from the .25, .50 and .75 quantile regressions of SRISK. We regress the SRISK measure on the CISS indicator of systemic stress, the Beta, the internal model dummy from January 1996, the Basel II dummy from June 2006 and the Basel III dummy for September 2008. The Beta is estimated from a GJR-DCC Garch model between the bank stock returns and the MSCI Europe index. We control for year effects, total assets, non-performing assets, market capitalization and leverage quantiles. The standard errors are clustered for banks (Parente et al. 2016).

Clearly, the aggregate risk enhancing effect dominated the intentional gains on the smaller and less risky banks.

Let us now turn to credit risk. One of the pillars of Basel II is the option to widen the scope for internal models also to cover credit risks. While at this stage we do not have sufficiently many (micro) data on the implementation or approval of internal models for market risk, such micro information about approval and/or adoption of internal credit rating models is available for a subsample of 83 European banks.<sup>18</sup>

Accordingly, let us now investigate the relation between SRISK and Basel regulation on the basis of the available bank-level data on the implementation of internal credit risk models. The variable IRBA takes the value 0 before 2006, the value 1 for standardized Basel models and the value 2 for internal models for credit risk). We report the results in Table 5.

On the basis of the weekly panel mean regressions it seems that internal models do exert a significant and positive effect on exposure to systemic risk. The consideration of standard risk models did not significantly contribute to systemic risk. These results are robust with respect to different measures of systematic risk or cost of capital. This evidence stands in stark contrast to the original goals of the Basel Committee in strengthening the safety and soundness of banks.

In order to address the non-linearities identified in the previous analysis we divide our sample into five separate risk buckets with increasing systemic riskiness. In other words, we run separate panel regressions for the SRISK quintiles. (Table 6).

As before we now find a more nuanced picture of market reactions to the regulatory process. In the smallest risk bucket the introduction of the standardized approach for credit risk did contribute to the desired goal of reducing the exposure to systemic risk. But this low risk quintile appears as the only quintile where the intended effect can be identified.

In this subsample internal models always contributed to increasing exposure to systemic risk. Internal models for market risk positively contributed to SRISK in the lowest quintiles as well as in the second highest. Internal models of credit risk did greatly contributed to increasing the exposure to systemic risk

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<sup>18</sup>We are in the process of extending this dataset to all banks. The SNL dataset is relatively small for European banks and needs to be complemented by search for hand-collected implementation dates for the institutions not reported in SNL. We gratefully acknowledge the support of the Bundesbank and the Bank of England in providing the data for all banks in their respective countries. The current subsample is already large enough to allow for meaningful analyses. Behn and Haselmann (2014) analyse an even smaller subsample of German banks.

Table 5: Weekly Panel Regressions

	(1)	(2)	(3)
Beta	2,873*** (866.5)		
Cost of Equity		-8,874*** (2,827)	
Delta CoVaR			478,518*** (118,506)
CISS	7,163*** (2,069)	3,463** (1,377)	2,559* (1,301)
MSCI Europe return	-1,157 (5,826)	14,770** (6,460)	11.99 (6,540)
EU Policy rate	-6,771 (11,185)	-32,993** (12,832)	-1,193 (10,646)
1.IRBA Standardized	546.5 (1,226)	484.8 (1,263)	74.82 (1,261)
2.IRBA Internal models	17,219*** (4,778)	17,881*** (4,736)	16,186*** (4,568)
Market Amendment	8,677*** (3,153)	6,859** (2,906)	10,080*** (3,403)
Basel 2	305.1 (305.2)	653.4** (314.0)	363.9 (315.2)
Basel 3	134.3 (707.7)	-313.2 (756.9)	-615.8 (784.2)
Constant	-8,908** (3,416)	-4,715* (2,775)	-9,998*** (3,632)
Firm and Year Effects	yes	yes	yes
Observations	10,002	10,002	10,002
R-squared	0.341	0.342	0.356
Number of gvkey	83	83	83

Clustered standard errors in parentheses

\*\*\* p&lt;0.01, \*\* p&lt;0.05, \* p&lt;0.1

<sup>a</sup> This table reports the results from panel regressions of SRISK. We regress the SRISK measure on the CISS indicator of systemic stress, the Beta, the internal model dummy from January 1996, the Basel II dummy from June 2006 and the Basel III dummy for September 2008. The Beta is estimated from a GJR-DCC Garch model between the bank stock returns and the MSCI Europe index. We control for year effects, total assets, non-performing assets, market capitalization and leverage quantiles. The standard errors are clustered for banks (Parente et al. 2016).

for the highest risk group, and hence, the most systemic banks.

This finding is confirmed also in proper quantile regressions without an exogenous allocation of banks into the different risk buckets. In Table 7 we report significant positive contributions of internal credit risk models. Moreover, these effects on risk exposure are increasing in the risk group. With the quantile regressions, however, the effect of internal models for market risk and the introduction of the standardized approach to credit risk get reversed. While the former do not appear to contribute to exposure to systemic risk anymore, the standardized approach now appears to contribute to systemic risk.<sup>19</sup>

In sum, we find no evidence that the introduction of internal models did succeed to increase bank resiliency, neither in the case of market models introduced in 1996 under Basel I, nor in the case of credit risk models introduced in 2006. The disgression given to the regulated banks apparently, while in compliance with statutory regulation, did not stop banks from engaging in (sophisticated) risk taking activities.

We thus confirm the empirical results of Behn and Haselmann (2014) about the unintended consequences of internal models for credit risk for German banks and extend them to European banks and financial institutions. Moreover, we find that the risk enhancing effect of internal models for credit risk are increasing in the systemical importance of banks; in larger and more systemic banks internal models contribute more strongly to an increase in SRISK of European banks and across risk classes. Based on our results the concerns raised about Basel II by Danielson et al. (2001) seem more than justified. By neglecting the endogeneity of systemic risk, Basel II regulation did not succeed to reduce systemic risk ironically precisely in those sectors that turned out to become the most vulnerable ones.

The implementation of Basel II in July 2006 has contributed to moderate the build-up of systemic risk. However, the moderating effect is less striking for precisely the major contributors to systemic risk. In this regard, the speculation of Hakenes and Schnabel (2011) is not supported by the data. Based on theoretical considerations Hakenes and Schnabel argue that the IRB-approach of Basel II induced smaller and medium-sized banks to take larger risks in order to compete effectively with larger banks employing the IRB-approach. We find that their basic assumption that IRB contributes positively to larger banks is not supported by the data.<sup>20</sup>

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<sup>19</sup>We intend to scrutinize these results by complementing our data with the specific timing of the supervisory approval of internal models for market risk.

<sup>20</sup>Even if the competitive effect of Hakenes and Schnabel (2011) is relevant at all, our evidence suggests that the direct (negative) implications for banks' risk management are dominant. However, our findings about the effects of internal models suggest that the assumption of an increase in resiliency or the largest banks due to the use of risk-models is not supported

Table 6: Weekly Panel Regressions per SRISK group

	(1)	(2)	(3)	(4)	(5)
	SRISK Gr1	SRISK Gr2	SRISK Gr3	SRISK Gr4	SRISK Gr5
Beta	56.16*** (19.18)	214.4* (105.5)	604.1*** (164.9)	2,664*** (915.1)	-47.68 (2,850)
CISS	231.4*** (70.82)	659.8*** (213.7)	2,085*** (502.9)	7,500*** (1,775)	30,667*** (9,234)
MSCI Europe return	-463.8 (478.1)	-825.4 (1,278)	4,991* (2,822)	-37,576* (21,022)	55,486** (23,831)
EU policy rate	1,120 (805.6)	-1,607 (3,191)	-19,134 (14,281)	-34,007 (43,978)	-15,929 (86,074)
1.IRBA Standardized	-106.8* (55.49)	171.2 (206.6)	305.0 (533.4)	1,966 (3,692)	15,638 (14,799)
2.IRBA Internal models	9.667 (76.23)	-281.5 (261.1)	901.4 (627.3)	4,681 (2,928)	49,314*** (13,666)
Market Amendment	406.3*** (120.3)	623.9** (259.2)	683.0 (858.2)	18,568** (6,802)	-3,743 (18,205)
Basel 2	-24.66 (75.26)	-2.618 (85.59)	2.060 (188.1)	994.8 (4,487)	-814.3 (4,151)
Basel 3	-88.67 (83.04)	37.63 (156.7)	-38.30 (236.0)	1,064 (4,926)	-7,263 (6,328)
Constant	70.84 (85.98)	393.1 (340.9)	2,080* (1,130)	-7,566 (5,180)	2,145 (12,964)
Firm and Year Effects	yes	yes	yes	yes	yes
Observations	422	685	1,096	1,106	1,359
R-squared	0.460	0.414	0.438	0.615	0.582
Number of gvkey	32	32	38	30	24

Clustered standard errors in parentheses

\*\*\* p&lt;0.01, \*\* p&lt;0.05, \* p&lt;0.1

<sup>a</sup> This table reports the results from the panel regressions performed separately on five quintiles of SRISK contribution (such as Equation 6). We regress the SRISK measure on the CISS indicator of systemic stress, the Beta, the bank-level IRBA dummy from January 2007, the Market Risk amendment dummy from January 1996, the Basel II dummy from June 2006 and the Basel III dummy for September 2008. The Beta is estimated from a GJR-DCC Garch model between the bank stock returns and the MSCI Europe index. We control for market investment opportunities, proxied by the European equity market return and policy rate. The standard errors are clustered for banks (Parente et al. 2016).

Table 7: Weekly Quantile Regressions

	(1) Q.25	(2) Q.50	(3) Q.75
Beta	389.0 (262.5)	1,044 (712.0)	4,020** (1,648)
CISS	254.4** (102.3)	363.6** (163.5)	581.4 (628.7)
MSCI Europe return	-168.4 (626.7)	-419.5 (926.9)	-2,103 (2,493)
EU Policy rate	-4,180** (1,875)	-483.1 (2,037)	5,573 (16,584)
1.IRBA Standardized	272.7** (117.5)	299.8 (238.9)	642.3*** (229.0)
2.IRBA Internal models	2,516 (2,167)	6,650** (3,255)	34,269** (16,751)
Market Amendment	-224.0 (429.2)	-199.6 (339.8)	-995.9 (1,338)
Basel 2	-123.5 (125.4)	-19.35 (84.58)	-254.9 (167.0)
Basel 3	-43.20 (146.3)	51.52 (92.55)	-5.957 (328.3)
Constant	347.3 (518.8)	455.9 (458.4)	2,812 (2,336)
Year Effects	yes	yes	yes
Observations	10,002	10,002	10,002
R-squared	0.213	0.232	0.229
Clustered standard errors in parentheses			
*** p<0.01, ** p<0.05, * p<0.1			

<sup>a</sup> This table reports the results from the .25, .50 and .75 quantile regressions of SRISK. We regress the SRISK measure on the CISS indicator of systemic stress, the Beta, the bank-level IRBA dummy from January 2007, the Market Risk amendment dummy from January 1996, the Basel II dummy from June 2006 and the Basel III dummy for September 2008. The Beta is estimated from a GJR-DCC Garch model between the bank stock returns and the MSCI Europe index. We control for market investment opportunities, proxied by the European equity market return and policy rate. The standard errors are clustered for banks (Parente et al. 2016).



If we consider the effect of Basel III separately, we see that the regulatory principles did not help to prevent the unfolding of the last crisis, and SRISK has significantly increased across all quantiles. This effect may be the consequence of the crisis rather than the dampening Basel III interventions that are still in the process of implementation.<sup>21</sup> Hence, during the course of Basel I to Basel III reforms the resiliency of the European banking system has declined considerably throughout. Despite the Basel III reforms, it has not retreated even closely to pre-Basel-I levels.

In summary, the intended consequences of the Basel regulation were achieved only for the safer banks, but ironically they were missed for the riskier banks. Obviously, banks' strategic incentives were not properly understood and the substitutability between capital rules and state guarantees was seriously underestimated throughout the various levels of the Basel process of capital regulation. Consequently, it was especially the systemic European banks that were ill prepared to deal with the subprime crisis in 2007 and even more in the subsequent European sovereign crisis.

## 5 Unintended Consequences

While the Basel process of capital regulation was designed to increase the stability and safety of the global banking system, we provide evidence that it did not succeed to achieve this aim in its first two decades of operation. While providing increasing incentives for prudent in-house risk management over time, regulators effectively also tolerated carve-outs of bank equity, and thus a serious decline in resiliency, particularly for the large and systemically most important banks after 2005. This is consistent with the view that risk models were chosen strategically (see Behn, Haselmann and Vig (2014) and Colliard (2015), but also Admati and Hellwig (2013).) Ironically, these carve-outs were one way of increasing return on equity through extensive stock repurchases at a time, when the cost of bank equity was actually low, and strengthening capitalization and resiliency was relatively cheap (in historical context).<sup>22</sup> Certainly, these reactions should be viewed as unintended consequences of the Basel process of capital regulation but they prove right the concern of Danielson et al. (2001) that the neglect of endogeneity of systemic risk being a major concern of the Basel II approach.

On the basis of our analysis it is not necessarily that capital rules per se were insufficient; it is rather the possibility to reduce effective capitalization by

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by the data. In this regard, also Colliard (2015) has investigated theoretically the impact of internal models on the risk-taking behaviour of banks.

<sup>21</sup>In unreported work we find that it we do not separate between Basel II and Basel III the combined effect of the two is significantly positive throughout the whole distribution. One way of reading this is that the combined of Basel II adoption and the consequent crisis had a negative effect on overall bank resiliency.

<sup>22</sup>Baron and Xiong (2014) provide a behavioural explanation based on over-optimism.

means of complex risk models under supervisory approval that causes the lack of resiliency. Our finding accords well with Miles et al. (2012). They seem to contradict Jackson (2015) in the sense that simple models, even at sub-optimal levels in terms of efficiency, may be more suitable to limit risks and, hence, safeguard resiliency.

There are even wider implications of the Basel process of capital regulation on the whole financial sector (Gehrig, Iannino, 2016). For example, the build-up of systematic risk in the insurance sector, while not as dramatic as in the banking sector, also significantly moves upwards with a structural break around 1996. Possibly these developments also exhibit unintended consequences across markets and industries. Hence, it should be illuminating to analyze the systemic consequences of the capital accord on the whole financial system in order to account for market feedback, both in the regulated as well as the unregulated segments.

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