Global analysis of the determinants of systemic risk during the Global Financial Crisis of 2008 and the European Sovereign Debt Crisis

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CATÓLICA-LISBON School of Business and Economics

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by Dominik Henzler

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Abstract

This Dissertation aims to provide a differentiated answer to the research question "What drives banks' contribution to systemic risk during periods of financial turmoil?" This research also distinguishes between contribution to local and contribution to global systemic risk in order to shed light on how banks' contribution to systemic risk differs across various regions. A sample of international banks covering 39 countries is analyzed for this purpose. The selected crisis periods are the Global Financial Crisis around the collapse of Lehman Brothers in 2008, as well as the first and the second peak of the European Sovereign Debt Crisis in 2010 and 2011 respectively. Supporting conjectures from earlier risk literature, several bank-specific accounting variables are found to enable banks' contribution to systemic risk during the Global Financial Crisis in 2008. More precisely, the size of a bank and its market-to-book ratio are found to be positively related to systemic risk while a bank's profitability is found to be negatively related. In addition, more powerful regulatory supervisors are found to be negatively related to systemic risk while greater capital stringency imposed by regulators is found to be negatively related to systemic risk. However, most of the variables lose their statistical significance during the European Sovereign Debt Crisis, which supports previous findings suggesting that drivers of systemic risk vary over crisis periods and might even be unique to each crisis episode.

[…]

Keywords: Marginal Expected Shortfall, Financial Crises, Systemic risk, International Banks

J.E.L Classifications: G01, G21, F30

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Resumo

Esta Dissertação tem como objetivo fornecer uma resposta diferenciada à pergunta de pesquisa "Quais os determinantes da contribuição dos bancos para o risco sistémico durante períodos de instabilidade financeira?" Esta investigação efectua igualmente uma distinção entre contribuição para o risco sistémico local e global, a fim de esclarecer como é que a contribuição dos bancos para o risco sistémico difere nas várias regiões. É analisado, para este fim, uma amostra de bancos internacionais que abrange 39 países. Os períodos de crise selecionados são a Crise Financeira Global em torno do colapso da Lehman Brothers em 2008, assim como o primeiro e o segundo pico da Crise das Dívida Soberana europeia nos anos de 2010 e 2011, respetivamente. Como complemento das conjeturas da literatura de risco anteriormente elaboradas, várias variáveis contabilísticas específicas dos bancos influenciam a contribuição dos bancos para o risco sistémico durante a Crise Financeira Global de 2008. Mais precisamente, a dimensão do banco e o rácio 'market-to-book' do mercado bancário estão positivamente relacionados com o risco sistémico, enquanto que a rentabilidade de um banco está negativamente relacionada. Além disso, os supervisores regulatórios mais poderosos estão negativamente relacionados ao risco sistémico, embora o major rigor dos requisitos de capital impostos pelos reguladores também seja considerado estar negativamente relacionado ao risco sistémico. Contudo, a maior parte das variáveis perde a sua significância estatística durante a crise da Dívida Soberana europeia, o que suporta as descobertas científicas anteriores, que sugerem que os fatores de risco sistémico variam ao longo dos períodos de crise e possam até ser exclusivos para cada uma das crises.

[…]

Palavras-chave: Marginal Expected Shortfall, crises financeiras, risco sistémico, banco internacionais

Classificações: J.E.L.: G01, G21, F30

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1 Introduction

This research analyzes key drivers of banks' contribution to both local and global systemic risk during recent prominent crisis periods on a global level. More precisely, the Global Financial Crisis around the collapse of Lehman Brothers in September 2008, as well as the first peak of the European Sovereign Debt Crisis around the Greek bailout agreement in May 2010 and the second peak of the European Sovereign Debt Crisis around the Greek austerity package in June 2011 are carefully analyzed.

In the academic literature systemic risk is defined as the risk of either malfunctions within the system or external shocks causing breakdowns in the entire regional or global economy, in contrast to the failure of just a few institutions (Kaufmann and Scott, 2003). It is characterized by co-movements among most or all institutions of the system, either due to a shock producing nearly simultaneous adverse effects on the entire economy, or by an event initiating a series of successive losses along a chain of institutions or markets (Kaufmann and Scott, 2003). As noted by Moreno and Peña (2012), the malfunctions and macro-shocks causing breakdowns can be related to a great variety of mechanisms. The latter range from excessive credit expansion or correlated exposures and asset bubbles to negative externalities arising from banks considered "too big to fail" for instance, or from information disruptions causing freezes in the interbank market. In this regard, it is of particular interest for regulators whether the determinants of banks' contribution to systemic risk persist over breakdowns related to these various types of shocks and malfunctions. If this is the case, regulation authorities could identify the most systemically important banks and take preventive actions. Lowering banks' contribution to systemic risk in the financial sector is of key interest, since, as shown by Klingbiel et al. (2007) and Chava and Purnanandam (2011) among others, banking crises have a real impact on the growth in other sectors and can spread over the entire economy. From 2008 on, when large banks stood in the center of the financial crisis and revealed shortcomings in systemic risk regulation, the debate on determinants of banks' contribution to systemic risk has intensified, involving more and more academics, economists and regulators. In fact, in the aftermath of the Global Financial Crisis in 2008, regulators around the world introduced new regulatory tools to lower the likelihood of bank failures, such as the Basel III protocol, restrictions on loan-to-value ratios for bank loans to particular sectors, and the accounting standard IFRS10, making it more difficult to hide risk off balance sheet for instance (Benoit et al., 2015). In addition, the said crisis led to the restructuring of

bank supervision in Europe and in the U.S. towards a more centralized architecture, with more power for the Federal Reserve and the European Central Bank (Benoit et al. (2015).

To measure banks' contribution to systemic risk, the Marginal Expected Shortfall (MES) measure proposed by Acharya (2010) is applied in this study. This measure is defined as the expected loss on a given bank´s equity return when the aggregated market experiences outcomes below a critical threshold over a selected time period. Accordingly, the main research question associated with this Dissertation thus addresses whether differences in this measure between pre- and post- crisis periods can be explained by a set of bank-specific accounting variables, regulatory variables accounting for differences in bank regulation across countries as well as a set of standard macroeconomic control variables. First, it is investigated whether the Marginal Expected Shortfall captures increases in local and global systemic risk during the selected crisis periods, and how banks' contribution to systemic risk differs across various regional areas. In a second step, cross-sectional regressions are estimated for each crisis period respectively, in order to identify determinants of banks' contribution to systemic risk, and to observe whether there exists any persistency among them. The findings suggest that several bank-specific and regulatory variables explain banks' contribution to both global and local systemic risk during the Global Financial Crisis of 2008. More precisely, bank size, the market-to-book ratio and the power of supervisor authorities are positively related to systemic risk. While a bank´s operating profit margin and the capital stringency imposed by regulatory regimes are negatively related to systemic risk. However, most of these variables lose their significance during the European Sovereign Debt Crisis, supporting previous findings sustaining that drivers of systemic risk vary across crisis periods.

This study is most closely related to Bostandzic et al. (2014), who analyze determinants of banks' contribution to systemic risk for numerous periods of international financial turmoil, ranging from the Mexican Peso crisis in 1994, over the terroristic attacks in 2001 to the Global Financial Crisis in 2008. However, their research does not cover an analysis of the more recent European Sovereign Debt Crisis, which is appropriately included in the present research.

This Dissertation is organized as follows: section two reviews some important related literature, section three explains the data used and the methodology applied in this research, section four provides an overview of the independent variables, section five

describes and discusses descriptive statistics, section 6 discusses the findings associated with this research, and, lastly, section 7 contains the conclusion.

2 Literature Review

The Global Financial Crisis in 2008, followed by the most severe global economic slowdown since the Great Depression, was a sterling example of financial contagion and risk spillovers across financial institutions (e.g. Chakrabarty and Zhang (2012), Dumontaux and Pop (2013), Longstaff (2010)). This extreme financial event motivated a great deal of academic studies to propose new ways of measuring systemic risk and to identify the key drivers of systemic risk during periods of financial turmoil. Size, leverage, and non-interest income are among the most prominently cited determinants of banks' contribution to systemic risk in the literature that emerged after the said financial crisis. These determinants have been found to be persistent drivers of systemic risk across various time periods and geographical areas as well as for an increasing variety of systemic risk measures.

Hovakimian et al. (2012) analyze variation in systemic risk at U.S. commercial banks with at least one million dollars in total assets during 1974 to 2010, using a measure of systemic risk that is based on the Merton model. Merton (1974) assumes that firms default if the asset value becomes lower than the face value of debt. Merton (1974) further shows that, whenever a firm`s equity value reaches zero, the corresponding shareholders have already lost everything and, as the limited liability principle states that shareholders are not obligated to put down extra capital, stockholders' stakes in such a firm can be viewed as a call option on firm assets. Risky debt then might be viewed as the value of risk-free debt plus a short put option on the firm´s assets. Hovakimian et al. (2012) divide the value of this limited liability put option by the face value of the banks' debt to obtain the fair value of the annual premium for insuring one dollar of debt against creditor losses due to default. In a subsequent step, these authors estimate this insurance premium measure for a value-weighted portfolio containing all sampled U.S. banks. Finally, the authors calculate the contribution of bank i to systemic risk as the difference between the insurance premium for the portfolio that includes bank i, and the insurance premium for the portfolio that excludes bank i. The authors estimate the annualized quarterly value of this systemic risk measure to construct a quarterly time series of this measure over the period from 1974 to 2010. The authors find that systemic risk reached unprecedented

highs during the financial crisis years 2008-2009, and that bank size, leverage, and asset risk are key drivers of systemic risk.

Brunnermeier et al. (2019) focus on publicly traded bank holding companies in the U.S. for a sample period from 1986 to 2008 and measure an individual bank´s contribution to systemic risk using the ΔCoVaR measure. The authors define this measure as the difference between the value at risk (VaR) of the overall financial system conditional on bank i being in distress, and the value at risk of the financial system, conditional on bank i performing in its median state. They find that banks with higher non-interest income, higher leverage, and larger total assets, as well as higher market-to-book ratio, contribute more to systemic risk.

De Jonghe (2009) finds similar results for listed European commercial banks and bank holding companies over the period from 1992 to 2007. The author measures systemic risk using tail-β estimates defined as the co-crash probability of a given bank and the overall banking sector. By running regressions of the tail-β estimates on a set of bank-specific variables, the author finds that this measure is increasing with a given bank´s size, leverage, and non-interest income. In addition, Black et al. (2016) analyze European banks that were included in the stress tests conducted by the European Banking Authority (EBA) in July 2011. The authors' analysis refers to a period from January 2001 to January 2013, thus covering both the Global Financial Crisis and the European Sovereign Debt Crisis. They measure systemic risk as a hypothetical distress insurance premium against catastrophic losses in the banking system, which is derived from credit default swaps, equity return correlations and a bank`s total liabilities. The authors find that size and leverage can forecast increases in systemic risk for European banks during both the Global Financial Crisis and the European Sovereign Debt Crisis. Moreover, Keasey and Vallascas (2012) also find supporting results for a sample of banks selected from 17 European countries that have been listed over the period from 1992 to 2008, using an alternative measure to address a bank`s contribution to systemic risk. Initially, they estimate daily values of the distance-to-default at the bank level, expressing the number of standard deviations that the market value of bank assets is above the default point where the market value of assets is below the book value of total liabilities. In a second step, they estimate the distance-to-default of the aggregate financial market, which they define for each bank as the weighted average of the distance-to-default of the remaining

banks in the sample. Then they measure a bank`s contribution to systemic risk as the slope coefficient of the regression of the daily relative change in bank i´s distance-to-default on the overall distance-to-default of the aggregate market. Accordingly, the authors are able to describe how the default risk of bank i reacts to changes in the risk of the banking system, with higher values denoting larger exposure to systemic shocks. By running OLS regressions of this slope coefficient on a broad set of bank characteristics, the authors find that bank size, the share of non-interest income and asset growth are key determinants of a bank's risk exposure.

The vast majority of empirical studies concerning banks' contribution to systemic risk have focused on developed markets either in North America or in Europe. Significantly less have aimed to analyze banks' contribution to systemic risk on a global level. One of the rare studies which does so is Laeven et al. (2016). They construct a local sample using publicly listed financial institutions available in the Bankscope database, in order to analyze systemic risk from the middle of 2007 to the end of 2008. They measure systemic risk using the ΔCoVaR measure and the SRISK index, which they define as the expected capital shortage faced by a given bank when the aggregate market declines substantially following the approach advanced by Brownlees and Engle (2012). Laeven et al. (2016) find that systemic risk grows with banks' size and bank capital, irrespective of which particular systemic risk measure is actually being used. In addition, Engle et al. (2014) construct a sample covering 38 countries including 191 banks, each with a market capitalization above five billion U.S. dollars. The authors address the period from 1996 to 2010 and measure banks' contribution to systemic risk by using the Marginal Expected Shortfall measure initially proposed by Acharya et al. (2010). Engle et al. (2014) define this measure as the expected loss on the equity return of bank i when the aggregate market experiences outcomes below a critical threshold during the selected time period. The authors find that non-interest income is significantly and positively associated with systemic risk.

Besides bank-specific accounting variables, there has been increasing evidence in support of the argument that differences in supervisory and regulatory regimes across countries constitute major determinants for financial stability and systemic risk. Beltratti and Stulz (2011) measure bank performance during the Global Financial Crisis, using buy-and-hold dollar stock returns over the period from July 2007 to the end of 2008, based on data obtained from Bankscope. For financial institutions with total assets above ten billion

U.S. dollars, the authors find that banks in countries with more powerful supervisors had worse stock returns between July 2007 and December 2008, suggesting that, during the crisis, stronger supervisors took more corrective measures that were costly for shareholders. Andriosopoulos et al. (2015) use the Marginal Expected Shortfall as a dependent variable, in order to measure banks' contribution to systemic risk during the Global Financial Crisis (onwards 2008) and the European Sovereign Debt Crisis (in 2011-2012), for a cross-section of global banks. They demonstrate that capital regulation and activity restrictions are negatively related to banks' contribution to systemic risk.

Bostandzic et al. (2014) also conduct a global study that analyzes the impact of both bank specific accounting variables and differences in cross-country regulatory regimes on banks' contribution to systemic risk. The authors also analyze the determinants of the contribution of international banks to both global and local systemic risk, in order to shed light on the degree at which market disturbances spread over different geographical areas and financial markets. Their research covers several prominent financial crises. Using pre- and post-crisis period differences in connection to the Marginal Expected Shortfall measure as a dependent variable, they find contrasting empirical evidence as follows. While for the Global Financial Crisis starting in 2008 many idiosyncratic variables and characteristics of regulatory systems can explain the cross-sectional variation in banks' contributions to systemic risk, for prior crisis periods like the East Asia crisis in 1997 or the Dotcom bubble in 2000, either accounting variables cannot explain banks' contribution to systemic risk or these variables lose their statistical and economic significance when shifting focus from local to global systemic risk. However, their analysis does not cover the more recent European Sovereign Debt Crisis. In the present research, their analysis of the determinants of banks' contribution to both local and global systemic risk is extended to include the European Sovereign Debt Crisis.

The literature on banks' contribution to both local and global systemic risk, is nevertheless still missing a global analysis, covering more recent periods of financial turmoil subsequent to the Global Financial Crisis in 2008. Researches that analyze determinants of systemic risk on a global level and distinguish between contribution to local and global systemic risk are still particularly rare to this date. The present Dissertation provides further evidence for the main drivers of banks' contribution to systemic risk on a global level and distinguishes between local and global systemic risk

in order to shed light on how the degree at which market disturbances spread over different geographical areas and financial markets. Therefore, the present Dissertation extends the existing academic literature on the fundamental analysis of banks' contribution to both local and global systemic risk by expanding the analysis across several financial crises, specifically including the European Sovereign Debt Crisis.

3 Methodology & Data Section

This section defines the selection of crisis dates, the pre-and post-crisis periods for the Global Financial Crisis in 2008 and the first and second phases of the European Sovereign Debt crisis. It further describes the sample design and explains the systemic risk measure herein used.

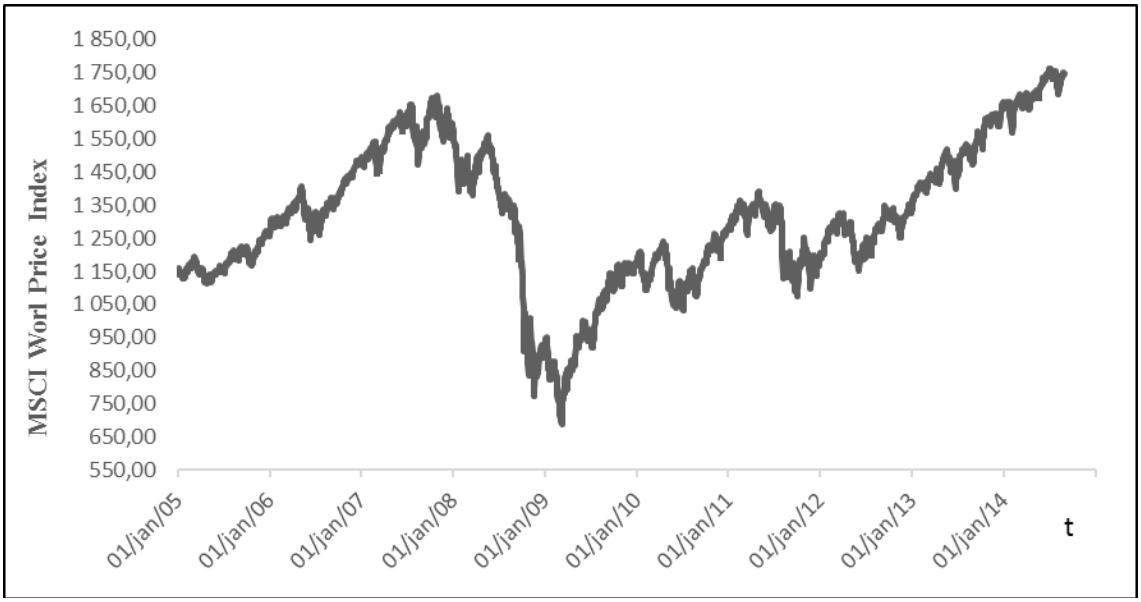
3.1 Selection of crisis events

As a first step, the starting dates of the selected financial contagion periods are adequately identified. For the Global Financial Crisis in 2008, the collapse of Lehman Brothers on September 15, 2008 (the Lehman moment), which aggravated the initially local U.S. credit crisis into a global financial disaster*,* is identified as a starting point. This approach adequately follows the related studies of Bostandzic et al. (2014) and Bartram et al. (2007). With respect to the European Sovereign Debt Crisis, the first Greek bailout agreement of May 2, 2010 is identified as a starting point of the first peak, while the Greek austerity package imposed by European authorities on June 29, 2011 is identified as the starting date of the second peak. This approach follows Filoso et al. (2017) who identify those two events as climaxes to the said crisis periods, and Black et al. (2016) who find that systemic risk of European banks reached its height following these events. In May 2010, Greece signed a three-year bailout agreement with the EU and the IMF, including a total of 80 billion euros in bilateral loans from other EU countries and another 30 billion from the IMF, at below market interest rates. In return, Greece committed itself to reduce its massive the deficit to three percent of its GDP by 2014 (Kosmidou et al. (2014)). In June 2011, eurozone ministers committed Greece to take new severe austerity measures before it might receive the next *tranche* of its loans and proposed harsh penalties for misaligned behavior (Kosmidou et al., 2014).

Figure 1 displays the price history of the MSCI World Index from January 2005 to December 2014, thus covering all three selected crisis events. Figure 2 displays the average systemic risk of sampled international banks measured by the Marginal Expected

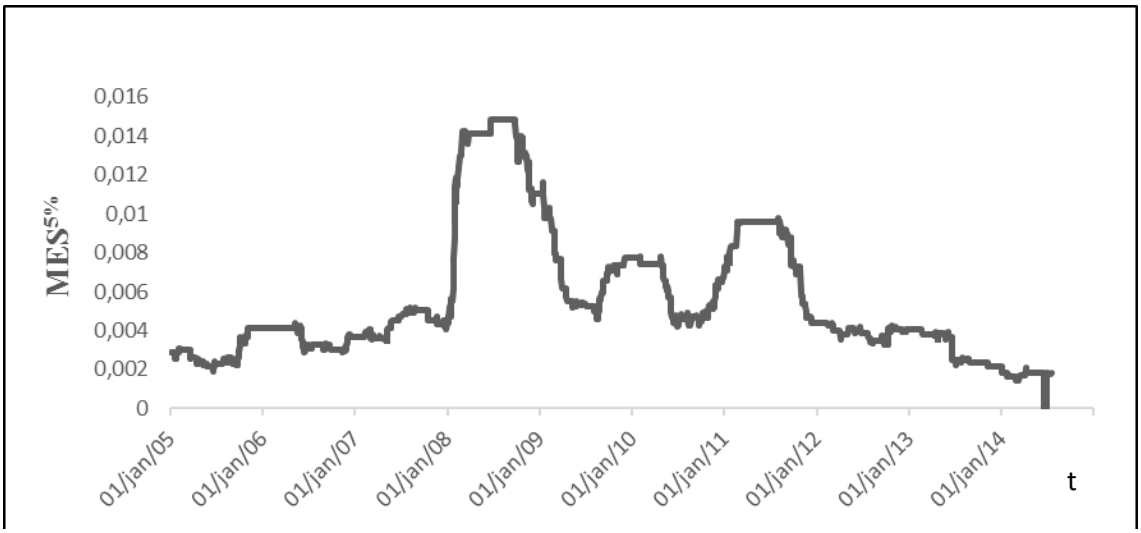
Shortfall proposed by Acharya et al. (2010) and estimated using rolling windows of 180 trading days. The Marginal Expected Shortfall is explained in greater technical detail in the following section. The global stock market index sharply decreased while systemic risk peaked during all the selected crisis periods. Both figures clearly identify the crisis around the collapse of Lehman Brothers as the most severe financial crisis.

Figure 1
Price history of the MSCI World Index from January 2005 to December 2014



Source: Daily closing prices of the MSC World index were obtained from Thomson Reuters Eikon

Figure2
Average systemic risk of sampled international banks measured by the Marginal Expected Shortfall measure proposed by Acharya et al. (2010)



Source: To calculate the average MES daily stock price data was obtained from Datastream

3.2 Measuring systemic risk

To estimate the contribution of an individual bank to the risk of the aggregated financial market, the Marginal Expected Shortfall (MES) measure proposed by Acharya et al. (2010) is applied, following Bostandzic et al. (2014). The MES is rapidly gaining recognition as a highly relevant systemic risk measure. This is not least because of the MES-based and frequently updated rankings of the systemic importance of U.S. financial institutions, that are published on the website of NYU, and because of the claims by Acharya et al. (2010), that the MES would have been capable to predict the losses incurred by financial institutions in the U.S during the Global Financial Crisis (Banulescu and Dumitrescu, 2013). Nevertheless, some authors have pointed out that the MES measure does not account for the level of firm characteristics. Thus, from a theoretical perspective a small unleveraged financial institution could appear more systemically relevant than a big and heavily leveraged one (Banulescu and Dumitrescu, 2013). The MES of an individual bank is defined as the expected loss on a given bank's equity return when the aggregated market experiences outcomes below a critical threshold over a selected time period (Acharya et al., 2010). This means that in order to calculate the MES for a time period [T1,T2] with a threshold level of five percent, the five percent worst returns for the aggregated market are selected, and then the average log return on the equity of an individual bank is computed for these days via the following:

$$MES^{5\%}_{i;[T_1T_2]} = -E\{R^i_t | M_t > P_M\,(1-0.5)\} \quad (1)$$

where R^i_t is individual bank i`s daily log equity return, M_t is the log equity return of the aggregate financial market and P_M is the percentile function of M. Following the usual convention in the risk literature dealing with the MES, CoVar, or other related systemic risk measures the sign is flipped to make the MES a positive number, simplifying interpretation.

Following Bostandzic et al. (2014), the change in an individual banks' contribution to systemic risk during financial turmoil episodes is estimated by computing the difference between the bank`s pre- and post-crisis MES with a threshold level of five percent. In line with Amihud et al. (2012) and Bostandzic et al. (2014), the chosen daily windows for the pre- and-post crisis periods are [-180; -11] and [+11; +180] respectively. The formula for the change in the pre- and post-crisis MES can then be written as follows:

$$\Delta MES^{5\%}_i = MES^{5\%}_{i;[+11;+180]} - MES^{5\%}_{i;[-11;-180]} \quad (2)$$

To estimate the degree at which market disturbances spread over different geographical areas and financial markets, the MES is computed with respect to value-weighted local and global bank indices constructed by using the entire sample of banks used in the analysis following the approach advanced by Bostandzic et al. (2014). In order to construct the value-weighted local bank indices, each bank is assigned to one out of five geographical areas (Africa, Asia/Pacific; Europe; North America; South America) based on the location of the respective headquarters. Then the individual banks' equity returns are value-weighted, by using their corresponding market capitalization.

3.3 Cross-sectional regressions

In order to identify the key factors driving changes in individual banks' contribution to systemic risk between the pre- and post-crisis periods, the change in the banks' MES with respect to both local and global indices is regressed on a set of firm-specific accounting variables, a set of macroeconomic control variables, and a set of variables controlling for the banks' regulatory environment. These cross-sectional regressions are estimated for each crisis respectively.

$$\Delta \mathrm{MES}_{i,t}^{5\%} = a_i + \beta_1' \mathrm{bank}_{i,t} + \beta_2' \mathrm{macro}_{i,t} + \beta_3' \mathrm{reg}_{i,t} \quad (3)$$

Where a_i represents the constant, $\mathrm{bank}_{i,t}$ is a vector of bank-specific accounting variables, $\mathrm{macro}_{i,t}$ is a vector of macroeconomic control variables, $\mathrm{reg}_{i,t}$ is a vector of regulatory control variables, and β_1', β_2',and β_3' are their associated coefficient vectors.

3.4 Data

Data for this research is obtained from three different databases, as follows: i) stock price data and bank specific accounting variables are obtained from Datastream; ii) macroeconomic control variables are obtained from the WDI database; and iii) regulatory control variables are obtained from the database constructed by Barth et al. (2013). Respectively for each of the selected periods of financial turmoil, a sample is constructed by obtaining daily stock-price data for all commercial banks (SIC codes: 6021; 6022; 6029) and savings institutions (SIC codes: 6035 and 6036) available on Datastream. By restricting the sample to commercial banks for each period, insurance companies, investment management companies, brokers and primarily investment banks are excluded from the sample. The selection also includes banks from Datastream`s dead-firm list, in order to avoid potential issues arising from survivorship bias. In order to deal with potential issues arising from outliers, the extreme values for bank-specific accounting

variables are limited by winsorizing the data at the 1th and 99th percentiles. Following Bostandzic et al. (2014), several screening procedures are also applied, as per the following four steps. First, all banks with incomplete stock-price data for the pre-and post-crisis period are excluded from the sample. Second, banks with incomplete accounting data with respect to the independent variables used in the cross-sectional regressions are also excluded. Bostandzic et al. (2014) note that, for the vast majority of banks with lacking accounting data in Datastream´s firmlist, annual reports could be obtained from public sources, which reduces potential biases caused by systemically riskier banks simply being less transparent. Third, banks with headquarters in countries that are not covered by the WDI database or the database constructed by Barth et al. (2013) are also excluded. Fourth, following Karolyi et al. (2012) and Hou et al. (2011), banks for which the stock price drops below $1 for the pre- or-post crisis period are likewise excluded from the sample.

Table 1 displays the regional distribution of banks in the sample for all three crisis periods. Banks are predominantly located in North America, followed by banks in Europe. The sample for the period around the collapse of Lehman Brothers comprises 642 banks of which 432 are located in North America and 154 in Europe. Only 33 banks are located in the Asia/Pacific region and 23 banks come from the remaining geographic areas. On the other hand, the samples for the crisis periods around the Greek bailout agreement and the Greek austerity package are comprised of 632 and 616 banks, respectively, and have a similar regional distribution of banks.

Table 1
The table displays the distribution of international banks by region for each crisis event analyzed.

	Lehman Brothers	Greek Bailout	Austerity Package
North America	432	403	383
Europe	154	146	144
Asia/ Pacific	33	52	59
Others	23	31	30
SUM	642	632	616

4 Independent Variables

This section presents the independent variables used to help explain sources of individual banks contribution to global and local systemic risk during the crisis around the collapse of Lehman Brothers (the Lehman moment) in 2008 and the two peaks of the European Sovereign Debt Crisis.

4.1 Firm-specific accounting variables

4.1.1 Profitability

The first bank-specific accounting variable used in the cross-sectional regression is a given bank´s operating profit margin (OPM), which stands as a proxy for profitability. In general, investors perceive more profitable banks to be equipped with better abilities to replenish capital reserves and thus to have lower exposure to tail and default risk. Consequently, this should reduce these banks' contribution to the systemic risk of the aggregate financial market (Oordt and Zhou, 2016). In addition, some authors like Konishi and Yasuda (2004) as well as Keeley (1990) argue that shareholders of banks with higher profits and higher expected future profits have more to lose if the bank becomes insolvent, which lowers risk taking incentives for more profitable banks. However, higher profitability could actually steam from successful engagement in risky non-lending trading activities and thus might indicate higher default risk (Bostandzic et al., 2014). Nevertheless, a given bank´s OPM is expected to have a negative effect on the said bank's contribution to local as well as global systemic risk regardless of the geographic regions the sampled banks come from.

4.1.2 Size

The natural logarithm of total asset (LNTA) is used as a measure of a bank`s size. The Basel Committee on Banking Supervision (2013) describes a bank`s size as a key measure of systemic importance. Financial distress or the bankruptcy of banks whose activities represent a larger portion of overall economic activity, are more likely to have a greater systematic impact. Larger banks tend to be more interconnected and to have greater overall complexity, making them more likely to cause financial distress in other banks. This process makes the liquidation of larger banks more costly and time consuming during crisis periods (Bostandzic and Weiß, 2018). In addition, an increased probability of governmental protection in the case of bankruptcy for banks that are considered "too big to fail" might strengthen their manager´s incentives to engage in additional risk-taking activities (Kaufmann, 2014). While some authors like Diamond (1984) and Freixas and

Rochet (2008) find that larger banks have a higher profitability and are more efficiently diversified, making them better protected when adverse events materialize, others like Barros et al. (2007) find that larger and more diversified banks perform more poorly, indicating that small and specialized banks can reduce asymmetric information problems associated with lending more efficiently. Overall, bank size is expected to have a significant positive effect on the banks' contribution to local as well as global systemic risk regardless of where the banks are located.

4.1.3 Market-to-book ratio

Rau and Vermalen (1998) find that managers of so-called glamour firms with a low book-to-market ratio tend to be more likely to engage in excessive risk taking to increase firm value than managers of high book-to-market firms. In order to proxy for the related overconfidence of bank managers a bank's market-to-book ratio (M/B) is included as an independent variable in the cross-sectional regressions. The market-to-book ratio is expected to enter the regressions with a positive sign.

4.1.4 Leverage

Following Bostandzic et al. (2014), the capital structure of a given bank is approximated by the ratio of total debt-to-total assets (D/A). Since the Global Financial Crisis, a number of authors have argued that high financial leverage contributed substantially to the failure of various financial institutions, by inducing banks to engage in risky subprime lending and trading activities (e.g. Acharya and Thakor (2016); Adrian and Shin (2010)). The debt-to-asset ratio is thus expected to enter the cross-sectional regressions with a positive sign, although unsecured bank liabilities may increase market discipline due to monitoring by unsecured creditors, and thus turn bank managers away from risky asset choices as noted by Diamond and Rajan (2001).

4.1.5 Non-interest income

Finally, the natural logarithm of non-interest-income (LN-NII) is used as an independent variable in the cross-sectional regressions, in order to measure income from activities other than the traditional deposit and lending activities, such as securitization and derivatives trading. It has been argued that greater dependence on non-interest income generating activities increases diversification by providing accesses to a broader range of markets and thus stabilizes profits (Lepetit et al., 2008). However, many authors have found non-interest income generating activities to represent a more volatile source of

banking revenues, and thus increasing vulnerability to macroeconomic shocks and adverse events. (e.g. Chen et al. (2016); Stiroh and Rumble (2006)). In addition, Wagner (2010) argues that banks engaging in non-interest income generating processes will increasingly hold similar portfolios, so that even though those activities might reduce individual bank risk, they will increase systemic risk due to a higher possibility of joint failure. In fact, banks' diversification into banks non-traditional banking activities has become a critical concern for regulators in the aftermath of the Global Financial Crisis and in the Dodd-Frank bill, which is actually aimed at curtailing proprietary trading (Moshirian, 2011). Brunnermeier et al. (2019) identify non-interest income as a significant factor driving the contribution of individual banks to the systemic risk of the aggregated system over several decades.

4.2 Macroeconomic control variables

Following Bostandzic et al. (2014), standard macroeconomic country controls obtained from the WDI database are included in the cross-sectional regressions. More precisely, the annual percentage growth of GDP and inflation, as measured by the annual growth rate of the GDP implicit deflator, are included. Furthermore, the rule of law estimator (ROL) capturing to what extent agents have confidence in contract enforcement, property rights, the police and courts as well as the likelihood of crime and violence is obtained for each country in the sample. The last country control included is the annual WDI political stability indicator capturing political stability and the absence of terrorism.

4.3 Regulatory control variables

Several regulatory variables are included in the regressions in order to control for differences in regulatory regimes across countries and to examine the hypothesis that a more restrictive regulation of banks prevents bank losses when adverse shocks materialize.

First, the overall capital stringency index (C.String.) measures the stringency of the minimum capital adequacy. Second, the supervisor power index (SUB.Power) measures to which extent authorities are able to take preventive or corrective actions if necessary. Third, the supervisory independence index (Indepen.) captures the degree to which the supervisory authority is legally protected from the financial industry and independent of the government.

Table 2

The table displays an overview of variable names, definitions and their data-sources.

Name	Definition	Database
Bank-specific accounting variables		
OPM	Operating profit margin in percent defined as the ratio of operating income over net sales	Datastream
LNTA	Natural logarithm of total assets	Datastream
M/B	Market to book ratio	Datastream
D/A	Ratio of total debt over total assets	Datastream
LNII	Natural logarithm of banks' Non-interest income	Datastream
Macroeconomic control variables		
GR.	Annual percentage growth of GDP	WDI database
Infl.	Inflation as measured by the annual growth rate of the GDP implicit deflator	WDI database
ROL	Rule of law estimator ranging from -2.5 to 2.5 with higher values indicating lower probability of crime and violence	WDI database
STAB	Political stability indicator ranging from -2.5 to 2.5 with higher value indicating greater stability	WDI database
Regulatory variables		
C.String.	Overall capital stringency index raging from 0-10 with higher values indicating greater stringency of capital regulations	Barth et al. (2013)
Sub.Power	Supervisor power index ranging from 0 to 14 with higher values indicating more powerful supervisor authorities	Barth et al. (2013)
Independ.	Supervisor Independence index ranging from 0 to 4 with higher values indicating greater independence	Barth et al. (2013)

5 Descriptive Statistics

This section presents descriptive statistics for the explanatory variables used in the analysis of the key drivers of systemic risk during recent financial crisis periods. Descriptive statistics for bank-specific accounting variables and the macroeconomic control variables are presented in Table 3, while descriptive statistics are displayed in the Appendix. As presented in Table 3, right before the collapse of Lehman Brothers in September 2008, banks in the sample had higher market-to-book ratios and were more heavily leveraged on average compared to the other crisis periods during the European Sovereign Debt Crisis. The average debt-to-asset ratio was 19.50 percent for the crisis

associated with the collapse of Lehman Brothers, 15.89 percent during the crisis around the Greek bailout agreement and 15.21 percent during the second peak of the European Sovereign Debt Crisis. The average market-to-book ratio during the crisis in 2008 was 1.28, whereas it was 1.11 and 1.05 during the first and second peaks associated with the European Sovereign Debt Crisis respectively. In addition, sampled banks had, on average a lower operating profit margin around the Global Financial Crisis in 2008. The average operating profit margin (defined as the ratio of operating income to net sales) was 11.11 percent for the Global Financial Crisis of 2008, 12.58 percent for the first peak and 15.58 percent for the second peak of the European Sovereign Debt Crisis, respectively.

Table 3
The table displays summary statistics for bank-specific data obtained from Datastream and for macroeconomic variables obtained from the WDI database used in the cross-sectional regressions. The dataset contains 642 banks for the financial crisis, 632 banks for the first phase of the European Sovereign Debt Crisis around the Greek bailout agreement in May 2010 and 616 banks for the second phase of the European Sovereign Debt Crisis around the Greek austerity package in June 2011. Ratios are presented in percentage terms while absolute items are presented in billions.

	Lehman Brothers (N=642)				**Greek Bailout (N=632)**				**Austerity Package (N=616)**			
	μ	Min	Max	σ	μ	Min	Max	σ	μ	Min	Max	σ
OPM	11.11	-40.67	35.36	13.15	12.58	-49.84	41.11	16.16	15.58	-54.34	43.90	15.48
LN-TA	15.23	11.70	21.74	2.36	15.46	11.88	21.60	2.37	15.61	11.87	21.68	2.39
MTBV	1.28	0.25	3.69	0.64	1.11	0.15	4.26	0.65	1.05	0.05	3.87	0.63
D/A	19.50	0.02	63.60	13.51	15.89	0.00	60.92	13.52	15.21	0.00	59.12	13.61
LN -NII	10.51	5.45	17.42	2.72	10.91	5.60	17.57	2.78	11.02	5.86	17.56	2.76
Infl.	3.02	-0.05	30.13	3.11	2.55	0.15	45.94	4.63	3.18	-0.02	28.14	3.36
Gr.	0.47	-1.28	9.25	1.52	2.99	-5.48	10.13	2.23	1.94	-9.13	8.40	1.92
ROL	1.41	-1.62	1.97	0.62	1.32	-1.65	1.97	0.67	1.26	-1.68	1.95	0.68
STAB	0.36	-2.12	1.49	0.53	0.32	-2.67	1.46	0.61	0.41	-2.81	1.39	0.65

Table 4 displays a comparison involving bank-specific accounting data of European banks, North American banks, and banks in the Asia/Pacific region for the three crisis periods respectively. With respect to all crisis periods, the European banks in the sample are on average larger in terms of total assets. The average natural logarithm of total assets ranges from 17.65 to 17.98 across the three crisis periods for European banks and from 14.18 to 14.44 for North American Banks. Moreover, European banks are more heavily leveraged and have higher non-interest income than North American banks and banks from the Asia/Pacific region, and on average have higher market-to-book ratios than

North American banks. All these variables are expected to be positively related to banks' contribution to local and global systemic risk.

Table 4
The table displays summary statistics for bank-specific accounting data obtained from Datastream and for macroeconomic variables obtained from the WDI database used in the cross-sectional regressions. The dataset contains 642 banks for the financial crisis around the collapse of Lehman Brothers in September 2008, 632 banks for the first phase of the European sovereign debt crisis around the Greek bailout agreement in May 2010 and 616 banks for the second phase of the European sovereign debt crisis around the Greek austerity package in June 2011. Ratios are presented in percentage terms while absolute items are presented in billions.

Panel A: North America

	Lehman Brothers (N=642)				Greek Bailout (N=632)				Austerity Package (N=616)			
	μ	Min	Max	σ	μ	Min	Max	σ	μ	Min	Max	σ
OPM	10.59	-40.67	35.36	14.05	10.63	-49.84	41.11	18.12	16.51	-54.34	43.90	16.46
LN-TA	14.18	11.70	21.32	1.68	14.31	11.88	21.54	1.71	14.44	11.87	21.46	1.72
MTBV	1.23	0.25	3.69	0.55	1.08	0.15	4.26	0.58	0.96	0.05	3.87	0.45
D/A	15.43	0.02	55.82	8.77	10.66	0.00	35.55	6.97	9.65	0.00	35.27	6.76
LN -NII	9.28	5.45	17.10	2.04	9.54	5.60	17.57	2.07	9.65	5.86	17.53	2.06

Panel B: Europe

	Lehman Brothers (N=642)				Greek Bailout (N=632)				Austerity Package (N=616)			
	μ	Min	Max	σ	μ	Min	Max	σ	μ	Min	Max	σ
OPM	10.84	-38.52	35.36	9.50	14.42	-34.78	36.66	10.47	12.43	-54.34	36.56	14.05
LN-TA	17.65	13.04	21.74	2.21	17.90	12.32	21.60	2.16	17.98	11.88	21.68	2.22
MTBV	1.35	0.25	3.69	0.72	1.12	0.15	4.26	0.63	1.01	0.05	3.87	0.77
D/A	33.21	0.46	63.60	16.06	32.04	0.37	60.92	15.46	31.41	0.00	59.12	15.83
LN -NII	13.12	7.77	17.42	2.27	13.56	7.43	17.57	2.36	13.55	7.98	17.56	2.45

Panel C: Asia Pacific

	Lehman Brothers (N=642)				Greek Bailout (N=632)				Austerity Package (N=616)			
	μ	Min	Max	σ	μ	Min	Max	σ	μ	Min	Max	σ
OPM	16.07	-40.67	33.59	15.64	17.23	-49.84	40.70	12.75	18.58	-54.34	43.91	12.56
LN-TA	16.76	12.80	19.22	1.29	17.06	12.51	19.60	1.24	16.95	12.18	19.72	1.41
MTBV	1.36	0.25	3.39	0.86	1.44	0.56	4.26	0.92	1.53	0.67	3.87	0.86
D/A	9.96	0.62	33.69	7.33	9.21	2.38	26.45	6.75	9.66	0.00	30.09	7.47
LN -NII	12.55	8.21	15.25	1.37	12.83	9.24	15.74	1.42	12.59	9.01	15.85	1.58

Remarkably, the banks covered by the sample and located in the Asia/Pacific region have on average the highest operating profit margins through all three crisis events. Overall, these statistics suggest that, on average, European banks tend to play a more important role for the systemic risk of the overall financial markets than North American do.

6 Results

This section discusses the main findings of the empirical analysis designed to identify the key drivers of international banks' contribution to systemic risk during the Global Financial Crisis in 2008, the first peak of the European Sovereign Debt Crisis around the Greek bailout agreement in May 2010 and the second peak of the latter crisis around the Greek austerity package in June 2011. First, the results for the estimates of the changes in the MES systemic risk measure between pre- and post-crisis periods are presented. In order to shed light on how financial contagion spills over to various geographical areas, results are presented with respect to both global and local market indices. In the second part the results of the cross-sectional regressions are also presented.

6.1 Contribution to systemic risk

Table 5 presents the changes in the MES systemic risk measure between pre- and post-crisis periods, to local and global sector indices and for each crisis respectively. Estimates are presented for the total sample as well as for subsamples of North American banks, European banks, and banks located in the Asia/Pacific region.

The average of the MES measure of a bank's contribution to systemic risk increased for all crisis episodes between pre- and post-crisis periods with respect to both local and global sector indices, providing evidence for regional as well as international financial contagion. All estimates are statistically significant at the one percent level. The difference is most pronounced for the Global Financial Crisis around the collapse of Lehman Brothers in September 2008. For the total sample of international banks, the difference in the average of the marginal expected shortfall of individual banks equals 0.0273 with respect to local value-weighted bank-sector indices and 0.0295 with respect to a global value-weighted sector index. Interestingly, the contribution of individual banks to local systemic risk is lower than to global systemic risk for the Global Financial Crisis around the collapse of Lehman Brothers in 2008, which might indicate the greater impact on the global system than on regional specific financial institutions. The estimates for the first peak of the European Sovereign Debt Crisis around the Greek bailout agreement in May 2010 equal 0.0061 with respect to local sector indices and 0.0046 with respect to a global sector index. For the second peak of the European Sovereign Debt Crisis around the Greek austerity package in June 2010, the estimates are 0.0136 with respect to local sector indices and 0.0155 with respect to a global sector index. Given these results, the average contribution of individual banks around the globe was

substantially greater during the second part of the European sovereign debt crisis compared to the first phase of the said crisis.

Table 5
The table displays the change between the average pre- and post-crisis Marginal Expected Shortfall of individual banks with respect to local and global value-weighted bank sector indices respectively around the three financial crises that are analyzed in this paper.

Crisis	Total		North America		Europe		Asia/Pacific	
	N	ΔMES_{LOCAL}	N	ΔMES_{LOCAL}	N	ΔMES_{LOCAL}	N	ΔMES_{LOCAL}
Panel A: Change between pre and post crisis Marginal Expected Shortfall with respect to a local, value –weighted bank sect index.								
Lehman-Brothers	642	0.0273***	432	0.0248***	154	0.0351***	33	0.0073***
Greek-Bailout	632	0.0061***	403	0.0076***	146	0.0035***	52	0.0072***
Austerity-Package	616	0.0136***	383	0.0172***	144	0.0075***	59	0.0038***
	N	ΔMES_{GLOBAL}	N	ΔMES_{GLOBAL}	N	ΔMES_{GLOBAL}	N	ΔMES_{GLOBAL}
Panel B: Change between pre and post crisis Marginal Expected Shortfall with respect to a global, value –weighted bank sector index.								
Lehman-Brothers	642	0.0295***	432	0.0268***	154	0.0377***	33	0.0254***
Greek-Bailout	632	0.0046***	403	0.0052***	146	0.0039***	52	0.0043***
Austerity-Package	616	0.0155***	383	0.0098***	144	0.0318***	59	0.0135***

*** Statistical significance at the 1% level, ** Statistical significance at the 5% level, * Statistical significance at the 10% level.

In the following, differences in the pre-and post- crisis change of banks' contribution to systemic risk across various subsamples of banks in distinctive geographical areas are described. As presented in Table 5 for the Global Financial Crisis in 2008, the average contribution to systemic risk did change most significantly for European banks with respect to both local and global indices. These results are not surprising, given the fact, that, as reported in Table 4, European banks are larger, have higher non-interest income, are more heavily leveraged and have higher market-to-book ratios than North American banks for all selected crisis periods. As described previously in the independent variable section, all those variables are expected to have a positive effect on a bank`s contribution to systemic risk. However, this does not continue to hold for the episodes around the first

and second peaks of the European Sovereign Debt Crisis. For these specific episodes, ΔMES estimates with respect to a local index are higher for North American banks than for European banks, although size, leverage, non-interest income and market-to-book ratio were also greater during those periods for European banks in the sample. In addition, the ΔMES estimate with respect to a global index is greater for North American banks than for European banks during the episode around the first peak of the European Sovereign Debt Crisis.

6.2 Cross-sectional regressions

This section represents the results of the cross-sectional regressions. The first part describes the result of the regressions for the crisis around the collapse of Lehman brothers in September 2008 and the second part focuses on the regression for the period associated with the European Sovereign Debt Crisis.

6.2.1 Financial crisis in 2008

As presented in columns (1) and (2) of Table 6, all bank-specific accounting variables enter the regressions with the expected sign. The size measured by the natural logarithm of total assets as well as the market-to-book ratio have a positive effect on banks contribution to both local and global systemic risk that is statistically significant at the one percent level. This is in line with the findings of Bostandzic et al. (2014) that larger and more sophisticated banks contributed more to systemic risk during the Global Financial Crisis in 2008. Table 6 also provides evidence that banks' profitability lowers its contribution to local and global systemic risk because it provides banks with better abilities to replenish capital reserves and thus lowers their exposure to tail and default risk. Profitability measured by a bank's operating profit margin has a negative effect on the contribution to global and local systemic risk of international banks, that is significant at the five percent level. However, there is no evidence for leverage effecting a bank's contribution to systemic risk, and similar to Bostandzic et al. (2014), there is no support for the findings of Brunnermeier et al. (2011) that non-interest income increases a bank´s contribution to systemic risk.

Stricter capital requirements imposed by regulatory authorities seem to have impacted banks' contribution to local and global systemic risk negatively, a fact which is in line with the hypothesis that that more restrictive regulation of banks can prevent bank losses when adverse shocks materialize. The coefficients for capital stringency are negative and

statistically significant at the one percent level. However, surprisingly, more powerful supervisory authorities and regulatory authorities that are more independent from the government as well as better legally protected from the financial industry, have a positive impact on banks' contribution to local and global systemic risk. Beltratti and Stulz (2009) argue that this is the case because stronger supervisory authorities tend to take more corrective actions that are costly and harmful to shareholders once the crisis has enfolded. The coefficient for the supervisor index is positive and statistically significant at the one percent level. The coefficient for the supervisor independence index is statistically significant at the one percent level for the global ΔMES measure and statistically significant at the ten percent level for the local ΔMES measure.

Table 6
The table displays the results of the cross-sectional regressions of the changes in the MES systemic risk measure on a set of accounting, macroeconomic and regulatory variables for the Global Financial Crisis around the collapse of Lehman Brothers in September 2008. The first two columns display the baseline regressions and columns 3-5 display various robustness checks. Heteroskedasticity-consistent standard errors are reported in parentheses.

	(1)	(2)	(3)	(4)	(5)	(6)
	$ES^{Local}_{5\%}$	$ES^{Global}_{5\%}$	$ES^{Global}_{2\%}$	$ES^{MSCI}_{5\%}$	$ES^{Size}_{5\%}$	$ES^{FE}_{5\%}$
OPM	-0.0003 **	-0,0002**	-0.0003*	-0.0004***	-0.0006***	0.0002**
	(0.0001)	(0,0001)	(0.0002)	(0,0001)	(0.0002)	(0.0001)
LNTA	0.0075***	0.0060***	0.0093***	0.0055***	0.0019	0.0062***
	(0.0020)	(0.0015)	(0.0021)	(0.0013)	(0.0019)	(0.0016)
M/B	0.0064 ***	0.0046***	0.0077***	0.0041**	0.0015	0.0018
	(0.0021)	(0.0017)	(0.0023)	(0.0018)	(0.0024)	(0.0018)
LNNII	0.0024	0.0023*	0.0028	0.0016	0.0060***	0.0033**
	(0.0017)	(0.0013)	(0.0018)	(0.0011)	(0.0018)	(0.0014)
D/A	0.0068	0.0127	0.0102	0.0142*	-0.0001	0.1539
	(0.0094)	(0.0083)	(0.0125)	(0.0076)	(0.10312)	(0.0098)
Infl.	-0.0003	-0.0005	-0.0061	-0.0005	-0.0005	
	(0.0004)	(0.0004)	(0.0005)	(0.0003)	(0.0005)	
Gr.	-0.0006	-0.0007	-0.0025**	-0,0004	-0.0006	
	(0.0012)	0.0008	(0.0011)	(0.0007)	(0.0011)	
ROL	0.0066	0.0086*	0.01975***	0.0074	0.0137***	
	(0.0051)	(0.0046)	(0.0060)	(0.0046)	(0.0052)	
STAB	0.0016	-0.0068*	-0.0165***	-0.0021	-0.0100**	
	(0.0048)	(0.0040)	(0.0052)	(0.0039)	(0.0044)	
C.String.	-0.0033 ***	-0.0043***	-0.0048***	-0.0030***	-0.0050***	
	(0.0011)	(0.0012)	(0.0014)	(0.0011)	(0.0015)	
Sub.Power	0.0048 ***	0.0033***	0.0065***	0.0025***	0.0020***	
	(0.0007)	(0,0005)	(0.0008)	(0.0005)	(0.0007)	
Indepen.	0.0046*	0.0068***	0.0126***	0.0024	0.0063**	
	(0.0026)	(0.0022)	(0.0028)	(0.0019)	(0.0025)	
FE	No	No	No	No	No	Yes
Obs.	642	642	642	642	206	642
R^2	0.32	0.33	0.31	0.35	0.46	0.42

*** Statistical significance at the 1% level, ** Statistical significance at the 5% level, * Statistical significance at the 10%. level

6.2.2 Robustness tests

Columns 3 to 5 of Table 6 represent various robustness checks to test whether the reported findings continue to hold under altered assumptions. Column 3 reports the results of the same regression as column 2, with the MES measure defined as a bank's average daily log return when the overall market experiences the two percent worst returns instead of the five percent worst returns. The coefficients for size and market-to-book ratio are still positive and statistically significant at the one percent level and there is still evidence of profitability negatively impacting banks' contribution to global systemic risk. Following Bostandzic et al. (2014), the MES measure is also re-estimated with respect to the MSCI World Index instead of using the value-weighted sector index of sampled banks, in order to ensure that the findings explain international banks' contribution to the systemic risk of the entire economy and not just to that of the financial industry. As presented in column 4 of Table 6, the main findings for the bank-specific accounting variables still continue to hold. The coefficient for a bank´s operating profit margin even becomes significant at the one percent level, while the statistical significance for the market-to-book ratio decreases to the five percent level. Moreover, the regression is also re-estimated for a subsample restricted to banks with total assets above ten billion U.S. dollars. As presented in column 5 the negative and significant impact of a bank`s profitability continues to hold, while the significance for the coefficient of a bank´s size disappears. Interestingly, for the subsample of larger banks non-interest income positively effects banks contribution to systemic risk, thus validating the importance of the 'Too-Big-To-Fail' status. The coefficient for non-interest income is highly significant at the one percent level. Finally, following Bostandzic et al. (2014), the regression of ΔMES is also re-estimated using country fixed effects (column 6). In order to avoid multicollinearity issues, macroeconomic control variables and regulatory control variables are omitted when running the regressions with country fixed effects. The coefficients for profitability and size continue to be statistically significant. However, the coefficient for the market-to-book ratio loses its statistical significance. Again, the regression results suggest that non-interest income positively impacts bank contribution to global systemic risk. Lastly, with respect to regulatory variables the negative impact of capital stringency and the positive impact of supervisory power continue to hold across all robustness checks.

6.2.3. European Sovereign Debt Crisis

In order to check whether the analysis can provide evidence for arguments that size, market-to-book ratio, and non-interest income are *persistent* determinants of banks' contribution to systemic risk across various time periods and geographical areas , the regressions of ΔMES are re-estimated for the episodes surrounding the two peaks of the European Sovereign Debt Crisis. As reported in Table 7, the results for the bank-specific accounting variables do not hold anymore for the European Sovereign Debt Crisis.

A bank´s operating profit margin positively enters the regression of the pre- and post-crisis change in the MES measure with respect to local indices for the first peak of the European Sovereign Debt Crisis around the Greek bailout agreement in May 2010, in apparent contradiction of the results for the 2008 Global Financial Crisis. However, as presented in columns 2, 3, and 4, a bank`s profitability does not seem to have affected a bank`s contribution to global systemic risk during the first peak of the crisis nor does it seem to have impacted contribution to local or global systemic risk during the second peak of the crisis. A bank's size only has a significant impact on ΔMES with respect to a global sector index during the episode around the second peak of the said crisis. The coefficient for the market-to-book ratio is not significant for any of the regressions. A logical and sound explanation for this apparent contradiction might have to do with the fact that, following Allen and Carletti (2006), the systemic risk present at the height of the Global Financial Crisis of 2008 had already been transferred to the public purse, resulting in higher public debt schedules, but lower systemic risk emanating from the global banking industry.

Furthermore, in contrast to the results for the Global Financial Crisis around the collapse of Lehman Brothers, greater capital stringency has a positive effect on banks contribution to both global and local systemic risk for the episodes around both peaks of the sovereign crisis. This is in line with the findings of Barth et al. (2004), suggesting that capital requirements can increase the likelihood for bank failure and might be value-destroying.

Table 7
The table displays the results of the cross-sectional regressions of the changes in the MES systemic risk measure on a set of accounting, macroeconomic, and regulatory variables for the first and second phases of the European Sovereign Debt Crisis respectively. Heteroskedasticity-consistent standard errors are reported in parentheses.

	(1)	(2)	(3)	(4)
	ES_{SDC1}^{Local}	ES_{SDC1}^{Global}	ES_{SDC2}^{Local}	ES_{SDC2}^{Global}
OPM	0.0001***	-0.0000	0.0001	-0.0000
	(0.0000)	(0.0000)	(0.0001)	(0.0001)
LNTA	0.0008	-0.0008	0.0016	0.0049***
	(0.0010)	(0.0009)	(0.0013)	(0.0010)
M/B	0.0015	0.0007	0.0019	-0.0003
	(0.0010)	(0.0009)	(0.0011)	(0.0008)
LNNII	-0.0003	0.0007	0.0021	-0.0001
	(0.0009)	(0.0008)	(0.0011)	(0.0008)
D/A	0.0048	0.0106***	-0.0085	-0.1093
	(0.0056)	(0.0044)	(0.0059)	(0.0049)
Infl.	-0.0000	0.0001	0.0008*	-0.0006**
	(0.001)	(0.0001)	(0.0005)	(0.0002)
Gr.	0.0005	0.0001	-0.0007*	-0.0002
	(0.0003)	(0.0002)	(0.0004)	(0.0003)
ROL	0.0040***	0.0019	0.0089***	-0.0065***
	(0.0019)	(0.0013)	(0.0021)	(0.0022)
STAB	-0.0006	-0.0005	-0.0005	0.0101***
	(0.0019)	(0.0012)	(0.0021)	(0.0021)
C.String.	0.0018***	0.0013***	0.0032***	0.0007**
	(0.0006)	(0.0004)	(0.0008)	(0.003)
Sub.Power	0.0010*	0.0003	0.0048***	0.0018***
	(0.0006)	(0.0004)	(0.0008)	(0.0005)
Indepen.	0.0016	0.0023	0.0006	-0.0036**
	(0.0015)	(0.0009)	(0.0014)	(0.0014)
FE	No	No	No	No
Obs.	632	632	616	616
R^2	0.0392	0.0274	0.2263	0.4868

*** Statistical significance at the 1% level, ** Statistical significance at the 5% level * Statistical significance at the 10% level

7 Conclusion

This study analyzes key drivers of banks' contribution to both local and global systemic risk on a global level during the Global Financial Crisis around the collapse of Lehman Brothers in September 2008 as well as during the first peak of the European Sovereign Debt Crisis around the Greek bailout agreement in May 2010 and during the second peak of the European Sovereign Debt Crisis around the Greek austerity package in June 2011. During all selected crisis periods, banks' contribution to local and global systemic risk increased significantly for the total sample of global banks as well as for the subsamples of North American banks, European banks and for the subsample of banks located in the Asia/Pacific region respectively. The difference between the pre- and the post-crisis

period marginal expected shortfall measures ΔMES is statistically significant at the one percent level across all crisis periods and across all subsamples. Banks' contribution to systemic risk is the highest during the Global Financial Crisis in 2008, and for, this specific period, the contribution of European banks to local and global systemic risk was higher than the contribution found in other geographic areas. These findings are in line with the observation that the European banks in the sample have on average the greatest total assets, are the most leveraged and have the highest non-interest income across all crisis periods. This is in strict accordance with the conjectures advanced on this matter by previous academic studies observing that all variables herein described are have been found to be persistent drivers of systemic risk. However, interestingly, larger and more leveraged European banks, on average, did not contribute more towards local and global systemic risk during the periods around the two peaks of the European Sovereign Debt Crisis.

The cross-sectional regressions of the difference between the pre- and the post-crisis period marginal expected shortfall measure ΔMES on a set of bank-specific variables, regulatory variables, and standard macroeconomic control variables provide evidence that size, and market-to-book ratio are positively related to banks' contribution to local and global systemic risk during the Global Financial Crisis of 2008. This is in line with the findings of Bostandzic et al. (2014), that suggest that larger and more sophisticated banks contributed more to systemic risk during the Global Financial Crisis. Furthermore, more profitable banks seem to have contributed less to the risk of the financial sector during the Global Financial Crisis. In line with Beltratti and Stulz (2009) and Andriosopoulos et al. (2014) the present findings demonstrate that higher capital stringency is negatively related to systemic risk while greater supervisor power is positively related to systemic risk, suggesting that during the crisis stronger supervisors took more corrective measures that were costly for shareholders. Overall, these findings are robust for alternative definitions of the marginal expected shortfall measure, for a subsample of banks including only banks with total assets in excess of 10 billion U.S. dollars and for regression models including country fixed effects rather than macroeconomic and regulatory control variables. However, in the global analysis of banks contribution to systemic risk these bank- specific accounting variables cannot not explain systemic risk during the European Sovereign Debt Crisis. This is in line with the findings of Bostandzic et al. (2014) that bank-specific accounting variables explaining systemic risk for the Global Financial

Crisis of 2008 cannot explain the contribution of global banks during other crisis periods such as the Mexican pesos crisis in 1994, the Asian crisis in 1977 , the dotcom bubble in 2000 or the terroristic attacks in 2001.

References

-Acharya V., Pedersen L., Philippon T., and Richardson M., (2010). Measuring systemic risk. *Review of Financial Studies*, Society for Financial Studies, Vol. 30(1), pp. 2-47. Available at: doi: https://doi.org/10.1093/rfs/hhw088

-Acharya V. and Thakor V., (2016). The dark side of liquidity creation: Leverage and systemic risk. *Journal of Financial Intermediation*, Vol 28, pp. 4-21. Available at: doi: https://doi.org/10.1016/j.jfi.2016.08.004

-Adrian T. and Shin H., (2010). Liquidity and leverage. *Journal of Financial Intermediation*, Vol. 19 (3), pp. 418-437. Available at: doi: https://doi.org/10.1016/j.jfi.2008.12.002

-Allen F. and Carletti E., (2006). Credit risk transfer and contagion. *Journal of Monetary Economics,* Vol. 53 (1), pp. 89-111.
Available at: doi : https://doi.org/10.1016/j.jmoneco.2005.10.004

-Amihud Y., DeLong G., Saunders, A., (2012). The effects of cross-border bank mergers on bank risk and value. *Journal of International Money and Finance*, Vol.21, pp. 857–877. Available at: doi: https://doi.org/10.1016/S0261-5606(02)00026-8

-Andriosopoulos D., Andriosopoulos K., Douady R. and Hoque H., (2015). Bank regulation, risk and return: Evidence from the credit and sovereign debt crises. *Journal of Banking & Finance,* Vol. 50, pp. 455-474. Available at: doi: https://doi.org/10.1016/j.jbankfin.2014.06.003

-Basel Committee on Banking Supervision, 2013. Global systemically imported banks updated assessment methodology and the higher loss absorbency requirement. Tech. rep., Bank for international Settlements. Available at: https://www.bis.org/publ/bcbs255.pdf

-Banulescu G., and Dumitrescu E., (2013). Which are the SIFs?: A Component Expected Shortfall (CES) to systemic risk. *Working Paper, EUI MWP, 2013/23.* Available at: doi: http://hdl.handle.net/1814/28103

-Barros C., Ferreira C., and Williams J., (2007). Analyzing the determinants of performance of best and worst European banks: A mixed logit approach. *Journal of Banking & Finance*, Vol. 31 (7), pp. 2189-2203. Available at: doi: https://doi.org/10.1016/j.jbankfin.2006.11.010

-Barth J., Caprio G. and Levine R., (2013). Bank regulation and supervision in 180 countries from 1999 to 2011, *Journal of Financial Economic Policy*, Vol. 5 (2), pp. 111-219.

-Bartram S., Brown G. and Hund J., (2007). Estimating systemic risk in the international financial system. *Journal of Financial Economics*, Vol 86 (3), pp. 853-869. Available at: doi: https://doi.org/10.1016/j.jfineco.2006.10.001

-Beltratti A. and Stulz R., (2011). The credit crisis around the globe: Why did some banks perform better? *Journal of Financial Economics*, Vol 105 (1) pp.1-17. Available at: doi: https://doi.org/10.1016/j.jfineco.2011.12.005

-Benoit S., Colliard J., Hurlin C., and Pérignon C., (2016). Where the Risks Lie: A Survey on Systemic Risk. *Review of Finance,* Vol. 21, pp. 109-152. Available at: doi: https://doi.org/10.1093/rof/rfw026

-Black L., Correa R., Huang X. and Zhou. H., (2016). The systemic risk of European banks during the financial and sovereign debt crises. *Journal of Banking & Finance,* Vol. 63, pp. 107-125. Available at: doi: https://doi.org/10.1016/j.jbankfin.2015.09.007

-Bostandzic D., Neumann S. and Weiß G., (2014). What factors drive systemic risk during international financial crises? *Journal of Banking & Finance, Vol.* 41, pp. 78-96. Available at: doi: https://doi.org/10.1016/j.jbankfin.2014.01.001

-Bostandzic D. and Weiß G., (2018). Why do some banks contribute more to global systemic risk? *Journal of Financial Intermediation*, Vol. 35, pp. 17-40. Available at: doi: https://doi.org/10.1016/j.jfi.2018.03.003

-Brownlees T. and Engle R., (2012). Volatility, Correlation and Tails for Systemic Risk Measurement. *Working Paper*.
Available at: http://idei.fr/sites/default/files/medias/doc/conf/finet/annee_2011/nv_engle.pdf

-Brunnermeier M., Dong G. and Palia D., (2019). Banks' Non-Interest Income and Systemic Risk. *Working Paper*. Available at: doi: http://dx.doi.org/10.2139/ssrn.3328890

-Chakrabarty B. and Zhang G., (2012). Credit Contagion Channels: Market Microstructure Evidence from Lehman Brothers' Bankruptcy. *Journal of Financial Managemen*t, Vol.41, pp. 320-343. Available at: doi: https://doi.org/10.1111/j.1755-053X.2012.01194.x

-Chava S., Purnanandam A., (2011). The effect of the banking crisis on bank-dependent borrowers. *Journal of Financial Economic*s 99, 116–135.
Available at: doi: https://doi.org/10.1016/j.jfineco.2010.08.006

-Chen C., Huang Y. and Zhang T., (2016). Non-interest Income, Trading, and Bank Risk. *Journal of Financial Services Research*, Vol. 51 (19), pp. 19-53. Available at: doi: https://doi.org/10.1007/s10693-015-0235-9

-De Jonghe O., (2009). Back to the basics in banking? A micro-analysis of banking system stability. *Journal of Financial Intermediation,* Vol. 19, pp. 387-417.
Available at: doi: https://doi.org/10.1016/j.jfi.2009.04.001

-Diamond D., (1984). Financial Intermediation and Delegated Monitoring. *The Review of Economic Studies*, Vol. 51 (3), pp. 393-414. Available at doi: https://doi.org/10.2307/2297430

-Diamond D. and Rajan R., (2001). Banks and Liquidity. *American Economic Review*, Vol. 91 (2), pp. 422-425. Available at: doi: 10.1257/aer.91.2.422

-Dumontaux N. and Pop A., (2013). Understanding the market reaction to shockwaves: Evidence from the failure of Lehman Brothers. *Journal of Financial Stability,* Vol.9 pp. 269-286. Available at: doi: https://doi.org/10.1016/j.jfs.2013.04.001

-Engle R., Jondeau E. and Rockinger M., (2014). Systemic Risk in Europe. *Review of Finance,* Vol. 19 (1), pp. 145-190. Available at: doi: https://doi.org/10.1093/rof/rfu012

-Filoso V., Panico C., Papagni E., Purificato F. and Suarez M., (2017). Causes and timing of the European debt crisis: An econometric evaluation. *EERI Research Paper Series 03/2017*. Available at: https://www.econstor.eu/handle/10419/179404

-Freixas, X. and Rochet, J., (2008). Microeconomics of Banking, second ed. MIT Press

-Hou K., Karolyi G. and Kho B., (2011). What factors drive global stock returns? *Review of Financial Studies*, Vol. 24, pp. 2527-2547. Available at: doi: https://doi.org/10.1093/rfs/hhr013

-Hovakimian A., Kane E. and Laeven L., (2012). Tracking Variation in Systemic Risk at US Banks During 1974-2013. *NBER Working Paper No. 18043*. Available at: doi: 10.3386/w18043

-Kaufmann G. and Scott K., (2003). What Is Systemic Risk, and Do Bank Regulators Retard or Contribute to It? *The Independent Review,* Vol. 7, No. 3, pp. 371-391. Available at: https://www.jstor.org/stable/24562449?seq=

-Karolyi G., Lee K. and Van Dijk M., (2012). Understanding commonality in liquidity around the world. *Journal of Financial Economics*, Vol. 105 (1), pp. 82-112. Available at: doi: https://doi.org/10.1016/j.jfineco.2011.12.008

-Keasey K. and Vallascas F., (2012). Bank resilience to systemic shocks and the stability of banking systems: Small is beautiful. *Journal of International Money and Finance*, Vol. 31(6) pp. 1745-1776. Available at: doi: https://doi.org/10.1016/j.jimonfin.2012.03.011

-Keeley M., (1990). Deposit Insurance, Risk, and Market Power in Banking. *The American Economic Review*, Vol. 80 (5), pp. 1183-1200. Available at: https://www.jstor.org/stable/2006769

Klingbiel D., Kroszner R., and Laeven L, (2007). Banking Crises, Financial Dependence and Growth. Journal of Financial Economics, Vol 84 (1) pp. 187-228. Available at: doi: https://doi.org/10.1016/j.jfineco.2006.05.001

-Konishi M. and Yasuda Y., (2004). Factors affecting bank risk taking: Evidence from Japan. *Journal of Banking & Finance*, Vol. 28 (1), pp. 215-232. Available at: doi: https://doi.org/10.1016/S0378-4266(02)00405-3

-Kosmidou K., Kousenidis D. and Negakis C, (2015). The impact of the EU/ECB/IMF bailout programs on the financial and real sectors of the ASE during the Greek sovereign crisis. *Journal of Banking & Finance,* Vol. 50, pp. 440-454. Available at: doi: https://doi.org/10.1016/j.jbankfin.2014.03.008

-Lepetit L., Nys E., Rous P. and Tarazi A., (2008). Bank income structure and risk. An empirical analysis of European banks. *Journal of Banking & Finance*, Vol. 32 (8), pp. 1452-1467. Available at: doi: https://doi.org/10.1016/j.jbankfin.2007.12.002

-Laeven L., Ratnovski L. and Tong H., (2016). Bank size, capital, and systemic risk: Some international evidence. *Journal of Banking & Finance*, Vol. 69 (1) pp. 525- 534. Available at: doi: https://doi.org/10.1016/j.jbankfin.2015.06.022

-Longstaff F., (2010). The subprime credit crisis and contagion in financial markets. *Journal of Financial Economics*, Vol. 97 pp. 463-450. Available at: doi: https://doi.org/10.1016/j.jfineco.2010.01.002

-Merton R., (1974). On the Pricing of Corporate Debt: The Risk Structure of Interest Rates. *The Journal of Finance*, Vol 29 (2), pp. 449-470. Available at: doi: https://doi.org/10.1111/j.1540-6261.1974.tb03058.x

-Moreno. M and Peña. J., (2012). Systemic risk measures: The simpler the better? *Journal of Banking & Finance, Vol* 37 pp. 1817–1831. Available at: doi: http://dx.doi.org/10.1016/j.jbankfin.2012.07.010 .

Moshirian F., (2011). The global financial crisis and the evolution of markets, institutions and regulation. *Journal of Banking & Finance*, Vol. 35 (3), pp. 502-5011. Available at: doi: https://doi.org/10.1016/j.jbankfin.2010.08.010

-Oordt M. and Zhou C., (2016). Systematic tail risk. *Journal of Financial and Quantitative Analysis*, Vol. 51 (2), pp.685-705 Available at: doi: https://doi.org/10.1017/S0022109016000193.

-Rau P. and Vermaelen T., (1998). Glamour, value and the post-acquisition performance of acquiring firms. *Journal of Financial Economics*, Vol 49 (2) pp. 223-253. Available at: doi: https://doi.org/10.1016/S0304-405X(98)00023-3

-Stiroh K. and Rumble A., (2006). The dark side of diversification: The case of US financial holding companies. *Journal of Banking & Finance*, Vol. 30 (8), pp. 2131-2161. Available at: doi: https://doi.org/10.1016/j.jbankfin.2005.04.030

-Wagner W., (2010). Diversification at financial institutions and systemic crises. *Journal of Financial Intermediation*, Vol. 19 (3), pp. 373-386. Available at: doi: https://doi.org/10.1016/j.jfi.2009.07.002

Appendix

Table

The table displays descriptive statistics for regulatory variables used in the cross-sectional regressions. The table presents the average of the capital stringency index, the supervisor power index and the supervisor independence index obtained from the database constructed by Bath et al. (2013) index for all the countries in the dataset. More precisely the table displays the average of the survey conducted in 2007 and the survey of 2011, for all variables and across all countries.

	C.String.	Sub.Power	Indepen.
Argentina	5.5	9.5	1.0
Austria	4.0	11.0	3.0
Bahrain	8.0	11.8	2.5
Belgium	5.5	11.0	2.0
Bosnia and Herzegovina	4.0	12.5	3.0
Botswana	10.0	6.5	1.5
Brazil	5.0	13.5	2.0
Bulgaria	8.5	11.0	3.0
Canada	5.0	8.5	3.0
Chile	6.0	12.5	0.0
Colombia	7.0	11.8	0.5
Croatia	6.5	11.5	3.0
Cyprus	8.5	11.5	3.0
Finland	6.0	9.0	2.5
France	8.0	9.3	2.5
Germany	7.5	9.5	1.0
Greece	5.5	9.5	1.5
Hungary	7.0	13.8	3.0
India	9.0	10.0	2.5
Indonesia	9.0	14.5	2.5
Italy	6.0	10.0	1.5
Kenya	8.0	13.5	1.5
Lithuania	5.0	12.8	1.5
Luxembourg	7.0	11.5	2.0
Mauritius	7.0	14.0	2.0
Norway	7.0.	8.5	2.5
Pakistan	9.0	13.5	2.0
Palestine	10.0	9.0	1.0
Peru	8.0	13.0	2.0
Poland	8.0	10.0	2.0
Portugal	6.5	13.0	3.0
Serbia	5.0	13.0	3.0
Spain	8.0	10.8	2.0
Sri Lanka	5.0	11.0	2.0
Switzerland	7.0	12.5	2.0
Thailand	9.0	12.0	2.0
United Kingdom	5.0	10.0	2.0
United States	7.5	13.8	2.0
Venezuela	9.0	13.5	1.0