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The effect of tax policy on leverage ratios and systemic risk contribution of European banks

Abstract

During the past decades, public and private debt levels across the world increased substantially compared to GDP. Encouraged by tax shields on debt, firms and households take advantage of relatively cheap debt financing. This paper illustrates that increasing debt levels increase the risk of the financial system. To manage systemic risk, tax policy must be taken into account. Furthermore, this paper provides a new approach to systemic risk measurement. It proposes the use of tail beta. This measure which is obtained using extreme value theory is linearly related to the well-known marginal expected shortfall. It allows to interpret systemic risk in a CAPM framework. Results indicate that investors receive a risk premium on systemic risk contributions. Using tail beta, it is illustrated that ING Groep, Barclays and Société Générale are the three most systemically risky banks of Europe during the 15-year sample period of 2001-2015. They suffer losses over 22% of their market-valued total assets in case of a severe crisis.

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Contents

1 Introduction

During the past decades, public and private debt levels across the world increased substantially compared to GDP. Encouraged by tax shields on debt, firms and households take advantage of relatively cheap debt financing. While a certain amount of debt is said to stimulate economic growth, it has adverse effects at higher levels. Economists agree that increasing debt levels increase the risk of the financial system. The financial crisis of 2008 exemplified how rapid credit growth can lead to serious instability. Very high financial leverage pushed banks to engage in illiquid and risky lending and securities activities. Within one year, Bear Stearns, Lehman Brothers and a significant amount of other important US institutions collapsed. To prevent the failure of these institutions to spillover to other firms and the real economy, the US government was forced to intervene. Certain systemically important institutions that were considered "too big to fail" (TBTF) or "too interconnected to fail" (TITF) were bailed out or placed under conservatorship. Despite this effort of the US government, stability of the financial system could not be guaranteed. Financial markets across the world experienced serious distress. In combination with high public debt levels, this resulted in the Sovereign Debt Crisis in Europe. Many European countries suffered from recessions and millions of people lost their jobs. To prevent such crises to happen again, banking regulation had to be reconstructed. Market participants, regulators and academics turned to the notion of systemic risk.

Systemic risk is generally defined as the risk that shocks to specific financial institutions lead to severe instability or a collapse of an entire industry or economy. Shocks can arise at the micro and macro level. Concerning micro level shocks, systemic risk comes from spillover effects. Idiosyncratic shocks can spillover to other institutions by network connections arising through banks' mutual transactions. These bank transactions create a direct link between the asset and liability sides of the banks' balance sheets. Theoretically, and in absence of insurances, any shock at the individual firm level influence the balance sheets of all banks with mutual connections. The actual impact of a spillover is dependent on the shock itself and a variety of factors such as the size and complexity of the institutions involved. Concerning macro level shocks, systemic risk comes from common exposures. Common shocks affect several banks simultaneously. Examples are changes in interest rates or asset prices. Alternatively, common exposures come from time-specific tendencies. These 'trends' can increase systemic risk in two ways. First of all, it increases the risk of panic contagion. Suppose one bank goes bankrupt due to excessive risk taking. All other banks with similar risk-taking activities will fear bankruptcy too. With panic in the market, asset prices might drop. This could lead to actual banking failures. Secondly, common trends might affect systemic risk directly. Regulation on innovative products is often imposed once its too late. The same holds for regulatory measures focusing on more subtle changes in the market. Regulation regarding bonuses is an example of this.

The Basel Committee on Banking Supervision proposed a new regulatory framework to improve regulation and monitoring of spillover effects and systemic risk, referred to as Basel III. The previous accords, Basel I and II, focused essentially on the level of loss reserves that banks are required to hold to contain idiosyncratic risk. Basel III concentrates more on systemic risk in the financial sector. Its objective is to reduce the risk of spillover from the financial sector to the real economy by improving the banking sector's ability to absorb shocks arising from financial and economic stress. Basel III incorporates a new macroprudential approach. It comprises a countercyclical capital buffer and frameworks for global and domestic systemically important banks. The countercyclical capital buffer is supposed to cover the time dimension of systemic risk. It ensures that banking sector capital requirements take account of the macro-financial environment in which banks operate. Suppose there is a time of macroeconomic growth. Expansionary times are associated with the build-up of system-wide risk. To protect the banking sector during this specific time, capital buffers are relatively high. Next to the discretionary counter-cyclical buffer, banks are still required to hold a capital conservation buffer. This standard requires banks to hold at least 2.5% of common equity for the amount of risk-weighted assets held by a bank. Furthermore, Basel III defines a minimum leverage and liquidity ratio. The leverage requirement states that the amount of capital divided by the amount total assets of a bank has to be at least 3%. Systemically important financial institutions (SIFI's) need to maintain a leverage ratio of 6%. The liquidity ratio demands a bank to hold sufficient high-quality liquid assets to cover its total net cash outflows over 30 days. This requirement will be fully implemented by 2019. The question remains whether the capital conservation buffer and the minimum leverage and liquidity ratios are able to provide sufficient coverage for the cross-sectional component of systemic risk. Additionally, it is important to ask whether these specific regulatory requirements are the best regulatory means available to monitor systemic risk.

This paper argues that tax policy is neglected erroneously in the current debate on banking regulation. Given its influence on debt levels, tax policy has considerable influences on financial stability. To illustrate that tax policy is important for systemic risk management, the following research question is addressed:

> *Does an increase in corporate income tax rate lead to a higher systemic risk contribution of large banks in Europe in the period of 2001-2015?*

The focus of this research is on Europe for two reasons. First, it contributes to a better insight on systemic risk in Europe relevant for policy makers and regulators. Most research regarding systemic risk contributions concerns the US. The European Sovereign Debt crisis illustrated how vulnerable Europe is. Any new perspective on large systemic risk contributors in Europe is therefore of added value. Second, Europe is of interest for this research because of the fiscal differences between countries. These differences allow to investigate the effect of tax policy on leverage ratios.

Concerning the theoretical relevance, this paper provides a new approach to systemic risk measurement. The tail beta measure that is proposed allows to interpret systemic risk in a capital asset pricing model (CAPM) framework. Tail beta is derived from the marginal expected shortfall (MES) which is calculated using extreme value theory. Extreme value theory minimizes problems often associated with the MES such as noise and underestimation of systemic risk as it focuses on the tail explicitly. If systemic risk contributions are underestimated, capital requirements might not be able to cover systemic risk when it is most necessary. When systemic risk contributions are overestimated, capital requirements might be set higher than necessary which harms banks' efficiency needlessly. Accurate measurement is of great importance to all market participants and regulators.

This research does not find clear evidence that corporate income tax rates influence leverage ratios for large European banks. Large banks are usually capital-tight, which implies that there is little room to increase leverage ratios in order to benefit from the tax shield. This does not mean that leverage ratios should go unmonitored. Evidence shows that leverage ratios are positively related to systemic risk contributions. Additionally, it is illustrated that increases in corporate income tax lead to higher systemic risk contributions for European banks. Although this does not seem to work through an increase in leverage ratio directly, there is reason to believe that tax shields affect risk taking in alternative ways. Also, using tail beta, it is shown that ING Groep, Barclays and Société Générale are the three most systemically risky banks of Europe during the 15-year sample period. ING will suffer a loss of 27% of its market-valued total assets (MVA) in case of a crisis. The average loss of a large European bank during a severe crisis is estimated to be 15% of MVA. These losses cannot be covered by the amount of capital that banks own. Regulators should continue to limit systemic risk and consider the role of tax policy and leverage ratios in doing so.

The outline of this paper is as follows. Section 2 presents relevant literature on tax policy, leverage and systemic risk. Section 3 gives the methodology of this research. It starts with a theoretical background regarding the CAPM and Modigliani-Miller theorem on financing decisions. Furthermore, it describes how the link between tax policy and systemic risk contributions is examined. Section 3 concludes with the methodology regarding tail beta. The data used for this research is discussed in Section 4. The empirical results of the research are presented in Section 5. Section 6 concludes. It provides a summary of this research and gives suggestions for further research.

2 Literature Review

This section presents literature regarding tax policy, leverage and systemic risk. First, relevant literature on leverage and tax policy is given. In addition, the corresponding hypotheses are presented. After this, literature on systemic risk is discussed and the last hypothesis of this research is formulated.

2.1 Tax Policy and Leverage

As mentioned in the introduction, firms are encouraged to finance with debt instead of equity. One of the most well-known theories regarding financing decisions comes from Modigliani and Miller (1961). Modigliani and Miller (MM) argue that the value of a firm is independent of its financing decision in absence of corporate taxes. When taxes are present, they derive that the value of a company with debt is higher than the value of a company with no or lower debt. The MM theorem will be fully explained in Section 3.1.2. The theory is to be regarded as a theoretical proposition rather than an empirical one. It represents one of the first formal uses of a no arbitrage argument in financial markets. More fundamentally it structures the debate on the conditions necessary for effective arbitrage. Most attempts to overturn the theorem's controversial irrelevance result lead to a variety of arguments about which of the assumptions to reject or amend (Villamil, 2008).

Some literature regarding the MM theorem focuses on the assumption that firms base their financing decision on the weighted average cost of capital. This contradicts the emergent consensus that only the marginal effective tax rate matters in capital allocation (Duanjie, 2000). MacKie-Mason (1990) investigates the tax effect on financing decisions using the marginal tax rate on interest. He finds clear evidence of substantial tax effects on the choice between issuing debt or equity. Graham (1996) studies over 10,000 firms and finds that high-marginal-tax-rate firms issue more debt than their low-marginal-tax-rate counterparts. Keen and De Mooij (2012) investigate the effect of debt tax shields using a simple model of bank's financing decisions. They find that for a large cross-country panel, tax effects on leverage are significant. The responsiveness to taxation varies significantly across banks. Larger banks are noticeably less sensitive to tax. The welfare impact of distortions could be large however. Even small changes in the leverage of very large banks could have a large impact on the likelihood of their distress or failure. Hence, small changes in the leverage of large banks influence the probability of a financial crisis substantially. Schepens (2016) examines how the introduction of a tax shield for equity affects leverage ratios in Belgium. He finds that a more equal treatment of debt and equity increases bank capital ratios. This provides an indication that a larger difference between tax treatment of debt and equity decreases bank capital ratios. Put differently, increases in the tax shield on debt relative to a tax shield on equity, increase leverage ratios. Based on the available literature, the first hypothesis of this research is formulated as follows:

H1: The corporate income tax rate is positively related to the leverage ratio.

2.2 Leverage and Systemic Risk

Increases in leverage ratios throughout the system are potentially dangerous to financial stability. There appears to be an emerging acceptance that increases in leverage increase the systemic risk of financial institutions. High bank leverage is regarded as a contributing factor to the financial crisis. Acharya, Schnabl and Suarez (2013) illustrate that high financial leverage encouraged banks to engage in illiquid and risky lending and securities activities. It is shown that this resulted in widespread failures of these institutions. Adrian and Shin (2010) confirm this. They illustrate that balance sheets in the US expanded very rapidly during the expansionary phase before the crisis. In order to liquidate surplus capital, intermediaries started to grant credit to borrowers that lacked means to repay their loans. This eventually aggravated the financial downturn that followed. Mian and Sufi (2011) focus on household leverage. Their results show that household leverage as of 2006 is a powerful statistical predictor of the severity of the 2007–09 recession across US counties. More generally, Acharya and Thakor (2016) illustrate that higher leverage ratios leads to a higher probability of inefficient bank liquidation. Shleifer and Vishny (2010) show that leveraged banks are relatively unstable during times of high volatility. De Mooij, Keen and Orihara (2013) find that increases in leverage ratios increase the probability of financial crisis. They base their empirical analysis on data identifying "systemic banking crises". Such crises are defined as an event in which there are both (1) significant signs of financial distress and (2) significant policy interventions in banking.

Another paper worth mentioning is written by Hamada (1972). Based on the MM theorem and the CAPM, he argues that the market dependency of high levered firms is stronger than the market dependency of an unlevered firm. In other words, the expected return of a highly levered firm is relatively dependent on the average market return. More specifically he states that the covariance of the asset's rate of return with the market portfolio's rate of return should be greater for the stock of a firm with a higher debt-equity ratio than for the stock of another firm in the same risk-class with a lower debt-equity ratio. In addition, he shows empirically that approximately 20% of observed systematic risk of common stock can be explained merely by the added financial risk taken on by the underlying firm with its use of debt and preferred stock. Based on the available literature, the second hypothesis of this research is:

H2: The leverage ratio is positively related to the systemic risk contribution of a bank.

Suppose Hypothesis 1 and 2 are both correct. It follows that the corporate income tax rate is positively related to the systemic importance of banks. This leads to the third hypothesis of this research:

H3: The corporate income tax rate is positively related to the systemic importance of a bank.

This hypothesis answers the research question of this paper. Empirically, there is scarce evidence related to the effects of corporate income taxation on systemic risk. Most existing papers concentrate on the connection between taxes and leverage, neglecting the effect on systemic risk. One paper investigates the effect of tax policy on bank portfolio risk. Horváth (2013) finds no significant evidence that corporate income taxation makes banks less safe. Overall, he concludes that the elimination of the tax shield on debt may not decrease portfolio risk as much as expected. He explains that regulated banks may substitute leverage risk for asset risk. This limits the impact of tax policy. Another paper investigates the relation between the corporate income tax rate and systemic banking crises in two separate steps relating to the first two hypotheses of this research. De Mooij, Keen and Orihara (2013) measure (1) the effect of tax on leverage and (2) the effect of leverage on the probability of a financial crisis separately. They conclude that tax bias makes crises much more likely.

2.3 Systemic Risk

To provide an answer to the research question, systemic risk must be measured. Traditionally, risk measurements focused on the risk of individual institutions to capture the risk of the financial system as a whole. Behind this focus was a believe that the risk of the financial system is simply the sum of idiosyncratic risk. At the end of the twentieth century, the literature started to question this point of view. Rochet and Tirole (1996) explain that interbank transactions create interdependency through the connection of the asset and liability side of bank's balance sheets.

Financial institutions are interdependent. One institution's distress can spillover to other institutions. Rochet and Tirole create a general model of systemic risk in an interbank market. They measure contagion through perceived correlations in bank asset returns. Dornbusch, Park, and Claessens (2000) extend this model by studying contagion in times of crises. They illustrate that shocks are transmitted differently in times of crisis.

Since the outbreak of the financial crisis, the amount of literature on systemic risk measurement increased tremendously. Acharya et al. (2010) use equity returns of financial institutions to calculate Systemic Expected Shortfall (SES) and Marginal Expected Shortfall (MES). The MES is an institution's average loss when the financial system is in its left tail. SES is calculated as the weighted average of the institution's MES and its leverage. Similarly, Brownlees and Engle (2012) present the SRISK measure. SRISK is a function of the size of the firm, its degree of leverage, and its expected equity loss conditional on a severe market decline. It is calculated using a bivariate GARCH model with non-parametric tail estimators. The specification decomposes the behaviour of returns into time varying volatility, correlation and tails. Inference on the tails is based on flexible methods that allow for potential nonlinear dependence without making specific distributional assumptions. The SES, MES and SRISK define the contribution to systemic risk as the amount of capital shortfall during a crisis. Conditioning on a crisis allows to capture extremal dependence of asset returns. This type of tail dependency is characteristic for financial markets (e.g. Cont, 2001). Concerning the probability of a joint failure, it provides insight into the probability of Bank B failing if bank A experiences serious distress. This dependency is generally absent during tranquil periods but materializes in crisis periods. Because of this feature, extremal dependence must be taken into account when measuring systemic risk.

Adrian and Brunnermeier (2008) develop the delta CoVaR measure which reverses the conditioning. They define the contribution of systemic risk as the change in the value at risk of the system conditioned on a particular institution experiencing serious distress. With this definition, the delta CoVaR serves as a useful benchmark for relative judgments of risk, rather than expressing systemic risk in terms of actual losses. The CoVaR measures the value at risk (VaR) of an institutions based on asset returns using quantile regression. Quantile regression estimates the location of a specific percentile of a conditional distribution. It allows to locate the VaR of the system conditioned on the distress of a specific institution. Gauthier, Lehar and Soussi (2012) use the CoVaR to estimate systemic risk exposures for the Canadian banking system. Roengpitya and Rungcharoenkitkul (2010) analyse the Thai banking sector and Wong and Fong (2010) estimate the CoVaR for the CDS of Asia-Pacific economies. López et al. (2012) use the CoVaR approach to identify the main factors behind systemic risk in a set of large international banks.

Benoit et al. (2013) conclude from discussions with central bankers and regulators that systemic risk measures such as MES, SES, SRISK and CoVaR are currently being used in practice for monitoring of individual firms' systemic risk. Meanwhile, literature within this field keeps arising. An ample amount of research papers have discussed, implemented, and adjusted these systemic risk measures. The CoVaR measure has received critique for not being subadditive and downplaying the importance of institutional size (e.g. Huang et al. (2009)). Also, Danielsson et al. (2011) find a 99% correlation between CoVaR and VaR over time which insinuates that CoVaR isn't really much of an improvement from traditional risk measurement. MES and SES are said to contain a lot of noise. Furthermore, all measures are unable to account for the stylized fact that market prices are quite different in crisis and non-crisis periods.

The performance of delta CoVaR can be improved if its conditioned on institution i being at most at VaR level. The quantile regression used by Adrian and Brunnermeier (2012) conditions on institution i being exactly at VaR. Due to this focus on the threshold, it is unable to provide information about what happens within this quantile. More specifically, it cannot capture information in the data available on the volatility of returns within the tail. To capture this volatility, GARCH models are typically used. More specifically, the use of GARCH models to determine delta CoVaR allows to consider more severe distress events and it improves consistency with respect to the dependence parameter (Mainik and Schaanning, 2012). In addition, Benoit et al. (2012) show that the use of a GARCH model indeed results in a weak relationship between VaR and CoVaR. Another advantage of GARCH models is that they allow to capture time-dynamics. Girardi and Ergün (2013) use a multivariate GARCH to model the time-varying correlation between an institution and the system. They illustrate that their measure improves consistency of CoVaR. Additionally, they provide evidence that depository institutions contribute the most to systemic risk. Engle and Manganelli (2004) develop the CAViaR, a dynamic quantile test which is a combination of quantile regression and GARCH to analyse tail behaviour of asset returns. They provide empirical support to this new test of model adequacy.

Another measure of systemic risk using market-based indicators is developed by Huang et al. (2009). Huang et al. (2009) use data on credit default swaps (CDSs) of financial institutions and equity return correlations to model systemic risk as the price of insurance (DIP) against financial distress. Segoviano and Goodhart (2009) also use data on CDSs. They evaluate how individual firms contribute to potential distress of the system within a multivariate setting using a copula function. Billio et al. (2012) provide an indication of systemic risk based on the interconnectedness within the financial system. They assess Granger causality across and within different parts of the financial sector. Cont et al. (2010) use a Contagion Index for analyzing potential contagion and systemic risk in a network of interconnected financial institutions. Contrary to the methods based on historical market data, this is a forward-looking simulation-based approach based on interbank exposures. Cont (2009) argues that exposures-based indicators are a useful complement to market-based indicators by providing information contained in exposures.

Another line of work focuses on the use of extreme value theory (EVT) to measure systemic risk. EVT approximates contagion by the interconnectedness of tail events without necessarily conditioning on the occurrence of a crisis. It models observations which are close to the observed minimum or maximum, or even beyond, and extrapolates the observed properties into an extreme level. Due to this extrapolation method, it requires much less input than most non-parametric methods focusing on tail events. Rocco (2014) finds that EVT outperforms other methods used to compute VaR for quantiles equal to and exceeding 99%. Longin (2000) also uses extreme value theory to compute VaR. Hartmann et al. (2004) use extreme value theory to directly measure and report the expected number of market crashes conditional on the event that at least one market crashes. Zhou (2010) uses a multivariate EVT framework to provide two measures of systemic risk: the systemic impact index and the vulnerability index. The former assesses the risk that an institution imposes on the system. The latter concerns the risk that the system imposes on the institution.

Some literature is available that compares the performance of different systemic risk measures. Rodgríguez-Moreno and Peña (2013) for example conclude that measures based on CDSs outperform measures based on interbank rates or stock market prices considering EU and US data from 2004-2009. Huang et al. (2010) on the other hand, find a high correlation between the outcomes of CoVaR, MES and DIP when analyzing the US financial market in 2008. This finding should be taken with a pinch of salt since it is based on 2008 alone. Based on the limited amount of empirical evidence, it is hard to determine which measure is the best. Fundamentally, the best method to use is highly dependent on the specific purpose at stake. Not one measure will always be the best for any type of measurement. Furthermore, as the financial system and global economy continue to evolve, no systemic risk measure will be best for anything at all times.

2.4 Tail Beta

This research introduces a new approach to systemic risk measurement. The use of tail beta allows to link systemic risk measurement to the CAPM. Suppose tail beta is equal to the market beta known from the CAPM. In this case, it shares two appealing features with the market beta. Firs, tail beta is easy to interpret since it measures co-movement with the market in absolute terms. That is, on a day that the market suffers a loss of 5%, an asset with a tail beta of 2 is expected to suffer a downward movement of 10%. Second, the tail beta is an additive measure of tail risk. The tail beta of the system is the weighted average of the tail betas of the individual institutions. This characteristic is helpful when assessing portfolio or market efficiency.

Tail beta is derived from the MES which is calculated using extreme value theory. The MES is chosen as baseline measure because it's easy to interpret. It is widely known and related to the popular VaR. One other paper is known that measures the sensitivity of assets to extreme market downturns using tail beta. Instead of deriving tail beta based on systemic contribution, Van Oordt and Zhou (2016) use regressions on daily returns in a CAPM framework. They test for the presence of a systematic tail risk premium in the cross section of expected return. They illustrate that assets with higher tail betas are associated with significantly larger losses during future extreme market downturns. Surprisingly, they find no evidence of a premium associated with tail betas. Based on CAPM, the fourth hypothesis reads:

H4: Financial markets price systemic risk efficiently.

Extreme value theory is used because it allows to minimize problems typically associated with tail estimation. Within this research, crises are defined as extreme tail events that happen once per decade. As mentioned, conditioning on a severe crisis allows to capture extremal dependence. To estimate the MES or tail beta for a corresponding high quantile, ordinary least squares (OLS) estimation or quantile regression does not suffice. Observations for a quantile this high are rare which makes it hard, if not impossible, to consistently estimate the tail distribution using OLS. Furthermore, financial returns are characterized by a heavy-tailed distribution. The tail distribution of asset returns is expected to best approximated by a power-law or Pareto-like distribution (Cont, 2001). When assuming a normal distribution, the probability of extreme events is underestimated. Extreme value theory allows to focus on the tail area specifically. It combines empirical tail observations with a parametric tail distribution further in the tail. This semi-parametric approach allows to extrapolate in-sample observations of moderately bad outcomes to out-of-sample extremes. This property makes it the best method available to estimate very high quantiles corresponding to a severe crisis.

3 Methodology

This section presents the methodology of this research. First, it provides background theory necessary to understand the CAPM and the MM theorem. After this, the regression equations are presented that are used to investigate empirically whether tax policy and leverage ratios are related. Additionally, the estimation specifications on leverage and systemic risk are provided. Last, it is discussed how systemic risk contributions are measured, concluding with the presentation of tail beta.

3.1 Theoretical background

To make a distinction between the idiosyncratic and systemic risk component in the empirical estimation of returns, consider the following specification for estimation:

$$\tilde{R_i} = \alpha_i + \beta_i \tilde{R_m} + \tilde{\varepsilon_i} \tag{1}$$

Where $\tilde{R_i}$ denotes the return for bank i. The return depends on the idiosyncratic constant component α_i, the sensitivity to market returns β_i, the random variable denoting market returns $\tilde{R_m}$ and a random error term $\tilde{\varepsilon_i}$. To gain a broader insight on equation (1) and see how it relates to basic concepts in financial theory, the CAPM and MM theorem are discussed first.

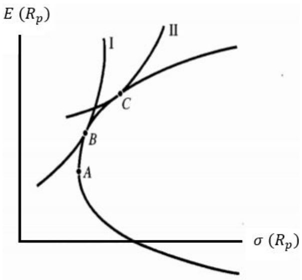
3.1.1 Capital Asset Pricing Model

Think of each bank i as having one investor. The investor is responsible for the asset management of the bank and wants to select an optimal portfolio on the market. All investors ('banks') in the market are risk averse. The investors will only take risk if they are compensated for this. More specifically, they demand a risk premium that compensates the utility cost of uncertainty. Each investor maximizes return for a given level of risk. Furthermore, assume that a market equilibrium exists. The prices of all assets adjust until the market clears. Assume all investors know this and have homogeneous expectations.[1] They face the same variance opportunity set and select efficient portfolios regardless of their individual risk-aversity as shown in Figure 1. The y-axis denotes expected return on the portfolio and the x-axis shows the standard deviation of the risky asset. If the standard deviation is higher, there is more uncertainty about the return of the asset. More

[1] For a more extensive proof of the efficient market hypothesis and its underlying assumptions see Fama (1970).

uncertainty implies more risk. Investors must be compensated for this risk by a higher expected return. In Figure 1, Investor I chooses efficient portfolio B. Investor II, who is less risk averse, chooses efficient portfolio C.

Figure 1: All investors select efficient portfolios

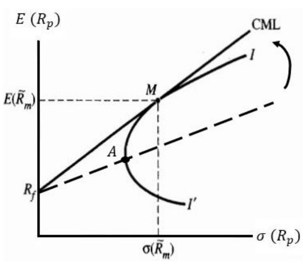


Now suppose there is one risk-free asset and a variety of risky assets in the market. More specifically, a market portfolio M exists which composes of all marketable risky assets. Each asset in M is held in proportion to their value weights for market equilibrium to exist. All investors try to hold some combination of the risk-free asset and the market portfolio M. Dependent on individual attitudes towards risk, the right combination of the risk-free asset and market portfolio M is chosen. All investors perceive the riskiness of assets in a similar manner. That is, they hold the same beliefs regarding the volatilities, correlations, and expected returns of securities. Recall each investor maximizes return for a given level of risk. Given these assumptions, each investor faces the same linear efficient set called the capital market line (CML):

$$E(R_p) = R_f + \frac{E(R_m) - R_f}{\sigma(R_m)}\sigma(R_p) \tag{2}$$

Which gives the simple linear relationship between the risk and return for efficient portfolios of assets. Figure 2 gives the graphical representation of the CML given that all investors try to hold some combination of the risk-free asset and the market portfolio M.

Figure 2: The capital market line



Each point on the CML denotes an efficient portfolio allocation. The opportunity set provided by different combinations of the risky asset and the market portfolio is denoted by the line IMI'. Dependent on the investor's risk attitude, one specific point on the IMI' will be chosen. In other words, investors will self-select the point that is most optimal given their risk attitude. The M denotes the highest possible point on the efficient frontier. This gives the highest possible expected returns. A very risk-averse investor might prefer A however. He settles for a lower expected return in order to minimize the costs of uncertainty.

Consider a portfolio consisting of $a\%$ invested in the risky asset I and $(1 - a\%)$ invested in the market portfolio M. The mean and standard deviation are given as follows:

$$E(R_p) = aE(R_i) + (1-a)E(R_m) \tag{3}$$

$$\sigma(R_p) = [a^2\sigma_i^2 + (1-a)^2\sigma_m^2 + 2a(1-a)\sigma_{im}]^{1/2} \tag{4}$$

To see how the mean and standard deviation change when a changes, take the first derivative with respect to the percentage of the portfolio a, invested in asset I. Evaluate this at market equilibrium where $a = 0$. This gives the slope of the risk-return trade-off evaluated at point M: [2]

$$\left.\frac{\partial E(R_p)/\partial a}{\partial \sigma(R_p)/\partial a}\right|_{a=0} = \frac{E(R_i) - E(R_m)}{(\sigma_{im} - \sigma_m^2)/\sigma_m} \tag{5}$$

Remember the equilibrium relationship of (2). Given market efficiency, the slope of the CML must be equal to the slope of the opportunity set at point M. Hence:

$$\frac{E(R_p) - R_f}{\sigma_m} = \frac{E(R_i) - E(R_m)}{(\sigma_{im} - \sigma_m^2)/\sigma_m} \tag{6}$$

Suppose $R_p = R_m$. The expected return on an efficient portfolio equals the expected return of efficient market portfolio M. The above equation can be rewritten as follows:

$$E(R_i) = R_f + [E(R_m) - R_f]\frac{\sigma_{im}}{\sigma_m^2} \tag{7}$$

Equation (7) is known as the capital asset pricing model (CAPM). The required rate of return on a risky asset is equal to the risk-free rate of return plus a risk premium. The risk premium is the

[2] For a more extensive explanation see Copeland and Weston (1988).

price of risk multiplied by the quantity of risk. The quantity of risk is often called beta, β_i:

$$\beta_i = \frac{\sigma_{im}}{\sigma_m^2} = \frac{COV(R_i, R_m)}{VAR(R_m)} \tag{8}$$

The quantity of risk is dependent on the covariance between the asset and market return and the variance in the market. Meaning the quantity of risk depends on (i) the extent to which the returns of the asset and the market move in tandem and (ii) the uncertainty in the market. This results in the traditional CAPM model:

$$E(R_i) = R_f + \beta_i[E(R_m) - R_f] \tag{9}$$

Investors can always diversify all idiosyncratic risk away.[3] For market risk this is not the case since it is present in each investment. The amount of market risk of is given by $[E(R_m) - R_f]$. The β_i gives the sensitivity to this risk. It can be interpreted as the risk premium for the investor. The β_i compensates the utility cost of uncertainty dependent on the covariance risk of the specific asset. Note that the total risk of any individual asset can thus be split up into two components. This leads back to equation (1) in which the specification equation for returns was given as a function of idiosyncratic and systemic risk:

$$\tilde{R_i} = \alpha_i + \beta_i \tilde{R_m} + \tilde{\varepsilon_i}$$

Suppose the CAPM holds and consider its implications for the above equation for estimation. Markets are efficient and no investor can outperform the market. In this case, the risk-free return, denoted by α_i, is expected to equal zero. No investor is able to obtain risk-free excess returns. Additionally, investors are able to diversify all idiosyncratic risk, ε_i, away. Hence, $E[\tilde{\varepsilon_i}] = 0$. Next, consider the β_i.

To see that the β_i from the specification for estimation is the same as the β_i from the CAPM, consider the statistical properties of ordinary least squares (OLS) estimation. Take the following simple regression model into account:

$$y = a + \beta \cdot x + u \tag{10}$$

[3]See Copeland and Weston (1988) for an explanation.

Where the y denotes a dependent variable, the a denotes a constant, the β estimates the correlation between x and y, the x is the independent variable and the u is the error term. Assume the above specification can be estimated based on a random data sample of x and y. Specifically, let $\{(x_i, y_i) : i = 1, ..., n\}$ denote a random sample of size n. The specification for estimation is given as follows:

$$y_i = a_i + \beta \cdot x_i + u_i \tag{11}$$

For each i. Note this specification is of the same form as equation (1). Here, the u_i is the error term for observation i because it contains all factors affecting y_i other than x_i. Under the assumption that u is uncorrelated with x, the $\hat{\beta}$ can be obtained as follows: [4]

$$\hat{\beta}_{OLS} = \frac{\sum(x_i - \overline{x}_i)(y_i - \overline{y_i})}{\sum(x_i - \overline{x}_i)^2} \tag{12}$$

Where x_i is an observed value of x taken from a random sample. The $\overline{x_i}$ denotes the sample average of x_i. Likewise for y. The specification for β shows that the estimated value for β is simply the sample covariance between x_i and y_i divided by the sample variance of x_i.

Now assume that y denotes the expected return on risky asset i, given as R_i. The x gives the expected return on the market, given as R_m. In this case, the β gives the sample covariance between R_i and R_m divided by the sample variance of R_m. This is the exact same β as obtained in the CAPM. The β obtained in CAPM is equal to the β obtained using OLS.

Getting back to the implications of the CAPM, recall the market is efficient. In this case, the market is simply the sum of all individual institutions. Hence:

$$E[R_m] = \frac{1}{n} \sum_{i=1}^{n} E[R_i] \tag{13}$$

Rewrite the CAPM as defined in equation (9) as the sum of all individual firms:

$$\frac{1}{n} \sum_{i=1}^{n} E(R_i) = R_f + [E(R_m) - R_f] \frac{1}{n} \sum_{i=1}^{n} \beta_i \tag{14}$$

It is clear that this only holds if $\frac{1}{n} \sum_{i=1}^{n} \beta_i$ equals 1. Hence, based on the CAPM it is expected that on average for large samples, α_i and ε_i equal zero and β_i equals 1.

[4] see e.g. Wooldrigde (2015) for a more extensive explanation of the basic assumptions underlying OLS

3.1.2 Modigliani-Miller Theorem

The CAPM provides a natural theory for the pricing of risk which is also relevant from a debtor's perspective. If a bank wants to raise its financing it can do so by issuing debt or equity. When issuing deposits or debt ('bonds'), the bank promises to pay fixed schedules of interest in the future to the bond holders in exchange for money now. Equity holders on the other hand, own a share. This share is a claim on the residual earnings of the bank in the future and is given in return for retained earnings now. Shareholders retain control of the investment decision of the firm and they only accept those projects that increase their expected utility of wealth.

Given the differences in legal status and the different costs related to debt and equity, it is expected that the appropriate mix of debt and equity is very important for the value of the firm. Despite this intuition, one of the most well-known theories in corporate finance shows that, in absence of any market imperfections including corporate taxes, the market value of the firm is independent of its capital structure. When taxes are present, it is derived that the value of a firm increases when more debt is used. This theory is known as the Modigliani-Miller theorem.

As written in Copeland and Weston (1992), MM assume either implicitly or explicitly that:

- Capital markets are frictionless.
- Individuals can borrow and lend at the risk-free rate.
- There are no cost to bankruptcy.
- Firms issue only two types of claims: risk-free debt and (risky) equity.
- All firms are assumed to be in the same risk class (implying that expected future cash flows from 2 projects are perfectly correlated).
- Corporate taxes are the only government taxes.
- All cash flow streams are perpetuities (i.e. no growth).
- Corporate insiders and outsiders have the same information.
- Managers always maximize shareholders' wealth (i.e. no agency costs).

Although many of these assumptions are unrealistic, the main conclusions of the model of firm behavior remain the same if they are relaxed (Copeland and Weston, 1992).

To understand MM's argument, write the value of an unlevered firm, V^U, as a function of its perpetual stream of free cash flows, FCF:

$$V^U = \frac{FCF_{t+1}}{1+r} + \frac{FCF_{t+2}}{(1+r)^2} + ... + \frac{FCF_{t+i}}{(1+r)^i} \tag{15}$$

Where r denotes the discount rate, i.e. the equity cost of capital. Note that in absence of debt, the equity cost of capital equals the weighted-average cost of capital (WACC). The WACC, to be denoted by ρ, is the rate that a company is expected to pay on average to all its security holders to finance its assets. Without debt financing, the WACC is only determined by on the equity cost of capital. Hence $r = \rho$. Later on, when debt is added to the model, the WACC differs from the equity cost of capital.

Suppose the average stream of cash flows of a firm with no debt does not change over time. The following condition holds:

$$E(FCF_{t+i}) = FCF_t \qquad \text{for all } i \tag{16}$$

Considering the expected cash flow is the same for each period, the value of the unlevered firm can be written as:

$$V^U = \frac{FCF}{1+r} + \frac{FCF}{(1+r)^2} + ... + \frac{FCF}{(1+r)^i} \tag{17}$$

In order to simplify this, multiply both sides of equation (17) by $(1+r)$:

$$V^U(1+r) = \frac{FCF}{1+r}(1+r) + \frac{FCF}{(1+r)^2}(1+r) + ... + \frac{FCF}{(1+r)^i}(1+r) \tag{18}$$

Next subtract equation (17) from equation (18):

$$\begin{aligned} V^U(1+r) - V^U &= FCF + \frac{FCF}{1+r} + \frac{FCF}{(1+r)^2} + ... + \frac{FCF}{(1+r)^i} && (19)\\ &\quad - \frac{FCF}{1+r} - \frac{FCF}{(1+r)^2} - ... - \frac{FCF}{(1+r)^i} && (20)\\ &= FCF && (21) \end{aligned}$$

Simplifying yields:

$$\begin{aligned} V^U(1+r) - V^U &= FCF && (22)\\ V^U &= \frac{FCF}{r} && (23) \end{aligned}$$

The value of an unlevered firm depends on its free cashflows and r. To clarify this, start with a model in which corporate taxes are absent. Take the following income statement into account as presented by Copeland and Weston (1992):

Table 1: Income Statement

Rev	Revenues
- VC	Variable costs of operations
- FCC	Fixed cash costs
- dep	Non-cash charges (depreciation and deferred taxes)
NOI	Net operating income
- $k_d D$	Interest on debt (interest rate on debt k_d · principal D)
NI	Net income

Where interest payments are zero for an unlevered firm. To start, take the net income from operations:

$$Rev - VC - FCC - dep \tag{24}$$

Note this is not yet a cash flow definition. A portion of total fixed costs are noncash expenses such as depreciation and deferred taxes. To convert operating income into cash flows, depreciation and other noncash expenses must be added back. Hence:

$$(Rev - VC - FCC - dep) + dep \tag{25}$$

Finally, consider that the firm has no growth by assumption. All cash flows are perpetuities. This implies that depreciation each year must be replaced by investment, I, in order to keep the same amount of capital in place. Therefore $dep = I$. The free cash flow available for payment to creditors and shareholders is:

$$FCF = (Rev - VC - FCC - dep) + dep - I \tag{26}$$
$$= (Rev - VC - FCC - dep) \tag{27}$$
$$= NI + k_d D \tag{28}$$
$$= NOI \tag{29}$$

Recall $k_d D$ is zero for a firm without debt. The following result is obtained:

$$V^U = \frac{E(FCF)}{r} = \frac{E(NOI)}{\rho} \tag{30}$$

Since it has been derived that for an unlevered firm in absence of taxes, $FCF = NOI$ and $r = \rho$.

Next, suppose that the firm issues debt as well. The value of the levered firm is denoted by V^L.

Again, the value of the firm will be written as a function of its free cash flows. First, the amount of free cash flows will be determined. For a levered firm, cash flows must be split up between debt holders and shareholders. Debt holders receive interest payments, i.e. $k_d D$. Shareholders receive residual earnings of the firm, i.e. $NI + dep - I$. The income of the firm can be expressed as follows:

$$NI + dep - I + k_d D = (Rev - VC - FCC - dep - k_d D) + k_d D \tag{31}$$

Where $k_d D$ drops out. This gives the following result:

$$NI + dep - I + k_d D = (Rev - VC - FCC - dep) \tag{32}$$

Note this is not yet a cash flow definition. A portion of total fixed costs are noncash expenses such as depreciation and deferred taxes. To obtain a cash flow definition, depreciation and other noncash expenses must be added back. Hence:

$$NI + dep - I + k_d D = (Rev - VC - FCC - dep) + dep \tag{33}$$

Finally, consider the firm has no growth by assumption. All cash flows are perpetuities. This implies that depreciation each year must be replaced by investment in order to keep the same amount of capital in place. Therefore $dep = I$. The free cash flow available for payment to creditors and shareholders is:

$$\begin{aligned} FCF &= (Rev - VC - FCC - dep) + dep - I && (34)\\ &= (Rev - VC - FCC - dep) && (35)\\ &= NI + k_d D && (36)\\ &= NOI && (37) \end{aligned}$$

The value of the levered firm is equal to the discounted value of the two cash flows that it provides. Recall that the expected cash flow is the same for each period and the firm has no growth. The NI is discounted by r again. The second part of (35) is assumed to be risk-free. It is discounted by the cost of risk-free debt, k_b. The value of the levered firm can be expressed as follows:

$$V^L = \frac{E(NI)}{r} + \frac{k_d D}{k_b} \tag{38}$$

Consider $r > k_b$. The required rate of return will always be higher for a risky asset than for a risk-free asset. In this case, the value of the firm increases when relatively more debt is used for financing. MM argue that a firm's leverage has no effect on the WACC. They argue that the following condition holds:

$$V^L = \frac{E(NI)}{r} + \frac{k_d D}{k_b} = \frac{E(NOI)}{\rho} \tag{39}$$

Where ρ denotes the WACC. Note that the WACC is determined by the cost of equity and debt now. MM argue that any gains from using more of the seemingly cheaper debt capital are offset by the correspondingly higher cost of equity capital. Equity capital becomes riskier and thus more expensive once debt has increased. The cost of equity capital is therefore a linear function of the debt-equity ratio. The WACC remains the same no matter what combination of financing sources the firm actually choses. In this case:

$$V^L = \frac{E(NOI)}{\rho} = V^U \tag{40}$$

Hence, the value of the levered firm is equal to the value of the unlevered firm.

3.1.3 Introducing Taxation

Next, consider the value of an unlevered firm when corporate taxes are present. The income statement is adjusted as follows:

Table 2: Income Statement with Tax

Rev	Revenues
- VC	Variable costs of operations
- FCC	Fixed cash costs
- dep	Non-cash charges (depreciation and deferred taxes)
NOI	Net operating income
- $k_d D$	Interest on debt (interest rate on debt k_d · principal D)
EBT	Earnings before tax
-T	Taxes (corporate tax)
NI	Net income

To convert operating income after tax into cash flows, depreciation and other non-cash expenses must be added back. When all cash flows are assumed to be perpetuities, free cash flow is the same thing as net operating income after taxes for a non-growing unlevered firm:

$$FCF = (Rev - VC - FCC - dep)(1 - \tau_c) = NOI(1 - \tau_c) \tag{41}$$

Since without debt, interest payments are zero. The value of the unlevered firm can be written in two ways:

$$V^U = \frac{E(FCF)}{r} \quad \text{or} \quad V^U = \frac{E(NOI)(1-\tau_c)}{r} \tag{42}$$

Suppose the firm issues debt as well. The after-tax cash flows must be split up between between debt holders and shareholders. Debt holders receive $k_d D$. Shareholders receive $NI + dep - I$. Hence:

$$NI + dep - I + k_d D = (Rev - VC - FCC - dep - k_d D)(1-\tau_c) + k_d D \tag{43}$$

Given that depreciation equals investment for a non-growing firm, the following result is obtained after rearranging:

$$NI + k_d D = (Rev - VC - FCC - dep)(1-\tau_c) + k_d D\tau_c \tag{44}$$

$$= NOI(1-\tau_c) + k_d D\tau_c. \tag{45}$$

The first part of the income stream can be discounted by r again. The second part of the stream, $k_d D$, discounted at the before-tax cost of risk-free debt, k_b. The value of the levered firm is the sum of the discounted value of the two types of cash flows that it provides. Hence:

$$V^L = \frac{E(NOI)(1-\tau_c)}{r} + \frac{k_d D\tau_c}{k_b} \tag{46}$$

The $k_d D$ is the perpetual stream of risk-free payments to bondholders and k_b is the before-tax market-required rate of return for the risk-free stream. Given that the stream is perpetual, the market value of the bonds is:

$$B = \frac{k_d D}{k_b} \tag{47}$$

Equation (46) can be rewritten as:

$$V^L = V^U + \tau_c B \tag{48}$$

Which illustrates that the value of a levered firm is equal to the value of an unlevered firm plus tax shield. The value of a levered firm will increase if relatively more debt is used for financing. With taxation, the cost of equity capital will increase less than the debt-equity ratio. The tax shield allows a firm to increase its value by issuing more debt. This is known as the MM theorem.

3.2 Tax Policy

To investigate whether tax policy affects financing decisions empirically, country average leverage ratios will be regressed on corporate income tax rates. The following panel regression is performed using the following specification:

$$lev_{j,t} = \alpha_j + \phi_t + \hat{\xi} \cdot tax_{j,t} + \varepsilon_{j,t} \tag{49}$$

Where leverage is defined as the average debt to equity ratio in country j at time t. The tax rate denotes the corporate income tax (CIT) rate. The t is denoted in months. The α_j captures country fixed-effects to account for country-specific regulation and governance. The ϕ_t captures time fixed-effects to absorb time trends such as increases in capital buffers due to stricter regulation after the financial crisis. The $\varepsilon_{j,t}$ denotes the error term.

To make a plausible comparison, the panel regression is limited to those countries that have at least 3 institutions within the data sample, i.e. Belgium, Denmark, France, Germany, Greece, Italy, Spain, Sweden, Switzerland and the United Kingdom. For these 10 countries, the average leverage ratio will be based on the country-specific institutions in the data sample. Recall Hypothesis 1: *The corporate income tax rate is positively related to the leverage ratio.* It is expected that $\hat{\xi}$ is positive and significantly different from zero.

In order to obtain the elasticity of leverage with respect to the corporate income tax rate, it would be interesting to rewrite equation (49) in a log-log model. This relates to the following specification:

$$log(lev_{j,t}) = \alpha_j + \phi_t + \hat{\delta} \cdot log(tax_{j,t}) + \varepsilon_{j,t} \tag{50}$$

As discussed in Section 4, Belgium and Greece experience negative average leverage ratios. It is not possible to take the log of a negative value. To ensure a balanced panel, all observations for Belgium and Greece are dropped from the sample when performing the regression specified in (50). To see what effect a limitation of the sample has, specification (49) will first be performed using the limited sample. Since the panel size is smaller, it is expected that the specified coefficient for equation (49) has less power when estimated using the limited sample. Concerning (50), it is expected that $\hat{\delta}$ is positive based on Hypothesis 1.

Alternatively, the regression could be run for the 1754 positive observations from the 10 countries. The resulting panel will be unbalanced however. It is therefore unable to account for country- and time-fixed effects. The regression equation will not be run without both fixed-effects to avoid model misspecification.

3.3 Synthesis of the CAPM and Modigliani-Miller Theorem

The next step in the analysis focuses on the relation between leverage ratios and systemic contribution as formulated in Hypothesis 2. The CAPM and MM theorem are used to derive the theoretical relation between leverage and systemic contribution first. After this, the specifications for empirical estimation are presented.

Recall that, according to MM:

$$V^L = V^U + \tau_c B$$

To relate this to the CAPM, the value of the firm will be rewritten as rate of return:

$$\Delta V^L = \Delta V^U + \Delta \tau_c B$$

The change in the value of the levered firm is equal to the change in the value of the unlevered firm plus the change in tax shield. From this it follows that:

$$E[R_{i,L}] > E[R_{i,U}] \tag{51}$$

The expected return of a levered firm is higher than the expected return of an unlevered firm. Connecting the CAPM to the MM theorem gives the following condition:

$$E[R_{i,L}] = R_f + \beta_L(E[R_m] - R_f) > E[R_{i,U}] = R_f + \beta_U(E[R_m] - R_f) \tag{52}$$

Given that the expected return on a levered firm is higher than the expected return on an unlevered firm, the above condition can be simplified as follows:

$$\beta_L > \beta_U \tag{53}$$

Which illustrates that the β for a levered firm is higher than the β for an unlevered firm. Put differently, the β increases with the leverage ratio. Interpreting this result from the CAPM point of view, it is concluded that firms' sensitivity to market risk increases with the leverage ratio. This is the main conclusion derived from the synthesis of the CAPM and MM theorem.

3.3.1 Introducing Extreme Events

To relate the synthesis of the CAPM and MM theorem to systemic risk, the 'tail beta' is introduced. The tail beta gives the sensitivity of a bank's returns to extreme market conditions. As explained earlier, these extreme market conditions are of interest when assessing systemic risk. The higher the tail beta, the larger the sensitivity of returns of bank i to a severe market crisis. Alternatively, tail beta can be interpreted as a measure of systemic risk contribution. The more i suffers from a crisis, the larger its adverse impact on the market will be. The mechanisms through which such shocks propagate throughout the market have been discussed in the Introduction.

Suppose tail beta is equal to the beta from the CAPM with the exception that it focuses on extreme tail risk. The conditional CAPM can be written to focus on extreme events as follows:

$$E(R_i|R_m > q) = R_f + \beta_i^T[E(R_m|R_m > q) - R_f] \tag{54}$$

Where the expected return of i is conditioned on a severe market crisis. As will be explained in Section 3.4, this crisis is defined by the event that market returns exceed a very high quantile q. The β_i^T denotes the tail beta, which is calculated using the methodology presented in Section 3.6. If the CAPM holds, the tail beta represents the risk premium on extreme tail risks. Using the main conclusions derived from the CAPM, it can be examined whether systemic risk is priced efficiently in the market. This will be tested by examining the following condition:

$$\frac{1}{n}\sum_{i=1}^{n}\beta_i^T = 1 \tag{55}$$

Additionally, it is investigated whether all idiosyncratic risk is diversified away. In this case, α_i is expected to equal zero for the full sample. To check whether α_i equals zero empirically, the following time series regression is performed:

$$\frac{1}{n}\sum_{i=1}^{n}R_{i,t} = \hat{\alpha}_i + \overline{\beta_i^T} \cdot R_{m,t} + \varepsilon_{i,t} \tag{56}$$

Where $R_{i,t}$, $R_{m,t}$ and $\overline{\beta_i^T}$ are input variables, denoting returns of the institutions in the sample, returns of the market index and the mean value of tail beta respectively. As mentioned in 3.1.1, it can be concluded that markets are efficient if $\frac{1}{n}\sum_{i=1}^{n}\beta_i^T$ equals 1 and a_i and ε_i equal zero.

Getting back to the synthesis of the CAPM and MM theorem in an extreme events setting, rewrite equation (53) using the tail beta. This gives the following result:

$$\beta_L^T > \beta_U^T \tag{57}$$

Which illustrates that the β^T for a levered firm is higher than the β^T for an unlevered firm. Put differently, the β^T increases with the leverage ratio. This implies that systemic risk contribution is an increasing function of the leverage ratio. This relation will be tested empirically.

3.3.2 Specifications for Regression

Similar to Hamada (1972) - with exception of the focus on the tail beta - the following cross-section analysis is run:

$$\hat{\beta_i^T} = \alpha + \hat{\gamma}(lev) + \varepsilon_i \qquad \text{for i=1,2,...,n} \tag{58}$$

Where the sample average of leverage, calculated as debt over equity, is taken for each bank. Given Hypothesis 2, it is expected to find a value for $\hat{\gamma}$ that is significantly different from zero and positive.

Lien et al. (2016) argue that linear regressions on ratio variables might lead to model misspecification. They show that the logarithm of the ratio variable performs slightly better than the ratio variable. As a robustness test, the following regression is estimated:

$$log(\hat{\beta_i^T}) = \alpha + \hat{\eta} \cdot log(lev) + \varepsilon_i \qquad \text{for i=1,2,...,n} \tag{59}$$

Which allows to interpret the relation between systemic risk contribution and leverage as an elasticity. The $\hat{\eta}$ estimates the percentage change in systemic contribution that occurs due to a percentage change in leverage.

In addition to the regressions using tail beta, an alternative measure for systemic risk is used as dependent variable. Section 3.4 introduces the marginal expected shortfall (MES). It is interesting to consider this measure on top of the tail beta because of its popularity and its straightforward interpretation. The following specification for estimation is used:

$$\widehat{MES}_i = \alpha + \hat{\tau}(lev) + \varepsilon_i \qquad \text{for i=1,2,...,n} \tag{60}$$

As a robustness check, MES_i will also be regressed in a log-log model. Recall that the log-log model gives the elasticity of systemic contribution with respect to the leverage ratio. As discussed in Section 3.6, the MES is linearly related to $\hat{\beta_i^T}$ by the factor ES_m. Given this linear relation, the elasticity of systemic contribution with respect to the leverage ratio should be independent of the choice for tail beta or MES. Whether the systemic contribution is measured by $\hat{\beta_i^T}$ or the related MES_i should not matter. The following specification for estimation is used:

$$log(\widehat{MES_i}) = \alpha + \hat{\kappa} \cdot log(lev) + \varepsilon_i \qquad \text{for i=1,2,...,n} \tag{61}$$

It is expected that the coefficient on leverage is the same as obtained in (59). Hence, $\hat{\tau} = \hat{\kappa}$.

Last, multiple regression is performed. This allows to address Hypothesis 3 directly rather than deriving it from the findings regarding Hypothesis 1 and 2. The systemic contribution is regressed on leverage and tax rates using the following specification:

$$\hat{\beta_i^T} = \alpha + \hat{\gamma}(lev) + \hat{\zeta} \cdot \overline{tax_i} + \hat{\psi}\Big(lev \cdot \overline{tax_i}\Big) + \varepsilon_i \qquad \text{for i=1,2,...,n} \tag{62}$$

Where $\hat{\psi}$ is included to account for the interaction effect of tax and leverage. Additionally, the log-log specification is regressed as well to (i) account for misspecification when regressing on ratio variables and (ii) help interpretation. The corresponding specification for regression is given as:

$$log(\hat{\beta_i^T}) = \alpha + \hat{\eta} \cdot log(lev) + \hat{\theta} \cdot log(\overline{tax_i}) + \hat{\phi}\Big(log(lev) \cdot log(\overline{tax_i})\Big) + \varepsilon_i \qquad \text{for i=1,2,...,n} \tag{63}$$

To ensure the results are widely interpretable, the same regressions are performed using the MES:

$$\widehat{MES_i} = \alpha + \hat{\tau}(lev) + \hat{\zeta} \cdot \overline{tax_i} + \hat{\psi}\Big(lev \cdot \overline{tax_i}\Big) + \varepsilon_i \qquad \text{for i=1,2,...,n} \tag{64}$$

Last, as a robustness check, MES_i will also be regressed in a log-log model:

$$log(\widehat{MES_i}) = \alpha + \hat{\kappa} \cdot log(lev) + \hat{\theta} \cdot log(\overline{tax_i}) + \hat{\phi}\Big(log(lev) \cdot log(\overline{tax_i})\Big) + \varepsilon_i \qquad \text{for i=1,2,...,n} \tag{65}$$

Where it is expected that all regression coefficients of equation (63) equal the regression coefficients obtained when estimating equation (65).

3.3.3 Partial Effects

For all specifications including interaction effects, the partial effects, denoted by δ, will be presented. As written in Wooldridge (2015), the coefficients on the original variables have to be reparametrized to allow meaningful interpretation. The coefficients for leverage (tax) present the effect of leverage (tax) assuming tax (leverage) is zero. It is more interesting to evaluate the partial effect of leverage (tax) at the mean value of tax (leverage). The partial effect of leverage is calculated as the estimated coefficient on leverage plus the estimated coefficient on the interaction effect times the mean value of tax. For explanatory purposes, assume x_1 = leverage and x_2 = tax. The coefficient on the interaction term is given by $\hat{\psi}$. The partial effect of leverage on systemic contribution, δ_1, is given as follows:

$$\delta_1 = \hat{\gamma} + \hat{\psi} * \mu_2 \tag{66}$$

Where μ_2 gives the mean value of tax. As stated in the Appendix, the mean value of tax is 26.8. For the log-log model, δ_1 is given by:

$$\delta_1 = \hat{\eta} + \hat{\phi} * log(\mu_2) \tag{67}$$

Similarly, the partial effect of tax on systemic contribution, δ_2, is given as follows:

$$\delta_2 = \hat{\zeta} + \hat{\psi} * \mu_1 \tag{68}$$

Where μ_1 gives the mean value of leverage. As illustrated in the data section, this value equals 18.45. For the log-log model, δ_2 is given by:

$$\delta_2 = \hat{\theta} + \hat{\phi} * log(\mu_1) \tag{69}$$

3.4 Marginal Expected Shortfall

Before the regressions specified in Section 3.3 can be performed, the MES and tail beta must be calculated for each institution in the sample. This section presents the derivation of MES in a CAPM framework. Section 3.6 describes how tail beta can be obtained.

The MES defines systemic risk contribution as the expected return (shortfall) of a bank conditioned on a crisis to occur. To estimate MES, start from equation (1) again:

$$\tilde{R_i} = \alpha_i + \beta_i \tilde{R_m} + \tilde{\varepsilon_i}$$

And take expectations. According to expectation theory the expected return of a constant is equal to the mean of the constant and the (ii) error term is zero on average:

$$E[R_i] = a_i + \beta_i \cdot E[R_m] \tag{70}$$

Note that the constant a_i and the (dropped-out) error term are independent of the market condition. Next, consider the expected return in case of an extreme. Suppose a crisis defined as an extreme tail event that happens once per decade. The probability of this crisis to occur is very small. The expected return in case of a crisis is defined as:

$$ES_q^i = E[a_i + \beta_i^T \cdot R_m | R_m > q] \tag{71}$$

Where the expected shortfall, ES_q^i, is given as positive number. A very high quantile q must be obtained for the crisis condition to apply. The tail beta captures systemic tail risk. Next, rewrite equation (71) as follows:

$$ES_q^i = \beta_i^T E[R_m | R_m > q] + E[a_i | R_m > q] \tag{72}$$

Recall that the idiosyncratic component a_i is independent of the market condition. Because of this independence it does not contain any information relevant for systemic risk measurement. To find the marginal contribution of i to systemic risk, the part of returns related to the market is of interest. The MES is given as the part of i's expected return that driven by the market factor during a crisis:

$$MES_q^i = \beta_i^T E[R_m | R_m > q] \tag{73}$$

The MES can also be written as follows:

$$MES_q^i = \beta_i^T ES_m[R_m | R_m > q] \tag{74}$$

Where ES_m denotes the expected shortfall of the market during the worst days. This illustrates that the marginal expected shortfall of i depends on the expected shortfall in the market and the sensitivity to market returns in a crisis situation, β_i^T. The expected shortfall of the market during the worst days, ES_m, is constant across the sample. It denotes the average loss of the system during the defined worst days. The cross-sectional dispersion in the MES is thus attributed to the cross-sectional difference in β_i^T. This conclusion resembles the intuition from the CAPM which showed that the return on a specific asset depends on the covariance risk, i.e. how much an asset moves in tandem with the market (Section 3.1.1).

3.5 Estimation Method: Extreme Value Theory

As mentioned in the Literature Review, crises are defined as extreme tail events that happen once per decade within this research. To estimate (74) for a corresponding high q, extreme value theory is used. It uses the semi-parametric properties of the data and provides an extrapolation method to establish the necessary connection between moderately bad outcomes of the market which are observed empirically and the extreme bad outcomes which are rare.

The first step to obtain (74) for individual institutions is to estimate the tail index and quantile of the returns of the system. Suppose the distribution function of the system's return is heavy-tailed. Then, for the losses, the distribution is in the domain of attraction of the Fréchet distribution and satisfies the following condition:

$$\lim_{t\to\infty} \frac{F(-tx)}{F(-t)} = x^{-a}, \qquad x > 0, a > 0 \tag{75}$$

Where a denotes the tail index governing the tail behaviour of the distribution function. It is equal to the number of bounded moments in the distribution. Note the power speed is slow compared to an exponential type of distribution such as the normal or log-normal distribution.

Suppose the tail can be expanded as follows:

$$F(x) = Ax^{-a}[1 + o(1)] \approx As^{-a} \qquad \text{for } x > s \tag{76}$$

Where A denotes the scale parameter. The distribution function of the tail varies regularly at infinity if condition (75) is met.[5] Due to the property of regular variation, it is possible to estimate the tail index a using quasi maximum likelihood over the range where (76) is supposed to be appropriate. Here, the empirical distribution function $F_n(x)$ is a mean square error unbiased

[5] For proof see e.g. Leadbetter et al. (1983)

estimator for the probability at x as the sample size $n \to \infty$ (keeping x fixed). Observed extremes within the sample, denoted by M_n, do not have this property however, since they depend on the sample size n. Starting from equation (76), consider the conditional distribution function:

$$F_{(X|X>s)}(x) = \left(\frac{x}{s}\right)^{-a} \tag{77}$$

And the conditional density is:

$$F_{(X|X>s)}(x) = a\left(\frac{x}{s}\right)^{-a-1}\left(\frac{1}{s}\right) \tag{78}$$

Apply the maximum likelihood principle. Take log of conditional density:

$$log f_{(X|X>s)}(x) = log(a) - (a+1)log\left(\frac{x}{s}\right) - log(s) \tag{79}$$

Differentiate with respect to a and equate to zero:

$$\frac{1}{a} - log\left(\frac{x}{s}\right) = 0 \tag{80}$$

Replace x by the observed value X_i if $X_i > s$ and sum. Let there be M observations above s:

$$\frac{M}{a} - \sum_{i=1}^{M} log\left(\frac{X_i}{s}\right) = 0 \tag{81}$$

Solve for a, find the Hill (1975) estimator as the quasi maximum likelihood estimator: [6]

$$\frac{\hat{1}}{a} = \frac{1}{M}\sum_{i=1}^{M} log\left(\frac{X_i}{s}\right) = 0 \tag{82}$$

The first step in obtaining a is to find the range where maximum likelihood estimation for a is appropriate. To find where the tail is located, a threshold s must be selected carefully. If s is too large, it can't be estimated consistently using the data from the sample. If s is too small, the Hill estimator will be biased. There is thus a trade-off between consistency and unbiasedness. In practice, s corresponds to an observed value, chosen using a Hill plot. The Hill plot shows where the stable region between too much variability and bias is located. Theoretically, the probability

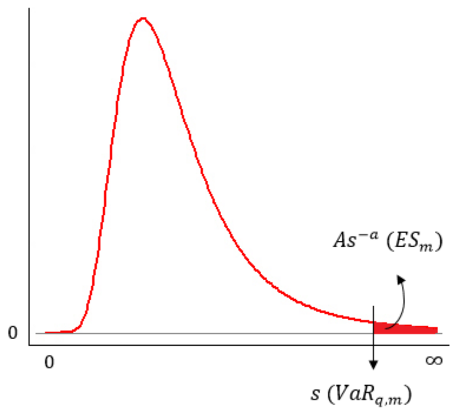
[6]For the statistical properties of Hill, see De Haan and Ferreira (2006).

mass above this threshold is approximated as follows:

$$Pr(X > s) \approx As^{-a} \tag{83}$$

Which corresponds to Figure 3:

Figure 3: Fréchet Distribution of Market Returns (Losses)



After obtaining s, the first step in calculating MES is to estimate MES for $p = k/n$ non-parametrically. The empirical, in-sample, estimator for each bank is given as follows:

$$\widehat{MES}_i(1 - k/n) = \frac{1}{k}\sum_{i=1}^{n} 1_{R_i|R_m<q} \tag{84}$$

Which gives the average return for bank i on the days that the system realizes returns equal to or below the threshold level. Recall that the MES as defined in (74) corresponds to a very high quantile q, such that the probability of being in this quantile is very low. It might even be lower than $(1/n)$, in which case the MES must be estimated out-of-sample. To determine the MES for a very small probability, below k/n, an extrapolation factor is used:[7]

$$\widehat{MES}_i(1 - p) = \widehat{MES}_i(1 - k/n)\left(\frac{k}{np}\right)^{1/\hat{a}} \tag{85}$$

[7] De Haan and Ferreira (2006) explain how this extrapolation factor follows from the statistical properties of the heavy-tailed distribution.

Given this tail distribution the following relation exists between ES and VaR:

$$MES_q^i = \hat{\beta_i^T} ES_m[R_m|R_m > q] \approx \hat{\beta_i^T} \frac{\hat{a_m}}{\hat{a_m} - 1} VaR_m[R_m|R_m > q] \tag{86}$$

For large q. This leads to the following proposition:

Proposition 1 *Expected shortfall and value-at-risk are linearly related*

$$ES_{q,m} \approx \frac{\hat{a_m}}{\hat{a_m} - 1} VaR_{q,m} \tag{87}$$

Proof. See Appendix.

This relation will be tested empirically. It allows to check whether the methodology for tail estimation is applied correctly. To check whether specification (87) holds for this sample, rewrite equation (87) as a function of the VaR:

$$VaR_{q,m} \approx \frac{ES_{q,m}}{\frac{a_m}{a_m - 1}} \tag{88}$$

$VaR_{q,m}$ is simply the observed value at risk of the sample. It is the return of the system realized at threshold s. The values for a_m and ES_q, m are estimated empirically. The value of $\hat{\alpha}_m$ is obtained using the Hill estimator as described. The next section shows how to obtain $\widehat{ES}_{q,m}$. Using these two estimated values, it is possible to obtain an estimation for $\widehat{VaR}_q$, using:

$$\widehat{VaR}_{q,m} = \frac{\widehat{ES}_{q,m}}{\frac{\hat{a}_m}{\hat{a}_m - 1}} \tag{89}$$

The derived value of $\widehat{VaR}_{q,m}$ must equal the observed value at risk of the sample, $VaR_{q,m}$. Hence:

$$\widehat{VaR}_{q,m} \approx VaR_{q,m} \tag{90}$$

If this condition holds, the condition stated in equation (87) is fulfilled. In this case, VaR and ES are linearly related.

3.6 Tail Beta

After $\widehat{MES}_i(1-p)$ is estimated for each bank, it is possible to derive the tail beta. This method allows to link systemic risk contributions to the CAPM model. The $\hat{\beta_i^T}$ can be estimated for each bank using equation (74):

$$MES_q^i = \beta_i^T ES_m[R_m|R_m > q]$$

To obtain tail beta, the above equation can simply be rewritten as a function of β_i^T:

$$\beta_i^T = \frac{MES_i(1-p)}{ES_m(1-p)} \tag{91}$$

Which shows that the cross-sectional difference in β_i^T is attributed to the cross-sectional dispersion in $MES_i(1-p)$. Note that the estimated values for $MES_i(1-p)$ are known, obtained using the methodology described in section 3.4. These values are calculated independent of the estimate for ES_m. The ES_m can be calculated as follows. Start with the average return of the system at $VaR_{q,m}$ using the empirical estimator:

$$\widehat{ES}_m(1-k/n) = \frac{1}{k}\sum_{i=1}^{n} 1_{R_m|R_m<q} \tag{92}$$

This gives the expected shortfall as simple average of the system's losses during the days that q is exceeded. The q corresponds to the threshold s which has already been determined using the methodology described in Section 3.5. To reliably estimate the expected return when the very high q is exceeded, extrapolate the empirical estimator to the extreme using the theoretical shape of the tail distribution:

$$\widehat{ES}_m(1-p) = \widehat{ES}_m(1-k/n)\left(\frac{k}{np}\right)^{1/\hat{a}} \tag{93}$$

This gives the expected shortfall of the system during the worst days of the market. After $MES_i(1-p)$ and $ES_m(1-p)$ are obtained, $\hat{\beta_i^T}$ can be estimated for each bank using equation (91).

4 Data

4.1 Sample Selection

This research focuses on a set of European countries. To allow for a sensible comparison of the MES across countries, the sample is limited to banks that are included in the Stoxx Europe 600 index at some point during the sample period considered. The Stoxx Europe 600 is a market capitalization weighted index with a fixed number of 600 components, including large companies capitalized across 17 countries in the European region. Banks are chosen because they are systemically more important than other financial institutions (e.g. Bilio et al, 2012). The sample set covers the period between January 2001 until December 2015. This sample period of 15 years is chosen because it allows to see how the European banks evolved before, during and after the financial crisis. The full sample that results consists of 104 banks from 19 European countries. Within the sample there are 43 banks with missing values. For 39 banks there is missing data for more than 5 of the defined worst days of the system. It is impossible to consistently estimate MES of these banks with the methodology presented. These banks are dropped from the sample. In total, 65 banks remain from 17 European countries. For each bank the sample consists of 3916 observations.

Daily market data and quarterly bank balance sheet data are gathered from Datastream. In addition, daily data on percentual returns of the Stoxx Europe 600 index is obtained, serving as a benchmark for the market returns. Within this benchmark, no distinction is made between banks and other financial institutions that constitute this index. Data on corporate income tax rates is obtained from the OECD database and listed in the Appendix. Table 3 shows the summary statistics of the corporate income tax rate (CIT).

Table 3: Descriptive Statistics CIT

	CIT
Mean	26.81
Median	28.0
Maximum	39.0
Minimum	8.5
Std. Dev.	7.97
Skewness	-1.02
Kurtosis	3.40
Observations	1800

This table shows the summary statistics of the central government statutory (flat or top marginal) corporate income tax rate of the 10 European countries that are used for the panel data analysis. It consists of monthly observations for the period 2001-2015.

4.2 Market-Valued Total Assets

The returns of the banks R_i are denoted by the growth rate of market-valued total assets (MVA). MVA is an intuitive measure in this framework. When MVA falls below the value of liabilities, the bank is insolvent. Following Adrian and Brunnermeier (2011):

$$R_{i,t} = \frac{MVA_t^i - MVA_{t-1}^i}{MVA_{t-1}^i} \tag{94}$$

Where

$$MVA_t^i = MVE_t^i * LEV_t^i = BVA_t^i * (MVE_t^i / BVE_t^i) \tag{95}$$

$MVA =$ market value of assets

$MVE =$ market value of equity

$LEV = BVA/BVE =$ financial leverage

$BVA =$ book value of total assets

$BVE =$ book value of equity

The leverage ratio, defined as book value of total assets divided by the book value of equity, is also known as the equity multiplier. Companies finance their operations with equity or debt. A high equity multiplier indicates that a larger portion of asset financing is attributed to debt. The equity multiplier is linearly related to the debt to equity ratio, the conventional definition of leverage. The balance sheet of a bank illustrates this more clearly. Consider the following bank balance sheet:

Table 4: Bank Balance Sheet

Assets		Liabilities	
Reserves	€10,000	Deposits	€100,000
Loans	€100,000	Debt	€30,000
Securities	€40,000	Equity	€20,000
Total Assets	€150,000	Total Liabilities	€150,000

It shows that the value of assets is exactly equal to the sum of liabilities and equity. If the ratio of assets over equity increases, this must be due to an increase in debt. Despite the similarity between the equity multiplier and the debt to equity ratio, only the latter is used in the remainder of this paper. The debt to equity ratio is more intuitive as it captures debt explicitly.

4.3 Descriptive Statistics

Table 5 in the Appendix shows a list of constituents of the 65 banks. It contains all European banks that have been listed as global systemically important banks (G-SIBs) by the Financial Stability Board (FSB) of the Basel Committee during the sample period. Denominators for G-SIB are size, cross-jurisdictional activity, interconnectedness, financial institution infrastructure and complexity. The sample institutions have an average total assets over the sample period ranging from €701 million for the global internet technology and financial services provider Wirecard, to €1,569 trillion for HSBC Holdings, one of the largest banking and financial services institutions in the world. The average leverage ratios, calculated as the average of total liabilities divided by total shareholder's equity, range from 1.10 for Wirecard to 52.15 for the Belgian bank Dexia. It's important to mention that Wirecard, Dexia, National Bank of Greece, Greek bank Ergasias, and the Greek bank of Piraeus have negative leverage during some months. Wirecard experienced a severe financial downturn in 2002. Operational difficulties caused the value of shareholder's equity to fall below zero. Dexia and the Greek banks obtained negative leverage ratios in 2011. The year 2011 was marked by an aggravation of the European sovereign debt crisis. This unprecedented deterioration of the economic and financial environment in the euro zone had a severe effect on the Dexia Group and Greek banks. Dexia was still fragile despite the efforts made since 2008 to improve its financial structure. The Greek banks suffered from the large recession that occurred within this country. Another point worth mentioning is that the top four banks with the highest leverage ratio were all dropped from the initial sample of 104 banks. These banks were sold or nationalized to prevent bankruptcy.

Table 5: Summary Descriptive Statistics

	Total Assets	Total Liabilities	Total Sh. Equity	Leverage
Mean	336,000	320,000	14.76	18.45
Median	96,083	88,700	7,121	17.31
Maximum	1,570,000	1,500,000	98,053	52.15
Minimum	701	367	334	1.10
Std. Dev.	454,000	434,000	19,281	9.26
Skewness	1.54	1.54	2.03	0.67
Kurtosis	4.15	4.14	7.50	4.46
Observations	65	65	65	65

This table shows the summary statistics of the averaged bank variables over the 65 European banks across the full sample period January 2001 to December 2015. The total assets, total liabilities and total shareholder's equity are in millions of euros. Leverage is calculated as total liabilities divided by total shareholder's equity. The number of observations denotes the number of banks in the sample. Average values are based on 3916 observations for each bank in the sample.

5 Empirical Results

This section presents the results of this research. First, the output of the regression equations regarding corporate income tax rates, leverage and systemic contribution are presented. After this, the systemic importance of the banks in the sample are discussed. Third, output related to the market efficiency test is provided. The section ends with the results of the methodology check.

5.1 Panel Data Regression

Relating to Hypothesis 1, the output for the panel data regressions is presented in Table 6.

Table 6: Estimated Regression Coefficient Panel Data

	tax	***tax***	***log(tax)***
leverage	1.525***	0.039	.
	(10.653)	(1.364)	.
log(leverage)	.	.	0.029
	.	.	(0.388)
R^2	0.279	0.718	0.730
Cross-sections included	10	8	8
Periods included	180	180	180
Total observations	1800	1440	1440

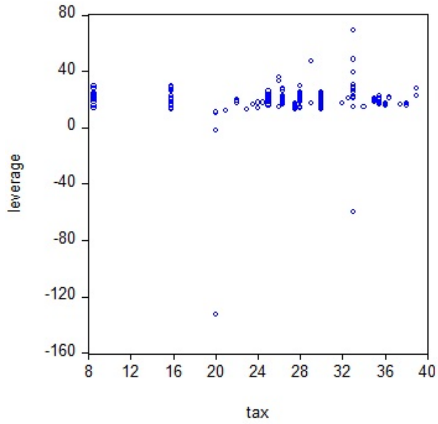
This table contains the estimated coefficients and R^2 of specifications (49) and (50). The t-statistics are listed below the regression coefficients in brackets. Recall specification (49):

$$leverage_{j,t} = \alpha_j + \phi_t + \hat{\xi} \cdot tax_{j,t} + \varepsilon_{j,t}$$

Leverage is given as total liabilities divided by total shareholder's equity. Tax denotes corporate income tax rate. Findings are based on monthly data for the 15 year sample period. *** denotes significance at 1% level.

Using the full sample, the regression coefficient obtained for specification (49), $\hat{\xi}$, is statistically significant at the 1% level. The estimated coefficient for $\hat{\xi}$ drops substantially in size and power if the sample is limited to 8 countries. The severe impact of the data limitation gives reason to believe that the first, full sample, output is largely influenced by the negative leverage ratios that are present. This gives reason to believe that the necessary OLS assumptions are not satisfied for specification (49). Because of this, no conclusion regarding the relation between leverage and taxes is formed based on this output. Figure 4 shows that indeed outliers are present:

Figure 4: Plot Full Sample



These outliers can cause a biased estimator. When limiting the sample to eight countries, the following plot is obtained:

Figure 5: Plot Limited Sample

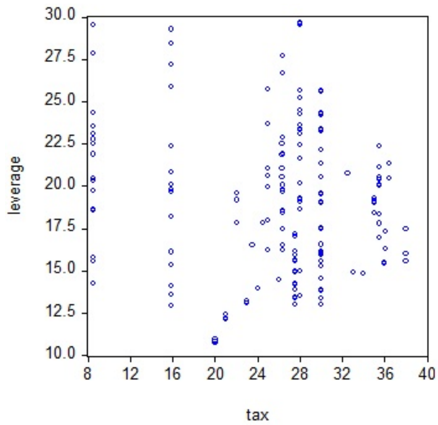


Figure 5 shows a weak positive relation between leverage and tax rates. Furthermore, it shows that the dispersion in tax rates is limited, reflecting that tax rates do not vary much in some countries. If a clear positive relation would be present, the plot would have the following structure:

Figure 6: Expected Plot

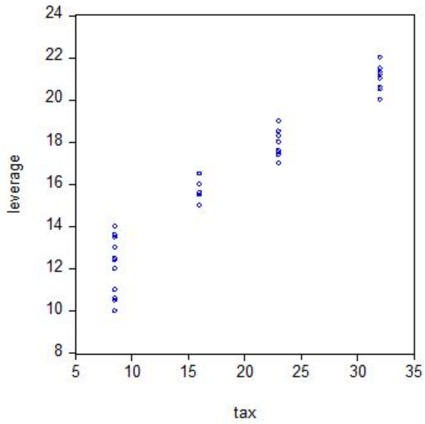


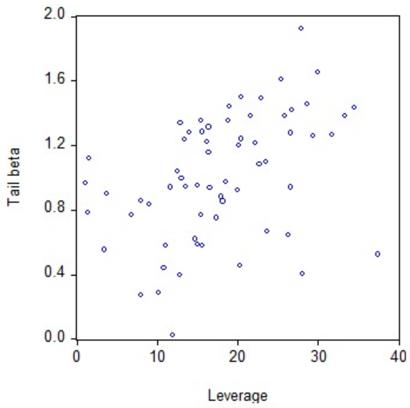
Table 6 illustrated that the regression coefficient of the limited sample, $\hat{\xi}$, is indeed small but positive. Additionally, it shows that the estimate is statistically insignificant. This gives an indication that no relation between the between the corporate income tax and leverage is present. Regarding specification (50), the regression coefficient obtained for $\hat{\delta}$ is small and positive. Again, the estimate is statistically insignificant at the 10% level. The results give an indication that no strong relation between the corporate income tax rate and leverage ratios is present. This finding is in line with the findings of Keen and De Mooij (2012). Keen and De Mooij (2012) studied 14,000 commercial banks in 82 countries over nine years. They find no significant impact of taxation on leverage when looking at the 5% largest bank in the sample. Additionally, they find a low responsiveness for capital-tight banks. Large banks are often capital-tight, holding relatively small buffers. This finding thus confirms that large banks are unresponsive to tax changes. For smaller banks, a significant positive impact is found.

Concerning Hypothesis 1, it is concluded that the corporate income tax rate does not influence the leverage ratio of large European banks as much as expected. Notwithstanding, it might very well be that European banks profit from tax shields on debt. One explanation for the unresponsiveness of leverage ratios is that large European banks maintain leverage ratios close to their regulatory ceiling. If leverage ratios are already at their maximum, they will be relatively unresponsive to tax rate changes. Hence, the results do not imply that leverage ratios are fundamentally unaffected by the tax shield on debt.

5.2 Cross-sectional Regression

Table 7 presents the regression output for the specifications regarding the relation between systemic risk contribution and leverage. For this analysis, the Belgian bank Dexia is dropped from the sample since its leverage ratio is far off the other leverage ratios. This outlier is excluded to avoid a biased estimator. The following plot is obtained:

Figure 7: Plot Limited Sample



Which illustrates no outliers are present. Additionally, it shows a positive relation between leverage ratio and tail beta. Table 7 presents the estimated regression coefficients.

Table 7: Estimated Regression Coefficients Beta

spec.		***leverage***	***log(leverage)***
(58)	β_i^T	0.019***	.
		(3.594)	.
	R^2	0.172	.
(59)	$log(\beta_i^T)$	.	0.187*
		.	(1.755)
	R^2	.	0.047
	Number of observations	64	64

This table contains the estimated coefficients and R^2 of regression specifications (58) and (59). The t-statistics are listed below the regression coefficients in brackets. Recall specification (58):

$$\hat{\beta_i^T} = \alpha + \hat{\gamma}(lev) + \varepsilon_i$$

Leverage is given as total liabilities divided by total shareholder's equity.
*** denotes significance at 1% level
* denotes significance at 10% level

The regression coefficient obtained for specification (58), $\hat{\gamma}$, is statistically significant at the 1% level. The β_i^T increases (decreases) on average by approximately 0.019 percentage points if the debt to equity ratio increases (decreases) by 1 percentage point. It shows that an increase in leverage, increases systemic contribution. The impact of leverage on systemic risk is considerable. Suppose that the CAPM holds for tail beta as discussed in Section 3.3.1. This leads to the following interpretation of the regression coefficient. Institution i's returns will experience an increase in volatility (risk) of 1.9 percentage points compared to the market's volatility for each extra unit of leverage. If markets price systemic risk efficiently, investors receive a risk premium associated with any increase in excess volatility. The risk premium demanded on top of i's expected returns will increase with 2 percentage point for each increase in leverage. Note that the estimated coefficient size might deviate considerably from the actual relation between β_i^T and leverage for any institution. Given the relatively low R^2, the variability in the relationship is large. Furthermore, the relatively low R^2 indicates that there are more factors that influence β_i^T. Micro-level bank characteristics such as size and connectivity are important too. Additionally, it is expected that macroeconomic influences such as the TBTF paradigm and the Greenspan put also influence β_i^T. Notwithstanding, the positive significant outcome for $\hat{\gamma}$ indicates that a positive relation exists between leverage and systemic risk contribution. This finding confirms Hypothesis 2.

The regression coefficient obtained for specification (59), $\hat{\eta}$, is statistically significant at the 10% level. The β_i^T increases (decreases) on average by 0.187% if the debt to equity ratio increases (decreases) by 1%. In other words, if the leverage ratio increases by 1%, institution i's contribution to systemic risk increases. Suppose that the CAPM holds for tail beta as discussed in Section 3.3.1. This leads to the following interpretation of the regression coefficient. Institution i's returns will experience an increase in volatility (risk) of 0.187% compared to the market's volatility for each percentage increase in leverage. Suppose markets price systemic risk efficiently. Investors receive a risk premium associated with any an increase in excess volatility. The risk premium demanded on top of i's expected returns will increase with 0.187% for each percentage increase in leverage. The relation between systemic contribution and leverage ratios is inelastic. Nevertheless, the impact of leverage on systemic risk should not be underestimated. A small change in tail beta can have large consequences because of the size of the institutions involved. Furthermore, if more banks decide to lever up, the effect on systemic risk becomes larger and larger. Suppose 20 banks in the system face a 1% increase in the tax rate. The total increase in systemic risk is simply the sum of the individual increases in systemic risk contribution. The expected increase in total systemic risk is therefore 3.74%.[8] This affects all banks as soon as systemic risk materializes. This affects the financial system as a whole. On another note, consider again that the estimated coefficient size might deviate considerably from the actual relation between β_i^T and leverage for any institution. Given the relatively low R^2, the variability in the relationship is large. Notwithstanding, the

[8]Since $20 * 0.187\% = 3.74\%$

positive significant outcome for $\hat{\eta}$ indicates that a positive relation exists between leverage and systemic risk contribution. Although the 10% significance is not as conclusive as the 1% level, this finding confirms Hypothesis 2.

To compare the findings for tail beta with the MES, leverage ratios are also regressed on MES_i. The results are presented in Table 8. The regression coefficient obtained for specification (60), $\hat{\tau}$, is statistically significant at the 1% level. The MES_i increases (decreases) on average by approximately 0.003 percentage points if the debt to equity ratio increases (decreases) by 1 point. The small coefficient size is inherent to the specification of MES. The actual impact of a change in MES should not be underestimated. The practical implications of a small change in MVA are large because of the size of the institutions involved. Note that the obtained result should be interpreted with caution. Given the relatively low R^2, the variability in the relationship is large. This means that any specific relation between MES_i and leverage might deviate considerably from the the average relation between MES_i and leverage that is given by the regression coefficient. Furthermore, the relatively low R^2 indicates that there are more factors that influence MES_i. These factors are the same as specified regarding β_i^T. To conclude, the obtained value for $\hat{\tau}_i$ differs from the results obtained when regression leverage on β_i^T. This is explained by the difference in the scale of the parameters. The main conclusion derived from the output are the same. The positive significant outcome for $\hat{\tau}_i$ indicates strongly that a positive relation exists between leverage and systemic risk contribution. This finding confirms Hypothesis 2.

Table 8: Estimated Regression Coefficients MES

spec.		***leverage***	***log(leverage)***
(60)	$\widehat{MES}_i$	0.003***	.
		(3.594)	.
	R^2	0.172	.
(61)	$log(\widehat{MES}_i)$	.	0.187*
		.	(1.755)
	R^2	.	0.047
	Number of observations	64	64

This table contains the estimated coefficients and R^2 of specification (60) and (61). The t-statistics are listed below the regression coefficients in brackets. Recall specification (60):

$$\widehat{MES}_i = \alpha + \hat{\tau}_i(lev) + \varepsilon_i$$

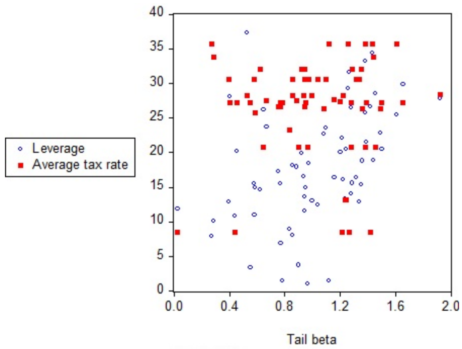
Leverage is given as total liabilities divided by total shareholder's equity.
*** denotes significance at 1% level
* denotes significance at 10% level

The regression coefficient obtained for specification (61), $\hat{\kappa}$, is statistically significant at the 10% level. The MES_i increases (decreases) on average by approximately 0.187% if the debt to equity ratio increases (decreases) by 1%. This result is exactly the same as obtained when regression leverage on β_i^T. This confirms that the difference between β_i^T and MES_i is merely a scale factor. The relation between leverage and systemic contribution is robust with respect to the systemic risk measure used. The positive significant outcome for $\hat{\kappa}$ shows that a positive relation exists between leverage and systemic risk contribution. This finding confirms Hypothesis 2.

5.3 Multiple Cross-sectional Regression

To conclude on Hypothesis 3, systemic contribution is regressed on leverage and tax simultaneously. Again, Dexia is dropped from the sample to avoid outliers. Figure 8 presents the plot of the tail beta, leverage and tax rates.

Figure 8: Plot Limited Sample



The plot illustrates no outliers are present. Additionally, it shows a positive relation between tail beta and leverage and a weak positive relation between tail beta and tax rate. The output for the multiple regression specifications is presented in Table 9.

Regarding the specification for estimation (62), the regression coefficient obtained for the leverage ratio, $\hat{\gamma}$, is positive and statistically insignificant at the 10% level. The same holds for the regression coefficient obtained for the tax rate, $\hat{\zeta}$. The estimated coefficient for the interaction term, $\hat{\psi}$ is negative but statistically insignificant at the 10% level. Although the signs are in line with expectations, no extensive interpretation of the estimated coefficients is given. The estimated coefficients are individually insignificant and should thus not be interpreted as representing a true relationship. Instead, consider the F-statistic for joint significance. It shows that the estimated coefficients are jointly significant. This gives some indication that tax rates and leverage ratios are related to systemic risk contribution. Hence, overall, the model is unable to provide a reliable insight into the exact relation between tax and leverage and tail beta, but it does give some reason to accept Hypothesis 2 and 3.

Table 9: Estimated Regression Coefficients Multiple Regression Tail Beta

spec.		***lev***	***tax***	***tax ∗ lev***	***log(lev)***	***log(tax)***	***log(tax) ∗ log(lev)***
(62)	$\hat{\beta_i^T}$	0.031	0.013	-0.000	.	.	.
		(1.531)	(0.816)	(-0.578)	.	.	.
	$\delta_{1,2}$	0.020	0.005	.	.	.	.
	$adj.R^2$		0.143			.	
	$F-stat$		4.502			.	
			(0.006)			.	
(63)	$log(\hat{\beta_i^T})$	.	.	.	2.335*	2.256**	-0.657*
		.	.	.	(1.985)	(2.144)	(-1.822)
	$\delta_{1,2}$	.	.	.	0.173	0.339	.
	$adj.R^2$		.			0.102	
	$F-stat$		.			3.383	
			.			(0.024)	
	No. of obs.		64			64	

This table contains the estimated coefficients and R^2 of specification (62) and (63). The t-statistics are listed below the regression coefficients in brackets. The partial effects are estimated using equations (66) - (69). Recall specification (62):

$$\hat{\beta_i^T} = \alpha + \hat{\gamma}(lev) + \hat{\zeta} \cdot \overline{tax_i} + \hat{\psi}\Big((lev) \cdot \overline{tax_i}\Big) + \varepsilon_i$$

Leverage is given as total liabilities divided by total shareholder's equity.
** denotes significance at 5% level
* denotes significance at 10% level

Regarding equation (63), the regression coefficient obtained for the leverage ratio and tax rate, $\hat{\eta}$ and $\hat{\theta}$ respectively, are positive and statistically significant at the 10% and 5% level. The regression coefficient obtained for the interaction term, $\hat{\phi}$, is negative and statistically significant at the 10% level. Assuming taxes are zero, the β_i^T increases (decreases) on average by approximately 2.335% if the debt to equity ratio increases (decreases) by 1%. More realistically, suppose taxes are fixed at the mean value. The δ_1 shows that β_i^T increases (decreases) on average by approximately 0.173% if the debt to equity ratio increases (decreases) by 1%. Suppose the CAPM holds for the tail beta as discussed in Section 3.3.1. Institution i's returns will experience an increase in volatility (risk) of 0.173% compared to the market's volatility for each percentage increase in leverage. Suppose markets price systemic risk efficiently. Investors receive a risk premium associated with any an increase in excess volatility. The risk premium demanded on top of i's expected returns will increase with 0.173% for each percentage increase in leverage. Note this effect is smaller than the effect suggested by the panel regression. Given the negative cross elasticity of leverage and tax, it is expected that the estimated effect of leverage decreases when taxes are added to the model. Both results indicate that on average, the systemic contribution of a bank increases by approximately 0.18% if leverage ratios rise. Although this effect size seems small, the impact on systemic risk is large if multiple banks increase their leverage ratio even slightly. Suppose 20 banks in the system increase their leverage ratio by 1%. The total increase in systemic risk is simply the sum of the individual increases in systemic risk contribution. The expected increase in total systemic risk is therefore 3.60%.[9] This affects all banks as soon as systemic risk materializes. Increases in leverage ratios affect financial stability strongly. This finding confirms Hypothesis 2.

Assuming leverage to be zero, the β_i^T increases (decreases) on average by approximately 2.256% if the corporate income tax increases by 1%. More realistically, suppose leverage is fixed at the mean value. The δ_2 shows that β_i^T increases (decreases) on average by approximately 0.339% if the tax rate increases (decreases) by 1%. Specifically, institution i's returns will experience an increase in volatility of 0.34% compared to the market's volatility for each percentage increase in corporate tax. Now suppose that markets are efficient. In this case, investors receive a risk premium associated with any increase in excess volatility. The risk premium demanded on top of i's expected returns will increase with 0.34% for each percentage increase in tax. The value of 0.35% indicates that corporate tax and systemic risk are inelastic. Nevertheless, the impact of tax should not be underestimated. As with an increase in leverage, a small change can have large consequences for financial stability. Suppose 20 banks in the system face a 1% increase in the tax rate. The total increase in systemic risk is simply the sum of the individual increases in systemic risk contribution. The expected increase in total systemic risk is therefore 6.80%.[10] This affects all banks as soon as systemic risk materializes. Increases in corporate taxes affect financial stability strongly. This finding confirms Hypothesis 3.

Given the conclusion regarding Hypothesis 1, it is interesting to find that corporate taxes influence systemic risk contributions so strongly. As stated earlier, the output of this research gives no indication that increases in the corporate tax rate influence the leverage ratios of large banks substantially. Hence, increases in the corporate income tax rate do not increase systemic risk via increases in the leverage ratio directly. Increases in the corporate tax rate must influence systemic risk contributions in an alternative way. Consider a large bank that is at its maximum allowed leverage ratio. An increase in the corporate income tax cannot induce this bank to increase its leverage ratio any more. It will benefit from the increase in corporate tax however. Even without increasing its leverage ratio, the tax shield on debt is relatively large now. The bank's financing costs decrease even without levering up. With lower financing costs, more money is available to invest. Perhaps these types of windfalls lead to excessive risk taking, increasing systemic risk.

The negative cross elasticity between tax and leverage, denoted by $\hat{\psi}$, confirm that large banks can not benefit from increases in the tax shield because of regulatory ceilings. Suppose a bank is

[9]Since $20 * 0.18\% = 3.6\%$
[10]Since $20 * 0.34\% = 6.8\%$

already close to its maximum leverage ratio. If corporate taxes increase, there is little room left for banks to increase their leverage ratio to take advantage of this. Since they can take little additional risk, their systemic risk contribution will not rise that much. Likewise, if the bank's leverage ratio is relatively low, an increase in the corporate tax rate creates an opportunity to profit from cheaper debt capital. This bank can take quite some additional risk until the capital limit is reached. This results in a relatively large increase in the systemic risk contribution of this bank.

To conclude, changes in leverage and tax rates cause an increase in systemic contribution. This result confirms Hypothesis 2 and 3. Furthermore, it is found that a negative cross elasticity exists between leverage ratios and tax rates. This cross elasticity partially offsets the individual impact of a change in tax or leverage on β_i^T. This negative elasticity could be an indication that banks can not benefit from increases in the tax shield because of regulatory ceilings. This puts a limit on the extent to which banks can profit from an increase in corporate taxes.

The output for the specifications regarding MES are presented in Table 10.

Table 10: Estimated Regression Coefficients Multiple Regression MES

spec.		$\boldsymbol{lev}$	$\boldsymbol{tax}$	$\boldsymbol{tax * lev}$	$\boldsymbol{log(lev)}$	$\boldsymbol{log(tax)}$	$\boldsymbol{log(tax) * log(lev)}$
(64)	$\widehat{MES}_i$	0.004	0.002	-0.000	.	.	.
		(1.531)	(8.816)	(-0.578)	.	.	.
	$\delta_{1,2}$	0.003	0.001	.	.	.	.
	$adj.R^2$		0.143			.	
	$F-stat$		4.502			.	
			(0.006)			.	
(65)	$log(\widehat{MES}_i)$	.	.	.	2.335*	2.256**	-0.657*
		.	.	.	(1.985)	(2.144)	(-1.822)
	$\delta_{1,2}$	.	.	.	0.173	0.339	.
	$adj.R^2$		.			0.102	
	$F-stat$		.			3.383	
			.			(0.024)	
	No. of obs.		64			64	

This table contains the estimated coefficients and R^2 of specification (64) and (65). The t-statistics are listed below the regression coefficients in brackets. Recall specification (64):

$$\widehat{MES}_i = \alpha + \hat{\tau}(lev) + \hat{\zeta} \cdot \overline{tax_i} + \hat{\psi}\Big((lev) \cdot \overline{tax_i}\Big) + \varepsilon_i$$

Leverage is given as total liabilities divided by total shareholder's equity.
*** denotes significance at 1% level
* denotes significance at 10% level

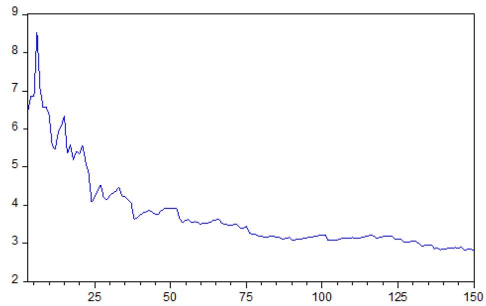
Regarding specification (64), the regression coefficient obtained for the leverage ratio, $\hat{\tau}$, is positive and statistically insignificant at the 10% level. The same holds for the regression coefficient obtained for the tax rate, $\hat{\xi}$. The estimated coefficient for the interaction term, $\hat{\psi}$ is negative but statistically insignificant at the 10% level. Although the signs are in line with expectations, no extensive interpretation of the estimated coefficients is given. The estimated coefficients are individually insignificant and should thus not be interpreted as representing a true relationship. Instead, consider the F-statistic for joint significance. It shows that the estimated coefficients are jointly significant. This gives some indication that tax rates and leverage ratios are related to systemic risk contribution. Hence, overall, the model is unable to provide a reliable insight into the exact relation between tax and leverage and tail beta, but it does give some reason to accept Hypothesis 2 and 3.

The results regarding (65) are equal to the output generated when using $log(\hat{\beta_i^T})$ as dependent variable. This confirms that MES and tail beta are linearly related. Additionally, it reaffirms the conclusions regarding specification (63). The output confirms Hypothesis 1,2 and 3.

5.4 Systemic Risk Contribution

To obtain the MES using extreme value theory, the shape of the tail distribution is estimated first. To determine the value of a for the market, the zoomed in Hill estimates of the daily loss returns of the market are plotted in Figure 9.

Figure 9: Hill Plot Stoxx 600 Europe 2001-2015



The plot is zoomed in on the 150 observations with the largest losses to see where the region between too much variability and bias is located. The stable region in the plot is approximately located between the 80th and 120th observation. Therefore, k is chosen to be 100. The corresponding value of tail index a_m is equal to 3.208. The next step is to estimate the MES_i for all banks in the system. Additionally, ES_m is estimated using equation (93). The value of ES_m is estimated to be 0.138. Using this, β_i^T is calculated using (91). Full sample results for the MES_i and corresponding β_i^T are listed in the Appendix. Table 11 presents the summary statistics of the MES_i and corresponding

β_i^T.

Table 11: Summary Statistics MES

	MES(1-k/n)	**MES(1-p)**	$\boldsymbol{\beta_i^T}$
Mean	0.038	0.140	1.012
Median	0.037	0.138	0.999
Maximum	0.072	0.265	1.924
Minimum	0.001	0.004	0.027
Std. Dev.	0.014	0.053	0.387
Skewness	-0.269	-0.269	-0.269
Kurtosis	2.549	2.594	2.594
Observations	65	65	65

MES(1-k/n) is obtained using (84) with $n = 3916$ and $k = 100$. For MES(1-p), equation (85) is used with 3.208 and $p = 1/2610$. This probability corresponds to a crisis that happens once per decade. The β_i^T is obtained using (91). The number of observations denotes the number of banks in the sample. For each bank, the MES and β_i^T are determined based on a total of 3916 observations.

Table 11 shows that MES(1-p) ranges from 0.004 for the private Swiss bank Valiant to 0.294 for ING Group. The skewness and kurtosis illustrate that the obtained MES and tail beta's are approximately normally distributed. The average loss in MVA is 15.6%. This means that, on average, large European banks lose more than 15% of their total assets during a severe crisis. This number is alarming. According to Basel III, banks are required to hold 2.5% of common equity for the amount of risk-weighted assets held by a bank. This amount of equity is far below the amount required to cover the losses of a crisis situation. The average value for tail beta equals 1.012. The mean value denotes 0.999. These numbers give reason to believe that the CAPM holds. This will be discussed in Section 5.5. To illustrate which European banks contribute most to systemic risk, the MES_i and β_i^T for the 10 largest contributing banks are presented in Table 12.

ING Groep, Barclays and Société Générale are the three European banks of highest systemic importance during 2001-2015. In case of a once per decade market crisis, ING Groep is estimated to experience on average a loss in MVA of 27%. This means that ING is expected to loose more than a quarter of its assets during a severe crisis. Barclays and Société Générale loose more than 22% of their MVA. ING Groep has the highest value of β_i^T, denoting 1.924. The value of 1.924 implies theoretically that ING's returns are 1.924% more volatile than market returns. Assuming markets are efficient, investors receive a risk premium to compensate for this uncertainty. They demand a premium of 1.924% of the expected excess return for ING's assets.

To compare, Valiant Bank is of lowest systemic importance of the banks in the sample. In case of a once per decade market crisis, Valiant is estimated to experience on average a loss in MVA of 0.4%. Valiant has the lowest value of β_i^T, denoting 0.027. Valiant's assets are theoretically 0.973% less volatile than the market.

Table 12: Systemic risk contributions of largest and smallest contributors

Rank	**Name**	**Country**	**MES(1-k/n)**	**MES(1-p)**	β_i^T
1	ING Groep	NL	0.072	0.265	1.924
2	Barclays	GB	0.062	0.228	1.656
3	Société Générale	FR	0.060	0.222	1.608
4	Royal Bank of Scotland	GB	0.056	0.207	1.502
5	SEB	SE	0.055	0.206	1.490
6	Commerzbank	DE	0.054	0.200	1.453
7	KBC Group	BE	0.054	0.199	1.440
8	Crédit Agricole de France	FR	0.053	0.198	1.432
9	Crédit Suisse Group	CH	0.053	0.196	1.419
10	Lloyds Banking Group	GB	0.052	0.191	1.387
...	...	...	...	...	...
63	Banque Nationale de Belgique	BE	0.011	0.039	0.286
64	Crédit Agricole d'Ile de France	FR	0.010	0.038	0.273
65	Valiant Bank	CH	0.001	0.004	0.027

MES(1-k/n) is obtained using (84) with $n = 3916$ and $k = 100$. For MES(1-p), equation (85) is used with with $a_m = 3.208$ and $p = 1/2610$. This probability corresponds to a crisis that happens once per decade. The β_i^T is obtained using (91).

With the exception of SEB and KBC Group, the 10 banks of highest systemic importance have been listed G-SIB during the sample period. These results imply that SEB and KBC should also be placed under special supervision.

5.5 Expected shortfall and Value at Risk

Recall equation (87) is verified within the sample as a test for the applied methodology. Equation (87) reads:

$$ES_{q,m} \approx \frac{\hat{a_m}}{\hat{a_m} - 1} VaR_{q,m}$$

And the condition that followed, explained in the methodology section:

$$\widehat{VaR_{q,m}} \approx VaR_{q,m}$$

Table 13 shows results obtained for the Stoxx 600 Europe for 2001-2015. Indeed $\widehat{VaR_{q,m}} \approx VaR_{q,m}$. The estimated value of VaR that is based on the estimated value for the tail parameter $\hat{\alpha_m}$ equals the observed VaR. This allow sto conclude that the tail index is estimated correctly. The condition given by equation (87) is fulfilled.

Table 13: Expected Shortfall and VaR for the market

Variable	Result
$\widehat{ES}_{q,m}$	0.037[a]
$\hat{a}$	3.208[b]
$\hat{a}$ / $(\hat{a}-1)$	1.453
$\widehat{VaR}_{q,m}$	0.0246[c]
$VaR_{q,m}$	0.0265[d]

[a] Obtained using equation (93).
[b] Obtained using equation (82).
[c] See equation (89).
[d] Observed from the sample.

5.6 The CAPM

To conclude on Hypothesis 4, this section discusses whether the obtained results confirm the expectations from the CAPM that $\overline{\beta}_i^T$ equals 1 and α_i equals zero.

Starting with $\overline{\beta}_i^T$, Table 11 shows that the mean value of β_i^T equals 1.012. The value of 1.012 implies theoretically that bank returns are 0.012% more volatile than average market returns. Investors demand a risk premium to compensate for this uncertainty. More specifically, they demand a premium of 0.012% of the expected excess return for banks. To conclude on Hypothesis 4, recall the average expected return to the market equals 1 if the CAPM holds. In this case, markets price risk efficiently. Investors obtain a risk premium that compensates for excess volatility. When relating the CAPM to tail beta, an average value of 1 indicates that markets price systemic tail risk efficiently. In this case, investors obtain a risk premium that compensates excess volatility that is present in times of extreme downturns. The value obtained for $\overline{\beta}_i^T$ is larger than 1. This is unsurprising. Banks are more systemically risky than other financial institutions. Given this excess risk, it seems reasonable that investors receive a risk premium. The value of 1.012 is plausible to conclude that investors receive a risk premium on systemic tail risk.

Table 14 shows results obtained for regression equation (56) which investigates whether it is reasonable to assume that α_i equals zero. The obtained value for a_i, when $\overline{\beta}_i^T$ equals 1.012 by assumption, is 0.001. This estimated constant is statistically significant at a 5% significance level. Recall α_i reflects the excess return on the risk-free rate. The value of 0.001 illustrates that investors are able to outperform the market slightly. Considering that α_i is estimated based on daily observations, the actual impact of a small positive number is large over time. In a year time, the average expected return equals 0.286 for the idiosyncratic component alone.[11] Apparently, some investors are able to outperform the market. Note however that the definition for market is limited to 65

[11] Based on 252 trading days a year, the yearly return equals $[(1.001)^{252} - 1] * 100\% = 0.286$

banks in the sample. Perhaps α_i is zero when looking at a more diversified dataset.

Regarding idiosyncratic risk, it is checked whether the error term equals zero on average. The mean value of the error term equals zero indeed.

Table 14: Estimated Regression Coefficients CAPM

	(56)
$\hat{\alpha}_i$	0.001**
	(2.383)
R^2	0.085
Number of observations	3916

This table contains the estimated coefficients and R^2 of regression equation (56). The t-statistic is listed below the regression coefficients in brackets. Recall equation (56):

$$\overline{R}_{i,t} = \hat{\alpha}_i + \overline{\beta}_i^T \cdot R_{m,t} + \varepsilon_{i,t}$$

$\overline{R}_{i,t}, \overline{\beta}_i^T$ and $R_{m,t}$ denote daily input variables. The $\overline{\beta}_i^T = 1.012$.
** denotes significance at the 5% level.

To conclude, the results give reason to believe that investors receive a risk premium on systemic tail risk. This confirms Hypothesis 4. Results also show however that the market, defined by a sample of 65 large European banks, isn't completely efficient. Investors are able to earn excess market return. Further research on α_i is necessary to derive a sound conclusion on Hypothesis 4.

6 Conclusion

This section presents the conclusion of this research. First, a summary is provided and the main findings of this study are presented. After this, the limitations of this analysis are discussed and ideas for future research are presented.

6.1 Summary and Practical Implications

During the past decades, public and private debt levels across the world increased substantially compared to GDP. Encouraged by tax shields on debt, firms and households take advantage of relatively cheap debt financing. While a certain amount of debt is said to stimulate economic growth, it has adverse effects at higher levels. Economists agree that increasing debt levels increase the risk of the financial system. This paper argues that tax policy should be used to manage debt levels and monitor systemic risk. To gain insight in this relation between tax policy, leverage and systemic risk, the following research question is addressed: *Does an increase in corporate income tax rate lead to a higher systemic risk contribution of large banks in Europe in the period of 2001-2015?*

To answer the research question, two individual effects are investigated first. The first hypothesis states: *The corporate income tax rate is positively related to the leverage ratio.* The results of the simple cross-section analysis provide no evidence that Hypothesis 1 is correct. Based on a panel of 8 countries for a period of 15 years, no significant impact of corporate income tax on leverage ratios of large European banks is found. This confirms earlier results of Keen and De Mooij (2012). They find that the corporate income tax rate has no significant influence on the leverage ratios of large banks. Notwithstanding, it might very well be that European banks profit from tax shields on debt. One explanation for the unresponsiveness of leverage ratios is that large European banks maintain leverage ratios close to their regulatory requirement. If leverage ratios are already at their maximum, they will be relatively unresponsive to tax rate changes. This does not imply that leverage ratios are fundamentally unaffected by the tax shield on debt. To gain further insight in the relation between tax shields and leverage ratios, a different type of study must be performed.

The second hypothesis of this research reads: *The leverage ratio is positively related to the systemic risk contribution of a bank.* Results of a cross-sectional regression analysis show that systemic risk contribution, measured by tail beta, increases (decreases) on average by approximately 0.019 percentage points if the debt to equity ratio increases (decreases) by 1 percentage point. Alternatively, the log-log model shows that systemic risk contribution increases (decreases) on average by 0.187%

if the leverage ratio increases (decreases) by 1%. The relation between systemic contribution and leverage ratios is inelastic. Nevertheless, the impact of leverage on systemic risk should not be underestimated. The size of the institutions involved is large. A 0.187% increase in the MES of a bank might have considerable consequences for financial stability. Furthermore, if many banks increase their leverage ratio even slightly, the overall effect on systemic risk is considerable. Suppose 20 banks in the system face a 1% increase in the tax rate. The total increase in systemic risk is simply the sum of the individual increases in systemic risk contribution. The expected increase in total systemic risk is therefore 3.74%.[12] This affects all banks as soon as systemic risk materializes. Increases in corporate taxes affect financial stability strongly. To conclude, changes in leverage ratios affect financial stability to a large extent.

In addition, a multiple cross-sectional regression is performed to regress systemic risk contributions on leverage and tax simultaneously. The results answer Hypothesis 2 and Hypothesis 3. Hypothesis 3 relates to the research question directly and reads: *The corporate income tax rate is positively related to the systemic importance of a bank.* Results show that an increase in tax rate and/or leverage ratio increases systemic contribution. It is found that a 1% increase in corporate income tax leads to an average increase in the systemic risk contribution of a large European bank of 0.34%. This illustrates that tax policy influences systemic risk. Additionally, it is illustrated that a 1% increase in leverage leads to an average increase in the systemic risk contribution of a large European bank of 0.173%. This finding confirms Hypothesis 2 and 3. Additionally, it reaffirms the findings of the simple cross-sectional regression which estimated the elasticity to be 0.187%. In the multiple regression it is found that a negative cross elasticity exists between leverage ratios and tax rates. This cross elasticity partially offsets the individual impact of a change in tax or leverage on β_i^T. It explains why the estimated coefficient on leverage is lower in the multiple regression than in the simple regression. The negative cross elasticity is intuitive. As mentioned, large banks are subject to regulatory ceilings. The higher the leverage ratio is ex ante, the less room their is to increase it after an increase in the corporate income tax rate.

The effect of the corporate income tax on systemic risk is even larger than the effect of leverage. This is striking. Recall it has been found that the corporate income tax rate does not influence the leverage ratio of large banks considerably. This implies that the tax rate influences systemic risk in another way than through the leverage ratio. One possible explanation could be that increases in the corporate income tax rate decrease the costs of debt financing. Perhaps these types of windfalls encourage excessive risk taking, increasing systemic risk.

[12]Since $20 * 0.187\% = 3.74\%$

The fourth hypothesis of this research reads: *Financial markets price systemic risk efficiently.* This paper proposed the use of tail beta to measure systemic contribution. It is shown that tail beta is easily derived from the MES when extreme value theory is used. It allows to interpret systemic contribution from a CAPM point of view. Regarding market efficiency, results indicate that a risk premium on extreme returns is present. The mean value of β_i^T equals 1.012. Given the systemic importance of banks, 1.012 is a very reasonable number for β_i^T to conclude that a risk premium on systemic tail risk of banks is present. In addition, it is shown that an excess market return is present. This gives reason to conclude that market are not efficient.

Last, this research shows that ING Groep, Barclays and Société Générale are the three most systemically risky banks of Europe during the 15-year period 2001-2015. ING Groep obtains the largest marginal expected shortfall. When conditioning on a once per decade crisis, ING is expected to experience a drop in market-valued total assets of 26.5%. Barclays and Société Générale experience losses over 22% of their MVA. From the 10 most systemically risky European banks, 8 are currently under special supervision of the Financial Stability Board. Surprisingly, the Swedish bank SEB and Belgian KBC Group lack supervision of this kind. It should be investigated whether these banks need special monitoring. The average loss of a large European bank during a severe crisis is estimated to be 15% of MVA. These losses cannot be covered by the amount of capital that banks own. During a crisis, governments would have to step in to limit the losses. This scenario could lead to severe, and potentially catastrophic, political and economic instability in Europe. Especially since public debt levels have continued to rise since the Sovereign Debt crisis. Systemic risk must be limited before a severe economic downturn will hit the markets.

To conclude, no evidence is found that tax shields on debt stimulate large European banks to lever up during 2001-2015. Large banks are usually capital-tight, which implies that there is little room to increase leverage ratios in order to benefit from the tax shield. This does not mean that leverage ratios should go unmonitored. Evidence shows that leverage ratios are positively related to systemic risk contributions. Additionally, it is illustrated that increases in corporate income tax lead to higher systemic risk contributions for European banks. Although this does not seem to work through an increase in leverage ratio directly, there is reason to believe that tax shields affect risk taking in alternative ways. Also, using tail beta, it is shown that the average loss of a large European bank during a severe crisis is estimated to be 15% of MVA. These losses cannot be covered by the amount of capital that banks own. Regulators should continue to limit systemic risk and consider the role of tax policy and leverage ratios in doing so.

6.2 Limitations and Suggestions for Future Research

One limitation of this research is that it is unable to capture the effect of a tax shield on debt explicitly. The corporate income tax rate alone is not enough to estimate the effect of tax discrimination. From this point of view, taxes on equity should be considered as well. Schepens (2016) provides a good example of this. His paper is mentioned in the Literature Review. Another suggestion for future research is to investigate how the corporate income tax rate relates to systemic contribution exactly. The results of this paper give reason to believe the corporate income tax rate influences systemic risk in another way than via the leverage ratio. Given the influence of tax on systemic risk, it is of great importance that this is examined.

On another note, it would be interesting to compare the findings regarding leverage and corporate income tax with other factors that influence systemic risk. The methodology of this research could be used to investigate the impact of size or complexity. These insights will help to fully understand the impact tax and leverage actually have.

Another limitation of this research concerns the methodology used to calculate systemic risk. Although the use of extreme value theory has many advantages, it limits the possibilities of this research in some ways. The use of extreme value theory requires a large data sample. It is therefore hard to gain insight in the short run dynamics of systemic risk contribution. To gain any insight in the time-series dynamics of systemic risk, a 15-year rolling window could be used. This will not be able to provide answers on recent dynamics in systemic risk, but could be interesting when looking at a longer time horizon. Alternatively, a different systemic risk measure could be used that is able to capture short run dynamics. Although this might be at the cost of accurate measurement, it could help to estimate the relation between systemic risk and leverage ratios and tax policy.

Another downside of this methodology is that it forced to drop banks from the sample that went bankrupt during the financial crisis. These banks had too many missing values during the worst days of the system to reliably estimate their MES and tail beta. It is therefore important to understand that ING Groep is the most systemically risky bank in Europe for 2001-2015 based on a sample of banks that are still operating.

To conclude, this research shows that the corporate income tax rate and leverage ratios are related to systemic risk. More research is necessary however to understand how the corporate income tax rate affects systemic risk exactly. Future research in this field can help to lay out the role for tax policy in the containment of systemic risk.

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Appendix

A Proofs

Proof of Proposition 1 *Expected shortfall and value-at-risk are linearly related*

$$ES_q \approx \frac{\hat{a_m}}{\hat{a_m}-1} VaR_q \tag{96}$$

Suppose the distribution function $F(x)$ is in the domain of attraction of the Fréchet distribution and satisfies the following condition:

$$\lim_{t\to\infty} \frac{F(-tx)}{F(-t)} = x^{-a}, \qquad x>0, a>0 \tag{97}$$

The density in the left tail is:

$$f(-x) \approx aAx^{-a-1} \tag{98}$$

Derive the expected shortfall using $y = -x$:

$$\begin{aligned}
ES &= \int_{-\infty}^{-t} x \frac{f(-x)}{F(-t)} dx \\
&= \frac{1}{F(t)} \int_t^{\infty} -yf(y)d(-y) \\
&= \int_t^{\infty} yf(y)d(y) \\
&\approx \frac{1}{At^{-a}} \int_t^{\infty} yaAy^{-a-1}d(y) \\
&= \frac{1}{t^{-}a} \frac{a}{-a+1} y^{-a+1}\Big|_t^{\infty} \\
&= 0 - \frac{1}{t^{-}a} \frac{a}{-a+1} t^{-a+1} \\
&= -\frac{a}{-a+1} t = \frac{a}{a-1} t = \frac{a}{a-1} VaR
\end{aligned}$$

B Tables and figures

Table 15: Corporate Income Tax Rate

Country	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Average
BE	39.0	39.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.8
CH	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
DK	30.0	30.0	30.0	30.0	28.0	28.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	24.5	23.5	26.6
ES	35.0	35.0	35.0	35.0	35.0	35.0	32.5	30.0	30.0	30.0	30.0	30.0	30.0	30.0	28.0	32.0
FR	36.4	35.4	35.4	35.4	34.9	34.4	34.4	34.4	34.4	34.4	36.1	36.1	38.0	38.0	38.0	35.7
GB	30.0	30.0	30.0	30.0	30.0	30.0	30.0	28.0	28.0	28.0	26.0	24.0	23.0	21.0	20.0	27.2
GE	26.4	26.4	28.0	26.4	26.4	26.4	26.4	15.8	15.8	15.8	15.8	15.8	15.8	15.8	15.8	20.9
GR	37.5	35.0	35.0	35.0	32.0	29.0	25.0	25.0	25.0	24.0	20.0	20.0	26.0	26.0	29.0	28.2
IT	36.0	36.0	34.0	33.0	33.0	33.0	33.0	27.5	27.5	27.5	27.5	27.5	27.5	27.5	27.5	30.5
SW	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	26.3	26.3	26.3	26.3	22.0	22.0	22.0	26.3
Total	30.7	30.3	29.7	29.4	28.9	28.5	27.6	25.5	25.4	25.3	24.8	24.6	24.9	24.6	24.5	26.8

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Table 16: Descriptive Statistics and Results

Bank Name	Country	Total Assets	Rank	Leverage	Rank	MES(1-k/n)	MES(1-p)	Beta	Rank	G-SIB
Aareal Bank	DE	41124005,03	47	26,49	12	0,048	0,176	1,277	23	
Abbey National***	GB	317765418	21	28,04	8	0,014	0,059	0,388	62	
AIB Group	IE	126241008	31	13,37	47	0,042	0,183	1,205	27	
Alpha Bank	GR	52668849	41	13,01	48	0,033	0,141	0,927	40	
Banca Carige	IT	29671630	52	11,03	54	0,023	0,098	0,643	54	
Banca Mediolanum	IT	25121528	54	23,52	18	0,041	0,174	1,148	29	
Banca Monte Dei Paschi	IT	174959685	28	18,46	30	0,035	0,151	0,993	34	
Banca Popolare di Milano***	IT	42821418	46	11,58	53	0,034	0,147	0,969	38	
Banca Ppo.Di Sondrio	IT	21821542	56	12,85	50	0,015	0,063	0,416	60	
Banco BPI	PT	36817643	48	23,67	17	0,025	0,109	0,719	51	
Banco BPM	IT	96083237	33	12,46	51	0,038	0,165	1,084	31	
Banco Comercial Português	PT	80038966	38	17,96	32	0,031	0,135	0,888	42	
Banco Popular Espanol***	ES	105227502	32	13,59	46	0,035	0,150	0,991	35	
Banco de Sabadell	ES	90352646,8	34	14,68	44	0,023	0,085	0,619	55	
Banco Santander	ES	905792494	10	15,42	41	0,048	0,207	1,364	16	Yes
Bank Of Greece	GR	82661182	37	37,36	2	0,018	0,079	0,518	58	
Bank Of Ireland Group	IE	143159746	30	20,48	23	0,048	0,205	1,352	18	
Bank Of Piraeus	GR	46547651	44	16,52	34	0,032	0,137	0,900	41	
Bankinter 'R'	ES	45512101	45	19,95	27	0,034	0,148	0,975	37	
Banque Nationale de Belgique	BE	83326751	36	10,14	56	0,011	0,049	0,323	63	
Barclays	GB	1431664476	5	29,89	5	0,057	0,246	1,623	3	Yes
BBV Argentaria	ES	481575513	16	15,60	38	0,046	0,196	1,294	22	
BNP Paribas	FR	1561471094	2	25,79	14	0,051	0,218	1,438	8	Yes
BPER Banca	IT	50410769	43	15,53	39	0,021	0,091	0,598	56	
Bradford & Bingley**	GB	51862557	42	20,20	25	0,015	0,066	0,436	59	

Table 16 continued from previous page

Bank Name	Country	Total Assets	Rank	Leverage	Rank	MES(1-k/n)	MES(1-p)	β_i^T	Rank	G-SIB
Close Brothers Group	GB	7294450	61	6,84	60	0,028	0,121	0,799	47	
Commerzbank	DE	566303445	14	28,59	7	0,053	0,229	1,508	6	Yes
Crédit Agricole d'Ile de France	FR	28780891	53	7,96	59	0,010	0,045	0,294	64	Yes
Crédit Agricole de France	FR	1287874584	6	25,79	14	0,052	0,191	1,384	15	Yes
Credit Suisse Group	CH	740043617	12	26,69	10	0,050	0,214	1,410	10	Yes
Danske Bank	DK	374016388	20	26,52	11	0,034	0,145	0,952	39	
Deutsche Bank	DE	1473522812	3	33,25	3	0,050	0,215	1,417	9	Yes
Dexia	BE	424679477	18	52,15	1	0,049	0,210	1,386	14	Yes
DNB	NO	193656156	26	16,37	36	0,043	0,185	1,218	26	
Erste Group Bank	AT	175468608	27	20,12	26	0,044	0,191	1,259	25	
Eurobank Ergasias	GR	58585778	39	18,14	31	0,028	0,122	0,801	46	
HSBC Holdings	GB	1568672557	1	14,93	43	0,035	0,149	0,983	36	Yes
IKB Deutsche Indstrbk***	DE	35423655	49	26,23	13	0,023	0,098	0,649	53	
ING Groep	NL	1053350893	7	27,88	9	0,068	0,294	1,940	1	Yes
Ingenico Group	FR	1198432	64	1,50	63	0,038	0,162	1,066	32	
Intesa Sanpaolo	IT	491084278	15	12,86	49	0,049	0,212	1,399	12	
Jyske Bank	DK	32441592	50	17,31	33	0,027	0,116	0,763	50	
KBC Group	BE	279617676	23	18,88	28	0,052	0,223	1,469	7	
Komercni Banka	CZ	24172963	55	9,00	57	0,030	0,127	0,839	44	
Lloyds Banking Group	GB	751984501	11	21,56	22	0,049	0,213	1,403	11	Yes
Mediobanca	IT	57929374	40	8,01	58	0,031	0,133	0,878	43	
MLP	DE	1682395	63	3,77	61	0,029	0,126	0,828	45	
National Bank of Greece	GR	87285786	35	16,16	37	0,041	0,175	1,151	28	
Natixis	FR	382588656	19	29,28	6	0,047	0,204	1,344	19	
Nordea Bank	SE	467328513	17	22,12	21	0,044	0,191	1,260	24	Yes
Pohjola Pankki**	FI	31510756	51	14,98	42	0,024	0,102	0,672	52	
Provident Financial	GB	2327676	62	3,36	62	0,020	0,088	0,579	57	
Royal Bank Of Scotland	GB	1435024448	4	20,47	24	0,055	0,235	1,548	4	Yes

Table 16 continued from previous page

Bank Name	Country	Total Assets	Rank	Leverage	Rank	MES(1-k/n)	MES(1-p)	β_i^T	Rank	G-SIB
Sainsbury J	GB	16595222	57	1,44	64	0,028	0,121	0,798	48	
SEB	SE	222331702	24	22,87	19	0,054	0,231	1,524	5	
Société Générale	FR	971991717	9	25,43	16	0,058	0,251	1,657	2	Yes
Standard Chartered	GB	313570937	22	14,03	45	0,046	0,200	1,315	21	Yes
Svenska Handelsbanken	SE	212039663	25	22,68	20	0,039	0,168	1,110	30	
Swedbank	SE	167164260	29	18,82	29	0,049	0,212	1,396	13	
Sydbank	DK	16495564	58	15,50	40	0,028	0,119	0,784	49	
UBS Group	CH	1048190271	8	31,61	4	0,047	0,202	1,334	20	Yes
Unicredit	IT	715412803	13	16,37	35	0,048	0,207	1,362	17	Yes
Valiant	CH	15055626	59	11,88	52	0,001	0,006	0,038	65	
VP Bank Vaduz	CH	7407302	60	10,81	55	0,014	0,059	0,389	61	
Wirecard	DE	701192	65	1,10	65	0,037	0,160	1,051	33	

This table shows the descriptive statistics and results obtained for each bank in the sample. Leverage is calculated as total liabilities divided by total shareholder's equity. MES(1-k/n) is obtained using (84) with $n = 3916$ and $k = 100$. For MES(1-p), equation (85) is used with with $a_m = 3.208$ and $p = 1/2610$. This probability corresponds to a crisis that happens once per decade. The β_i^T is obtained using (91).

Table 17: Summary Statistics Daily Average Leverage

	Belgium	Denmark	France	Germany	Greece	Italy	Spain	Sweden	Switzeland	GB
Mean	24.99	20.30	18.72	20.02	11.08	14.88	17.20	22.31	21.35	17.75
Median	27.55	20.55	18.35	19.64	17.85	14.90	18.44	22.52	21.90	16.02
Maximum	69.00	25.75	22.35	29.29	47.29	17.16	20.75	25.64	29.51	29.66
Minimum	-59.95	16.20	15.56	12.92	-132.69	13.02	13.02	17.37	14.24	10.78
Std. Dev.	25.83	2.48	2.05	4.55	39.80	1.13	2.50	2.22	4.14	5.38
Skewness	-1.97	0.26	0.04	0.42	-3.05	0.11	-0.39	-0.40	0.10	0.81
Kurtosis	8.39	2.79	1.70	2.32	11.37	2.07	1.72	2.20	2.52	2.48
Observations	3916	3916	3916	3916	3916	3916	3916	3916	3916	3852

This table shows the average leverage ratios per country for the period 2001-2015. Leverage ratios are calculated as total liabilities divided by total shareholder's equity.