The effectiveness of the Basel Accords
Evidence from European banks
Thanks

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Abstract

Title: The effectiveness of the Basel Accords: Evidence from European Banks

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Purpose: The purpose is to investigate the adequacy of the Basel Accords to fulfill the underlying ideas of reducing risk and stabilizing the financial sector, or if it allows banks to use regulatory arbitrage to maintain a desired productive efficiency- and risk level.

Methodology: A two-step analysis is constructed where each bank’s efficiency is first estimated, followed by a panel data regression on the efficiency-score and on a proxy for bank risk.

Conclusion: We found evidence supporting that the third Basel Accord have been more effective, by a reduced risk as a consequence of both an increased capital adequacy ratio and the implementation. However, we cannot confirm that the capital requirements inhibit bank efficiency, but there is evidence of an impaired efficiency since the implementation of the third accord, suggesting that the supervision, for instance, has a weakening effect on efficiency. Moreover, there are also implication of the strengthened capital requirements, in terms of quantity and quality of capital, more efficiently fulfilling the accords purpose of reducing risk.

Keywords: Basel Accords, Regulatory Arbitrage, Bank regulation, Data envelopment analysis,
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1 Introduction

Banks have an important role for the financial stability in today’s society since it offers different financial products to companies and individuals (Lind 2005). Companies are provided with loans for investments and payment solutions for their daily activities while individuals are given the ability to borrow money for purchasing a household or a car. By offering loans, the societies investments and spending will increase which favors the economic growth. Moreover, the banks largest source of income is the loans (Saunders & Cornett 2015) and since they operate on a competitive market, there will be a great competition of customers. When increasing the amount of customers or the volume of lending, there is a risk that the banks increase their lending to less creditworthy clients and thus increases the insolvency risk (Jappelli, Pagano & Bianco 2005). Due to the banks importance for the society and their possible opportunistic lending, they need to be regulated (Lind 2005). The Basel Committee on Banking Supervision (BCBS) publish capital requirements and supervision regulation that the member countries must implement. BCBS published the first Basel Accord in 1988 and a revised accord, the Basel II Accord, in 2004 (BCBS 1988; BCBS 2006). Yet, the financial crisis of 2007 and 2008 was, to a great extent, a consequence of the banks opportunistic and naive lending operations (BCBS 2010), and occurred 30 years after the first Basel publication. Thus, it is of interest to investigate how efficiently the accords fulfill its core purpose, namely reducing risk and stabilizing the financial sector.

The thesis purpose is to investigate whether the Basel Accords have fulfilled their underlying idea or if the banks have used regulatory arbitrage to maintain their efficiency-level. Our idea is that the regulations in the Basel Accords have inhibited the efficiency of the banks and extensionally reduced their profits. Then, to be able to remain the same level of return as before the publications of the Basel Accords, the banks are trying to find loopholes in the regulation to increase the risk in other ways. To investigate this, a regression with an efficiency variable as dependent variable is first conducted to determine whether the publication of the Accords in fact did reduce the efficiency of the banks. To distinguish if the risk of the banks has changed and thus, get an indication on if the banks has performed regulatory arbitrage, a regression with a risk variable as dependent variable is conducted.

The accords have been implemented by 60 central banks (BIS 2018c). However, we chose to only study banks within the European Union since it gave us the largest sample with the most
comparable banks. In contrast to previous studies, the thesis is conducted on each time-period corresponding to the publication of the three Basel Accords. There are two main reasons to why the study investigates the effect of every accord. First, it gives more robust results of how regulations generally affect the efficiency and risk of the banks. Second, it makes it possible to compare the effect of the different accords and, by evaluating the differences of the accords, examine what kind of regulations that best fulfills the purpose.

1.1 Background

1.1.1 Structure of a bank

A bank’s major income is the interest from loans, which are financed mainly by their deposits, on which they pay rent to the deposit owners. A bank’s efficiency is therefore commonly measured by how efficiently the bank converts deposits to loans (Beck, Demirguc-Kunt and Levine 2010). The bank’s earning assets is thus the loans while the deposits are categorized as debt. Hence, a bank differs from a regular firm by having opposite balance sheet. The easiest way to explain the logic behind the reversed balance sheet is that nonfinancial firms, and consumers, are the customers of banks which mean that the nonfinancial firms’ loans are debt to them while it is the opposite, assets, to the banks. It can perhaps be easier to understand from a consumer’s point of view; your mortgage is an asset to the bank since you borrowed money from them and are thus in debt to them (Saunders & Cornett 2015). To finance the lending operations, the bank need deposits which then function as both debt and as an input in the production of their earnings assets (Thakor 2014). Banks tend to be relatively high leveraged, compared to other industries, mainly due to the deposits being a cheap and easy funding method for their lending operations. However, loans are relatively illiquid in contrast to deposits, creating a large exposure toward credit- and liquidity risk (Saunders & Cornett 2015). Moreover, funding with deposits always comes with a risk of bank-run\(^1\) which is why debt financing, especially deposits, is associated with increased risk of financial distress. Balancing the debt with more capital would reduce the severity from depositor’s potential bank-run and function as a buffer for losses (Diamond & Rajan 2000).

According to the Modigliani and Miller theorem (section 4.1.1), the capital structure does not affect the value of a bank. However, the theory assumes that there are no taxes, bankruptcy costs or asymmetric information, assumptions that are not likely to hold in the reality. Berger,

\(^1\) Bank-run refers to the collective actions of depositors leaving the bank with their claims if they feel as they are exposed to a great risk (Diamond & Rajan 2000)
Herring and Szegö (1995) relaxes these assumptions and argues that by doing so, the capital structure does affect the costs and the value of the banks. Asymmetric information can cause agency problems (section 4.1.4), both between the shareholders and the manager and between the shareholders and the creditors. The agency problem between the shareholders and the creditors, which for banks mainly is the depositors, and the agency costs that it leads to, can be reduced if the bank increases its capital level. The shareholders might have more information about the financial situation of the bank and since they have the right to the residual claim, and thus get a higher return if the bank increases its profits, they can have incentives to increase the risk. In contrast, the interest rates that the bank pays to the creditors is determined and do not change when the return is increased, but it is affected if the bank goes bankrupt. Capital can function as a buffer against shocks, and the risk of bankruptcy can be reduced with a higher capital level. That means that higher capital levels reduce the risk for the creditors, which can decrease their demanded return and lower the cost of debt for the banks (Berger, Herring & Szegö 1995).

In contrast to the shareholders’ agency problem with the creditors, the problem with the manager can be decreased by holding a lower level of capital. A higher leverage ratio induces risk of bankruptcy which give the manager incentives to perform better, especially if the manager own shares in the bank (Berger, Herring & Szegö 1995). Moreover, the transaction costs of issuing debt are lower than for raising external equity and a more leveraged firm experience tax reductions. A trade-off is thus created between reducing bankruptcy costs and the transaction- and tax reductions (Berger, Herring & Szegö 1995).

Furthermore, increasing the capital level indirectly reduces the portion of deposits which leads to less input factors in the production of earning assets. The capital impairs liquidity creation by not being able to finance loans and would thus reduce the volume of lending (Diamond & Rajan 2000). Due to the reduced liquidity creation and the higher cost of capital, banks tend to not hold as much capital as socially requested, and thus stay more exposed to risk.

1.1.2 Bank Regulation

Banks are, in contrast to other type of firms, protected by government safety nets to reduce contagion effects and secure the stability of financial systems. Consequently, depositors of a defaulting bank are insured and their loss will be covered by the government. However, such safety nets induce moral hazard behavior in banks. When the cost of financial distress is
reduced, it makes it more favourable for the bank to finance with debt (Berger, Herring & Szegö 1995). By being aware of depositors insurance, banks tend to ignore the riskiness in their operations since their depositors are protected regardless and pursue a high leverage (Thakor 2014). Furthermore, the depositors do not feel the same need to monitor the banks when there are safety nets protecting their deposits (Hellmann, Murdock & Stiglitz 2000).

Because the failure of banks might impair the stability of the financial system, and of the government safety nets, there is great political interest that the bank holds enough capital to cover stress-periods. High enough capital levels reduce the likelihood of bank default, and thus the necessity of expensive government bailouts. A bank in financial distress can perhaps be bailed out by the government without any severe consequences for the economy, but several defaulting banks are likely to have a great effect on the economic condition. Banks tend to hold similar assets that are exposed to the same risks which increases the likelihood of several banks going into financial distress and default at the same time if they do not hold enough capital to absorb the losses. Hence, it is of governmental interest to keep banks in financial distress from defaulting, which could be done by forcing them to hold more capital. However, due to the reasons explained above regarding cost of capital and the moral hazard behavior in the presence of government safety nets, the bank does not have enough incentives themselves to hold a higher level of capital. One solution is to implement capital requirements which forces banks to hold a certain level of capital in relation to its assets (Thakor 2014).

When there are no capital requirements, it is assumed that each individual bank would have an optimal capital structure dependent on their business model (Boyson, Fahlenbrach & Stulz 2014) and the market. However, regulators require larger capital levels than what the market does since they, in contrast to the market, considers social costs, such as the risk that the problem of one bank can spread to other banks and impair the stability of the economy. When the banks level of capital is higher than what the market requires, the cost of the bank increases and the value is reduced (Berger, Herring & Szegö 1995).

Capital requirements from the regulators that are higher than the capital levels from the market can inhibit the efficiency of the banks. For a bank to be efficient, they should convert as large part of their deposits into lending as possible. When the banks costs increase, for example due to increased transaction cost and decreased tax reductions, the cost of production inputs used to produce its outputs are higher. That means, that less of the deposits will become loans, indicating that efficiency is inhibited by capital requirements. Furthermore, Chortareas,
Girardone and Ventouri (2011) argue that the regulations further inhibit the banks efficiency by impeding the operations it can perform.

1.1.3 The Basel Accords

In the aftermath of an unstable international currency- and banking market, representatives from ten countries’ central banks formed a committee on banking regulations and supervisory practices in 1974, later called the Basel Committee on banking supervision (BCBS) (BIS 2019a). BCBS are the primary global standard setter for banking regulations and has the purpose to improve the financial stability which is done by strengthening the regulation and supervision of banks (BIS 2018a). BCBS develops and publish the Basel Accords which contains regulations for banking.

To be able to investigate how well the Basel Accords are fulfilling its underlying purpose of reducing the bank risk and improving the financial stability, it is important to know what regulations that are included in the Accords and to understand what the purpose with the regulations are. It is also important to know what the regulations state in each accord and how the accords differ from each other to be able to distinguish what regulations that are fulfilling its purpose in the best way. Consequently, each Basel Accord is presented below. Notice that the Basel Accords only applies to the countries that are members of the Bank for International Settlements (BIS), where the regulation is imperative. Hence, they are not voluntary for the banks in the member countries (BIS 2018a). Moreover, each accord replaces the former and in between publications of new accords are the old ones continuously amended.

1.1.3.1 Basel I Accord

In the early 80’s, the committee noticed decreasing capital ratios at the same time as globalization increased the international risks (BIS 2019a). The concerns were shared among many countries and at the time they had variating capital requirements, creating unequal competition. The attention toward decreasing capital ratios and the unequal competition was among several incentives for the Basel I accord. With the Basel I accord, the Basel Committee wanted to strengthen the stability and the soundness of the international banking system. By the endeavour that the regulation has a high degree of consistency in the application between banks in different countries they also wanted to decrease the inequality in the competitiveness between banks (BCBS 1988).
The Basel I accord focused on regulating the bank's capital and its main focus was to reduce the credit risk of the banks, while only mentioning other risks that needs to be taken into consideration as well. The Accord established minimum levels of capital for the banks that are active internationally. The Basel I accord stated that at least half of the banks’ capital base should consist of core capital, which is equity capital and disclosed reserves (BCBS 1988). Furthermore, it regulated the capital adequacy of the banks. It stated that all international banks should hold a capital to risk-weighted asset ratio of at least 8 percent by the end of 1992. This means, that if a bank gains more risk, their risk-weighted assets increase and they are obligated to hold more capital (BCBS 1997).

1.1.3.2 Basel II Accord

Already in 1999, the committee proposed a new Basel Accord which was published in 2004 and implemented in all member countries in 2007. The purpose with the revised accord was to further strengthen the stability of the international banking system (BCBS 2006). The second accord consisted of three pillars meant to cover all the essential risks of the bank, not only credit risk (BCBS 2006; Lind 2005). The first pillar covers the minimum capital requirements consisting of the same requirement as the Basel I accord, with a minimum capital to risk-weighted asset ratio of 8 percent. Furthermore, at least half of the capital must consist of Tier 1 capital (BCBS 2006), which consists of common equity and retained earnings (BCBS 1988). However, the choice of method for measuring the capital was more generous and thus allowed banks to measure the credit-, market- and operational risk in a way that reflect their business and by that get a more precise measure of their risks (BCBS 2006).

A large difference from the first accord was that the Basel II did not just focus on regulations of capital requirement. It also had a focus on market discipline and supervisory review to cover those risks which was not accounted for in the first pillar. The second pillar, which focused on the supervisory review, stated that the supervisors should control how well the banks estimated their need for capital and should encourage the banks to use good risk management techniques. If they considered that a bank did not have adequate capital in relation to their risk, they should take actions against the bank (BCBS 2006) According to Lind (2005) banks that were assessed to be risky could face increased capital requirements.

The third and last pillar was thought of as a complement for the first two as it had demands for disclosure leading to better transparency for stakeholders (BCBS 2006).
1.1.3.3 Basel III Accord

In 2010, the three pillars were revised and strengthened into a new accord, the Basel III Accord, and will be implemented during a 7-year long process starting in 2013. The Basel III Accord was a response to the financial crisis of 2007 and 2008. The Basel Committee claim that the main cause to the severity of the crisis was the high leverage and low liquidity within the banking sector. The purpose of the revised accord was to strengthen the capital and liquidity regulation and thus be more prepared for future shocks (BCBS 2010).

The Basel III Accord builds on the three pillars from the second accord (BCBS 2010). Some main points in the new regulation are stricter requirements of the quantity and quality of capital, minimum requirements of both leverage- and liquidity ratio, the latter which should cover funding for a 30-days stress period (BCBS 2012). The capital requirement of capital to risk weighted assets is the same as in the previous accords, 8 percent. However, there are stricter regulations of how much of the capital that must be Tier 1 capital (see appendix 1 for definition). The capital must consist of 6 percent, rather than the previous 4 percent, of tier 1 capital and 4.5 percent of common equity, compared to the previous 2 percent (BCBS 2012). Another improvement of the Basel III Accord is that it specifies what criteria the capital must meet to be counted as Tier 1- or Tier 2 capital and by that, it enhances the transparency and consistency of the capital of the banks.

Besides the stricter capital regulations, Pillar 2 and Pillar 3 are also revised, with enhanced supervisory review process and strengthened disclosures (BCBS 2010).

1.1.4 Regulatory Arbitrage

The purpose of the regulation is mainly to reduce risk and stabilize the financial sector (BCBS 1988). However, when banks are regulated, the potential operations that the banks can perform might be reduced (Chortareas, Girardone & Ventouri 2011). To retain their efficiency- and profitability level while meeting the requirements, banks might perform regulatory arbitrage (Chortareas, Girardone & Ventouri 2011). It can be performed by holding riskier assets to increase return and efficiency at the same time as they are meeting the required capital level (Calem & Follain 2007).

There is no general definition of regulatory arbitrage and the there are many different operations that the bank can perform to circumvent the regulations (Willesson 2016). Fleisher (2010) defines regulatory arbitrage as taking advantage of the limited ability of the legal system to
precisely capture the economic transactions. This is done by exploiting the gap between the economic substance of a transaction and the regulatory treatment of it. According to Willesson (2016), performing regulatory arbitrage is not an illegal activity, but a utilization of loopholes. Regulatory arbitrage can be divided into two different categories where the first consist of approaches that can be seen as measurement adjustments. Regulatory arbitrage that belongs to this category can be modifications of the numbers in their capital ratios. The second approach of regulatory arbitrage can be categorized as strategic loopholes which can be strategic decisions with the purpose to avoid becoming more capitalized. For instance, it can be done by optimizing the balance sheet, changing the banking business line or reshuffle the assets (Willesson 2016).

Although it is not illegal to use arbitrage opportunities, it can be quite costly. Jones (2000) argue that the banks willingness to engage in regulatory arbitrage depends on how high their structuring costs of doing so are. The structuring costs can be both internal, for example updated information systems, and external, for example expenses paid to third party that arise because of the regulatory arbitrage. If the structuring costs are lower, the bank has more incentives to engage in regulatory arbitrage (Jones 2000).

1.2 Problem

The banks have been given the responsibility of the society’s payment solutions and lending opportunities for the good of the society, however the banks’ quest toward maximized profits creates an agency problem which is why the Basel Accord was established. The Basel Accords consist of both regulation on supervision and capital requirements, with the aim to reduce the banks’ risk (BCBS 2006). It is of great, political interest that the requirements are met since it reduces the likelihood of bank default, stabilizing the financial market and decreases the necessity of expensive government bailouts. The capital requirements are based on the socially optimal capital level and are most likely larger than the bank’s individual capital level since it accounts for the social costs of bank failure (Thakor 2014). Holding a higher capital level than what is optimal for the bank will increase its cost and make the bank less efficient. Moreover, since capital is relatively more expensive than debt, making the banks less profitable, banks will be reluctant to meet capital requirements. To compensate for the increased cost of capital and the impaired efficiency, banks might perform regulatory arbitrage by finding loopholes in the regulation to increase risk and maintain a satisfactory efficiency level.
The research in the field of banking regulation has been divided into two sides; one which believe that the Basel Accord is efficient and the other which believe that banks find loopholes in the regulation to meet the requirements but at the same time not fulfilling its underlying purpose (Calem & Follain 2007; Willesson 2016). Willesson (2016) found that the bank’s risks are not reduced although they meet the required capital level, supporting that banks exploit regulatory arbitrage. Koehn and Santomero (1980) further argue that banks facing stricter regulations alter the distribution in their asset portfolios to increase the risk. This suggest that other risks, such as interest rate risk, is increased while credit risk is reduced, thus not reducing the total risk as intended. That indicates that the Basel Accords do not fulfill its underlying purpose.

Several studies on the subject of how bank regulation affect the efficiency and risk of banks have already been conducted (Chortareas, Girardone & Ventouri 2012; Lee & Chi 2013; Mester 1996). However, the previous studies show varying results and due to the banks’ importance for the financial system and society, further studies are of relevance. Furthermore, the banks’ irresponsible lending and naive risk-taking were contributing factors to the severe consequences of the financial crisis of 2007 and 2008 (BCBS 2010). The third Basel Accord was developed as a response to the financial crisis which makes it interesting to examine if the revised regulation fulfills its purpose in a more preferable way than the previous accords.

1.3 Purpose
The purpose is to investigate the adequacy of the Basel Accords to fulfill the underlying ideas of reducing risk and stabilizing the financial sector, or if it allows banks to use regulatory arbitrage to maintain a desired efficiency- and risk level.

1.4 Disposition
The thesis outline is organized as follows. Section 2 discuss the research approach and design. Section 3 cover previous research followed by the theoretical framework and hypotheses in section 4. The following chapter (5) describes that thesis methodology, including data, followed by empirical results and the analysis in chapter 6 and 7, respectively. In the end, there is a concluding chapter (8) of the study and its result together with thoughts for further studies on the subject.
2 Method

2.1 Research approach and design

The thesis is conducted with a quantitative method and deductive approach where we departure from theories concerning bank efficiency and risk. The theories form hypotheses which are tested for a statistically significant relationship between the independent and dependent variable. It seems to be the most appropriate approach since the research problem request a generalizable answer regarding the efficiency of a regulation, rather than for a specific bank (Bryman & Bell 2017). It is also the most common approach among previous studies on the subject (Chortareas, Girardone & Ventouri 2011; Mester 1996; Lee & Chi 2013).

Since the purpose of thesis is to examine the regulation’s effect on bank efficiency and risk, we need to investigate the relation before and after the publication. Therefore, the most appropriate research design is the longitudinal. If the purpose would have been to study the efficiency differences among European banks, or how banks has reacted differently to the implementation of Basel, a cross sectional research design could have been appropriate. The choice of research design is further supported by previous studies, which also was of longitudinal design (Chortareas, Girardone & Ventouri 2011; Mester 1996; Lee & Chi 2013).

To distinguish the effect from the regulation, the reality has to be compared to how it would be if the regulation was not implemented. According to Coglianese (2012), there are three possible approaches when comparing the reality to how it would have been if the regulation was not implemented. These are controlled experiments, randomized experiments and quasi-experiments. The first two approaches are not possible when evaluating the effect of regulation since controlled experiments requires that all other variables remain constant and randomized experiments requires that what is studied has been introduced randomly, which regulation are not (Coglianese 2012). In this study, we will use the approach of quasi-experiments to examine the effect of the regulations. When conducting quasi-experiments, variations in the regulations are being exploited and then statistic controlled for other factors that can have a potential effect on the result (Coglianese 2012).
2.2 Reliability and Validity

There is no universal and optimal measure of either efficiency or risk, which can put the validity of the variables in question. There are several different definitions and interpretation of efficiency, mostly depending on what the study’s aim is. The choice of measuring efficiency with a data envelopment analysis where we have two inputs, interest- and operating expenses, and one output, interest income, is partly made based on the research purpose but also supported by previous papers on the subject (Chortareas, Girardone & Ventouri 2011; Mester 1996; Lee & Chi 2013). However, to enhance the validity and reliability of the measures, we conduct a robustness test with two additional efficiency measures. Furthermore, throughout the thesis, the variables for efficiency and risk are always considered as proxies of the two. We are aware that there are several approaches to measure risk, but since Z-score is a commonly used proxy for the studied risk we have condemned it to be suitable (Chortareas, Girardone & Ventouri 2011; Lee & Chi 2013).
3 Prior Research

Lee and Chih (2013) investigated how the financial regulations in China affected the efficiency and risk of Chinese commercial banks in during the time period from 2004 to 2011. They divide the bank into two categories, depending on their size. To estimate efficiency, they use a data envelopment analysis (DEA) and to estimate risk they use Z-score. They use the intermediation approach of DEA with two input- and two output- variables. The input variables are deposits and fixed assets and the output variables are investments and loans. They use profit efficiency to estimate the efficiency of the banks. To investigate the relationship between financial regulation and efficiency they use Tobit regression model and to investigate the relationship between financial regulation and risk they use an ordinary least square (OLS) regression. The dependent variable in the Tobit regression is the efficiency score from DEA and the dependent variable in the OLS regression is the Z-score. They have two types of variables of financial regulation in their regressions, variables of indicators that are already implemented and variables of indicators that are expected to be implemented in the Basel III regulations.

Their results show that the impact of capital adequacy ratio is insignificant on both efficiency and risk for large banks. For small banks the effect of the capital adequacy ratio is insignificant on efficiency while it has a negative relationship with risk, indicating that a higher capital adequacy ratio can reduce risk. The effect of the leverage ratio on large banks is insignificant on both efficiency and risk while the result on small banks show a positive effect on efficiency and a negative effect on risk. To test how liquidity affects the efficiency and risk of banks they test the impact of the current ratio and loan to deposit. Their results show that the current ratio had negative effect on efficiency for large banks but positive effect on efficiency in small banks. The effect on risk was insignificant in both large and small banks. In small banks loan to deposit had a negative impact on efficiency and a positive impact on risk. The results were insignificant for large banks.

Tan and Floros (2013) also did a study on Chinese banks. They used a dataset of 101 commercial banks from China with observations between 2003 and 2009 to investigate the relationship between capital, risk and efficiency in banks. Capital, they calculated as the ratio of book value of equity to total assets. They used three different measures of efficiency, technical efficiency, that was calculated by the DEA CCR model and pure technical efficiency and scale efficiency which were calculated by the DEA BCC model. To estimate risk, they used four different measures. These are the ratio between loan- loss provision and total loans, Z-score, the return on assets, and the non-performing loans ratio.
score and the volatility of ROA and ROE. Their results show a negative relationship between risk, when it is measured by z-score, and capital, indicating that the more capital the bank has the less risky it is. However, they did not find a relationship between capital and the other risk measures. Their results show no significant relationship between capital and any of the efficiency measures.

While Lee and Chih (2013) find a positive relationship between leverage and efficiency, thus not supporting capital requirements as a method to increase bank efficiency, there are several studies with contradicting evidence (Chortareas, Girardone & Ventouri 2011; Fiordelisi, Marques-Ibanez & Molyneux 2011; Barth, Lin, Ma, Seade & Song 2013). Chortareas, Girardone and Ventouri (2011) found net interest margin, or cost of intermediation, and cost-to-income ratio to be negatively influenced by the implementation of capital requirements. Lower cost of intermediation indicates that the deposits (and other input variables) are more efficiently converted into lending (and other output variables), and a lower cost-to-income ratio imply of lower cost in relation to income (or higher income in relation to costs) and thus is an indication of efficiency. The positive relationship was also found, however weak, by Barth, Lin, Ma, Seade and Song (2013). Their study was made during 1999 and 2007 on a sample of 4050 banks within 72 countries worldwide, and disclosed that the less developed countries had on average less efficient banks than those in more developed countries.

Fiordelisi, Marques-Ibanez, Molyneux (2011) investigates the relationship between capital, efficiency and risk in banks. They use data from 26 commercial banks from the EU-area during from the time-period 1995-2007. To get their results they use Granger-causality technique. Bank capital adequacy is measured as total equity divided by total assets, where total equity is measured by summing Tier 1 and Tier 2 from Basel. To get the efficiency measures they use stochastic frontier approach. They use both revenue and cost efficiency. To estimate risk they use two variables, expected default frequency and nonperforming loans to total assets. Their results show that capital ratio has a positive effect on cost efficiency, however when capital is estimated by the book value of total equity they find no significant relationship between capital and efficiency. They do not find a significant relationship between capital and risk.

Altunbas, Carbo, Gardener and Molyneux (2007) studied banks from 15 European countries between 1992 and 2000. They estimated the relationship between capital, efficiency and risk by using a Seemingly Unrelated Regression approach. The capital-variable was measured by the bank’s ratio of equity to total assets, the risk-variable by loan-loss reserve to total assets.
and the efficiency measure was cost efficiency obtained by using stochastic frontier approach. They find a positive relationship between capital levels and risk and a negative relationship between capital and efficiency for their full sample. However, when they divide the banks in their sample into different groups depending on what type of bank it is, they get mixed results for the different types of banks. For savings banks and commercial banks, the results are the same as for the full sample but for co-operative banks they find a negative relationship between capital levels and risk and a positive relationship between capital level and efficiency.

In contrast to previous studies on the relationship between efficiency, risk and capital ratio, Bitar, Pukthuanthong and Walker (2017) separates nine different definitions of capital and try to determine which enhances banks’ stability and performance the most. The study measures risk with the ratio of loan loss reserves to total assets, profitability is proxied by the net interest margin and efficiency is measured with the cost to income ratio. It is found that both traditional, non-risk based capital, such as common equity and tangible assets, and risk-based capital increase bank efficiency and probability. However, the non-risk based capital require banks to hold higher loan loss reserves while risk-based capital do not. Furthermore, Tier 2 capital disclose a negative association with bank efficiency and profitability, which is in line with Basel’s recommendations of less reliance on Tier 2 capital (Bitar, Pukthuanthong & Walker 2017).

Regulation on capital requirements are implemented to reduce risk, but even too much capital can be risky. It was found that banks with the most and with the least capital during the financial crisis performed worst (Lindblom & Willesson 2012; Haq & Heaney 2012). Too little capital leads to limited capacities to absorb losses while too much capital may lead to inability to raise the share of risky assets when faced with profitable opportunities (García-Herrero, Gavilá & Santabárbara 2009).

Koehn and Santomero (1980) investigates how a regulatory increase in the minimum capital asset ratio affects the bank portfolio risk. They argue that when stricter capital regulations are introduced, the banks reshuffle their asset portfolio so it contains more risky assets than it did before the stricter capital regulations. Because of that, the banks may be riskier after the regulations than they were before. They argue that how much a bank reshuffles its asset portfolio depends on how risk-avert it is. Banks that are less risk-avert are more likely to reshuffle its asset portfolio and become riskier than it was before the stricter capital regulations were introduced.
The loophole strategy described by Koehn and Santomero (1980) is further presented by Willesson (2016) as a response to capital requirements and is called regulatory arbitrage. The strategy is based on the assumption of moral hazard, that increased capital eliminates the benefit of transferring risk from the banks to society. Because of regulatory arbitrage, the capital requirements of, for instance Basel II, is assumed to not have any effect on bank risk. From studying 344 commercial banks within the Europe, the result shows a positive association between increased capital requirements and increased bank risk, to some part supporting the theory of regulatory arbitrage that capital requirements at least do not decrease bank risk as intended. However, the banks still comply with regulation, though the reason is to create legitimacy for themselves rather than reducing the liquidity- or solvency risk (Willesson 2016).
4 Theoretical frame of reference

4.1 Theory

4.1.1 Modigliani-Miller theorem

The Modigliani-Miller theorem states that the capital structure is irrelevant in a perfect market without taxes, bankruptcy costs and information asymmetry. However, none of the theory’s assumptions tend to hold in the real economy which proves the capital structures’ importance for firm valuation. Moreover, even if the assumptions hold would a higher debt-to-equity ratio increase the cost of equity since the equity holders of more leveraged, and thus risky, firms require a higher return (Modigliani & Miller 1958).

Capital requirement eliminate the bank’s ability to choose the capital structure themselves and can impede the possibility to hold the optimal capital structure, from a financial point of view.

4.1.2 Trade-off theory

The Modigliani & Miller Theorem was based on an economy without taxes and concluded that the value of a firm is not affected by the financing choice. The trade-off theory is another theory regarding optimal capital structure but based on an economy with taxes. The theory argues that there are tax benefits of debt funding as the interest rate on debt reduces the profit of the company, and thus the taxable amount. However, there is also an increased probability of default with increased debt since a higher leverage ratio result in larger payment obligations and probably a decreased liquidity. Less liquidity in combination with greater debt reduces the ability to cover losses and stress-periods. The optimal level of debt is thus a balance between tax benefits and bankruptcy costs where firms generally will not increase debt when the cost of bankruptcy exceeds the tax benefits (Kraus & Litzenberger 1973).

The cost of debt arises from the likelihood of bankruptcy and is thus legal expenses for restructuring or liquidation but also the cost for potential income etcetera. Consequently, the cost of debt is believed to be comparable within an industry, making the optimal capital structure similar between firm of the same industry (Miller 1977). We can thus assume, to some extent, that the banks in our study should have similar optimal capital structure.
4.1.3 Pecking order theory

The pecking order theory assumes that corporations have a preferred pecking-order when choosing capital structure, where internal funds are preferable to external funding. Retained earnings is one source of internal financing but it is often not enough to cover the financing needs, which is when a pecking-order arise between the two external sources; debt and new equity. Although increased debt is associated with risk, it is the preferable alternative over raising new equity. Raising new equity is done by issuing shares and thus changes the ownership structure, either by introducing new owners or changing the ownership of current (Myers 1984). Moreover, issuing new shares is a common tool to alter the value of an overvalued stock. Thus, if the stock is not overvalued and the company issues shares, investor will most likely pay less and the company’s market value will be reduced due to information asymmetry. Hence, there is a great risk to issuing new shares which is why debt financing is preferred (Myers 1984; Myers & Majluf 1984).

In the banking sector, the Basel Accords has restrictions on the capital level of banks. There is a minimum level of tier 1 and tier 2 capital that must be held by the company (BCBS 1988; BCBS 2006; BCBS 2010), which is why it is not always possible for them to choose debt over raising new equity.

4.1.4 Agency theory

When someone, called the principal, employ someone else, called the agent, to perform services on their behalf, an agency problem arises. The agency theory assume that everyone acts out of self-interest. That means that when the principal delegates control to the agent, there is a risk that the agent acts opportunistic and commit actions that are not in line with the interest of the principal (Jensen & Meckling 1976). The separation of ownership and control between the principal and agent can lead to asymmetric information, since the agent have more information about the company than what the principal has. The problem with asymmetric information leads to a moral hazard problem, which arise when the principal and the agent has different incentives (Holmström 1979). The agent has the decision control but not the residual claim and thus does not have to bear the risks of their decisions (Fama & Jensen 1983). To control the agent’s opportunistic behavior, the principal can set up incentives for the agent with the aim to make its interests align with the principal’s. The controlling of the agent generates agency costs, for instance bonding costs and monitoring costs (Jensen & Meckling 1976).
4.2 Hypotheses

To test if the regulations in the Basel Accords are fulfilling its underlying purpose of reducing risk within the financial sector, eight hypotheses are constructed. Hypotheses 1-4 are constructed to test if the regulation inhibits the efficiency of the banks while hypotheses 5-8 are constructed to test if the regulation increases the risk of the banks. Our idea is that higher capital levels and stricter capital regulation inhibits the efficiency of the banks and that the banks, to be able to maintain the same efficiency as before the publication of the accords, increases the risk by performing regulatory arbitrage. If the tests give statistically significant results for rejecting the null hypotheses, it would give an indication of the Basel Accord not fulfilling its underlying purpose.

4.2.1 Efficiency hypotheses

Modigliani and Miller (1958) argue that the capital structure is irrelevant for the value of a company. However, their theory relies on the assumptions that there are no taxes, no bankruptcy costs and no asymmetric information, these are assumptions that tend not to hold in reality. The trade-off theory, which relaxes these assumptions, argue that by funding the business with debt, a company can get tax reductions. However, more debt also results in higher interest expenses and will probably make the bank less liquid which reduces its ability to cover losses and stress periods. Hence, there is a trade-off between tax reductions and bankruptcy costs in the choice of capital structure (Kraus and Litzenberger, 1973). The trade-off is interrupted by the capital requirements since they limit the banks' ability to hold their optimal capital structure. According to Boyson, Fahlenbrach and Stulz (2014) it is assumed that if there were no capital requirements, each individual bank would have an optimal capital structure dependent on their business model. When there are regulations that specifies how much capital the banks have to hold, the efficiency of banks can decrease if their optimal capital level is below the required. It is likely that the required capital level is higher than the banks optimal level since the regulation also considers the social costs (Berger, Herring & Szegö 1995).

Previous studies have shown varying result on how the level of capital is related with the efficiency of the banks. Lee and Chih (2013) and Altunbas et al. (2007) support the theory that increased capital has a negative association with efficiency, however several other studies show for the opposite relationship (Chortareas, Girardone & Ventouri 2011; Barth et al. 2013, Fiordelisi, Marques- Ibanez, Molyneux 2011). The key seems to be to hold a sufficient level of
capital to be able to absorb losses while also being able to seize profitable opportunities, as those banks who had too high- or too low capital level during the financial crisis of 2007 and 2008 were the ones who performed the worst (García-Herrero, Gavilá, & Santabárbara 2009; Lindblom & Willesson 2012; Haq & Heaney 2012). Furthermore, Chortareas, Girardone & Ventouri (2011) argue that the regulations can reduce the potential operations of the banks. Holding more capital in relation to debt reduces the creation for liquidity and thus the funding for loans and potential profit (Diamond & Rajan 2000). Higher capital requirements can therefore impair the efficiency of the banks.

**Hypothesis 1:**

H$_0$: Banks that are more capitalized are not less efficient.  
H$_1$: Banks that are more capitalized are less efficient.

**Hypothesis 2:**

H$_0$: The Basel I Accord did not inhibit the efficiency of European banks.  
H$_1$: The Basel I Accord inhibited the efficiency of European banks.

**Hypothesis 3:**

H$_0$: The Basel II Accord did not inhibit the efficiency of European banks.  
H$_1$: The Basel II Accord inhibited the efficiency of European banks.

**Hypothesis 4:**

H$_0$: The Basel III Accord did not inhibit the efficiency of European banks.  
H$_1$: The Basel III Accord inhibited the efficiency of European banks.

**4.2.2 Risk hypotheses**

Sharpe (1964) argue that an investor, in this case the bank, can increase its expected return by borrowing money and invest it in assets with a higher expected return than the interest rate of the loan. The expected return should increase with increased leverage since it yields a higher risk. When the capital regulation of the banks becomes stricter, the banks cannot leverage their capital as much as they could before the regulation and thus not yield as high return (Koehn & Santomero 1980).

The stricter regulations can, by forcing them to hold a non-optimal capital level, inhibit the efficiency and reduce the profits of the banks. To remain the same efficiency level as before, the banks might perform regulatory arbitrage to increase its risk. This can for example be...
performed by including more risky assets in their asset portfolios (Koehn and Santomero 1980).

Another reason for the banks to increase the risk when facing stricter capital regulation can be that it is the most favourable approach for increasing their capital base to fulfill the capital requirements. Fiordelisi, Marques-Ibanez and Molyneux (2011) argue that banks with a high efficiency can more easily generate higher profits which they can use to increase their capital level. When the efficiency decreases, due to the stricter capital requirements, the possibility to use this approach decreases as well. According to the pecking order theory, internal funding, for example retained earnings, is the most favourable approach for a company to fund its business and increase its level of capital while issuing equity externally is the least preferred approach (Myers, 1984). By increasing its risk, the bank can increase its profits and thus their retained earnings, which they can use to build up their capital level. This is supported by Blum (1999) who argue that when the banks are facing stricter capital requirements and external capital is too expensive, the only way for them to increase their capital level is to increase the risk.

Fiordelisi, Marques-Ibanez and Molyneux (2011) argue that inefficient banks might spend less resources on controlling the borrowers that they are lending money to, increasing the risk of nonperforming loans. This can be a reaction to stricter capital requirement, in case they are inhibiting the efficiency of the bank. By doing so, they seem to be more efficient but actually it is the risk that has increased.

As with the relationship between capital and efficiency, previous studies show varying results of the relationship between capital and risk. Evidence for that the regulation is reducing the risk of the banks are difficult to find (Lee & Chih 2013; Fiordelisi, Marques-Ibanez & Molyneux 2011; Altunbas et al. 2007). Altunbas et al. (2007) and Lee and Chi (2013) found contradicting evidence of a positive association between capital levels and risk, indicating that the capital requirements do not lower bank risk. However, neither Lee and Chih (2013) or Fiordelisi, Marques-Ibanez and Molyneux (2011) found any significant relation between capital ratio and risk in larger banks. Willesson (2016) argue that the banks are maintaining the capital level that are required by the accords, but the risk does not seem to have been reduced. An assumption can be made that banks perhaps only implement the accords to gain legitimacy, and instead exploit regulatory arbitrage by increasing their exposure to other risks to maintain a suitable risk-, return- and efficiency level (Willesson 2016).
Despite that the Basel committee has evaluated and tried to strengthen the regulations, with the Basel II- and the Basel III accord, it might still be possible for the banks to execute regulatory arbitrage even with these regulations in place. Manlagnit (2015) argue that the financial crisis exposed shortcomings with the Basel II accord which then should be covered in the third accord. However, according to Willesson (2016), there are studies arguing that there still is room for regulatory arbitrage in the Basel III accord. Thus, a continued investigation on the third accord’s impact on efficiency and risk is of interest, although it is not yet fully implemented.

**Hypothesis 5:**
H.: Banks that are more capitalized are not riskier.
H.: Banks that are more capitalized are riskier.

**Hypothesis 6:**
H.: The Basel I Accord did not increase the risk of banks.
H.: The Basel I Accord increased the risk of banks.

**Hypothesis 7:**
H.: The Basel II Accord did not increase the risk of banks.
H.: The Basel II Accord increased the risk of banks.

**Hypothesis 8:**
H.: The Basel III Accord did not increase the risk of banks.
H.: The Basel III Accord increased the risk of banks.
5 Methodology

The Basel Accords are supposed to reduce the risk of banks, but regulations might also disrupt the operations of a bank and impede its efficiency (Chortareas, Girardone & Ventouri 2011). To measure the effect of the Basel Accords and the potential regulatory arbitrage, we first investigate the change in efficiency to detect any incentive to use regulatory arbitrage. To find evidence of regulatory arbitrage, we study the change in total bank risk. Hence, the investigation of the Basel Accords effect on efficiency and risk will be made in two steps in accordance with the two-stage efficiency analysis of Simar and Wilson (2007). First, an input-oriented Data Envelopment Analysis is conducted to estimate the efficiency of the banks, differing from Simar and Wilson (2007) who presented an output-oriented analysis. The Data Envelopment Analysis (DEA) produces an efficiency score that measures how efficient a bank is relative to the other banks in the sample which is used as a dependent variable in the second stage. The first regression intends to study the accords impact on bank efficiency while the other regression investigates the accords impact on bank risk.

To measure the Basel Accords effect on efficiency and risk of banking, a comparison has to be made between regulated and unregulated banks. According to Coglianese (2012), examining the effects of a regulation can be done either by comparing over time or between places. Therefore, we employ the dummy-variable approach and study European banks over a longer period of time to make a comparison of the same banks before and after the publication of the accords. The dummy variable in the regression takes the value 1 when the accord is implemented.

Another common method for estimating the effect of regulation is the difference-in-difference method which makes a comparison of jurisdictions that has been treated with the regulation to a control group of jurisdictions that have not implemented the regulation (Coglianese 2012). It is important for comparison reasons that the control group has the same characteristics and the same trend as the jurisdiction that has been treated by the regulation, otherwise the result could be misleading (Jones 2009). The Basel Accords cover all countries within the Organization for Economic Cooperation and Development (OECD) and have been implemented by both the European Union and the United States, which leaves us with few, if any, comparable countries left that have not implemented the regulation. Those who still have not implemented the Basel Accords either have similar regulation themselves or are too different from the banks in our sample to serve as control group. Due to the difficulties to gather an appropriate control group,
we choose not to use the difference-in-difference method and instead use the dummy-variable approach.

5.1 Data Envelopment Analysis

The non-parametric method Data Envelopment Analysis (DEA) is used as research approach instead of other parametric or non-parametric methods to estimate how efficient the banks are. The input-oriented DEA, based on Farrell’s (1957) input-output analysis, with variables to scale is applied rather than the output-oriented. The banks are believed to have a greater control over the input variables, such as cost of labor, than the output variables, such as interest income from loans. The banks’ interest income (output) tend to be constrained by the market and they are relatively more able to control the costs (input) themselves, which is why banks often focus on minimizing costs rather than maximizing interest income. By measuring the change in input levels while holding output constant, an efficiency score of the production is estimated. If the banks would have had relatively better control over the interest income (output), an output-oriented DEA would perhaps be more suitable (Chortareas, Girardone & Ventouri 2011).

The DEA creates a virtual, weighted score from all banks’ input and output and set it as a benchmark efficiency score \( Y_i = 1 \). The benchmark efficiency score creates an efficient production frontier, where all scores below the benchmark \( y_i < 1 \) is productive inefficient (see figure 1) (Farrell 1957). Notice that the efficient frontier is unobserved, but true. Each bank’s productive efficiency, measured by its input and output, is compared against the benchmark efficiency score which then gives us a relative measure of each bank’s efficiency score ranging between 0 and 1 \( 0 \leq y_i \leq 1 \). Each bank’s efficiency score is later used as a dependent variable in the regression examining capital requirement’s relationship with bank efficiency. One benefit of the non-parametric approach is that is does not require a specific functional form, and thus not a specific shape of the efficient frontier. If we would have chosen an approach requiring a specific functional form, the measurement between the benchmark efficiency score and the individual bank’s productive efficiency score would be dependent on how accurately the functional form captures the true relationship. Moreover, the DEA estimates individual observations and not the sample average as a regular regression analysis. A bootstrap method is applied in the DEA as a sensitivity analysis of the observed efficiency scores relative the sampling variation. Bootstrapping is done by resampling and creating a simulated sample, followed by applying the original estimator to each new sample to obtain representative
estimators. The bootstrapped method manages the possible problems with serial correlation among the inputs and outputs (Simar & Wilson 2007).

![Figure 1: The efficient frontier with made-up efficiency scores \(Y_i < 1\) as dots.](image)

5.2 Truncated regression with double bootstrap

In the second stage, we estimate a panel data regression (1) with left-sided truncation corresponding to each studied time-period to answer the first four hypotheses, regarding whether the Basel Accords have inhibited productive efficiency.

\[
EFF_{i,t} = a_{i,t} + \beta_1 \text{Basel} + \beta_2 \text{CAR}_{i,t} + \beta_3 C_{i,t} + \epsilon_{i,t}
\]

- \(EFF_{i,t}\) = the efficiency scores from the data envelopment analysis
- \(\beta_1\) = bank efficiency’s sensitivity to the publication of the Basel Accord.
- \(\beta_2\) = bank efficiency’s sensitivity to the bank’s capital adequacy ratio
- \(\beta_3\) = bank efficiency’s sensitivity to both endogenous and exogenous control variables
- \(\text{CAR}_{i,t}\) = the capital adequacy ratio for each separate bank
- \(C_{i,t}\) = the control variables; the natural logarithm of return on assets and the natural logarithm of total assets for each separate bank, the natural logarithm of interest rate and the natural logarithm of GDP-growth for each country.
- \(\epsilon_{i,t}\) = the error term which captures the disturbance that is not explained by the explanatory and control variables

Since the DEA’s efficiency score ranges between 0 and 1 and are thus not normally distributed, an ordinary least square (OLS) regression could result in estimation bias. According to Chortareas, Girardone & Ventouri (2011), the tobit regression has been the most commonly used method to solve this in previous studies. However, the Tobit estimator has been shown to be inappropriate in this framework, partly since it ignores that the DEA score is calculated from a common sample and not independent observations, thus not considering the problems of serial
correlation (Simar & Wilson 2007). Instead, a truncated regression (see figure 2) with bootstraps is used as it provides non-biased standard errors and confidence intervals although the estimated efficiency scores are correlated. The bootstrapped standard errors and confidence intervals means that they will be based on a larger sample than regular standard errors and confidence intervals, and thus be more precise. Furthermore, the bootstrapped method allows for and manages the problems of correlation between the efficiency score and the explanatory variables (Simar & Wilson 1998; Simar & Wilson 2007). This method has according to Wanke, Barros and Emrouznejad (2016) been proved to be the best method for overcoming the problem with serial correlation.

![Graph showing normal distribution with black, thin curve and the truncation, with the dotted lines and the thick, blue curve, of the regression.](image)

*Figure 2 show a normal distribution with the black, thin curve and the truncation, with the dotted lines and the thick, blue curve, of the regression.*

To answer the hypotheses 5-8, regarding whether the Basel Accords and higher capital level increases total bank risk, another regression is conducted on the different time periods corresponding to the publication of each Basel Accord. Regression (2) is conducted on a proxy for bank risk, Z-score, with the same explanatory- and control variables as in the previous regression, to estimate how the risk of the banks have been affected by the Accords. If Z-score has decreased even though the banks have met the criteria of the accord, it might be an implication of regulatory arbitrage.
\[ Z_{i,t} = a_{i} + \beta_{1} \text{Basel} + \beta_{2} \text{CAR}_{i,t} + \beta_{3} C_{i,t} + \epsilon_{i,t} \] (2)

\[ Z_{i,t} = \text{bank individual Z-scores, proxying for bank risk} \]
\[ \beta_{1} = \text{bank efficiency’s sensitivity to the publication of the Basel Accord.} \]
\[ \text{Basel} = \text{a dummy variable for the publication of the Basel Accord. Takes the value 1 after the publication and 0 prior.} \]
\[ \beta_{2} = \text{bank efficiency’s sensitivity to the bank’s capital adequacy ratio} \]
\[ \text{CAR}_{i,t} = \text{the capital adequacy ratio for each separate bank} \]
\[ \beta_{3} = \text{bank efficiency’s sensitivity to both endogenous and exogenous control variables} \]
\[ C_{i,t} = \text{the control variables; the natural logarithm of return on assets and the natural logarithm of total assets for each separate bank, the natural logarithm of interest rate and the natural logarithm of GDP-growth for each country.} \]
\[ \epsilon_{i,t} = \text{the error term which capture the disturbance that is not explained by the explanatory and control variables} \]

5.3 Robustness test

To obtain more robust results, we estimate the regression on efficiency again but with other efficiency measures; net-interest-margin and cost-to-income ratio (Chortareas, Girardone & Ventouri 2011). Since an OLS-regression cannot manage panel data or potential heteroscedasticity and serial correlation, we conduct a panel data regression with fixed effects.

\[ C/I_{i,t} = a_{i} + \beta_{1} \text{Basel} + \beta_{2} \text{CAR}_{i,t} + \beta_{3} C_{i,t} + \epsilon_{i,t} \] (3)

\[ C/I_{i,t} = \text{the cost-to-income for each bank, proxying for bank efficiency} \]
\[ \beta_{1} = \text{bank efficiency’s sensitivity to the publication of the Basel Accord.} \]
\[ \text{Basel} = \text{a dummy variable for the publication of the Basel Accord. Takes the value 1 after the publication and 0 prior.} \]
\[ \beta_{2} = \text{bank efficiency’s sensitivity to the bank’s capital adequacy ratio} \]
\[ \text{CAR}_{i,t} = \text{the capital adequacy ratio for each separate bank} \]
\[ \beta_{3} = \text{bank efficiency’s sensitivity to both endogenous and exogenous control variables} \]
\[ C_{i,t} = \text{the control variables; the natural logarithm of return on assets and the natural logarithm of total assets for each separate bank, the natural logarithm of interest rate and the natural logarithm of GDP-growth for each country.} \]
\[ \epsilon_{i,t} = \text{the error term which capture the disturbance that is not explained by the explanatory and control variables} \]

\[ \text{NIM}_{i,t} = a_{i} + \beta_{1} \text{Basel} + \beta_{2} \text{CAR}_{i,t} + \beta_{3} C_{i,t} + \epsilon_{i,t} \] (4)

\[ \text{NIM}_{i,t} = \text{the net-interest-margin for each bank, proxying for bank efficiency} \]
\[ \beta_{1} = \text{bank efficiency’s sensitivity to the publication of the Basel Accord.} \]
\[ \text{Basel} = \text{a dummy variable for the publication of the Basel Accord. Takes the value 1 after the publication and 0 prior.} \]
\[ \beta_{2} = \text{bank efficiency’s sensitivity to the bank’s capital adequacy ratio} \]
\[ \text{CAR}_{i,t} = \text{the capital adequacy ratio for each separate bank} \]
\[ \beta_{3} = \text{bank efficiency’s sensitivity to both endogenous and exogenous control variables} \]
\[ C_{i,t} = \text{the control variables; the natural logarithm of return on assets and the natural logarithm of total assets for each separate bank, the natural logarithm of interest rate and the natural logarithm of GDP-growth for each country.} \]
\[ \epsilon_{i,t} = \text{the error term which capture the disturbance that is not explained by the explanatory and control variables} \]
5.4 Data

Since the purpose is to study the effect of the Basel Accords, we gather data from before and after each publication. Most of the data is collected from the Thomson Reuters Datastream database, however GDP growth is gathered from World Development Indicators and the interest rates from OECD database. To avoid any bank doublets, only equities of major securities and on their primary quote is chosen. Furthermore, all absolute values are collected in US dollar to facilitate comparisons. The dataset only includes banks that are members of the European Union (EU) and Bank for International Settlements (BIS) during each studied time period. The sample is later reduced due to data deficiency during the entire time periods and on some essential variables, which yield a sample of 102 banks.

The first dataset consists of 25 banks that were active from 1985 to 1995 (see Appendix 2). Basel I was published in 1988 (BCBS 1988) but was not confirmed implemented in the G10 countries until the end of 1993 (BIS 2018b). It is probable to believe that several banks changed their capital structure successively from the publication until the implementation of the accords was confirmed. To capture the effect of the regulation, we must study a sufficient amount of years before any effect of the regulation appears, which is why this sample begin in 1985.

The second dataset consist of 21 European banks covering the period between 2000 and 2010 (see appendix 2). The Basel II Accord was published in 2004 and the implementation was intended to occur during 2007 in most countries but there are implications that some countries were not done until 2008 which makes the starting point quite unclear. Moreover, during the same time period there was an ongoing financial crisis which affected banks tremendously, especially in 2007 and 2008 (Haq & Heaney 2012). To be able to separate the direct and temporary consequences of the crisis from the effect of the regulation, we will study a few years before and after the implementation and the beginning of the financial crisis, namely between 2000 and 2010. It can be difficult to distinguish the effect of the Basel Accord from the effect of the crisis, however, the crisis must be under consideration in the analysis later on. The selection of banks is done by excluding European banks that were not members of Bank International Settlement (BIS) and whose country was not in the European Union (EU), since those countries are more comparable due to similar, and to some extent, shared legal system etcetera. Several countries within the EU also has a great economic cooperation through a monetary union with a shared currency. At last, since the study require active banks during the entire studied period of 2000 to 2010, banks without sufficient data due to bankruptcy or
acquisition during the financial crisis will be excluded. The exclusion of the bankrupt and acquired banks can perhaps result in the dataset consisting of the most efficient and least risky banks during the period, since the less efficient and more risky entities probably were the ones who became victims of the crisis. The potential bias of the dataset will be carefully considered in the analysis.

The third dataset is of 56 banks investigating the effect of Basel III during the period of 2008 to 2017. The banks in the sample are chosen by the same criterion as in the second dataset, that they should be members of both the EU and BIS (see appendix 2). The third Basel Accord was published in 2010 (BCBS 2010) and has been under implementation since 2013, thus not confirmed implemented yet. To capture the effect on the third accord, a sufficient amount of data before the publication must be included. Since the third accord was published shortly after the second was implemented, the study will begin already in 2008, two years before the publication, and end in 2017. Furthermore, the analysis must consider that the accord is not yet fully implemented and eventual effects from it might not exist.

5.4.1 Variables within the DEA

The intermediation approach is used when choosing input- and output variables to the DEA. In the intermediation approach the bank is seen as an intermediator of funds between depositors and borrowers, in contrast to the production approach, in which the role of the bank is seen to be a producer of services for its customers. In the intermediation approach, interest expenses should be included as input in the DEA, while the production approach only include the cost of physical inputs (Berger & Humphrey 1997). The inputs that are most commonly chosen, is according to Mester (1996), cost of labor, physical assets and deposits. Mester (1996) herself used labor, physical assets and borrowed money to estimate the DEA in her study. Tan and Floros (2013) used similar input-variables, they had total costs, including price of funds, price of labor and price of capital as inputs in their DEA. Lee and Chih (2013) used deposits and fixed assets as inputs in their DEA. However, our input variables will be \( x_1 = \text{cost of labor (salaries and benefit expense)} \), \( x_2 = \text{interest expense on deposits, federal funds, short term borrowing, long term debt and commercial papers} \), and \( x_3 = \text{interest expense on other borrowed money} \), as in previous studies (Mester 1996; Lee & Chi 2013; Chortareas, Girardone & Ventouri 2011), but also \( x_4 = \text{cost of premises} \) and \( x_5 = \text{cost of equipment} \), since they are major non-interest cost for banks.
While input variables are what generates costs, the output variables are those assets which generates income. Berger and Humphrey (1997) argue that loans and other major assets should be used as outputs in DEA since the major income of a bank is interest rates and fees on loans. Thus, the output variables used in this study are: \( z_1 \) = interest income from real estate loans, \( z_2 \) = interest income from commercial and industrial loans, lease financing receivables, agricultural loans, loans to depository institutions, acceptances of other banks, loans to foreign governments, obligations of state and political subdivisions, and other loans, \( z_3 \) = interest income from loans to individuals. According to Lee and Chih (2013) using loans and investments as outputs, which is done here, are fairly standard in studies.

5.4.2 Dependent variables

5.4.2.1 Efficiency variables
Bank’s productive efficiency is estimated by three different variables; the efficiency score from the DEA, net interest margin and cost-to-income ratio. The two latter efficiency measures are included to receive a more robust result than only the first would give.

5.4.2.1.1 Efficiency score from the DEA
The efficiency score from the Data Envelopment Analysis (DEA) creates a virtual, weighted output from all banks’ output into a benchmark efficiency score, creating a fictional bank that is efficient (\( Y_i = 1 \)). Each bank’s productive efficiency, measured by its input and output, is compared against the benchmark efficiency score which then gives us a relative measure of each bank’s efficiency score ranging between 0 and 1 (\( 0 \leq y_i \leq 1 \)). To reject the null hypothesis of hypotheses 1-4, the independent variables must have negative relation with the DEA score.

5.4.2.1.2 Net interest margin
Chortareas, Girardone & Ventouri (2011) argue that net interest margin (NIM) is an indicator of how efficient the banks’ intermediation are, considering their borrowing and lending operations. To reject the null hypothesis of hypotheses 1-4, the independent variables must have a positive relation with NIM. According to Beck, Demirguc-Kunt and Levine (2010) a higher level of net interest margin indicates lower efficiency since it indicates that the bank’s process between deposits and lending are less independent and incurs higher costs. The negative relationship can be difficult to comprehend since a bank that have a high net interest income in relation to its earning assets can seem to be an efficient bank. However, Kasman, Tunc, Vardar
& Okan (2010) argue that the reason why some banks have a high net interest income can be because they are inefficient and have to increase the interest rate to compensate for their inefficiency. They argue that banks who have higher operating costs and greater risks associated with their lending operations require a higher interest rate from the borrowers.

Net interest margin (NIM) is, according to the definition of Beck, Demirguc-Kunt and Levine’s (2010), the ratio of a firm’s net interest income to its total interest-bearing assets. Since a bank’s interest-bearing assets almost conclusively consist of their lending, it is used as a proxy for interest bearing assets in this thesis.

\[ NIM = \frac{\text{net interest income}}{\text{total loans}} \]  

Eq. (1)

5.4.2.1.3 Cost-to-income ratio
The cost-to-income ratio (C/I) is the third efficiency measure and is calculated by operating expenses to operating income, since we are interested in the direct efficiency of production. The ratio measures how inefficient each bank is, meaning that larger cost-to-income ratio imply a lower productive efficiency. Thus, to reject the null hypothesis of hypotheses 1-4, the independent variables must have a positive relation with C/I.

\[ \text{Cost to income} = \frac{\text{operating expenses}}{\text{operating income}} \]  

Eq. (2)

5.4.2.2 Bank risk
The total risk of the banks is proxied by Z-score which measures a bank’s probability of insolvency. Z-score estimates how many standard deviations the bank’s return on asset (ROA) has to fall below its expected value before the losses exceeds the banks equity (Beck, Demirguc-Kunt and Levine 2010). It has previously been used as a proxy for the bank’s total risk in studies by for example Lee and Chih (2013), Tan and Floros (2013) and Chortareas, Girardone and Ventouri (2011). According to Lee and Chih (2013), Z-score differ from the key financial ratios described above by taking the diversification of risk into account and not only consider the risks that are related to the business of the bank, but also how well the bank has coverage for the risks. They argue that this makes it a suitable proxy for bank risk (Lee and Chih, 2013).
In favor of the analysis, we will use the natural logarithmic value of Z-score to receive a more normal distributed value.

We are calculating Z-score by:

$$Z - score = \ln\left(\frac{ROA + \text{common equity}}{\text{total assets} \div SD~of~ROA}\right)$$  \hspace{1cm} \text{Eq. (3)}$$

To reject $H_0$ on hypotheses 5-8, Z-score should be negatively correlated with the independent variables. A higher Z-score is an indication of lower risk, which is supposed to be the effect from the Basel Accords. However, if the theory on regulatory arbitrage holds, there should be a reduction in Z-score when the coefficients of the independent variables are positive.

Z-score is a proxy for the total risk in banking. Regulatory arbitrage can be performed by holding the total risk constant, or even reducing it, by opening up a risk exposure and reducing another. This can be detected by investigating the Basel Accords effect on different types of risks, such as credit-, liquidity- and interest rate risk. However, obtaining data to proxy these risks over the studied periods were not without issues. A trade-off was made between gathering alternative data to proxy some of the risk during some parts of the studied period, but these results would have been difficult to compare with the rest of the study. Partly because they would cover different time periods, but also because the study on the different types of risk would have a relatively smaller sample of banks and would therefore be difficult to analyze from a global perspective.

### 5.4.3 Explanatory variables

The first explanatory variable is the capital adequacy ratio. The capital adequacy ratio (CAR) is supposed to somewhat proxy the capital requirements regulated in the Basel Accords and is measured by dividing the sum of a bank’s Tier 1- and Tier 2 capital with its risk-weighted assets (BCBS 2006).

$$CAR = \frac{\text{Tier 1 capital} + \text{Tier 2 capital}}{\text{risk weighted assets}}$$  \hspace{1cm} \text{Eq. (4)}$$

The majority of the banks in the first data sample, covering the period of 1985-1995, did not present tier 1 and 2 capital or risk weighted assets which is why CAR is measured here with an
alternative proxy. Measuring CAR with total capital to total assets would have been an alternative since it displays the same sort of relationship. However, the Basel committee recommends that less reliance should be put on Tier 2 capital (Bitar, Pukthuanthong, & Walker 2017). Common equity gives a more detailed measurement and is a more resembling proxy to tier 1 capital than total capital would be. Furthermore, there are greater possibilities for banks to manipulate total capital than common equity, which enhances the comparability between banks (Montgomery 2005). Due to this, we choose to calculate $CAR_2$ with common equity instead of total capital.

$$CAR(2) = \frac{\text{common equity}}{\text{total assets}} \quad \text{Eq. (5)}$$

The second explanatory variable is constructed to let the regressions know when the Basel Accord have been implemented, to be able to capture the effect not covered by CAR. The variable is a dummy which takes the value 0 prior the regulation, and 1 when it has been published. However, since the banks get a transitional period from the publication of the accords until they are supposed to be implemented, they will probably make changes over time and it will differ between countries (BCBS 1988). Because of the gradually implementation of the accords, the dummy takes the value 1 the year after the announcement and not the year when it is supposed to be implemented.

$$0 = \text{prior the publication of the accord}$$
$$1 = \text{after the publication of the accord}$$

To reject the null hypothesis on hypothesis 1, CAR should have a negative relationship with the DEA’s efficiency score and to reject the null hypothesis of hypothesis 2-4, the Basel dummy should have a negative relationship the DEA’s efficiency score. That would give us indications on that banks with higher capital ratios are less efficient and that the publication of the Basel Accords have inhibited the efficiency of the banks. In the robustness tests, there should be a positive relationship between CAR and the dependent variables, NIM and C/I to reject $H_0$ on hypothesis 1 and a positive relationship between the Basel dummy and the dependent variables, NIM and CI, to reject $H_0$ on hypotheses 2-4. To reject $H_0$ on hypothesis 5, CAR should have a negative relationship with Z-score and to be able to reject the null hypothesis on hypotheses 6-8, the Basel dummy should have a negative relationship with Z-score. Meaning that a bank’s
with higher capital levels are riskier and that the banks have become riskier after the publication of the Basel Accord. This could give an indication that the regulation impedes bank efficiency and that they exploit regulatory arbitrage by increasing risk.

5.4.4 Control variables
To successfully capture the explanatory variables true relation to bank efficiency and risk, the study must also consider other factors affecting the dependent variables, both over time and between banks (Coglianese 2012). The control variables included in the regressions are both endogenous; size of bank and return on assets, and exogenous; interest rate level and GDP growth. The exogenous variables are country specific based on where the bank has its headquarter. There are banks that operates in and trade with several different countries, making them dependent on other countries GDP- and interest rate level. However, this is not considered in our study due to the complexity of gathering information on which countries factors that affect which bank. Furthermore, both exogenous variables will capture some of the effect from the financial crisis of 2007 and 2008.

All control variables are growth-variables, thus they are estimated as the natural logarithmic value.

5.4.4.1 Size of bank
Large banks can have size advantages such as increased investment opportunities, diversification and greater access to capital, which can affect the efficiency and risk of banks (Altunbas et al. 2007; Rime 2001). Because of this, the size of the bank is included in the regressions to control for differences between banks and over time. There are several proxies for the size of a company, whereas the most common are number of employees, total revenue or total assets. Most of the other variables in the regressions will be dummies or ratios, which is why we use the natural logarithmic value of total assets. This is in line with for example Fiordelisi, Marques-Ibanez and Molyneux (2011) and Chortareas, Girardone and Ventouri (2011). It is expected that size will have a positive relationship with efficiency and a negative relationship with risk.

5.4.4.2 Return on assets
The profitability of a bank can have a relationship with both efficiency and risk in several ways. A high profitability can be due to both the bank being efficient (Fiordelisi, Marques-Ibanez & Molyneux 2011) or that it is highly exposed to risk (Sharpe 1964), indicating that it is a positive
relationship between profitability and both efficiency and risk. However, the relationship might be the contradicting. When a bank already has a high return, they might not have incentives to increase neither its efficiency or risk (Tan & Floros 2013).

In this study, profitability is proxied by return on assets (ROA). We expect a positive relationship between ROA and efficiency, which would be in line with previous studies that included return on assets in their regressions and found a positive correlation with bank efficiency (Chortareas, Girardone & Ventouri 2013; Sufian & Habibullah 2014). Furthermore, we also expect a positive relationship between ROA and risk. That is because for the bank to get a higher expected return, it has to increase its risk.

5.4.4.3 Interest rate level
Altunbas et al (2007) argue that the performance of banks in different countries can be affected by differences in interest rates and that higher interest rates can provide opportunities for higher profits. Higher interest rates generate higher interest income on loans to customers, but it also increases the demand of the currency and in turn increases the amount of deposits. It is also important to control for the variability in interest rates since varying interest rates can affect the operations of the banks, their efficiency and risk (Altunbas et al 2007). To control for the differences in interest rate level, each country’s 10-year government bond will be included in the regression, gathered from the OECD database. The essential role of this variable is to control for interest rate differences between countries and does thus not have to be the overnight rate or more practically used interest rates. Moreover, there were more sufficient and comparable data on a long-term government bond than those of shorter maturity. Hence, there is a trade-off between comparability and practically use, where comparability weigh more in this study.

5.4.4.4 GDP-growth
The general growth of the economy will most likely affect the efficiency and risk taking of any firm. During recession, banks will most likely not increase risk exposures or make large investments, just like their lending and investments from customers will decrease due to uncertainty. Thus, to estimate bank efficiency and risk, the GDP-level must be under consideration to capture the economic situation. The GDP-level differs between countries to a great extent, to avoid such country-differences in GDP we will look at the GDP-growth for year to year. Moreover, since all other independent and control variables are ratios or logarithmic value, it is more appropriate to use GDP-growth as a proxy for each country’s GDP-level rather than any absolute value.
Tan and Floros (2013) argue that technical improvement, which is a part of the GDP growth, can lead to the banks becoming more efficient. Furthermore, an increased GDP probably leads to increased consumption and spending, which would enhance the demand on the bank’s products. Because of this, we expect a positive relationship between GDP-growth and bank efficiency.
6 Empirical results

6.1 Efficiency

6.1.1 Basel I Accord

The regression (1) on the first time period test hypotheses 1 and 2. The results show that the coefficient for the Basel I publication is positive and significant on a 5 percent level, implying that the publication of the Basel I Accord increase the banks average productive efficiency (see table 1). This indicate that the Basel I accord enhanced the efficiency of the banks and we cannot reject $H_0$ on hypothesis 2, that the Basel I accord has inhibit the efficiency of the banks.

The results also show a positive and statistically significant relationship on a 1 percent level between the capital to asset ratio and efficiency, indicating that banks that holds more capital in relation to their total assets are more efficient. This indicate that more capitalized banks are more efficient and thus we cannot reject $H_0$ on hypothesis 1.

Of the control variables, the proxy for bank size and GDP-growth are shown to have a positive and statistically significant relationship on a 1 percent level with efficiency in regression 1. The positive relation with the bank’s size ($lnassets$) indicates that larger banks are more efficient and the positive GDP-growth coefficient indicates that banks that are based in high-growth countries are more efficient than those banks that are based in countries with lower growth. However, neither return on assets or interest rate were statistically significant and thus their impact on productive efficiency cannot be interpreted further.

The significant result of the Wald test indicates that the variables that are included in the regression to explain the dependent variable, both the independent and the control variables, improve the fit of the model.
Table 1: A table summary of the panel data regression (1) with left-sided truncation and double bootstrap on the efficiency score from the DEA. The bootstrapped coefficients are presented first and the standard errors are in between brackets. The statistical significance level is denoted by stars: * = 10 percent level, ** = 5 percent level, *** = 1 percent level.

### 6.1.2 Basel II Accord

The regression (1) on the second time period test the hypotheses 1 and 3. The result shows a positive relationship between capital adequacy ratio (CAR) and productive efficiency on a 1 percent statistical significance level (see table 2). The relationship indicates that banks holding more Tier 1 and Tier 2 capital in relation to their risk-weighted assets are relatively more efficient. Thus, we cannot reject the null hypothesis that higher capitalized banks are less efficient. The third hypothesis cannot be interpreted since the dummy for the accords’ publication show no statistical significance.

As during the first period, the coefficients for size and GDP growth are positive and statistically significant on a 1 percent level, indicating that increased GDP growth and larger bank size improves efficiency. ROA showed statistical significance on a 10 percent level, indicating a negative relationship with efficiency which is not expected. The control variable for interest
rate is not statistically significant during this period. However, the Wald test is statistically significant on 1 percent level, indicating that all the variables included improves the fit of the model.

<table>
<thead>
<tr>
<th>Efficiency (DEA)</th>
<th>Basel 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basel dummy</td>
<td>-0.0097</td>
</tr>
<tr>
<td></td>
<td>(0.0297)</td>
</tr>
<tr>
<td>CAR</td>
<td>1.1068 ***</td>
</tr>
<tr>
<td></td>
<td>(0.3732)</td>
</tr>
<tr>
<td>Ln ROA</td>
<td>-1.3200 *</td>
</tr>
<tr>
<td></td>
<td>(0.7539)</td>
</tr>
<tr>
<td>Ln GDP</td>
<td>1.5560 ***</td>
</tr>
<tr>
<td></td>
<td>(0.4837)</td>
</tr>
<tr>
<td>Ln Assets</td>
<td>0.0308 ***</td>
</tr>
<tr>
<td></td>
<td>(0.0073)</td>
</tr>
<tr>
<td>Ln Interest rate</td>
<td>0.9639</td>
</tr>
<tr>
<td></td>
<td>(2.3212)</td>
</tr>
</tbody>
</table>

Table 2: A table summary of the panel data regression (1) with left-sided truncation and double bootstrap on the efficiency score from the DEA. The bootstrapped coefficients are presented first and the standard errors are in between brackets. The statistical significance level is denoted by stars: * = 10 percent level, ** = 5 percent level, *** = 1 percent level.

6.1.3 Basel III Accord

The regression (1) on the third time period test the hypotheses 1 and 4. The results show a negative coefficient for the publication of the Basel III accord, indicating that the third Basel Accord impairs productive efficiency (see table 3). Since the relationship is statistically significant on a 1 percent level, $H_0$ on hypothesis 4 can be rejected. Thus, there is evidence for the Basel Accord inhibiting productive efficiency. Moreover, the statistically significant coefficient for $CAR$ is positive which indicates that more capitalized banks are more efficient. Thus, we cannot reject $H_0$ on hypothesis 1. This result is in line with the results from the previous two time periods.
As in the previous studied period, the coefficients for bank size and GDP-growth are positive and statistically significant on a 1 percent level while the coefficients for interest rate and return on assets are not significant. However, since the Wald test shows statistically significant results, the variables are estimated to fit the model.

<table>
<thead>
<tr>
<th>Efficiency (DEA)</th>
<th>Basel 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basel dummy</td>
<td>-0.1102 ***</td>
</tr>
<tr>
<td></td>
<td>(0.0214)</td>
</tr>
<tr>
<td>CAR</td>
<td>1.4896 ***</td>
</tr>
<tr>
<td></td>
<td>(0.2032)</td>
</tr>
<tr>
<td>Ln ROA</td>
<td>-0.0249</td>
</tr>
<tr>
<td></td>
<td>(0.4385)</td>
</tr>
<tr>
<td>Ln GDP</td>
<td>1.1101 ***</td>
</tr>
<tr>
<td></td>
<td>(0.3252)</td>
</tr>
<tr>
<td>Ln Assets</td>
<td>0.0368 ***</td>
</tr>
<tr>
<td></td>
<td>(0.0036)</td>
</tr>
<tr>
<td>Ln Interest rate</td>
<td>0.0162</td>
</tr>
<tr>
<td></td>
<td>(0.3961)</td>
</tr>
</tbody>
</table>

Table 3: A table summary of the panel data regression with left-sided truncation and double bootstrap on the efficiency score from the DEA. The bootstrapped coefficients are presented first and the standard errors are in between brackets. The statistical significance level is denoted by stars: * = 10 percent level, ** = 5 percent level, *** = 1 percent level.

6.1.4 Robustness test

To get more robust answers to the hypotheses, further tests have been done with two other proxies for bank efficiency; net interest margin and cost-to-income ratio. Before conducting the regressions, a Hausman test was performed to determine whether a random- or fixed effect model were more appropriate. For the regressions with the cost-to-income ratio as dependent variable the results of the Hausman test showed significant results for both Basel 1, 2 and 3 (see appendix 16-17, 22-23 and 28-29). This indicate that a regression model with fixed effects is more appropriate. For the regressions with net interest margin as dependent variable the Hausman test yielded varying results. For the regression concerning Basel I, the results showed
significant results but for the second and third Basel Accords, the results were not statistically
significant. However, the null hypothesis of the Hausman test is that both random- and fixed-
effects models are appropriate, thus, even when the null hypothesis cannot be rejected, a fixed
effect model can still be used. Hence, we chose to estimate with fixed effects in all regressions.

We do also test for nonconstant variance, heteroscedasticity, in its error term with the Whites
test. The test is suitable since it does not rely on the assumption of normality, and none of our
error terms are normally distributed (Damodar & Dawn 2009). The regressions are also tested
for serial correlation with a Wooldridge test, appropriate for panel data regressions (Wooldridge
2010). The results were varying but there was either heteroscedasticity or serial correlation, or
both, present in all estimated regressions (see appendix 12-15, 18-21 and 24-27). Both
heteroscedasticity and serial correlation were managed by estimating robust standard errors.

6.1.4.1 Basel I Accord

The first robust regression (3) with cost-to-income ratio as dependent were conducted of the
first Basel Accord and showed a positive relationship between the dummy-variable for
regulation and the cost-to income ratio, indicating a negative relationship between Basel I and
efficiency (see table 4). Since the relationship was statistically significant on a 5 percent level,
we reject the null hypothesis of hypothesis 2 and find support for the theory that increased
regulation inhibits bank efficiency. The relation between cost-to-income and the CAR- proxy
is however not statistically significant, and the first hypothesis cannot be rejected.

Regression 4, on net interest margin, shows statistical insignificant result on the coefficient of
the publication of Basel I Accords, therefore we cannot interpret the studied relationship
between the publication of the Basel I Accord and efficiency (see table 4). The relationship
between capital to asset ratio and efficiency is positive and statistically significant on a 10
percent level, which supports hypothesis 1 that more capitalized banks are less efficient, and
we can reject the null hypothesis.
Table 4: A table summary of the robustness tests. The coefficients are presented first and the standard errors are in between brackets. The statistical significance level is denoted by stars: * = 10 percent level, ** = 5 percent level, *** = 1 percent level.

6.1.4.2 Basel II Accord

The robustness tests on both cost to income and net interest margin, regression 3 and 4, yielded no statistical significance of the publication of the second Basel Accord (see table 5), which is in line with the result on regression 1 during the second period. Consequently, the null hypothesis of hypothesis 3 can still not be rejected.

The relationship between CAR and cost to income were not statistically significant in regression 3 (see table 5). However, the relationship between CAR and net interest margin is positive and significant on a 10 percent level, which gives support for hypothesis 1.
<table>
<thead>
<tr>
<th>Basel 2</th>
<th>CI</th>
<th>NIM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basel Dummy</td>
<td>0.0241</td>
<td>0.0009</td>
</tr>
<tr>
<td></td>
<td>(0.0250)</td>
<td>(0.0021)</td>
</tr>
<tr>
<td>CAR</td>
<td>-0.0073</td>
<td>0.0728*</td>
</tr>
<tr>
<td></td>
<td>(0.2514)</td>
<td>(0.0405)</td>
</tr>
<tr>
<td>Ln ROA</td>
<td>-22.0817**</td>
<td>-0.0552</td>
</tr>
<tr>
<td></td>
<td>(8.7938)</td>
<td>(0.2583)</td>
</tr>
<tr>
<td>Ln GDP</td>
<td>-0.8725**</td>
<td>-0.0365*</td>
</tr>
<tr>
<td></td>
<td>(0.3409)</td>
<td>(0.0193)</td>
</tr>
<tr>
<td>Ln Assets</td>
<td>0.0315</td>
<td>-0.0052**</td>
</tr>
<tr>
<td></td>
<td>(0.0261)</td>
<td>(0.0021)</td>
</tr>
<tr>
<td>Ln Interest rate</td>
<td>8.9550***</td>
<td>0.1497</td>
</tr>
<tr>
<td></td>
<td>(2.2656)</td>
<td>(0.1437)</td>
</tr>
</tbody>
</table>

Table 5: A table summary of the robustness tests. The coefficients are presented first and the standard errors are in between brackets. The statistical significance level is denoted by stars: * = 10 percent level, ** = 5 percent level, *** = 1 percent level.
6.1.4.3 Basel III Accord

Neither robust regressions during the third period show any statistically significant results for either of the independent variables, thus the robustness tests on the Basel III Accord is not further interpreted (see table 6).

<table>
<thead>
<tr>
<th>Basel 3</th>
<th>CI</th>
<th>NIM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basel Dummy</td>
<td>0.0018</td>
<td>0.0013</td>
</tr>
<tr>
<td></td>
<td>(0.0327)</td>
<td>(0.0012)</td>
</tr>
<tr>
<td>CAR</td>
<td>-0.2411</td>
<td>-0.0135</td>
</tr>
<tr>
<td></td>
<td>(0.3180)</td>
<td>(0.0188)</td>
</tr>
<tr>
<td>Ln ROA</td>
<td>-8.3702 *</td>
<td>0.2990 ***</td>
</tr>
<tr>
<td></td>
<td>(4.6421)</td>
<td>(0.1123)</td>
</tr>
<tr>
<td>Ln GDP</td>
<td>-0.9021 **</td>
<td>0.0047</td>
</tr>
<tr>
<td></td>
<td>(0.3910)</td>
<td>(0.0131)</td>
</tr>
<tr>
<td>Ln Assets</td>
<td>0.0442</td>
<td>-0.0078 **</td>
</tr>
<tr>
<td></td>
<td>(0.0625)</td>
<td>(0.0038)</td>
</tr>
<tr>
<td>Ln Interest rate</td>
<td>2.0160</td>
<td>0.0459</td>
</tr>
<tr>
<td></td>
<td>(1.2435)</td>
<td>(0.0369)</td>
</tr>
</tbody>
</table>

Table 6: A table summary of the robustness tests. The coefficients are presented first and the standard errors are in between brackets. The statistical significance level is denoted by stars: * = 10 percent level, ** = 5 percent level, *** = 1 percent level.

6.2 Risk

To examine how the Basel Accords have affected bank risk, regression 2 is conducted with the natural logarithm of Z-score as proxy for risk. The independent- and control variables are the same as in the previous regressions. The publication of each Basel Accord and the capital adequacy ratio, capital-to-assets ratio for the Basel I Accord, are independent variables and the natural logarithm of return on assets, natural logarithm of GDP growth, natural logarithm of interest rate and the natural logarithm of total assets are control variables.
As for the robustness tests, the Hausman test was performed to examine whether a random- or fixed effect regression model is more appropriate to use. The result of the Hausman test was insignificant for the regression concerning the Basel I Accord (see appendix 16-17), while it was statistically significant for the regression corresponding to the time for the publication of the second Basel Accord (see appendix 22-23). The test corresponding to the third Basel Accord yielded a negative chi2 value (see appendix 28-29). The negative chi2-value can be interpreted as strong evidence for rejecting the null hypothesis which means that a fixed effect model is more appropriate to use. Even though the Hausman tests gave shifting result for the different regressions, where we could reject the null hypothesis for the first and third regression but not for the second regression, we decide to use a fixed effect model in all the regressions with Z-score as dependent variable.

We do also perform tests to detect if the error terms contain heteroscedasticity or serial correlation. This is done with the same tests as the for the robustness regressions; the White's test to search for heteroscedasticity and Wooldridge test for serial correlation in panel data. The tests showed significant results for both heteroscedasticity and serial correlation in all three regressions, which is managed with robust standard errors and gives us more precise estimators (see appendix 12-15, 18-21 and 24-27).

6.2.1 Basel I Accord
Regression (2) on Z-score during the first period, corresponding to hypotheses 5 and 6, showed insignificant results on the coefficient for the publication of the Basel I Accord, thus we cannot interpret the first Basel Accord’s effect on bank risk (see table 7). The coefficient for the capital to asset ratio was positive and statistically significant on a 1 percent level, indicating that if banks increase their common equity in relation to total assets, the value of their Z-score increases as well. Since a higher Z-score is equivalent with lower risk, the interpretation is that the positive relationship between capital to asset ratio and Z-score indicates a negative relationship between more capitalized banks and risk. This means that the fifth hypothesis cannot be rejected, and it seems as more capitalized banks in fact are less risky. The coefficient of CAR is abnormally large. An explanation for this can be the relatively small sample, making the result more sensitive for outliers. The minimum value of CAR during the first period was 0.6 percent while it ranged between 7 and 8 percent during the other two periods (see appendix 3-5).
Return on assets and the proxy for bank size are statistically significant and displays a positive relationship to Z-score, indicating that higher return and larger banks tend to be less risky.

<table>
<thead>
<tr>
<th></th>
<th>Basel 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Z-score</strong></td>
<td></td>
</tr>
<tr>
<td>Basel dummy</td>
<td>-0.0173</td>
</tr>
<tr>
<td></td>
<td>(0.0242)</td>
</tr>
<tr>
<td>CAR2</td>
<td>22.2562 ***</td>
</tr>
<tr>
<td></td>
<td>(2.6049)</td>
</tr>
<tr>
<td>Ln ROA</td>
<td>14.6167 ***</td>
</tr>
<tr>
<td></td>
<td>(3.2292)</td>
</tr>
<tr>
<td>Ln GDP</td>
<td>-0.4510</td>
</tr>
<tr>
<td></td>
<td>(0.4147)</td>
</tr>
<tr>
<td>Ln Assets</td>
<td>0.0920 **</td>
</tr>
<tr>
<td></td>
<td>(0.0430)</td>
</tr>
<tr>
<td>Ln Interest rate</td>
<td>0.1480</td>
</tr>
<tr>
<td></td>
<td>(0.3804)</td>
</tr>
</tbody>
</table>

Table 7: A table summary of regression (2) during the first period. The coefficients are presented first and the standard errors are in between brackets. The statistical significance level is denoted by stars: * = 10 percent level, ** = 5 percent level, *** = 1 percent level.

### 6.2.2 Basel II Accord

The test corresponding to the seventh hypothesis, the coefficient for the publication of the Basel II Accord is positive, indicating a negative relationship between risk and the publication of the second Basel Accord (see table 8). However, neither the relationship with the publication of the accord or the capital adequacy ratio is statistically significant on any level, and can thus not be interpreted.

The control variables interest rate and size (lnassets) are both statistically significant on a 5 percent level and indicates a positive relationship with risk. Furthermore, return on asset is statistically significant on a 10 percent level and imply a negative relationship with risk.
<table>
<thead>
<tr>
<th>Z-score</th>
<th>Basel 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basel dummy</td>
<td>0.0661</td>
</tr>
<tr>
<td></td>
<td>(0.0773)</td>
</tr>
<tr>
<td>CAR</td>
<td>1.4340</td>
</tr>
<tr>
<td></td>
<td>(0.9473)</td>
</tr>
<tr>
<td>Ln ROA</td>
<td>47.7128 **</td>
</tr>
<tr>
<td></td>
<td>(21.6961)</td>
</tr>
<tr>
<td>Ln GDP</td>
<td>-1.2441</td>
</tr>
<tr>
<td></td>
<td>(0.7779)</td>
</tr>
<tr>
<td>Ln Assets</td>
<td>-0.1960 **</td>
</tr>
<tr>
<td></td>
<td>(0.0829)</td>
</tr>
<tr>
<td>Ln Interest rate</td>
<td>-15.6131 ***</td>
</tr>
<tr>
<td></td>
<td>(4.9220)</td>
</tr>
</tbody>
</table>

Table 8: A table summary of regression (2) during the second period. The coefficients are presented first and the standard errors are in between brackets. The statistical significance level is denoted by stars: * = 10 percent level, ** = 5 percent level, *** = 1 percent level.

6.2.3 Basel III Accord

The regression corresponding to the eighth hypothesis, showed a positive relationship between the publication of the Basel III Accord and Z-score (see table 9). The coefficient of the Basel publication had a coefficient on 0,1103 and since Z-score is a logarithmic value, we must calculate the exponential value to find out the relationship. This indicates that the third Basel Accord decreases the total risk of the banks by approximately 41 percent. The relationship is statistically significant on a 10 percent level but is not in line with the hypothesis, which is why we cannot reject the null hypothesis. The regression found the same significant and positive relationship between CAR and Z-score, indicating the more capitalized banks are approximately 159 percent less risky. This relationship is also significant on a 10 percent level. Although the coefficient is statistically significant and not as large as for the Basel I publication, it is still an unlikely estimate and should therefore be interpreted with caution. It could be because of an unfitting measure or a calculation error.
All control variables, besides GDP, are statistically significant on a 1 or 5 percent statistical significance level (see table 9). Both size and interest rate imply a positive relationship with risk while return on assets imply a negative relationship.

<table>
<thead>
<tr>
<th>Z-score</th>
<th>Basel 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basel dummy</td>
<td>0.1103*</td>
</tr>
<tr>
<td></td>
<td>(0.0514)</td>
</tr>
<tr>
<td>CAR</td>
<td>1.4656*</td>
</tr>
<tr>
<td></td>
<td>(0.8713)</td>
</tr>
<tr>
<td>Ln ROA</td>
<td>23.5288 ***</td>
</tr>
<tr>
<td></td>
<td>(4.6614)</td>
</tr>
<tr>
<td>Ln GDP</td>
<td>-0.0760</td>
</tr>
<tr>
<td></td>
<td>(0.705)</td>
</tr>
<tr>
<td>Ln Assets</td>
<td>-0.3621 ***</td>
</tr>
<tr>
<td></td>
<td>(0.1136)</td>
</tr>
<tr>
<td>Ln Interest rate</td>
<td>-2.7078**</td>
</tr>
<tr>
<td></td>
<td>(1.3446)</td>
</tr>
</tbody>
</table>

Table 9: A table summary of regression (2) during the third period. The coefficients are presented first and the standard errors are in between brackets. The statistical significance level is denoted by stars: * = 10 percent level, ** = 5 percent level, *** = 1 percent level.

6.3 Further testing
In a regression analysis, it is essential that all independent and control variables act independent from one another and does not correlate. If two of the independent variables seem to be correlated, they are not allowed in the same regression as they are not independent. None of this study’s independent or control variables correlated to such an extent that they were omitted (see appendix 6-8).
7 Analysis

The study on efficiency found statistical significance in the independent variables in five instances (see tables 1-3). The dummy variable of the Basel publication was only found statistically significant during the time period covering the Basel III Accord, which showed a negative relationship. Therefore, we cannot reject $H_0$ on either hypotheses 2 or 3. However, $H_0$ of the fourth hypothesis can be rejected, supporting the theory of the Basel III Accord inhibiting productive efficiency in banks. The robustness test on cost-to-income (see table 4) also give support to reject the null hypothesis of hypothesis 2, implying that the publication of the Basel I Accord also inhibited efficiency. Furthermore, the capital adequacy proxy (CAR) was statistically significant on a 1 percent level and positive during all three time periods (see table 1-3). The positive CAR implies that more capitalized banks have higher efficiency. Consequently, $H_0$ of hypothesis 1 cannot be rejected.

The result of regression 2 indicate that the second and third Basel Accords efficiently reduces bank risk (see table 8 and 9), the contrary to our hypotheses. This is an indication of the Accords efficiently managing the agency problem of opportunistic banks. However, neither the efficiency nor the risk regressions show complete, statistically significance during the first two periods, preventing us from any further conclusions regarding the publication of the first and second Basel Accord. Nonetheless, the result from the third period display a statistically significant and negative relationship with both productive efficiency and risk, suggesting that the third accord reduces risk while inhibiting efficiency. The result is an indication of Basel III efficiently fulfilling its underlying purpose of reducing risk in banking operations, and perhaps reducing the banks possibility to perform regulatory arbitrage. The third Basel Accord has been revised from the first two accords and the results in this study might be evidence that the updated accord is fulfilling its purpose by capturing the risks of the banks and making the financial sector more stable. The mean and median of CAR has increased from the second to the third period (see appendix 4 and 5), somewhat confirming that the banks meet the higher capital requirements. The higher CAR in combination with its negative relation to risk can be an implication of the third accord’s increased tier 1 and common equity-regulations more efficiently reduces bank risk. However, since the third accord is not fully implemented (BCBS 2018), the banks has perhaps not utilized their arbitrage opportunities yet. Finding loopholes in the regulation to exploit regulatory arbitrage might be possible but more complex than in previous regulations, creating a time lag of its effect.
The third accord’s negative impact on productive efficiency could also be a confirmation that the capital requirements were met. Efficiency should be negatively affected by a higher capital level since it reduces the ability to create liquidity and thereby extending loans. After the financial crisis, the social costs of bank default became even more distinct. Therefore, the capital requirements in the third accord were both stricter in quantity and quality, which perhaps made the gap between the socially optimal capital level and the banks optimal capital level even larger, and by extension made the banks less efficient. Although, the mean and median of the efficiency scores are relatively smaller during the third period (see appendix 3-5), implying that the banks are less efficient in general. The relative smaller efficiency score might be a consequence of the financial crisis of 2007-2008 since the crisis had a long-term and severe effect on the financial sector. Thus, there is a possibility that the crisis caused the negative relationship, explaining why it differ from the previous periods, and not that the new Basel Accord has inhibited productive efficiency.

Since there were a lot of banks going bankrupt in connection to the financial crisis of 07-08, the banks might focus more on avoiding that it happens to them. The advantages of holding more equity, such as the reduction of bankruptcy risk, might be worth more than the tax benefits from debt. Hence, the reason to why the dummy for the publication of the Basel III Accord showed a negative relationship with both efficiency and risk might not only be because the regulations became stricter. It can also be because the banks have become willing to forgo a part of their efficiency in order to reduce their risk of going bankrupt, and thereof choosing to hold a higher capital level than what is optimal for them.

It is assumed that banks, and firms in general, would hold an individual, optimal capital level if there were no regulation on capital. Meaning, that if it was not the capital requirements forcing the banks to hold more capital, they have chosen their capital structure for financial- and risk tolerance reasons. The trade-off theory claim that the optimal capital structure for a company is a trade-off between tax benefits and bankruptcy costs. When a bank increases their equity ratio, their taxable amount increases, leading to larger tax charges. However, having more capital also decreases the risk of default, and the reduced risk can lower the interest on their obligations (Kraus & Litzenberger 1973). Although, increasing the capital level can be relative costly for the banks. If their internal funds, such as retained earnings, is not enough, then raising new equity externally is the second choice according to the pecking order theory. Raising new equity externally is relative costly but it also means changing the ownership
structure by either introducing new owners or increasing the share of existing ones (Myers 1984). Furthermore, raising new equity can weaken the stock price because issuing shares is a tool to reduce stock price when it is overvalued. There can be a situation of asymmetric information between the bank and the investors, and the issuing of shares can weaken the value without it being overvalued in the first place (Myers & Majluf 1984). In the descriptive statistics (see appendix 4 and 5) it can be seen that the bank’s capital levels are larger than the levels required by the Basel Accords for the second and third time-period. A reason to that might be that the banks predict that the capital requirements will become even stricter in the future. Even if the Basel regulations have an implementation period, in which the banks successively can build up their capital level, they perhaps fear that they cannot be able to increase their capital and meet the stricter requirements only with retained earnings. To avoid having to issue capital externally, they might choose to hold a higher capital level in advance.

Apart from that capital can be a more expensive funding source, increasing capital levels reduces the liquidity creation and thus the ability to issue loans (Diamond & Rajan 2000). Since loans are the major income source, this would lead to lower profitability. That is, capital can decrease agency- and bankruptcy costs, creating a more stable financial sector. Nevertheless, it can also be costly and decrease lending opportunities which can reduce the bank’s profitability. Therefore, the bank, as an opportunistic and profit maximizing firm, has few incentives to hold a capital level above its optimal level without being forced to. The significance and positive coefficient of CAR can thus be an indication of the bank’s optimal capital level is in line with the requirements. Furthermore, the result can be interpreted as an indication of capital requirements enhancing bank efficiency. However, it is essential to be able to distinguish whether the banks hold their level of capital because it is their optimal level or because of the requirements.

If the assumption is made that the capital level is not increased on any other grounds than the capital requirements, we might instead have an indication of the Basel Accord not efficiently reducing risk as intended, or even evidence of regulatory arbitrage. Although the study found a negative relationship with risk, the increased capital level can be evidence of regulatory arbitrage. When banks engage in more riskier assets, they increase the capital level to have enough liquidity to cover potential losses from the investments. However, the study only found increased risk during the Basel I publication, but not statistically significant. The total bank risk decreased during the second and third time period, but was only statistically significant during
the latter. Nevertheless, the decrease in total risk does not have to imply that some risk in fact did not increase, since the increased risk from holding riskier assets might be relatively smaller than the decrease in risk from raised capital. That is, although the total risk decreased, the distribution among them might have changed. If we would have measured different types of risk we might have witnessed an increase in interest rate risk, which is covered by an even larger decrease in liquidity or credit risk as a consequence of increased capital levels. It is important to note that the risk exposure of one type of risk cannot be hedged with the decrease of another risk exposure, if the two are not negatively correlated. That is, the exposure toward interest rate fluctuations is now even greater and the bank is more sensitive to changes in the interest rate, even though the total bank risk, proxied as Z-score, is reduced.

An explanation to why the results of the third period showed a positive relationship between the level of capital and efficiency while it showed a negative relationship between the level of capital and risk, might be that the efficient banks can increase their capital level through their earnings. Fiordelisi, Marques-Ibanez and Molyneux (2011) argued that banks that are more efficient can build up their level of capital more easily. Banks that have high efficiency can, by their high efficiency, generate higher profits. The profits that they earn can they use to build up their level of capital. Moreover, according to the pecking order theory, companies tend to prefer funding their business with retained earnings ahead of debt. The banks that are more efficient and generates higher profits can use the earnings to fund their business and thus, they do not have to borrow as much money as less efficient banks might have to do. Then they do not have to increase risk to generate higher profits. Furthermore, banks that are efficient might want to proceed the business as it is and do not want to gain excessive risk since it increases the risk of default.
8 Conclusion

The necessity of the Basel I Accord was evident after a period of unstable global financial markets (BCBS 1988), similar to the arguments for the third accord published in the aftermath of the financial crisis of 2007 and 2008 (BCBS 2010). Although 30 years had passed, the grounds for the accords does not seem to have changed which raises the question of how effective they are. Each accord replaces the previous and is thought to be more effective or to solve more problems, but have they?

We found evidence supporting that the third Basel Accord have been more effective, by a reduced risk as a consequence of both an increased capital adequacy ratio and the Basel publication. Even though there are indications of the Basel Accords inhibiting productive efficiency, higher capitalized banks seem to be relatively more efficient. Thus, we cannot confirm that the capital requirements inhibit bank efficiency, but there is evidence of an impaired efficiency since the implementation of the third accord, suggesting that the supervision, for example, has a weakening effect on efficiency. However, there are also implication of the strengthened capital requirements, in terms of quantity and quality of capital, more efficiently fulfilling the accords purpose of reducing risk.

For future research, it would be of interest to measure the accord’s impact on different categories of risk to see a potential change in the distribution of risks. For instance, the strengthened capital requirement perhaps reduces liquidity risk but at the same time, the bank alter the asset-portfolio to longer maturities and increase their exposure to interest rate fluctuations. Thus, they can hold the required capital level but at the same time not reducing their risk.
References


https://www.bis.org/bcbs/charter.htm?m=3%7C14%7C573%7C70 [2019-05-23]

https://www.bis.org/bcbs/history.htm [2019-04-30]

https://www.bis.org/about/member_cb.htm?m=1%7C2%7C601 [2019-05-17]

https://www.bis.org/about/history_4global.htm [2019-05-20]

https://www.bis.org/basel_framework/index.htm?m=3%7C14%7C697 [2019-05-23]


https://www.bis.org/publ/bcbs04a.pdf

https://www.bis.org/publ/bcbs30a.pdf


Appendices

Appendix 1: Definition of Tier 1 and Tier 2 Capital

Tier 1:

- Common equity:
  - Common shares issued by bank.
  - Stock surplus from tier 1 capital
  - Retained earnings
  - Accumulated and comprehensive income and other disclosed reserves
  - Common shares issued by consolidated subsidiaries and held by a third party.

- Additional Tier 1 capital
  - Instruments issued by bank, not included in common equity.
  - Stock surplus from these instruments
  - Instruments issued by consolidates subsidiaries and held by third party

Tier 2:

- Instruments issued by bank, meeting tier 2 criteria.
- Stock surplus from these instruments
- Instruments issued by consolidates subsidiaries and held by third party, meeting tier 2 criteria.
- Certain loan loss provisions

Appendix 2: Sample of banks
## Basel 1, Basel 2, Basel 3

<table>
<thead>
<tr>
<th>Country</th>
<th>Basel 1</th>
<th>Basel 2</th>
<th>Basel 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>2</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Belgium</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Czech Republic</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Denmark</td>
<td></td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Finland</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>France</td>
<td>6</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Germany</td>
<td>4</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Greece</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Ireland</td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Italy</td>
<td>6</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>Poland</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Portugal</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Slovakia</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Spain</td>
<td></td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Sweden</td>
<td>1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>United Kingdom</td>
<td>6</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>25</td>
<td>21</td>
<td>56</td>
</tr>
</tbody>
</table>

This table displays the number of banks and their origin included in the different time periods studied.

### Appendix 3: Descriptive statistics of first time-period

<table>
<thead>
<tr>
<th></th>
<th>Obs</th>
<th>Mean</th>
<th>Median</th>
<th>Std Dev</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EFF</strong></td>
<td>275</td>
<td>0.8976</td>
<td>0.9137</td>
<td>0.0799</td>
<td>0.6188</td>
<td>1</td>
</tr>
<tr>
<td><strong>C/I</strong></td>
<td>275</td>
<td>0.9565</td>
<td>0.9475</td>
<td>0.1122</td>
<td>0.7453</td>
<td>1.6240</td>
</tr>
</tbody>
</table>
## Appendix 4: Descriptive statistics of second time-period

<table>
<thead>
<tr>
<th>Obs</th>
<th>Mean</th>
<th>Median</th>
<th>Std Dev</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>EFF</td>
<td>231</td>
<td>0.8379</td>
<td>0.8584</td>
<td>0.1198</td>
<td>0.4364</td>
</tr>
<tr>
<td>C/I</td>
<td>231</td>
<td>0.8536</td>
<td>0.8580</td>
<td>0.1447</td>
<td>0.3822</td>
</tr>
<tr>
<td>NIM</td>
<td>231</td>
<td>0.0302</td>
<td>0.0261</td>
<td>0.0169</td>
<td>0.0058</td>
</tr>
<tr>
<td>CAR</td>
<td>231</td>
<td>0.1349</td>
<td>0.1263</td>
<td>0.0393</td>
<td>0.0892</td>
</tr>
<tr>
<td>Basel 2</td>
<td>231</td>
<td>0.5455</td>
<td>1</td>
<td>0.4990</td>
<td>0</td>
</tr>
<tr>
<td>ROA</td>
<td>231</td>
<td>0.0100</td>
<td>0.0070</td>
<td>0.0143</td>
<td>-0.0215</td>
</tr>
<tr>
<td>Assets</td>
<td>231</td>
<td>618279032</td>
<td>302284142</td>
<td>820150465</td>
<td>555271</td>
</tr>
<tr>
<td>GDP</td>
<td>231</td>
<td>0.0173</td>
<td>0.0236</td>
<td>0.0247</td>
<td>-0.0562</td>
</tr>
<tr>
<td>Interest Rate</td>
<td>231</td>
<td>0.0436</td>
<td>0.0431</td>
<td>0.0068</td>
<td>0.0274</td>
</tr>
</tbody>
</table>

## Appendix 5: Descriptive statistics of third time-period

<table>
<thead>
<tr>
<th>Obs</th>
<th>Mean</th>
<th>Median</th>
<th>Std Dev</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>EFF</td>
<td>560</td>
<td>0.6673</td>
<td>0.6509</td>
<td>0.2100</td>
<td>0.2603</td>
</tr>
<tr>
<td>C/I</td>
<td>560</td>
<td>0.9141</td>
<td>0.8929</td>
<td>0.2224</td>
<td>0.3660</td>
</tr>
</tbody>
</table>
### Appendix 6: Correlation among the explanatory variables during the first period

<table>
<thead>
<tr>
<th></th>
<th>Capitalizes</th>
<th>LnROA</th>
<th>LnAssets</th>
<th>LnGDP</th>
<th>LnInterest-e</th>
<th>Basel1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capitalizes</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LnROA</td>
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<td>1.0000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LnAssets</td>
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<td>-0.0524</td>
<td>1.0000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LnGDP</td>
<td>0.0397</td>
<td>-0.0291</td>
<td>-0.1276</td>
<td>1.0000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LnInterest-e</td>
<td>0.3000</td>
<td>-0.1355</td>
<td>-0.3625</td>
<td>-0.0836</td>
<td>1.0000</td>
<td></td>
</tr>
<tr>
<td>Basel1</td>
<td>0.0334</td>
<td>-0.0209</td>
<td>0.3489</td>
<td>-0.3894</td>
<td>0.0063</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

### Appendix 7: Correlation among the explanatory variables during the second period

<table>
<thead>
<tr>
<th></th>
<th>CAR</th>
<th>Lnassets</th>
<th>LnROA</th>
<th>LnGDP</th>
<th>LnInterest-e</th>
<th>Basel2</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAR</td>
<td>1.0000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lnassets</td>
<td>-0.3356</td>
<td>1.0000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LnROA</td>
<td>0.1979</td>
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<td>1.0000</td>
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</tr>
<tr>
<td>LnGDP</td>
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<td>-0.0755</td>
<td>0.0934</td>
<td>1.0000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LnInterest-e</td>
<td>-0.1063</td>
<td>-0.1425</td>
<td>0.0377</td>
<td>0.2490</td>
<td>1.0000</td>
<td></td>
</tr>
<tr>
<td>Basel2</td>
<td>0.0214</td>
<td>0.2540</td>
<td>-0.0716</td>
<td>-0.2934</td>
<td>-0.6133</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

### Appendix 8: Correlation among the explanatory variables during the third period
Appendix 9: Histogram of the efficiency scores during the first period

A histogram of the DEA-efficiency score during the first period, 1985-1995.

Appendix 10: Histogram of the efficiency scores during the second period
A histogram of the DEA-efficiency score during the second period, 2000-2010.

Appendix 11: Histogram of the efficiency scores during the third period

A histogram of the DEA-efficiency score during the third period, 2007-2017.
Appendix 12: The White’s test for heteroscedasticity in regression 3, first period

White’s test for H0: homoskedasticity
against Ha: unrestricted heteroskedasticity

\[
\begin{align*}
\text{ch}'t2(26) &= 148.01 \\
\text{Prob} > \text{ch}2 &= 0.0000 \\
\end{align*}
\]

Cameron & Trivedi’s decomposition of IM-test

<table>
<thead>
<tr>
<th>Source</th>
<th>ch2</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heteroskedasticity</td>
<td>148.01</td>
<td>26</td>
<td>0.0000</td>
</tr>
<tr>
<td>Skewness</td>
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<td>Kurtosis</td>
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Heteroskedasticity test for regression 3, on cost-to-income.

Appendix 13: The White’s test for heteroscedasticity in regression 4, first period

White’s test for H0: homoskedasticity
against Ha: unrestricted heteroskedasticity

\[
\begin{align*}
\text{ch}''t2(26) &= 137.82 \\
\text{Prob} > \text{ch}2 &= 0.0000 \\
\end{align*}
\]

Cameron & Trivedi’s decomposition of IM-test

<table>
<thead>
<tr>
<th>Source</th>
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<th>df</th>
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<tr>
<td>Heteroskedasticity</td>
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Heteroskedasticity test for regression 4, on net interest margin.

Appendix 14: The Wooldridge test for serial correlation in regression 3, first period

Wooldridge test for autocorrelation in panel data
H0: no first-order autocorrelation

\[
\begin{align*}
F(1, 24) &= 11.682 \\
\text{Prob} > F &= 0.0023 \\
\end{align*}
\]

Appendix 15: The Wooldridge test for serial correlation in regression 4, first period

Wooldridge test for autocorrelation in panel data
H0: no first-order autocorrelation

\[
\begin{align*}
F(1, 24) &= 151.229 \\
\text{Prob} > F &= 0.0000 \\
\end{align*}
\]
Appendix 16: Hausman test for regression 3, first period

Test:  Ho: difference in coefficients not systematic

\[ \chi^2(6) = (b-B)'[(V_{b-V_B})^{-1}](b-B) \]

\[ = 19.83 \]

Prob>\chi^2 = 0.0030

(V_{b-V_B} is not positive definite)

Appendix 17: Hausman test for regression 4, first period

Test:  Ho: difference in coefficients not systematic

\[ \chi^2(6) = (b-B)'[(V_{b-V_B})^{-1}](b-B) \]

\[ = 17.66 \]

Prob>\chi^2 = 0.0071

(V_{b-V_B} is not positive definite)

Appendix 18: The White’s test for heteroscedasticity in regression 3, second period

White's test for Ho: homoskedasticity
against Ha: unrestricted heteroskedasticity

\[ \chi^2(26) = 163.48 \]

Prob > \chi^2 = 0.0000

Cameron & Trivedi’s decomposition of IM-test

<table>
<thead>
<tr>
<th>Source</th>
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<th>df</th>
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</thead>
<tbody>
<tr>
<td>Heteroskedasticity</td>
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<td>Kurtosis</td>
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Heteroskedasticity test for regression 4, on cost-to-income.

Appendix 19: The White’s test for heteroscedasticity in regression 4, second period
White's test for Ho: homoskedasticity
against Ha: unrestricted heteroskedasticity
\[ \chi^2(26) = 23.23 \]
\[ \text{Prob} > \chi^2 = 0.6199 \]

Cameron & Trivedi's decomposition of IM-test

<table>
<thead>
<tr>
<th>Source</th>
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<th>p</th>
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</thead>
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<td>Skewness</td>
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<td>Kurtosis</td>
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</table>

**Heteroskedasticity test for regression 5, on net interest margin.**

**Appendix 20: The Wooldridge test for serial correlation in regression 3, second period**

Wooldridge test for autocorrelation in panel data
H0: no first-order autocorrelation
\[ F(1, 24) = 11.682 \]
\[ \text{Prob} > F = 0.0023 \]

**Appendix 21: The Wooldridge test for serial correlation in regression 4, second period**

Wooldridge test for autocorrelation in panel data
H0: no first-order autocorrelation
\[ F(1, 24) = 151.229 \]
\[ \text{Prob} > F = 0.0000 \]

**Appendix 22: Hausman test for regression 3, second period**

Test: Ho: difference in coefficients not systematic
\[ \chi^2(6) = (b - B)'[\{V_{b-B} \}^{-1}](b - B) \]
\[ = 19.83 \]
\[ \text{Prob} > \chi^2 = 0.0030 \]
\( V_{b-B} \) is not positive definite

**Appendix 23: Hausman test for regression 4, second period**
Test: Ho: difference in coefficients not systematic

\[ \chi^2(6) = (b-B)'[(V_b-V_B)^{-1}](b-B) \]
\[ = 17.66 \]
\[ \text{Prob} > \chi^2 = 0.0071 \]
\[ (V_b-V_B \text{ is not positive definite}) \]

Appendix 24: The White’s test for heteroscedasticity in regression 3, third period

White's test for Ho: homoskedasticity
against Ha: unrestricted heteroskedasticity

\[ \chi^2(26) = 256.55 \]
\[ \text{Prob} > \chi^2 = 0.0000 \]

Cameron & Trivedi’s decomposition of IM-test

<table>
<thead>
<tr>
<th>Source</th>
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<th>p</th>
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<td>Heteroskedasticity</td>
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Heteroskedasticity test for regression 3, on cost-to-income.

Appendix 25: The White’s test for heteroscedasticity in regression 4, third period

White's test for Ho: homoskedasticity
against Ha: unrestricted heteroskedasticity

\[ \chi^2(26) = 9.35 \]
\[ \text{Prob} > \chi^2 = 0.9989 \]

Cameron & Trivedi’s decomposition of IM-test

<table>
<thead>
<tr>
<th>Source</th>
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<th>df</th>
<th>p</th>
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<tbody>
<tr>
<td>Heteroskedasticity</td>
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<td><strong>33</strong></td>
<td><strong>0.9973</strong></td>
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</tbody>
</table>

Heteroskedasticity test for regression 4, on net interest margin.
Appendix 26: The Wooldridge test for serial correlation in regression 3, third period

Wooldridge test for autocorrelation in panel data
H0: no first-order autocorrelation
\[ F(1, 55) = 2.829 \]
\[ \text{Prob } F = 0.0983 \]

Appendix 27: The Wooldridge test for serial correlation in regression 4, third period

Wooldridge test for autocorrelation in panel data
H0: no first-order autocorrelation
\[ F(1, 55) = 19.377 \]
\[ \text{Prob } F = 0.0000 \]

Appendix 28: Hausman test for regression 3, third period

Test: Ho: difference in coefficients not systematic
\[ \text{chi}^2(6) = (b-B)'[(V_{b-V_B})^{-1}](b-B) \]
\[ = 45.65 \]
\[ \text{Prob} > \text{chi}^2 = 0.0000 \]
(V_{b-V_B} is not positive definite)

Appendix 29: Hausman test for regression 4, third period

Test: Ho: difference in coefficients not systematic
\[ \text{chi}^2(6) = (b-B)'[(V_{b-V_B})^{-1}](b-B) \]
\[ = 10.18 \]
\[ \text{Prob} > \text{chi}^2 = 0.1173 \]
(V_{b-V_B} is not positive definite)