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The impact of a more intrusive banking supervisor on productivity: Evidence from the Single Supervisory Mechanism.

Enforced in 2014, the Single Supervisory Mechanism (SSM) has provided the European Central Bank (ECB) with the responsibility of supervising significant institutions and their subsidiaries. An attempt to create more stability within the Euro Zone and to ensure consistent supervision among Europe's largest financial institutions. In this article, I provide evidence of a positive impact on productivity as a result of the increased regulatory scrutiny that the banks received under ECB supervision. Additionally, I provide evidence that the increase in productivity is driven by more efficient allocation of inputs. Contrary to expectations, a greater increase in productivity was identified among the subsidiaries of the significant institutions compared to the significant institutions themselves. Nevertheless, this result can be explained by knowledge spill-over and the "small bank advantage".

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1. Introduction

The study of productivity and its accelerators has created an elaborate branch of research in both theoretical and empirical economics. From an evidential perspective, productivity research is compelling due to its accessibility as a concept to all layers of the economy. The majority of the analysis is based on aggregated micro-economic data (Silber (1983), Drake et al. (2006), Grace & Gardner (1993), Hulten (2000)), often scoped to specific sectors. However, productivity research has also provided relevant perspectives on macro-economic subjects, with significant attention having been dedicated to productivity trajectories of certain regions and countries (Färe et al. (1994), Chambers et al. (1996)). At conception, the study of productivity was mainly restricted to the manufacturing and agricultural sectors, i.e. sectors where productivity could relatively directly be measured by its output. See for instance Farrell (1957), where the agricultural sector in the United States was used as an illustrious example. However, instigated by Jorgenson and Griliches (1967), the services industry has received increasing interest due to the magnitude of its contribution to the real economy. As highlighted by Solow (1992, p.7) in his introduction to the Scandinavian Journal of Economics: "Production of goods and production of services is different, no doubt, but just not very much. Analytical techniques that originate in one set of studies are very likely to find uses in the other."

In this paper, I will exploit the establishment of the Single Supervisory Mechanism (SSM) in 2014, to analyse if the productivity of banks is impacted by the level of intrusiveness of their supervisor. The origination of the SSM provided supervisory responsibilities to the ECB. However, these responsibilities are restricted to an exclusive number of large institutions and their subsidiaries, as the remaining banks continued to be supervised by their National Supervising Authority (NSA).

This paper aims to examine if the new supervisor sparked a change in behavior among the significant institutions, with specific regard to productivity. Prior research has researched the impact of banking regulation on productivity. Silber (1983), while examining what drives financial innovation, found that banking legislation drove approximately 30% of financial innovation between 1970-1982. A consequence of banks attempting to maximize utility with new financial products, while being subject to more strict governmental restrictions (Silber, 1983) (Baer & Pavel, 1988). On the other hand, Drake et al. (2006) found that deregulation within the banking system of Hong Kong did not have an impact on efficiency among banks.

This suggests that changes in the level of productivity might only take place in the direction of more stringent banking legislation. Regarding the SSM, note that there was no change in the formal legislature of the significant institutions following the establishment of the SSM. However, the papers listed above remain highly relevant, as the ECB was perceived by the banks as more intrusive compared to the NSAs (Wymeersch, 2014) (Fiordelisi et al., 2017). Therefore, it is expected that the establishment of the SSM stimulated productivity growth among the banks supervised by the ECB, similar to more restrictive legislation.

Limited research has been performed on examining how the type of legislative supervisor impacts banking performance. Most notably, Agarwal et al. (2014) discovered that federal regulators were systematically stricter compared to the state authorities in the United States. Resulting in differences in asset quality and efficiency. These findings serve as a catalyst to assess if the disparity in intrusiveness of the ECB compared to the NSAs produced a material impact on productivity. Additionally, recent research has been examining the impact of the establishment of the SSM on various aspects of banking. Fiordelisi et al. (2017) performed a difference-in-difference regression on the profitability and capitalization behavior of European banks during the early stages of the SSM (2013-2014). They show that banks subject to the comprehensive assessment put measures in place to increase their equity ratios without increasing equity capital. Moreover, the researchers produce evidence that banks portrayed the national regulators as more lenient compared to the ECB.

In general, the previously mentioned dimensions suggest that the conditions surrounding the establishment of the SSM could have driven the significant institutions to accelerate productivity. Therefore, the main research question will be:

Does a more intrusive regulator stimulate acceleration in productivity?

To answer this question, I explore a dataset of European banks containing bank-level information from 2011 to 2017, retrieved from Bureau van Dijk's Bankscope database. Providing the opportunity of trailing key statistics from individual banks over the sample period. The key statistics utilized in this paper concern balance sheet items and income statement items. Combining items from both financial statements with Data Envelopment Analysis provides the possibility of deriving the Malmquist measure of total factor productivity. Additionally, the total factor productivity change measure will be decomposed into technical change and allocative efficiency change, to concretize the source of any impact on productivity. For difference-in-difference regression purposes, the group of banks has been separated into a control group, consisting of banks that remained under the supervision of their NSA, and a treatment group, consisting of banks that were put under the supervision of the ECB. Accordingly, the analysis will commence with a review of relevant literature to extract evidence on the expectation that the ECB is more intrusive compared to the NSAs. Secondly, I predict that the productivity measures can be correlated with asset size. However, by means of a restriction on the treatment group, I hypothesize that the impact of the size bias on the productivity measures becomes negligible. This provides the possibility of establishing a difference-in-difference framework, where a positive relationship between ECB supervision and the Malmquist productivity measures is expected, consistent with more restrictive regulation. According to expectations, this would provide the grounds for a positive conclusion on the main research question.

The empirical results start with an analysis of possible bias that could be concealed within the sample selection approach. Mukherjee et al. (2001), provide evidence that there is an underlying correlation between a bank's total assets size and its productivity growth. Utilizing an OLS regression of the total assets on the Malmquist measures, I show that this correlation also appears in my sample. Every billion extra in assets increases the yearly improvement in total factor productivity by 1.3%, and in efficiency allocation by 0.8%. Solely the technical change variable provides insignificant coefficients. Subsequently, I introduce a restriction on the sample group to reduce the skewness in total assets, by excluding the significant institutions. Consequently, the remaining banks are either supervised by their NSA or supervised by the ECB as subsidiaries of significant institutions. Ultimately, this restriction does not fully remove the bias, but it does provide an expectation for the subsequent difference-in-difference regressions, where the restriction will also be performed. The larger asset size within the unrestricted treatment group, containing the significant institutions, is expected to drive the coefficients in the main regressions further upwards, compared to the restricted treatment group, due to the size bias.

The main regressions consist of three tests that have been performed within a difference-in-difference framework. First, evidence was sought for whether the trend in total factor productivity of banks under ECB supervision differed from banks under national supervision after the establishment of the SSM. Based on the assumption that a more stringent supervisor has an effect with a similar direction to more restrictive regulation. Aligned with expectations, I show that the banks under ECB supervision experienced an 11% higher improvement in total factor productivity, compared to the banks that remained under national supervision. However, this measure does not capture if the banks under the ECB supervisor actively adapted their operational strategy, or if technological capabilities facilitated them to increase their productivity. Therefore, the total factor productivity measure was dissected into technical change and allocative efficiency change. The results showed that banks under ECB supervision actively optimized the allocation of their inputs, resulting in higher efficiency growth of 10%. Consequently, the increase in allocative efficiency was attributed as the main driver for the increase in productivity among the banks supervised by the ECB.

Notably, the results indicate higher total factor productivity and efficiency growth among the restricted treatment sample, compared to the total treatment sample. This contradicts the expectation that the unrestricted treatment sample would have higher productivity growth due to the higher level of total assets. Therefore, implying a limited impact of the size bias, induced by the difference in total assets between the control and treatment groups. Nevertheless, these results can be explained by a higher level of adaptability of smaller institutions. Furthermore, knowledge spillover from the parent to the subsidiary can explain this movement. In this case, the higher growth in productivity and efficiency can be considered an attempt of the parent banks to bridge the gap with their subsidiaries. The incentive is that both parties are now supervised by a common supranational institution, the ECB. Consequently, any reputational damage instigated by the subsidiary towards the supervisor could also have a direct impact on the significant institution's relationship with the ECB.

The remainder of the paper is organized in the following manner. In section 2, a review of relevant literature is provided. The data is presented in chapter 3, and the methodology in chapter 4. Section 5 discusses the results, and provides a conclusion.

2. Related Literature

In response to the global financial crisis of 2008, banking regulation regained considerable attention among national and supranational legislators. As a consequence, many decided to reshape their banking sector with more stringent regulations. Examples are the Dodd-Frank act in the United States and the Capital Requirement Directives (CRD II, III & IV) in the European Union. Nevertheless, while the United States focused primarily on the stability of the financial sector, the European Union saw an additional opportunity of transforming its supervisory banking system. Proposed by the European Commission in 2012 (EC, 2012), but officially ratified in 2013 with legislature from the Council of the European Union, the ECB became equipped with legal authority on prudential supervision of significant institutions (Council of the European Union, 2013). The first step towards a European Banking Union, where due to the sole authority and responsibility of the ECB, a single supervisory mechanism (SSM) was established.

Enforced from November 2014 onwards, the SSM provided the ECB with the capacity to closely monitor economical developments within individual member states. Aiming to ensure financial stability and integration, while establishing consistent ECB supervision across the Eurozone. However, not all European banks are under the supervision of the ECB. Prior to implementation, in December 2012, the Financial and Economic Council of Europe decided that the ECB will solely supervise significant institutions and their subsidiaries (ECOFIN, 2012). The main condition for banks to be considered significant institutions concerns total assets in surplus of thirty billion Euros (ECB, 2014). Ultimately, this induced direct oversight of the ECB on one hundred and thirty significant institutions and all their subsidiaries across Europe, after the implementation of the SSM (Nouy, 2014). For the remaining banks, no change in supervision occurred, as the direct supervisor continued to be their National Supervising Authority (NSA).

A main assumption that serves as the basis of this paper, is that the ECB is more intrusive with regard to its supervision compared to the national regulators. Fiordelisi et al. (2017) utilize the first step of the SSM, where the ECB performed a comprehensive assessment on the lending portfolio of significant institutions. Based on the prudent measures that were put in place by the banks under ECB oversight, they were able to conclude that the ECB was more demanding than the national supervisors. Similarly, in a report analyzing the consequences of Swedish banks joining the SSM. The Swedish government concluded that it would result in more intrusive supervision, which is illustrated by the unique participation of ECB representatives in board meetings (Ministry of Finance (Sweden), 2019). Additionally, Cerulli et al. (2021) identified that stricter ECB supervision drove banks to alter the composition of their balance sheet. This could mainly be observed in the banks' lending behavior, as ECB oversight moved banks to be more risk-averse in their lending. Nevertheless, most instructive of the ECBs intrusiveness is the fact that banks are willing to litigate, in order to return to the previous state of affairs, being supervised by the national regulator (Gould, 2015).

The rationale for researching the ECB as a supra-national supervisor can primarily be attributed to Agarwal et al. (2014). The researchers compared the behavioral discrepancies in the application of identical rules by state and federal regulators in the US between 1996 and 2010. The identification strategy was by means of the CAMELS rating, which was assigned by the regulator. CAMELS is an acronym for its six elements: capital adequacy, asset quality, management and administration, earnings, liquidity, and sensitivity to market risk. The researchers found that federal regulators are systemically more inclined to downgrade the CAMELS rating of banks, compared to state regulators. Furthermore, they produce evidence that rules were implemented inconsistently due to differences in both institutional design and incentives between the two supervisors. Specifically, state regulators were more lenient to ensure that banks would not move to a different state. As a consequence of this inequality in strictness, banks under federal supervision reported worse asset quality, but higher efficiency. Nevertheless, the leniency of state regulators came with costs, as banks under state supervision recorded relatively higher default rates.

Tziogkidis et. al (2020) examined convergence in innovation among banks under ECB supervision. Utilizing a macroeconomic measure (β-convergence), the researchers captured that supervisory harmonization caused innovation to converge to a common frontier among banks. Additionally, the researchers conclude that the SSM has marked an increase in technical efficiency across all dimensions. However, the researchers came to this conclusion solely by looking at average descriptive statistics. Concluding that the SSM accelerated technical efficiency, by comparing the average efficiency scores prior to the SSM with the averages after the establishment of the SSM. My paper aims to provide concrete evidence that the SSM impacted productivity by performing a difference-in-difference analysis, capturing the true impact of the intervention on the treatment group, i.e. ECB supervised banks, compared to a control group.

To measure innovation, the Malmquist total factor productivity index, utilizing Data Envelopment Analysis (DEA), will be employed. This Malmquist index, introduced by Caves et al. (1982), examines the operations of two different periods against a fixed period's reference productivity frontier. The foundation of this index can be attributed to Malmquist (1953), who proposed an index where a rank was assigned to observations based on the ratio of distance functions, relative to an indifference curve. An indifference curve was used, as Malmquist (1953) decided to focus on consumer data. Caves et al. (1982) replaced the indifference curve with a technology frontier, providing the opportunity to employ the Malmquist index as a productivity measure. To estimate the technology frontier, DEA will be used. Presented initially by Banker et al. (1984), DEA captures the direction in productivity of decision-making units (DMUs), relative to the productivity of other DMUs and their respective productivity in previous periods. DEA is a non-parametric frontier estimation technique based on optimization with linear programming. It provides more flexibility when compared to Stochastic Frontier Analysis (SFA) since an underlying regression function (e.g. Cobb-Douglas function) is not required. Additionally, DEA is multi-dimensional in its input and output vectors, unlike SFA, where solely a single input and output can be incorporated into an analysis (Hjalmarsson et al., 1996).

The DEA methodology has been an established technique for assessing productivity across industries. Both, Grace & Gardner (1993) and Cummins et al. (1999) decided to apply the framework to the insurance industry. In their highly cited paper, Grace & Gardner (1993) try to identify rent-seeking behaviour among American insurers from 1985-1990. Rent-seeking behaviour can be illustrated by firms that drive up their costs to negatively impact the costs of competitors. Another example of this behaviour is purposely increasing the firm's output at the expense of competitors, while ensuring that the total industry output does not increase. Utilizing the DEA (in)efficiency measures, the researchers were able to evidence that insurers under the voluntary New York regulation were more efficient compared to insurers that opted to remain unregulated. Indicating that regulation can also drive efficiency in a non-banking context. Furthermore, Cummins et al. (1999) opted to assess the efficiency gains from mergers & acquisitions among insurers from 1988–1995 in the United States. Exploiting the DEA-Malmquist framework, the researchers found efficiency benefits from M&As. Moreover, the researchers provided evidence of a relationship between higher efficiency and the active nature of the acquirer.

Besides, the insurance sector, a recent stream of literature is applying the DEA-Malmquist methodology to the energy sector, with an increased focus on renewables. Notably, Yang et al. (2017) found that the Chinese carbon intensity constraint policy had a negative impact on green production performance due to contracting industrial output. Furthermore, Li et al. (2019) introduced a DEA-Malmquist framework, comprised of factors related to governance, productivity and environmental pollution. They evidenced that, overall, environmental governance endured a decreasing trend from 2005 to 2014. Additionally, with regard to regulation, environmental governance possesses an inverse-U shape. This implies that regulations initially manifest positive effects, but continuously increasing the level of intrusiveness would eventually induce a negative effect on environmental governance.

In a banking context, the DEA-Malmquist framework is also being utilized. Mukherjee et al. (2001) assessed productivity growth among American commercial banks during the deregulation period of 1982 until 1990. Their main findings indicate that productivity grew during this period, mainly driven by an increased level of technology. However, their first sample year was 1984, when the deregulation was already in progress. Therefore, no visibility exists on the change in productivity growth compared to a control period prior to the deregulation. Casu et al. (2004) researched productivity change in European banking from 1994 to 2000. This period was of interest due to a constant drive for integration within the European banking sector. In their paper, the researchers used both parametric and non-parametric approaches in order to observe if different conclusions appeared. Their results show that productivity growth had mainly occurred due to increases in the level of technological best practices among the European banks. Moreover, the parametric and non-parametric approaches did not yield significant outcome differences.

3. Data

3.1 Data sources

To measure productivity, an input-output system (Malmquist-Productivity index) is utilized. This system views banks as financial intermediaries where capital and labor convert liabilities into assets (Sealey and Lindley, 1977). In deciding the required inputs and outputs, the selection procedure by Tziogkidis et al. (2020) is followed. Under their method, banks use capital (Fixed Assets), labor (Staff Expenses), and deposits (Customer Deposits) to produce loans (Net Loans) and other income-generating securities (Other Earning Assets). Moreover, the degree of non-performing loans (NPLs) can be considered a troublesome output and is therefore incorporated in the model as an input to capture risk aversion. These variables each represent a dimension of the Malmquist index of productivity change. This measure provides a value relative to the input-output combination of the previous year (T-1), where a value of 1 means that there has been no improvement. The total factor productivity measure can furthermore be decomposed into technical change and allocative efficiency change. Technical change variable is defined as a bank's ability to produce the maximum output from a given set of inputs. Allocative efficiency change consists of a bank’s capability to equalize the marginal cost of the inputs with the marginal value of its outputs.

Following similar literature that investigates the impact of the SSM, the time window of the sample data covers banks from 2011 until 2017 (Avgeri et al., 2021) (Tziogkidis et al., 2020). Within the difference-in-difference framework, I will be employing two treatment groups. The first treatment group contains all banks that were placed under the direct supervision of the ECB in 2014, the year that the SSM was established. The second treatment group contains solely the banks that were placed under ECB supervision, while they did not satisfy the significant institution requirements themselves. This restricted treatment group is referenced as the group of non-significant institutions under ECB supervision. Further explanation of the rationale behind the second treatment group will be provided in the methodology section. Data is assigned to the control era if the observation took place prior to 2014. The control group consists of banks that remained under their national supervisory authority. To be able to answer the research question, data from the financial statements of commercial banks is required. To extract the financial data, Bankscope, a Bureau Van Dijk service, is exploited.

In order to control for omitted variables, vectors of macroeconomic and bank-specific variables are incorporated into the framework. To control for heterogeneity, the bank-specific variables are the natural logarithm of total assets as an indicator for bank size, the ratio of equity to total assets as a proxy of bank capital, the ratio of loan loss reserves to gross loans as an indicator of risk, and the cost to income ratio as an indicator of operational profitability. The macroeconomic variables include the growth rate of each country’s real Gross Domestic Product and the profit-tax ratio (corporate taxes paid as a percentage of corporate profits). The macro-economic data is sourced from World Bank.

3.2. Descriptive statistics of the DEA input variables

Per group, Table 1 provides the yearly averages of the input and output variables utilized to derive the Malmquist measures, as well as the average value of total assets. The total assets variable has been included in this table, to demonstrate the impact of the treatment group sample restriction on the average asset size. Panel A provides the descriptive statistics for the control group in the main regressions, consisting of the institutions that remained under national supervision. At first glance, one can observe that there was a stark decline among almost all the variables in the years prior to 2014. This decrease can partially be explained by a sentiment of deleveraging in the European banking sector after the 2008 global financial crisis, as banks were able to increase their equity-to-assets ratio between 2012 and 2014 by 200 basis points (ECB, 2015). Additionally, the early 2010s saw the rise of shadow banks and FinTech companies (classified as Other-financial institutions). Attributing to a decrease in financial services of traditional credit institutions. Accordingly, the ECB reports that total assets from the European banking zone decreased from EUR 33 trillion in 2008 to EUR 28 trillion in 2015. Meanwhile, the Other-financial institutions were able to increase the size of their assets from EUR 5.6 trillion in 2008 to EUR 11.4 trillion in 2015 (Constâncio, 2016).

Panel A reports positive post-treatment trends of all the input variables, i.e. the fixed assets, staff expenses, customer deposits, and total non-performing loans. However, this positive trend cannot be observed when looking at the output variables, net loans and advances, and other earnings. The decreasing trend in net loans and advances indicates subdued loan demand with banks under national supervision. This possibly drove the banks to seek borrowers of a higher risk rating, as the volume of non-performing loans did not decrease in parallel with the volume of net loans and advances. However, the risk nature of the banks could have also remained identical, with the stability of the non-performing loans being driven by a descending macro-economic climate. The decrease in demand for loans post-treatment is also partly reflected in the negative trend of other earnings, which consists mostly of servicing fees and commission income.

The two treatment groups utilized in the main difference-in-difference regressions can be observed in panels B and C. Panel B consists of the total sample of banks under the supervision of the ECB. Panel C contains the restricted sample, where banks are included if they are supervised by the ECB, while not satisfying the EUR 30 billion in total assets condition. Consequently, one can observe that the total assets average in panel C is consistently less than half the volume of the respective average in panel B. The pre-treatment total asset delta values indicate that the large significant institutions included in panel B undertook more efforts in reducing the size of their balance sheet. Comparatively, the asset volume of the non-significant institutions in panel C remained generally stable. Additionally, the deltas presented, in relation to the non-performing loans, point to an increasing risk-averse attitude among the banks in Panel B, when compared to the restricted sample. Nevertheless, in 2014, the level of impaired loans divided by the total assets of the non-significant institutions in panel C is 5.4%, while among the general sample, this percentage stands at 11.2%. Therefore, the data indicates that the sample from panel B had a higher absolute risk attitude, driven upwards by the significant institutions included in its sample. Furthermore, both panels report similar changes year-on-year among the input and output variables post-treatment. Notably, the group of non-significant institutions enforces less downward pressure on staff expenses. This group expands its staffing expenses, while the significant institutions appear to decrease these expenses. Lastly, the non-significant institutions from panel C are generally capable of maintaining a positive trend in Other Earnings and Customer Deposits, while minimizing the overall reduction in Loans and Advances. The overall sample is also capable of increasing the volume of deposits received but is more troubled by a deficiency in Other Earnings and Net Loans and Advances.

Table 1
Average values and year-on-year change of the input and output variables of the Malmquist measures

Panel A: Institutions under National supervision

Year	2011	2012	2013	2014	2015	2016	2017
Total Assets	5,990,000,000	5,680,000,000	5,540,000,000	6,080,000,000	5,930,000,000	6,030,000,000	6,180,000,000
Year-on-Year Delta		-5%	-2%	10%	-2%	2%	2%
Fixed Assets	74,300,000	63,200,000	62,600,000	67,900,000	74,200,000	80,300,000	87,500,000
Year-on-Year Delta		-15%	-1%	8%	9%	8%	9%
Staff Expenses	59,700,000	51,300,000	51,100,000	52,000,000	53,200,000	54,700,000	56,800,000
Year-on-Year Delta		-14%	0%	2%	2%	3%	4%
Total Customer Deposits	2,350,000,000	2,220,000,000	2,300,000,000	2,380,000,000	2,520,000,000	2,690,000,000	2,830,000,000
Year-on-Year Delta		-6%	4%	3%	6%	7%	5%
Net Loans and Advances	814,000,000	865,000,000	824,000,000	798,000,000	666,000,000	543,000,000	518,000,000
Year-on-Year Delta		6%	-5%	-3%	-17%	-18%	-5%
Other Earnings	2,670,000,000	2,550,000,000	2,550,000,000	2,600,000,000	2,410,000,000	2,220,000,000	2,070,000,000
Year-on-Year Delta		-4%	0%	2%	-7%	-8%	-7%
Total Non-performing Loans	223,000,000	221,000,000	254,000,000	259,000,000	263,000,000	277,000,000	290,000,000
Year-on-Year Delta		-1%	15%	2%	2%	5%	5%

Panel B: All institutions under ECB supervision

Year	2011	2012	2013	2014	2015	2016	2017
Total Assets	35,900,000,000	25,100,000,000	24,300,000,000	24,300,000,000	24,600,000,000	26,300,000,000	26,900,000,000
Year-on-Year Delta		-30%	-3%	0%	1%	7%	2%
Fixed Assets	337,000,000	299,000,000	306,000,000	312,000,000	306,000,000	304,000,000	334,000,000
Year-on-Year Delta		-11%	2%	2%	-2%	-1%	10%
Staff Expenses	287,000,000	245,000,000	238,000,000	235,000,000	235,000,000	227,000,000	232,000,000
Year-on-Year Delta		-15%	-3%	-1%	0%	-3%	2%
Total Customer Deposits	15,900,000,000	13,700,000,000	14,300,000,000	14,800,000,000	15,000,000,000	15,200,000,000	15,800,000,000
Year-on-Year Delta		-14%	4%	3%	1%	1%	4%
Net Loans and Advances	5,040,000,000	3,700,000,000	3,500,000,000	3,320,000,000	3,150,000,000	3,010,000,000	2,840,000,000
Year-on-Year Delta		-27%	-5%	-5%	-5%	-4%	-6%
Other Earnings	16,200,000,000	11,600,000,000	10,800,000,000	11,100,000,000	10,400,000,000	9,750,000,000	8,840,000,000
Year-on-Year Delta		-28%	-7%	3%	-6%	-6%	-9%
Total Non-performing Loans	2,030,000,000	2,180,000,000	2,580,000,000	2,730,000,000	2,620,000,000	2,360,000,000	2,200,000,000
Year-on-Year Delta		7%	18%	6%	-4%	-10%	-7%

Panel C: Non-significant institutions under ECB supervision

Year	2011	2012	2013	2014	2015	2016	2017
Total Assets	10,900,000,000	10,100,000,000	10,400,000,000	10,900,000,000	11,800,000,000	12,300,000,000	12,600,000,000
Year-on-Year Delta		-7%	3%	5%	8%	4%	2%
Fixed Assets	204,000,000	168,000,000	177,000,000	182,000,000	181,000,000	194,000,000	202,000,000
Year-on-Year Delta		-18%	5%	3%	-1%	7%	4%
Staff Expenses	100,000,000	91,300,000	92,700,000	95,000,000	98,600,000	100,000,000	105,000,000
Year-on-Year Delta		-9%	2%	2%	4%	1%	5%
Total Customer Deposits	4,480,000,000	4,330,000,000	4,550,000,000	4,870,000,000	5,460,000,000	5,810,000,000	6,140,000,000
Year-on-Year Delta		-3%	5%	7%	12%	6%	6%
Net Loans and Advances	1,630,000,000	1,580,000,000	1,560,000,000	1,580,000,000	1,710,000,000	1,590,000,000	1,470,000,000
Year-on-Year Delta		-3%	-1%	1%	8%	-7%	-8%
Other Earnings	2,940,000,000	2,840,000,000	2,980,000,000	3,180,000,000	3,370,000,000	3,420,000,000	3,160,000,000
Year-on-Year Delta		-3%	5%	7%	6%	1%	-8%
Total Non-Performing Loans	430,000,000	423,000,000	489,000,000	589,000,000	649,000,000	657,000,000	585,000,000
Year-on-Year Delta		-2%	16%	20%	10%	1%	-11%

This table reports the year-on-year statistics of the underlying variables of the Malmquist measures. The underlying variables of the Malmquist measures consist of: Fixed Assets (input), Staff Expenses (input), Total Customer Deposits (input), Net Loans and Advances (output), Other Earnings (output) and Total Non-Performing Loans (negative output, incorporated as an input). Additionally, the total assets variable has been included to reflect the impact of the restriction on the treatment group comparability with the control group. All yearly averages are displayed in Euros. For a better understanding of the movements, year-on-year deltas have been included, representing the change in percentages.

3.3. Descriptive statistics of the Malmquist measures and the regression variables

The descriptive statistics for the Malmquist measures and the control variables utilized in the regressions are presented in table 2. This table has a group classification identical to table 1. Panel A contains the control group, the banks that remained under national supervision. Panel B represents the baseline treatment group and contains all banks under ECB supervision. Panel C is comprised of the restricted treatment group, where all banks above the EUR 30 billion

threshold have been omitted from the baseline treatment group. Focusing on the Malmquist measures firstly, table 2 indicates that over the sample period 2011-2017, all groups have on average experienced improvements in total factor productivity, efficiency, and technology. This can be inferred by the exclusivity of values above 1 for all the Malmquist measures. Regarding total factor productivity, one can observe that the average total factor productivity change of significant institutions was lower than that of the non-significant institutions under ECB supervision. This can be inferred from the higher average values in Panel C compared to that of Panel B. Meanwhile, the average total factor productivity improvement of banks under national supervision remains between that of the two treatment groups. The efficiency change, which is related to the allocation of the inputs, displays a higher average for the baseline treatment group in panel B, compared to the control group and the restricted treatment group in Panel A and C. Note, the efficiency change variable is mostly expected to be impacted by the size bias, as the significant institutions should be able to benefit more in efficiency due to economies of scale. With regard to technical change, the banks under national supervision were able to achieve a higher average compared to all banks under ECB supervision. Implying that the banks from Panel A were more capable of optimizing their output for a given input, compared to the treatment groups.

Comparing the control variables in table 2, it can be observed that banks under national supervision grew their total assets, relatively, nearly double as much as the banks under ECB supervision. Between the two treatment groups, the descriptive statistics indicate downward pressure from the significant institutions on the average accumulation of total assets. This downward pressure on the total assets by the significant institutions was also observable in table 1. Additionally, banks under national supervision held on average the greatest amount of equity as a percentage of their assets, suggesting more risk aversion. However, this notion gets disproven by the difference in impairment reserves to gross loans, as banks under ECB surveillance try to avoid downside risk to a larger degree. Furthermore, banks under the supervision of NSAs had higher costs relative to their income compared to both treatment groups, suggesting less profitability. The difference in cost to income between the two treatment groups implies a higher level of relative profitability among the significant institutions, included in panel B. No considerable differences can be observed among the macro-economic control variables, indicating a similar spread across Europe between the banks under NSA oversight and banks under ECB oversight in both the control and treatment groups. The banks under national supervision do appear to remain in countries with lower GDP growth, compared to the control groups. Moreover, between the two treatment groups, the sustained poverty in standard deviation across the macro-variables suggests that the non-significant institutions in panel C are more concentrated to specific countries.

Table 2
Descriptive statistics regression variables

A: Banks under national supervision					
Variable	Observations	Mean	Std. dev.	Min	Max
Total Factor Productivity	2,174	1.07	0.60	0.00	12
Efficiency Change	2,181	1.01	0.31	0.07	8.806
Technical Change	2,170	1.11	0.61	0.00	7.18
Change in total assets	2,255	0.04	0.16	-0.95	1.46
Equity to assets	2,254	0.11	0.07	0.00	0.90
Loan loss reserves to gross loans	2,111	0.04	0.08	0.00	1.00
Cost to income	2,245	0.68	0.91	-36.53	12.28
GDP Growth	2,385	1.03	1.76	-7.09	25.18
Profit tax to profits	2,385	17.65	7.34	0.00	32.40
B: Banks under ECB Supervision					
Variable	Observations	Mean	Std. dev.	Min	Max
Total Factor Productivity	2,033	1.05	0.50	0.00	7.34
Efficiency Change	2,037	1.07	0.37	0.00	8.47
Technical Change	2,032	1.03	0.52	0.09	7.47
Change in total assets	1,875	0.02	0.12	-0.73	1.12
Equity to assets	1,831	0.09	0.05	0.00	0.37
Loan loss reserves to gross loans	1,887	0.06	0.08	0.00	0.75
Cost to income	1,958	0.55	1.42	-30.50	15.53
GDP Growth	2,081	1.18	2.63	-7.09	25.18
Profit tax to profits	2,081	19.60	7.93	0.00	32.40
C: Non-significant institutions under ECB Supervision					
Variable	Observations	Mean	Std. dev.	Min	Max
Total Factor Productivity	1,297	1.09	0.57	0.00	7.35
Efficiency Change	1,301	1.04	0.43	0.09	8.47
Technical Change	1,296	1.10	0.59	0.01	7.47
Change in total assets	1,302	0.03	0.12	-0.65	1.12
Equity to assets	1,277	0.10	0.05	0.00	0.37
Loan loss reserves to gross loans	1,223	0.05	0.08	0.00	0.75
Cost to income	1,266	0.61	0.62	-13.49	15.53
GDP Growth	1,328	1.25	2.16	-7.09	25.18
Profit tax to profits	1,328	16.90	6.78	0.00	32.40

This table reports the descriptive statistics of the control variables over the period 2011-2017. The descriptive statistics include the number of observations, the mean, the standard deviation, and, the minimum and maximum value. Panel A consists of the control group used in every difference-in-difference regression. Panel B is the baseline treatment group, consisting of all banks under ECB supervision. Panel C is the restricted treatment group, where the banks with total assets above the EUR 30 billion treshold are excluded from the sample.

4. Methodology

4.1. Deriving the Malmquist measures

The DEA-Malmquist is defined as an input-oriented model, under the assumption that banks can individually manage their inputs. Furthermore, in the model, constant returns to scale will be assumed, as banks do not consider short-term movements, but benchmark by means of long-term objectives.

The dynamics of the Malmquist index can be explained through figure 1. The figure contains two time periods, *t* and *t+1*. The company represented in the figure exploits one input, X and one output, Y. The lines depicted by V^t and V^{t+1}, visualize the production frontiers, which can be interpreted as the level of technology. One can observe by looking at the production frontiers, that firms have generally become more technologically advanced, as the companies are able to produce an equal amount of output with using less input. Assume a company i that has the input-output mixes $\{x_i^t; y_i^t\}$ and $\{x_i^{t+1}; y_i^{t+1}\}$, respectively in period *t* and *t+1*. Comparing the two points, multiple conclusions can be extracted. Firstly, as a consequence of technical progress the company requires less input to produce more output. In period *t*, the company would have to use *d* number of inputs (visible on the x-axis) to produce a number of outputs equal to *t+1*. Additionally, it can be concluded that the firm allocated its inputs more efficiently, which can be derived from the closer distance to the production frontier.

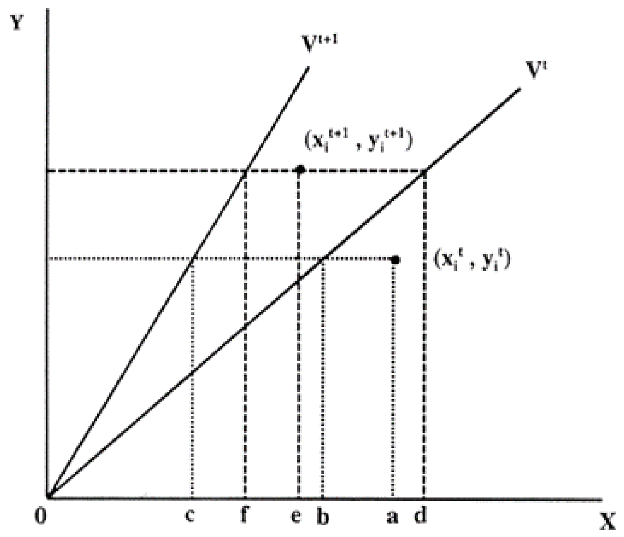

Figure 1
Graphical representation of the Malmquist framework

To derive the Malmquist measures, for each of T time periods $t = 1, \dots, T$ a set of n banks using p inputs to produce q outputs will be observed. Let bank j in time period t be represented by input-output combination $(x_{t,j}, y_{t,j})$, where $x_{t,j} \epsilon R_{+}^{p}$ is observation j's usage of inputs $(i = 1, \dots, p)$ in time period t, and $y_{t,j} \epsilon R_{+}^{q}$ is bank j's production of outputs $(h = 1, \dots, q)$ in time period t. To calculate the main Malmquist index measure, which will be referred to as the total factor productivity variable *(TFP)*, the ideal benchmark frontier for a given input-output combination$(x_{t,j}, y_{t,j})$ will be defined through the directional matrix $g = (g_x ; g_y) \in \mathbb{R}^{h+i}$, with $g_x = (g_{x1}, \dots, g_{xp})$ and $g_y = (g_{y1}, \dots, g_{xh})$. Additionally, I introduce β, a factor to calculate the potential improvements required to make the individual inputs and outputs fully efficient. Ultimately, one can define the directional distance out of the feasible set Ψ, where the distance vector is proportional to time periods $\{t;\ t+1\}$, with $t+1$ attributed to any observation after t.

$$\vec{D}(x, y; g_x , g_y) = \max \{\beta \in \mathbb{R}^{+} | (x - \beta g_x , y + \beta g_y) \in \Psi\} \tag{1}$$

$\vec{D}^t$ captures the technological frontier at time t. $\vec{D}^t\ (x_t, y_t; g)$ is considered a contemporaneous distance function, as it relates the potential improvement of bank (x_t, y_t) relative to the technology at time t. Similarly, $\vec{D}^t\ (x_{t+1}, y_{t+1}; g)$ is regarded as a cross-period distance function, since the technology at time t is the benchmark for bank (x_{t+1}, y_{t+1}). When the reference technology is at time t, the total factor productivity is defined as:

$$TFP^t = \frac{\vec{D}^t\ (x_{t+1}, y_{t+1}; g)}{\vec{D}^t\ (x_t, y_t; g)} \tag{2}$$

Instead of selecting the technological frontier at time t as the benchmark reference. One could also elect the technology at time $t+1$ as the reference period. Note, that $t+1$ can be every period after t, and is therefore not constrained to the period exactly subsequent to t. When the reference technology is at time $t+1$, the Malmquist productivity index is defined as:

$$TFP^{t+1} = \frac{\vec{D}^{t+1}\ (x_{t+1}, y_{t+1}; g)}{\vec{D}^{t+1}\ (x_t, y_t; g)} \tag{3}$$

In this paper, the utilized Malmquist-index function is constructed by taking the geometric mean of the contemporaneous and cross-period specifications. Introduced by Färe et al. (1992) to avoid ambiguously selecting a certain period as the benchmark. The Malmquist index specification applied in this paper is:

$$TFP(x_t, y_t, x_{t+1}, y_{t+1}) = \left[\frac{\vec{D}^t\ (x_{t+1}, y_{t+1}; g)}{\vec{D}^t\ (x_t, y_t; g)} \times \frac{\vec{D}^{t+1}\ (x_{t+1}, y_{t+1}; g)}{\vec{D}^{t+1}\ (x_t, y_t; g)}\right]^{\frac{1}{2}} \quad (4)$$

Additionally, one can disintegrate the Malmquist-index' total factor productivity into two components, efficiency change (EC) and technological change (TC). EC will provide evidence that a bank has achieved an efficiency increase in its input dimensions, therefore containing solely contemporaneous distance functions. The TC explains the magnitude of the technical frontier change between two periods. The EC element is defined as:

$$EC = \frac{\vec{D}^{t+1}\ (x_{t+1}, y_{t+1}; g)}{\vec{D}^t\ (x_t, y_t; g)} \quad (5)$$

The TC element is defined as:

$$TC = \left[\frac{\vec{D}^t\ (x_t, y_t; g)}{\vec{D}^{t+1}\ (x_t, y_t; g)} \times \frac{\vec{D}^t\ (x_{t+1}, y_{t+1}; g)}{\vec{D}^{t+1}\ (x_{t+1}, y_{t+1}; g)}\right]^{\frac{1}{2}} \quad (6)$$

These elements have been identified by utilizing a revised specification of the Malmquist index. This amended function is a combination of both TC and EC elements and can be observed in equation (7), but it is in essence identical to the specification formulated in equation (4).

$$TFP(x_t, y_t, x_{t+1}, y_{t+1}) = \frac{\vec{D}^{t+1}\ (x_{t+1}, y_{t+1}; g)}{\vec{D}^t\ (x_t, y_t; g)} \times \left[\frac{\vec{D}^t\ (x_t, y_t; g)}{\vec{D}^{t+1}\ (x_t, y_t; g)} \times \frac{\vec{D}^t\ (x_{t+1}, y_{t+1}; g)}{\vec{D}^{t+1}\ (x_{t+1}, y_{t+1}; g)}\right]^{\frac{1}{2}} \quad (7)$$

DEA is utilized to obtain the results of the four distance functions required per bank. DEA picks benchmarks, such that the movement in the input-output mix is proportionate to the possible improvement. Providing not solely the productivity status but also the productivity patterns of different banks from both a technical and an efficiency perspective. Each distance function requires a set of linear programming conditions to be solved. Under the that banks set long-term objectives, to which performance is benchmarked, I employ a DEA-Malmquist framework with Constant Return to Scale (CRS), as well as an input-orientation. To compute the various distance functions, the linear programming problems are defined as:

$$\vec{D}^{t}\,(x_t, y_t; g) = \max\,(\theta) \quad \text{s.t.,} \tag{8}$$

$$\sum_{k=1}^{n} \lambda_k x_{i,k}^{t} \le \theta x_{j,i}^{t} \qquad i = 1, \dots, p$$

$$\sum_{k=1}^{n} \lambda_k y_{h,k}^{t} \ge y_{h,j}^{t} \qquad h = 1, \dots, q,$$

$$\lambda_k \ge 0 \qquad \text{for all } k = 1,2, \dots, n.$$

$$\vec{D}^{t+1}\,(x_t, y_t; g) = \max\,(\theta) \quad \text{s.t.,} \tag{9}$$

$$\sum_{k=1}^{n} \lambda_k x_{i,k}^{t+1} \le \theta x_{j,i}^{t} \qquad i = 1, \dots, p$$

$$\sum_{k=1}^{n} \lambda_k y_{h,k}^{t+1} \ge y_{h,j}^{t} \qquad h = 1, \dots, q,$$

$$\lambda_k \ge 0 \qquad \text{for all } k = 1,2, \dots, n.$$

$$\vec{D}^{t}\,(x_{t+1}, y_{t+1}; g) = \max\,(\theta) \quad \text{s.t.,} \tag{10}$$

$$\sum_{k=1}^{n} \lambda_k x_{i,k}^{t} \le \theta x_{j,i}^{t+1} \qquad i = 1, \dots, p$$

$$\sum_{k=1}^{n} \lambda_k y_{h,k}^{t} \ge y_{h,j}^{t+1} \qquad h = 1, \dots, q,$$

$$\lambda_k \ge 0 \qquad \text{for all } k = 1,2, \dots, n.$$

$$\vec{D}^{t+1}\,(x_{t+1}, y_{t+1}; g) = \max\,(\theta) \quad \text{s.t.,} \tag{11}$$

$$\sum_{k=1}^{n} \lambda_k x_{i,k}^{t+1} \le \theta x_{j,i}^{t+1} \qquad i = 1, \dots, p$$

$$\sum_{k=1}^{n} \lambda_k y_{h,k}^{t+1} \geq y_{h,j}^{t+1} \qquad h = 1, \dots, q,$$

$$\lambda_k \geq 0 \qquad \text{for all } k = 1,2, \dots, n.$$

4.2. Linear regression methodology for the size bias

The main source of possible internal validity complications will be produced by the underlying positive correlation between the productivity measures and asset size. Random selection of banks into either the treatment or the control group would designate this bias as negligible. However, the treatment group selection is not random, since banks are classified as significant institutions based on the size of their asset balance. To understand the impact of asset size on the productivity measures, I will first perform a series of linear regressions, consisting of the control group and the complete treatment group. These regressions will produce a baseline impact of the size bias and will consist of the following structure.

$$Y_{j,c,t} = \beta_0 + \beta_1 TotalAssets_j + \beta_2 x_{j,t} + \beta_3 z_{c,t} + \epsilon_{j,t} \qquad (12)$$

Initially, the $Y_{j,t}$ term will represent the main Malmquist measure from specification (7), which embodies the growth in total factor productivity and is derived using DEA. Subsequently, I will substitute the total factor productivity variable with both its individual segments, efficiency change, and technical change, which are presented in equations (5) and (6), respectively. The variable of interest is β_1, which will provide the magnitude of the total assets size impact. Represented by the vector $x_{j,t}$, the bank-level controls include the ratio of loan loss reserves to gross loans, the ratio of equity to total assets, and the cost-to-income ratio. On a country level, the control variables vector $z_{c,t}$ will consist of the GDP growth rate and the profit-tax ratio. The existence of the bias will be inferred based on a significant and positive total assets coefficient.

Once the first series of linear regressions has been completed, and a baseline has been established, I restrict the sample group to banks that did not satisfy the EUR 30 billion condition. By performing this restriction, the significant institutions are excluded from the data sample and only their subsidiaries remain. An additional series of linear regressions with this restricted sample will be completed to infer in what manner the size bias changes, compared to the baseline. This restriction will also be performed in the subsequent difference-in-difference regressions, to increase the comparability between the control group and the treatment group.

4.3. Difference-in-difference regression methodology on bank productivity

The difference-in-difference framework will be utilized to examine the effect of the change to ECB supervision on productivity. The establishment of the SSM is incorporated as an exogenous shock, of which the trend before the 2014 shock (pre-treatment era) and after the shock (post-treatment era) is compared between a treatment and a control group. Prior to being able to interpret the results of the difference-in-difference regressions, two assumptions will need to be satisfied. Firstly, parallel trends must be observable between the control group and the treatment group prior to the intervention. Secondly, the stable unit treatment value assumption (SUTVA) will need to be satisfied. Within the SUTVA assumption, interference of another entity's treatment on the outcome is not allowed, and treatment should be equal among the banks with the treatment group.

$$Y_{j,c,t} = \beta_0 + \beta_1 SSM_t + \beta_2 ECB_j + \beta_3 SSM_t ECB_j + \beta_4 x_{j,t} + \beta_5 z_{c,t} + \epsilon_{j,t} \qquad (12)$$

To test if banks under ECB supervision obtained a higher level of total factor productivity change, the formula above is used. The treatment era dummy SSM_t assigns a 1 after the SSM is established in 2014, and a 0 otherwise. ECB_j is the treatment group dummy variable, being equal to a 1 if the bank belongs to the group under the supervision of the ECB. The control group includes banks within the Euro Zone that remained under the supervision of their NSA. The two dummy variables are regressed both independently and as an interaction term, together with vector $x_{j,t}$ and $z_{c,t}$ of control variables. As mentioned previously, the vector x_{jt} of bank-level control variables includes the natural logarithm of total assets, the ratio of loan loss reserves to gross loans, the ratio of equity to total assets, and the cost-to-income ratio. On a country level, represented by $z_{c,t}$, the control variables include the GDP growth rate and the profit-tax ratio. The variable of interest is β_3, as this will provide evidence if a stricter regulator accelerates productivity. The dependent variable $Y_{j,c,t}$, represents the relative total factor productivity growth in the initial difference-in-difference regressions.

The control group remains stable and consists of the banks that kept being under the supervision of the national supervisor. However, two different treatment groups will be examined in order to derive robust results. The first treatment group contains all banks under ECB supervision and will serve as a baseline regression. Accordingly, this group contains the banks that satisfy the significant institution condition and their subsidiaries. The second treatment group solely contains the banks that were placed under ECB supervision due to their parent company. These provide a treatment group more similar in size to the control group, as can be observed from Table 1. Consequently, the results of the second treatment group will produce a higher level of internal validity due to their comparability with the control group. Moreover, it will also indicate possible mechanisms in the relationship between the parents and the subsidiaries within the treatment group.

A Hausman test will provide guidance on the use of either random effects regressions or fixed effects regressions. The difference is that random effects models assume a possibility of estimation with partial pooling of samples, where deviation from the mean follows a random variable. Considering, that banks do not become significant institutions randomly in the framework of the SSM, fixed effects will be expected to be required. Furthermore, the standard errors will be clustered on a bank-level or a country-level in the regressions.

Subsequent to the total factor productivity regression, a similar equation will be utilized. However, this regression contains as the dependent variable, $Y_{j,c,t}$, the technical change section of the Malmquist index, which can be observed in the specification (6). This variable captures the banks' ability to adopt the best-practice technology, from a given set of inputs and technology. Serving to provide evidence that the increase in total factor productivity for banks under ECB supervision is due to their capacity of obtaining a higher common frontier. Lastly, to obtain evidence for whether the change in productivity can be attributed to the banks' response to the intrusive ECB supervisor, the efficiency change section (specification (5)) will be regressed. Both regression specifications will contain identical control variables to the initial framework. Moreover, the approach of two treatment groups will also be employed for this hypothesis, in order to create increase the internal validity of this analysis. Similar to the total factor productivity, the parallel trend assumption will also have to be satisfied.

For further robustness checks, regressions containing placebo variables will be performed on the variables from the main regressions. The placebo variables are dummy variables that will be attributed to a year on either side of the event year, 2013 and 2015, respectively. In the case that the placebo variable reports significant coefficients, an alternative event could have driven the changes in productivity.

5. Results

5.1 Linear regression results on the size bias

Table 3 presents the results of the OLS regressions, which will provide the relationship between the total asset size and the three Malmquist attributes. The results from this table will give an initial indication of the possible bias due to the difference in average size between the control and treatment groups. In panel A, the sample data contains the nationally supervised banks, as well as the total group of banks under ECB supervision. One can observe highly significant coefficients relating to the total assets in the first and third columns. Both are significant at a 1% level. The magnitude of the total assets coefficient in the first column reveals that an additional one billion euros in assets increases the total factor productivity change measure by 1.28% over the complete sample. Besides the total assets variable, the regression coefficients indicate that a higher level of equity relative to the volume of total assets has a positive impact on the total factor productivity measure. Therefore, a higher level of risk in a bank's structure does not correlate with a higher level of productivity. Additionally, the control variables suggest that the geographical location correlates with the productivity level. As one expects, banks within countries that experience a decrease in their GDP growth are negatively impacted in their productivity. Moreover, countries with a higher tax rate relative to overall profits are positively correlated with total factor productivity. Both variables point towards a higher probability of productivity gains for banks that were established in the relatively more wealthy western part of Europe, compared to for instance the south of Europe. Similar observations can be made when looking at the third column. With regards to the efficiency change variable, an additional one billion in total assets can be observed to correlate with a 0.75% gain in efficiency change. This implies that a substantial component of the increase in total factor productivity change is driven by a more efficient allocation of inputs. Therefore, economies of scale appear prevalent within the data sample, and this would create a size bias in the difference-in-difference regressions. Ultimately, only the technical change variable is not correlated to the volume of total assets. The level of technology is negatively associated with the year variable, while the level of efficiency is weakly positively significant with regard to the year variable.

In panel B, identical regressions have been performed compared to panel A. However, banks that satisfy the 30 billion euros condition for significant institutions have been excluded from the underlying dataset. Consequently, the remaining banks are either under national supervision or under ECB supervision due to their parent bank. This new group intends to mitigate or decrease the size bias due to the underlying size disparity within the total sample. Looking at panel B, the t-values, give a clear indication that the total assets variable has a less significant impact on the Malmquist measures, compared to panel A. As displayed in panel A, the total assets coefficient ceases to have a significant impact on efficiency change, while the coefficient is less significant in relation to the total factor productivity measure. The control variables display a similarly significant impact in panel B, compared to panel A. This signals that no unexpected underlying relationship has been unveiled regarding the control variables, due to the restriction on the sample group. Ultimately, the size effect has been reduced, but it appears to not yet have disappeared completely. Conclusive evidence on the existence of this bias in a difference-in-difference setting will be established when the results from the complete baseline treatment group are compared with the restricted sample of ECB-supervised banks.

Table 3
Size bias regressions

A: All institutions under national and ECB supervision

	(1) Total Factor Productivity	(2) Technical Change	(3) Efficiency Change
Total Assets	1.28E-11***	1.70E-12	7.47E-12***
	(4.73)	(1.17)	(2.97)
Year	-0.011	-0.021***	0.016*
	(-1.37)	(4.7)	(1.96)
Equity to Total Assets	1.961**	-0.102	-0.270
	(1.65)	(-0.37)	(-0.40)
Loan Loss Reserves to Gross Loans	-0.318	-0.321	-0.072
	(-0.92)	(-1.25)	(-0.27)
Cost to Income	-0.002	0.007	-0.003
	(-0.92)	(0.79)	(-0.54)
GDP Growth	-0.017***	0.002	-0.029***
	(-2.26)	(0.68)	(-3.2)
Profit Tax to Profits	0.008***	-0.001	0.012***
	(2.19)	(-0.28)	(3.01)
R^2	0.2144	0.3125	0.2582
N	3.642	3.651	3.636

B:All institutions under national supervision and the non-significant institutions under ECB supervision

	(1) Total Factor Productivity	(2) Technical Change	(3) Efficiency Change
Total Assets	2.44E-11**	3.87E-12	1.34E-11
	(2.49)	(0.91)	(1.44)
Year	-0.013	-0.020***	0.015
	(-1.40)	(-3.87)	(1.48)
Equity to Total Assets	2.740**	0.208	-0.183
	(2.22)	(0.65)	(-0.24)
Loan Loss Reserves to Gross Loans	-0.417	-0.393	-0.065
	(-1.18)	(-1.63)	(-0.23)
Cost to Income	-0.003	0.020	-0.009
	(-0.45)	(1.00)	-0.82
GDP Growth	-0.009	0.009***	-0.031***
	(-0.98)	(2.30)	(-2.8)
Profit Tax to Profits	0.012***	0.004	0.009***
	(2.58)	(1.55)	(1.8)
R^2	0.2156	0.3015	0.2554
N	3.090	3.099	3.084

This table presents the results of the size bias OLS-regressions. The variables of interest is the Total Assets variable. The unit of observation are individual banks, with observations clustered on a bank-level. The Malmquist measures have been calculated using data envelopment analysis. In panel A, the sample consists of all banks under ECB supervision and all banks under supervision of their NSA. In panel B, the data sample contains non-significant instutions under ECB supevision and all banks under supervision of their NSA. The bank-level control variables are Equity to Total Assets, Loan Loss Reserves to Gross loans, the Cost to Income ratio. Contry-level control variables are the GDP Growth and the Profit Tax to Profits ratio. To control for variance over time, the Year variable has also been included.
**p<0.1, **p<0.05, *** p <0.01.*

5.2 The assumptions of the difference-in-difference framework

In order to provide valid results, the difference-in-difference framework requires two assumptions to be satisfied. Firstly, the parallel trend assumption between the treatment and control group has to be evidenced. This assumption demands that the trend of the dependent variable remains consistent between both groups pre-treatment. The second assumption is the stable unit treatment value assumption (SUTVA). SUTVA contains two components. There should be no interference, meaning that the outcome of the dependent variable is not affected by another entity's exposure to the treatment. Additionally, the second component states that different versions of treatment should not exist.

5.2.1 The parallel trend assumption

The parallel trend condition relates to the existence of counterfactual outcomes. I argue that this assumption is satisfied with regard to the dependent variables in the regressions. Firstly, to illustrate, both Fiordelisi et al., (2017) and Avgeri et al., (2021) have been able to satisfy the condition using a comparable control group within the SSM framework. Fiordelisi et al., (2017) graphically showed a parallel trend in average loan growth between the two groups prior to the intervention. Moreover, after introducing a vector of macroeconomic variables and a set of country dummies, Avgeri et al., (2021) were able to conclude that the parallel trend assumption seems sufficiently satisfied with regard to ROA and ROE.

It is impossible to directly test parallel trends. Nevertheless, the possibility exists to visualize the trends of the dependent variables prior to the treatment. Consequently, similar trends pre-treatment would imply that the dependent variables behave similarly post-treatment in absence of the intervention. Figures 2 to 7 display the trends of the three dependent variables between 2009 and 2017, with the unrestricted treatment sample in figures 2 to 4 and the restricted treatment sample in 5 to 7. Figures 5 to 7 can be viewed in the appendix, but depict a comparable progression to the figures below. It is visible that the efficiency change and technical change trends are moving in a very similar manner between the groups, pre-treatment. Therefore, both variables can be considered to satisfy the parallel trend condition. The total factor productivity variables in figures 2 and 5 show a less clear parallel trend. However, I argue that the parallel trend can still be considered satisfied, as the average movement between 2011 and 2014, which is the exact pre-treatment period in the regressions, has an identical average slope. This slope has been visualized with the red dotted line in figures 2 and 5.

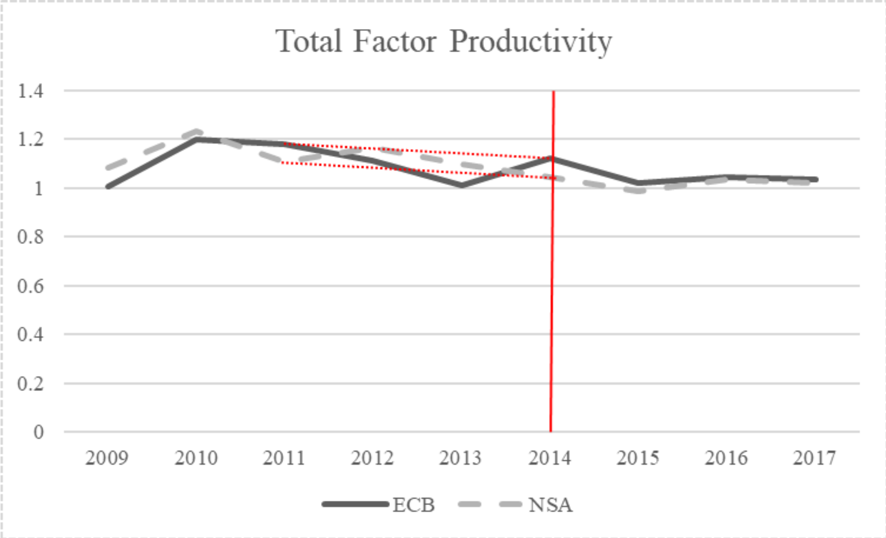

Figure 2
Trend of Total Factor Productivity

This figure shows the trend of the Total Factor Productivity variable from 2009 -2017. The variable is relative to the previous year, with a value of 1 indicating that there was no improvement. The treatment group is the uninterrupted dark line, named in the legend as ECB. The control group is represented with the dotted line, named in the legend as NSA. The vertical line represents the establishment of the SSM in 2014. The treatment group consists of the unrestricted sample of banks under ECB supervision

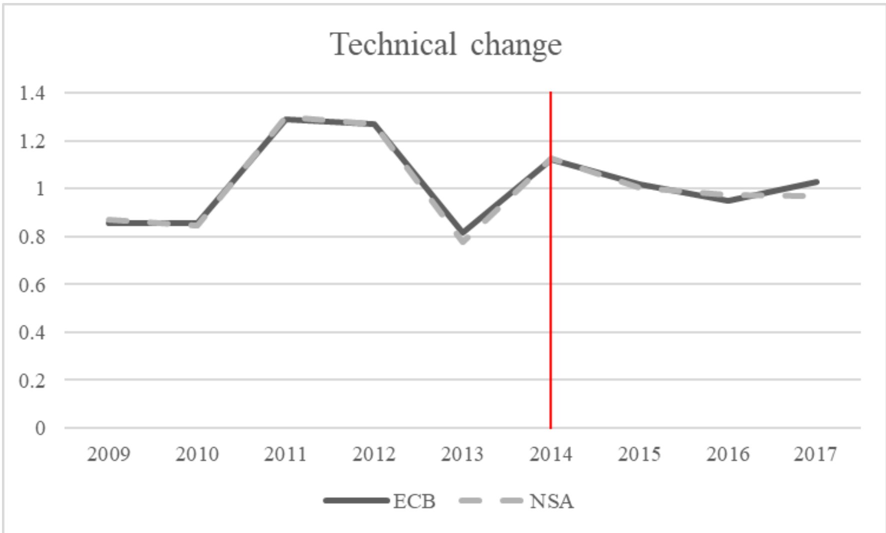

Figure 3
Trend of Technical Change

This figure shows the trend of the Technical Change variable from 2009 -2017. The variable is relative to the previous year, with a value of 1 indicating that there was no improvement. The treatment group is the uninterrupted dark line, named in the legend as ECB. The control group is represented with the dotted line, named in the legend as NSA. The vertical line represents the establishment of the SSM in 2014. The treatment group consists of the unrestricted sample of banks under ECB supervision

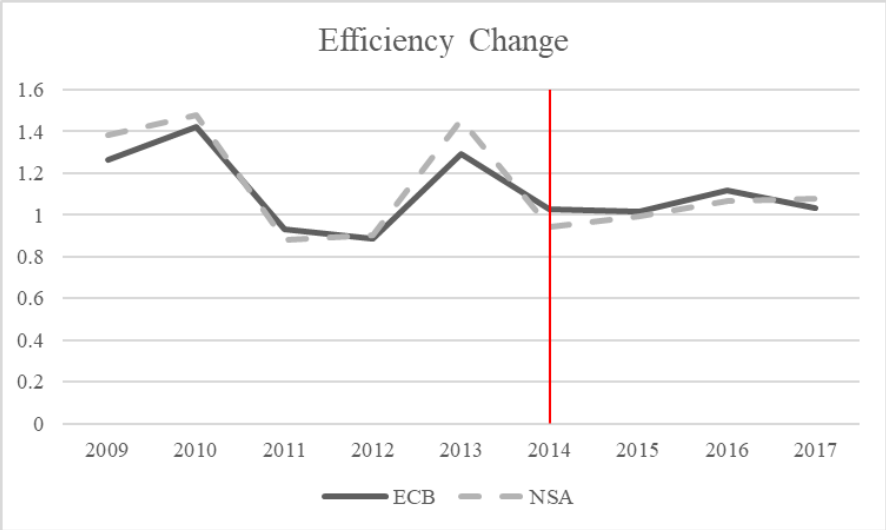

Figure 4
Trend of Efficiency Change

This figure shows the trend of the Efficiency Change variable from 2009 -2017. This variable is relative to the previous year, with a value of 1 indicating that there was no improvement. The treatment group is the uninterrupted dark line, named in the legend as ECB. The control group is represented with the dotted line, named in the legend as NSA. The vertical line represents the establishment of the SSM in 2014. The treatment group consists of the unrestricted sample of banks under ECB supervision

5.2.2 The stable unit treatment value assumption (SUTVA)

The two components of the SUTVA are, no interference and stability in treatment. The first component means that a bank under national supervision should not be affected in productivity, due to other banks being supervised by the ECB. We satisfy this condition as a consequence of the ECB's decision to supervise both the parent company and the subsidiaries. The banks under national supervision are always separate entities from the banks under ECB supervision. There would be interference if company-wide policy had to be altered due to the parent company being placed under ECB supervision, while the subsidiary remained under the supervision of their national supervisory authority.

The second component implies that there should exist no difference between versions of the treatment. Therefore, the ECB treatment should be identical between the banks in the treatment group. This cannot be tested but will be assumed going forward. The foundation of this assumption lies in European law, which has as its fundamental principles, equal treatment and prohibition of discrimination[1]. As a formal body of the European Union, the ECB has to abide by these fundamental principles. Therefore, two comparable cases should not be treated differently by the ECB, unless a high degree of justification can be provided.

5.3 Difference-in-difference regression results for the Malmquist measures

The results of the difference-in-difference regressions have been displayed in tables 4 to 6. In each table, the variables of interest will be regressed initially using bank-level fixed effects, yearly fixed effects, and bank-level control variables. Subsequently, we will introduce individual specifications containing country-level control variables, and country fixed effects. Furthermore, in consideration of standard errors, clusters will be maintained across the specifications on a bank level. However, once the bank-level fixed effects are substituted for country level fixed effects, the clusters will also be adjusted to a country-level. Prior to performing the regressions, a Hausmann test has been performed. The results of the Hausmann test can be observed in table 9 in the Appendix. This test provides confirmation on the use of fixed effects in the regressions, instead of random effects. The rationale can mainly be attributed to the non-random nature of the treatment group selection requirements within the SSM framework.

5.3.1 Total Factor Productivity Change

The result of the first analysis is presented in table 3, where the main variable of interest concerns the total factor productivity change measure. Panel A, the baseline regression, indicates that the total sample of banks under ECB supervision was not able to increase their total factor productivity significantly, compared to the banks that stayed under national supervision. Across the specifications (columns 1-3), the regressions differ in controls and fixed effects. The results imply that country controls relieve the variable of interest of noise. Nevertheless, the impact on significance is marginal. In the last column, country fixed effects are included in the analysis and bank fixed effects are excluded. This column was included to control for any detected and undetected time-varying characteristics that are common among banks from the same country. Adding country fixed effects to the regression increases the

[1] See Article 2 and Articles 3(3) and 4(2) of the Treaty of the European Union; Articles 8, 10 and 18 of the Treaty on the functioning of the European Union

significance of the total factor productivity variable. However, the reduction in the R-squared value indicates that considerably less of the movement in total factor productivity can be explained by the interaction term in specification 3. Therefore, with regard to total factor productivity, the coefficients in specification 2 provide the most valid results. Ultimately, in panel A the coefficient indicates that banks under ECB supervision have a higher level of relative total factor productivity post-SSM, but this increase cannot be concluded as significant from zero.

To further explore the impact of the SSM on total factor productivity, the treatment group is modified. The significant institutions are removed, and solely the subsidiaries remain, which would not be placed under ECB oversight on a stand-alone basis. As a consequence, the treatment and control groups move towards a more comparable size. Panel B of table 3 displays the results of this exercise, and shows highly significant results across all specifications. One can observe that the country-level clustering and fixed effects in specification 3 have a direct impact on the magnitude of the total factor productivity coefficient, and its significance. However, similar to Panel A, this increase coincides with a considerable reduction in the R-squared value. Thus, as displayed in specification 2, the non-significant institutions under ECB supervision experience an 11% higher relative total factor productivity growth after the establishment of the SSM, compared to banks remaining under national oversight. Considering this sample contributes to a treatment group more akin to the control group, it provides a more accurate representation of the impact of ECB supervision on total factor productivity. Notably, the analysis indicates that a larger bank size does not drive higher total factor productivity growth in the difference-in-difference model. This is contrary to the size effect that was observed in the previous linear regressions.

Table 4
Regressions on Total Factor Productivity

A: Total Factor Productivity, all institutions under ECB supervision

	(1) Total Factor Productivity	(2) Total Factor Productivity	(3) Total Factor Productivity
ECB*SSM	0.046	0.047	0.062
	(1.29)	(1.20)	(1.32)
R^2	0.250	0.252	0.054
N	3.660	3.627	3.644

B: Total Factor Productivity, Non-significant institutions under ECB supervision

	(1) Total Factor Productivity	(2) Total Factor Productivity	(3) Total Factor Productivity
ECB*SSM	0.093**	0.113**	0.127**
	(2.25)	(2.16)	(2.88)
R^2	0.255	0.257	0.066
N	3.109	3.090	3.103
Firm Controls	Yes	Yes	Yes
Country Controls	No	Yes	Yes
Bank Fixed Effects	Yes	Yes	No
Time Fixed Effects	Yes	Yes	Yes
Country Fixed effects	No	No	Yes

*This table presents the results of a difference-in-difference regression, with the variable of interest being the interaction term of the SSM and ECB dummy variables. The unit of observation is the individual banks, with observations clustered on the a bank-level in specification 1 and 2, and clustered on a country-level in specification 3. In panels A and B, the dependent variable is the banks' Malmquist Total Factor Productivity, a relative value that stands in proportion to a common benchmark. This common benchmark was calculated using data envelopment analysis. In panel A, the treatment group consists of all banks under ECB supervision. In panel B, the treatment group contains solely banks under ECB supervision which themselves are not considered significant institutions. SSM is a dummy variable that adopts a 1 if observation are in 2014 or later. ECB is a dummy variable that adopts a 1 if the institution is supervised by the ECB after establishment of the SSM. Bank-level controls include the natural logarithm of total assets, the ratio of loan loss reserves to gross loans, the ratio of equity to total assets and the cost to income ratio. Country-level controls include the GDP growth rate and the profit-tax ratio. t-statistics are reported in parentheses. *p<0.1, **p<0.05, *** p <0.01.*

5.3.2 Technical Change

To determine if growth in the level of technology drove the increase in total factor productivity, the total factor productivity is substituted for technical change, a sub-section of the Malmquist index. Similar to the previous regression, multiple specifications were performed containing varying controls and fixed effects. The results are displayed in table 4. Utilizing both treatment groups in panels A and B respectively, one cannot observe a significant difference between the banks under national supervision, and the banks under ECB supervision. Note, the coefficient of the variable of interest turns positive once the significant institutions are excluded from the treatment group. Implying a downwards pressure from the significant institutions on the magnitude of the technical change coefficient. Nevertheless, under both treatment groups, the impact of the interaction variable cannot confidently be considered different from zero.

Table 5
Regressions on Technical Change

A: Technological Change, all institutions under ECB supervision			
	(1) Technical Change	(2) Technical Change	(3) Technical Change
ECB*SSM	-0.009	-0.013	-0.010
	(-0.39)	(-0.55)	(-0.33)
R^2	0.309	0.313	0.191
N	3.669	3.636	3.653

B: Technological Change, Non-significant institutions under ECB supervision			
	(1) Technical Change	(2) Technical Change	(3) Technical Change
ECB*SSM	0.029	0.032	0.032
	(0.98)	(1.01)	(0.99)
R^2	0.298	0.302	0.175
N	3.118	3.099	3.112
Firm Controls	Yes	Yes	Yes
Country Controls	No	Yes	Yes
Bank Fixed Effects	Yes	Yes	No
Time Fixed Effects	Yes	Yes	Yes
Country Fixed effects	No	No	Yes

*This table presents the results of a difference-in-difference regression, with the variable of interest being the interaction term of the SSM and ECB dummy variables. The unit of observation is the individual banks, with observations clustered on the a bank-level in specification 1 and 2, and clustered on a country-level in specification 3. In panels A and B, the dependent variable is the banks' Malmquist Technical Change, a relative value that stands in proportion to a common benchmark. This common benchmark was calculated using data envelopment analysis. In panel A, the treatment group consists of all banks under ECB supervision. In panel B, the treatment group contains solely banks under ECB supervision which themselves are not considered significant institutions. SSM is a dummy variable that adopts a 1 if observation are in 2014 or later. ECB is a dummy variable that adopts a 1 if the institution is supervised by the ECB after establishment of the SSM. Bank-level controls include the natural logarithm of total assets, the ratio of loan loss reserves to gross loans, the ratio of equity to total assets and the cost to income ratio. Country-level controls include the GDP growth rate and the profit-tax ratio. t-statistics are reported in parentheses. *p<0.1, **p<0.05, *** p <0.01.*

5.3.3 Efficiency Change

To determine if a more optimized input allocation accelerated the increase in total factor productivity, the efficiency change segment of the Malmquist index will be introduced as the dependent variable in table 4. Conceptually, the allocative efficiency increases from t to $t+1$, in case the operating point of a bank moves more towards the technology frontier in $t+1$, as shown in figure 1. Panel A and B of table 4 provide the results of the regressions using the full and the restricted treatment groups, respectively. In all the specifications of panel A, highly significant coefficients can be detected. The coefficients indicate that ECB supervision after the establishment of the SSM, drives an increase in the allocative efficiency change of the supervised banks by 9,6%. In panel B, where the significant institutions are excluded from the treatment group, coefficients of a similar magnitude can be observed. However, the coefficients are exclusively higher in panel B compared to panel A, implying that there is no positive correlation between the size of a bank and its allocative efficiency growth in this difference-in-difference framework. Comparing specification 2 of panel B to panel A, the coefficient of interest decreases in significance to slightly above the 5% mark, while the magnitude of the coefficient increases to 10.1%. Moreover, the coefficient of the third specification experiences a considerable increase in significance, once the fixed effects are on a country-level. Compared to table 4, the R-squared value decreases to a lesser degree in specification 3 of table 6. Consequently, more within-country variation can be explained with efficiency change, in comparison to total factor productivity change. Nevertheless, in table 6, the R-squared with country-level fixed effects remains slightly below half of the R-squared of the bank-level fixed effects. Aligning with the previous findings related to total factor productivity, also in table 6 the second specification provides the results with the highest degree of internal validity. Ultimately, the three regressions corroborate that ECB supervision had a positive impact on the productivity capabilities of the supervised banks.

From the perspective of the two treatment groups, the results possibly also highlight an important dynamic within a parent-subsidiary relationship, the transfer of knowledge. In this case, the knowledge transfer manifests itself through efficient allocation of inputs. Higher governance on both the parent and the subsidiary reduces the agency problems between both entities. It could be a consequence of the parent company realizing that the more intrusive supra-national supervisor will look negatively upon operational issues with any of its subsidiaries. This is in contrast to the national supervisors, that tend to protect solely their domestic financial system. This finding is consistent with the evidence provided by Agarwal et al. (2014), who identified a similar mechanism between state and federal regulators in the United States. Consequently, the subsidiary will become more scrutinized not only by the supervisor, but also by the parent company. Increasingly driving the involvement of the parent bank in the allocation of the subsidiary’s inputs. Ultimately, this could explain why a larger relative increase in total factor productivity and efficiency change can be observed among the subsidiaries compared to the parent companies.

Additionally, the variance in the magnitude of the coefficients between the restricted sample and the total sample can be explained by the flexibility and transparency of the smaller banks. The “smaller bank advantage”, relates to the increase in agency problems within a bank when its organizational structure becomes more complex, due to growth in size (Song & Zhong, 2016). This lack of complexity is attractive to supervisors and reduces the need for intrusive inspections. This provides the smaller banks with more resources to focus on the efficient allocation of inputs, while the larger banks are distracted by additional supervisory requirements and inspections.

Table 6
Efficiency Change Regressions

A: Pure Efficiency Change, all institutions under ECB supervision			
	(1) Efficiency Change	(2) Efficiency Change	(3) Efficiency Change
ECB*SSM	0.093**	0.096**	0.084**
R^2	(2.32)	(2.29)	(2.76)
	0.2843	0.2866	0.1159
N	3.654	3.621	3.638

B: Pure Efficiency Change, Non-significant institutions under ECB supervision			
	(1) Efficiency Change	(2) Efficiency Change	(3) Efficiency Change
ECB*SSM	0.096**	0.101*	0.097***
R^2	(2.02)	(1.84)	(3.14)
	0.2841	0.2863	0.1247
N	3.103	3.084	3.097
Firm Controls	Yes	Yes	Yes
Country Controls	No	Yes	Yes
Bank Fixed Effects	Yes	Yes	No
Time Fixed Effects	Yes	Yes	Yes
Country Fixed effects	No	No	Yes

*This table presents the results of a difference-in-difference regression, with the variable of interest being the interaction term of the SSM and ECB dummy variables. The unit of observation is the individual banks, with observations clustered on the a bank-level in specification 1 and 2, and clustered on a country-level in specification 3. In panels A and B, the dependent variable is the banks' Malmquist Total Factor Productivity, a relative value that stands in proportion to a common benchmark. This common benchmark was calculated using data envelopment analysis. In panel A, the treatment group consists of all banks under ECB supervision. In panel B, the treatment group contains solely banks under ECB supervision which themselves are not considered significant institutions. SSM is a dummy variable that adopts a 1 if observation are in 2014 or later. ECB is a dummy variable that adopts a 1 if the institution is supervised by the ECB after establishment of the SSM. Bank-level controls include the natural logarithm of total assets, the ratio of loan loss reserves to gross loans, the ratio of equity to total assets and the cost to income ratio. Country-level controls include the GDP growth rate and the profit-tax ratio. t-statistics are reported in parentheses. *p<0.1, **p<0.05, *** p <0.01.*

5.4. Further robustness analysis

To confirm that the increase in productivity can be attributed to the establishment of the SSM, two placebo tests have been performed. In these placebo tests, the treatment era has been changed to reflect a year outside of 2014. The internal validity could be questioned in case significant results are obtained for total factor productivity and efficiency change. The rationale is, that one cannot attribute the improvement of the productivity measures to the establishment of the SSM, if significant results are obtained in the placebo regressions. The results of the placebo treatment year 2013 are visible in table 9 and the results of the placebo year 2015 are in table 10. As can be seen, neither of the variables that reported significant results in the main tables, report significant results in either placebo test. Thus, providing more evidence to the narrative that the results can be attributed to the establishment of the SSM.

Table 7
2013 Placebo Regressions

A: Pure Efficiency Change, all institutions under ECB supervision

	(1) Total Factor Productivity	(2) Technical Change	(3) Efficiency Change
ECB*Placebo2013	0.037	0.085**	-0.075
	(0.44)	(2.56)	(-1.20)
R^2	0.255	0.303	0.2855
N	3.090	3.099	3.084

B: Pure Efficiency Change, Non-significant institutions under ECB supervision

	(1) Total Factor Productivity	(2) Technical Change	(3) Efficiency Change
ECB*Placebo2013	-0.021	0.032	-0.082
	(-0.30)	(1.12)	(-1.62)
R^2	0.2518	0.3127	0.2858
N	3.627	3.636	3.621
Firm Controls	Yes	Yes	Yes
Country Controls	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes
Time Fixed Effects	Yes	Yes	Yes
Country Fixed effects	No	No	No

*This table presents the results of a difference-in-difference regression, with the variable of interest being the interaction term of the SSM and ECB dummy variables. The unit of observation are individual banks, with observations clustered on bank-year-country. In panels A and B, the dependent variable is the banks' Malmquist Total Factor Productivity, a relative value that stands in proportion to a common benchmark. This common benchmark was calculated using data envelopment analysis. In panel A, the treatment group consists of all banks under ECB supervision. In panel B, the treatment group contains solely banks under ECB supervision which themselves are not considered significant institutions. SSM is a dummy variable that adopts a 1 if observation are in 2014 or later. ECB is a dummy variable that adopts a 1 if the institution is supervised by the ECB after establishment of the SSM. Bank-level controls include the natural logarithm of total assets, the ratio of loan loss reserves to gross loans, the ratio of equity to total assets and the cost to income ratio. Country-level controls include the GDP growth rate and the profit-tax ratio. t-statistics are reported in parentheses. *p<0.1, **p<0.05, *** p <0.01.*

Table 8
2015 Placebo Regressions

	(1) Total Factor Productivity	(2) Technical Change	(3) Efficiency Change
A: Technological Change, all institutions under ECB supervision			
ECB*Placebo2015	0.019	-0.002	0.046
	(0.58)	(-0.11)	(1.43)
R^2	0.2519	0.3124	0.2856
N	3.627	3.636	3.621
B: Technological Change, Non-significant institutions under ECB supervision			
ECB*Placebo2015	0.043	0.018	0.042
	(0.96)	(0.70)	(0.99)
R^2	0.2554	0.3018	0.2854
N	3.090	3.099	3.084
Firm Controls	Yes	Yes	Yes
Country Controls	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes
Time Fixed Effects	Yes	Yes	Yes
Country Fixed effects	No	No	No

*This table presents the results of a difference-in-difference regression, with the variable of interest being the interaction term of the SSM and ECB dummy variables. The unit of observation are individual banks, with observations clustered on bank-year-country. In panels A and B, the dependent variable is the banks' Malmquist Technical Change, a relative value that stands in proportion to a common benchmark. This common benchmark was calculated using data envelopment analysis. In panel A, the treatment group consists of all banks under ECB supervision. In panel B, the treatment group contains solely banks under ECB supervision which themselves are not considered significant institutions. SSM is a dummy variable that adopts a 1 if observation are in 2014 or later. ECB is a dummy variable that adopts a 1 if the institution is supervised by the ECB after establishment of the SSM. Bank-level controls include the natural logarithm of total assets, the ratio of loan loss reserves to gross loans, the ratio of equity to total assets and the cost to income ratio. Country-level controls include the GDP growth rate and the profit-tax ratio. t-statistics are reported in parentheses. *p<0.1, **p<0.05, *** p <0.01.*

6. Discussion and conclusion

This paper analyses if the establishment of the SSM in 2014 had real implications on the productivity of a significant share of European banks, due to ECB supervision. As a first step towards a European banking union, it was decided that the ECB should replace the national regulator for significant institutions, i.e. banks with total assets over EUR 30 billion, and their subsidiaries. Prior studies (Fiordelisi et al., 2017) (Cerulli et al., 2021) have evidenced that the ECB performs its supervisory responsibilities in a more intrusive manner, compared to the national regulators. Based on the findings from Agarwal et al. (2014), a possible rationalization was identified. Being that national regulators were more lenient, out of a fear that banks might settle in a neighboring country. As the ECB was not restricted by country borders, it could maintain a higher degree of stringency. This was exhibited, among others, by their demanding attitude and active presence at board meetings (Ministry of Finance (Sweden), 2019).

Once the evidence on the increased degree of intrusiveness of the ECB was captured, findings from Mukherjee (2011) initiated an investigation into a possible size bias between the control and the treatment group. To understand the magnitude of this bias, an OLS regression between the total assets and the Malmquist measures was established on the entire data sample. To provide the Malmquist measures, i.e. total factor productivity change, technical change and efficiency change, data envelopment analysis was utilized. The outcome indicated that an additional one billion in assets correlates with an increase in the total factor productivity change measure of 1.28%. Moreover, one could observe that the efficiency change variable also reflected strong significance, with an additional one billion in assets related to an increase in efficiency change of 0,75%. Solely, the technical change variable remained insignificant. The non-randomness nature of the treatment selection provided ample justification for the potential harm that the size bias could cause to the internal validity of any findings. As a consequence, the underlying sample was restricted in a manner similar to the following difference-in-difference regressions. Notably, by excluding the significant institutions from the regressions, the relationship between the total assets and the efficiency change measure became insignificant. Moreover, the total factor productivity did remain significant, although weaker compared to the previous regression. Therefore, no concrete evidence could be found for the expectation that the sample restriction would decrease the bias to a negligible impact. Nevertheless, the outcomes provided the expectation that within the subsequent difference-in-difference regressions, one would still need to take the size bias into consideration

The exogenous nature of the establishment of the SSM provided an opportunity to utilize a difference-in-difference strategy, to identify the impact of ECB supervision on productivity. For the analysis, it was decided to maintain two treatment groups. One baseline treatment group with all banks under ECB supervision, and an additional treatment group where the significant institutions were excluded and solely subsidiaries remained. The control group consisted of the banks that remained under the supervision of their national supervisory authority. Lastly, the sample period within the difference-in-difference regressions was from 2011 until 2017.

The difference-in-difference results showed that an increase in total factor productivity could be identified amongst solely the restricted treatment group. Most notably, I provide evidence that the growth in productivity can almost entirely be attributed to the more efficient allocation of inputs, and not to an increase in the level of technology. In total, the difference-in-difference regressions indicate an 11% higher growth in total factor productivity change in relation to banks under ECB, compared to banks that remained under the supervision of the national legislator. Additionally, I found that 10% out of the total 11% in higher total factor productivity change can be attributed to the more efficient allocation of inputs. This implies a conscious decision from the banks to manage their inputs more prudently, as a consequence of ECB supervision. This resulted in a higher level of efficiency, and ultimately, a higher level of productivity. This aligns with the findings from Agarwal et al. (2014), who highlighted higher efficiency growth among the federally supervised banks, compared to the banks supervised by the state. Additionally, coefficients with larger magnitudes were reported for the restricted treatment group. Indicating that bank size does not drive the coefficient of the productivity measures upwards. The discharge of the size bias can be explained by knowledge spill-over from the parent company to the subsidiary with regard to the efficient allocation of inputs. A consequence of a decrease in agency problems between the parent company and the subsidiaries following ECB supervision. Additionally, the "smaller bank advantage" could explain the reversal of the size effect, as larger banks face more difficulties in adapting to the demands of the new regulator, due to their complex structure.

Policy implications could be derived based on the results presented in this paper. Primarily, the results highlight possible positive externalities of strict supra-national regulators, compared to national regulators. Therefore, the findings can serve as a driver for more regional supervisors globally. Additionally, other major financial sectors within the European Union could benefit from being placed under ECB supervision. For instance, insurance companies, asset managers and brokerage firms. Nevertheless, in general, the results indicate that a more intrusive regulator does not imply a direct negative correlation with a financial system of inferior performance.

A number of limitations in the analysis have had the possibility of composing biased results. Primarily, data of higher frequency would have raised the internal validity of the results. Quarterly data on the European banks was not available from Bankscope prior to 2014. Therefore, it was decided to use the annual data. Furthermore, one could object to the approach of identifying the parallel trend assumption with regard to the total factor productivity variable. Both the efficiency change and the technical change variables showed clear parallel trends. However, the parallel trend assumption could only be satisfied with the assistance of the variable’s mean change within the control period. Lastly, one could protest the Data Envelopment Analysis approach of this paper. DEA uses real observations and calculates a relative measure based on the utilization of inputs to produce the desired outputs. However, one could disagree with the inputs and outputs chosen to construct the DEA measure in my analysis.

As a recommendation for future research, I would suggest researchers to investigate the underlying inputs of the increase in productivity. The results from this paper have provided a general direction of an efficiency increase under ECB supervision. However, it would provide added value if one could identify the input that attributed most to this efficiency increase. Furthermore, little research has yet been performed on the parent-subsidiary dynamic during periods of increased regulatory burden. Significant insights can be gained from the perspective of the parent company, on how knowledge is shared. Moreover, a subsidiary-like perspective can demonstrate, the degree of cost-saving that can be achieved by leveraging on the parent’s knowledge. Lastly, additional research should be performed on intrusive banking regulators. Significant insights can be gained from the identification of different levels of intrusiveness among different banking regulators. Consequently, one could infer if the level of productivity behaves in an inverse U-shape based on the level of intrusiveness, as evidenced by Li et al. (2019) with regards to environmental governance.

7. Appendix

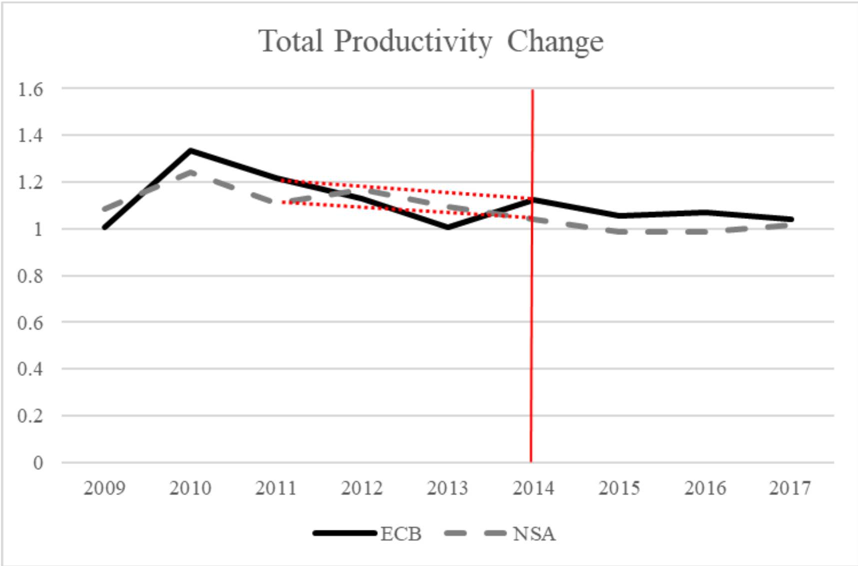

Figure 5

Trend of Total Factor Productivity for non-significant institutions

This figure shows the trend of the Total Factor Productivity variable from 2009 -2017, for institutions that did not satisfy the significant institution requirements. The variable is relative to the previous year, with a value of 1 indicating that there was no improvement. The treatment group is the uninterrupted dark line, named in the legend as ECB. The control group is represented with the dotted line, named in the legend as NSA. The vertical line represents the establishment of the SSM in 2014. The treatment group consists of the unrestricted sample of banks under ECB supervision

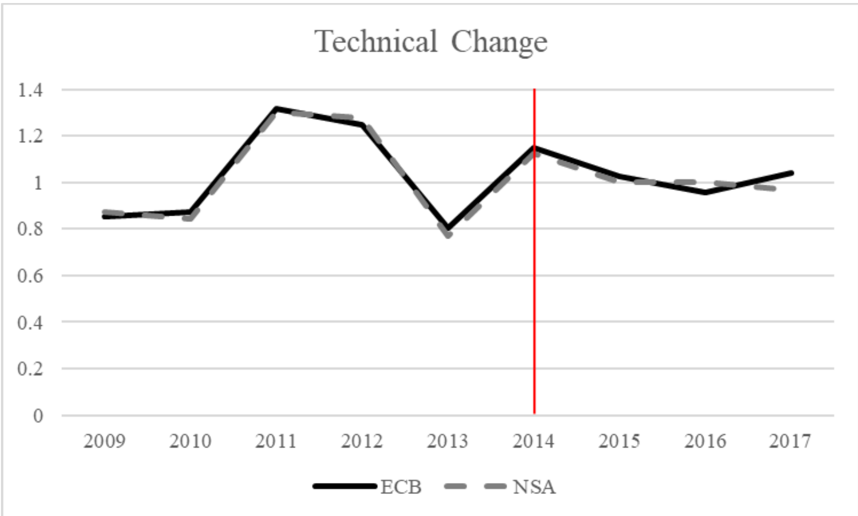

Figure 6

Trend of Efficiency Change for non-significant institutions

This figure shows the trend of the Efficiency Change variable from 2009 -2017, for institutions that did not satisfy the significant institution requirements. This variable is relative to the previous year, with a value of 1 indicating that there was no improvement. The treatment group is the uninterrupted dark line, named in the legend as ECB. The control group is represented with the dotted line, named in the legend as NSA. The vertical line represents the establishment of the SSM in 2014. The treatment group consists of the unrestricted sample of banks under ECB supervision

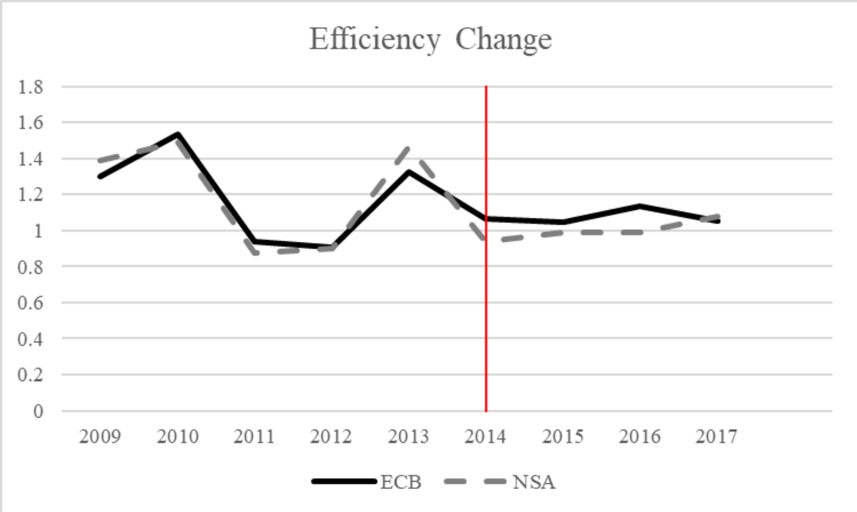

Figure 7
Trend of Efficiency Change for non-significant institutions

This figure shows the trend of the Efficiency Change variable from 2009-2017, for institutions that did not satisfy the significant institution requirements. This variable is relative to the previous year, with a value of 1 indicating that there was no improvement. The treatment group is the uninterrupted dark line, named in the legend as ECB. The control group is represented with the dotted line, named in the legend as NSA. The vertical line represents the establishment of the SSM in 2014.

Table 9
Hausman Tests

A: Total sample of European banks

	(1) Total Factor Productivity	(2) Efficiency Change	(3) Technical Change
Total sample of treatment banks	62.00***	26.66***	41.31***
Restricted sample of treatment banks	66.87***	22.41***	50.51***

This table represents the results of the Hausman test on the tree variables of interest, Total Factor Productivity, Efficiency Change and Technical change, over the 2011-2017 sample period. On both treatment groups, the Hausman test has been performed, comparing the use of random effects with fixed effects. The results indicate strongly towards the use of fixed effects.

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