FACULTY OF ECONOMICS AND BUSINESS ADMINISTRATION

Green Central Banking

The impact of the ECB's green monetary policy announcement on stock returns

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I declare that the research was conducted in accordance with the rules governing scientific and academic integrity. I have read, and acted in accordance with, the Code of Ethics of the Faculty.

Preface

This thesis brings me to the finish line of my master's in Economics. Five years ago, I was looking for a degree that would cover as many of my interests as possible. It has been a ride, and it was not always easy, but to this day, I am grateful for my choice. I do not think there is a discipline that suits me better.

I want to thank my parents for the opportunities and support they have always given me. Thank you for allowing me to go on Erasmus to Geneva, which I consider some of the best months of my life. I am grateful for my sisters, even though I did not get to see them as often as I wish for since I moved to Ghent. It has been amazing to witness their growth into the individuals they are today. Thank you to Frank for proofreading this thesis multiple times with much care, as always. A special thought to Anaïs and Corneel, who I met through this degree and who became some of my closest friends. Valentine and Rosan, who have been my roommates for two years now, you made my last years at UGent finish in the best way possible. Aron, thank you for your love and interest, as always, despite having to write a thesis of your own.

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List of abbreviations

ABPP Asset-Backed Purchase Programme

APP Asset Purchase Programme

AR Abnormal Returns

CAR Cumulative Abnormal Returns

CBPP3 Covered Bond Purchase Programme

CSPP Corporate Sector Purchase Programme

ECB European Central Bank

ESG Environmental, Social and Governance

EU European Union

FED Federal Reserve System

GDP Gross Domestic Product

LTRO Longer-Term Refinancing Operations

MRO Main Refinancing Operations

PBoC People's Bank of China

PEPP Pandemic Emergency Purchase Programme

PSPP Public Sector Purchase Programme

QE Quantitative Easing

TLTRO Targeted Longer-Term Refinancing Operations

UK United Kingdom

US United States

WACI Weighted Average Carbon Index

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Introduction

The primary role of the European Central Bank (ECB) is to maintain price stability in the Eurozone. Its mandate also binds the central bank, in second place, to support the general economic policies of the European Union (EU). Despite this, the ECB is legally independent and thus not allowed to take instructions from EU institutions or any government of one of the Member States. The central bank must abide by the open market economy principle with free competition, per its mandate.

The impact of climate change has sparked a debate among central bankers, regarding the balance between taking action and maintaining impartiality. With the risks posed by global warming to financial stability, this is a complex and pressing matter. The consequences of climate change, such as a rise in natural disasters, pose a significant danger to everyone. On the other hand, efforts to transition towards a sustainable economy could also disrupt financial stability by severely restricting highly-polluting activities. The ECB's responsibility is to account for both types of risk appropriately. While some central bankers advocate for more proactive measures such as greening the asset portfolio or supporting sustainable investments through cheaper credit, others believe that the central bank's role should not exceed accounting for climate risk. They argue that there are alternative ways to combat climate change without resorting to monetary policy and that taking a more involved approach could compromise the ECB's impartiality.

In July 2021, the ECB revealed its *Monetary Policy Strategy Review*, disclosing the foundation of its monetary policy in the years to come. Their latest strategy places a significant emphasis on integrating climate change efforts. Since then, three announcements have been made regarding proactive measures to mitigate climate change rather than purely incorporating the new financial risks. The ECB disclosed on July 4$^{\text{th}}$ 2022 that they would integrate climate considerations into their asset purchase reinvestments and reform their collateral framework, effective October 2022. More details were shared on September 19$^{\text{th}}$ 2022 regarding how the ECB will evaluate a firm's climate performance. On February 2$^{\text{nd}}$ 2023, an additional asset tilt was announced on its reinvestment purchases.

This study examines how European stock market investors perceived and reacted to these three announcements. The policies that have been put into place are a starting point, which implies they serve more as a signal to both investors and companies. While their contribution to climate change may not be substantial on its own, they go beyond mere risk assessment, which may have surprised investors. This makes it crucial to determine how much of an impact the policies had. This paper employs an event study, as modelled by Fama and French (1992), to evaluate the returns on European stock markets to measure the effect of each announcement.

The first part of the research extensively reviews the literature on green central banking. It explores the potential for making the ECB's asset portfolio, collateral framework, longer-term financing operations, and forward guidance more environmentally friendly. The second part discusses sustainable finance more broadly and proposes a framework for better implementation of green central banking. The third chapter examines the literature on stock market reactions, serving as a reference point for the investigation outcomes in chapters four and five. This analysis examines stock returns and delves into the varying impacts of each of the three announcements on green firms compared to brown firms. Another aspect of the analysis looks into the distinctions between firms within and outside the Eurozone to understand the mechanisms behind the obtained results. In chapter six, robustness checks are performed to confirm the validity of the results. Chapters seven and eight include a thorough discussion and conclusion.

1 Green monetary policy

Climate change is one of the biggest challenges of the 21st century. In 2015, The Paris Agreement was signed, which formalised the international coordination to limit the global average temperature increase well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius (United Nations, 2015). In the following years, central governments worldwide implemented policies to support a transition towards a less polluting economy. For example, the European Union (EU) presented their European Green Deal in 2019, planning to decrease greenhouse gas emissions by 55% by 2030 compared to 1990 levels (European Commission, 2019). This so-called *green transition* of the economy needs to be well implemented, as it brings significant risks to carbon-intensive economic sectors and activities. Policies aiming to reduce emissions could increase production costs and decrease profits from firms that rely on non-renewable energy or are highly polluting. In the literature, these risks are referred to as *transition risks* and should be controlled. Still, the green transition is necessary to neutralize the *physical risks* of climate change. These refer to the economic impact of the expected increase in natural hazards, such as production lines being disrupted by storms or floods. According to the IPCC (2023), if the temperature rises by more than 4 degrees Celsius, the decline in global GDP by the end of this century could be greater than the impact of the Global Financial Crisis in 2008. Newell et al. (2021) predict that this could result in a 1% to 3% decrease in global GDP by 2100. However, other models suggest that the impact could be even more severe, up to a 7% decline, if the Greenland Ice Shelf were to melt (Kahn et al., 2019). According to Burke et al. (2015), the outlook is not so positive, as they predict a potential decrease in GDP of up to 23%. The true extent of the impact of climate change on the global GDP remains uncertain, but it will certainly negatively affect matters such as inequality, migration, and public debt. It is therefore essential to consider both types of risks to lessen the potential harm to the global economy (Breckenfelder et al., 2023).

The *transition risks* and the *physical risks* both put financial stability in peril. To determine how climate change could affect the financial sector, the ECB conducted a comprehensive stress test on the Eurozone economy to determine how climate change could affect the financial sector. The physical risks prove to bring huge financial losses from natural hazards. Especially in hard-hit regions, banks face greater expected damages, mainly due to the danger to their physical collaterals. The transition risks, on the other hand, could increase the likelihood of borrowing counterparties, active in high-emitting sectors, to default on their debt (Breckenfelder et al., 2023). The asset prices of the counterparties could be at risk of plummeting and jeopardizing banks' portfolios (Alogoskoufis et al., 2021). The report emphasizes that an early and organized transition towards a sustainable economy would benefit nearly all banks (Breckenfelder et al., 2023). While Eurozone banks face a 1.5% increase in their risk of defaulting until 2030 if a transition to a more sustainable economy is implemented, failure to take action could result in a 7% higher probability of defaulting by 2050 due to the impact

of climate change. In a third scenario, where climate action is taken in an unorderly manner, losses of roughly 8.5 percentage points are expected on the banks' credit portfolios in the euro area. In the event of a smooth and timely implementation of the transition, only 3.5 percentage points in losses are anticipated. Although this is sizeable, it remains manageable (Alogoskoufis et al., 2021).

Gradually, some central banks are adapting their policies to anticipate these economic changes. In 2015, Mark Carney, the Governor of the Bank of England and Chairman of the Financial Stability Board paved the way by holding a speech discussing the importance of including climate-related risks when looking at financial stability. In the following years, many central bankers and financial regulators held related speeches, and research around the greening of monetary policy developed (Campiglio et al., 2018). Proponents of green central banking claim that by not acting, central banks would inadequately fulfil their role as protectors of monetary stability. Others argue that targeted fiscal policies and regulations, such as a carbon tax, are better equipped to combat climate change. They suggest that the ECB should concentrate on its primary objective. Buiter (2021) argues that climate change will cause financial instability, and therefore, the central bank should avoid taking on any further responsibilities. The author explains that using financial stability measures like capital and liquidity requirements to address global warming is as illogical as employing carbon taxes or emissions-trading schemes to target financial stability. Șimandan and Păun (2021) also take on a critical stance. They highlight that there are potential risks involved for central banks when adopting a green framework, including the possibility of politicization, loss of legitimacy and independence, higher inflation, and a reduced countercyclical capacity.

Nearly all discussion concerning green central banking focuses on unconventional monetary tools to support climate change mitigation. The reason for the conventional monetary tools to remain unaddressed is twofold. First, when looking at textbook economics, conventional monetary tools are used to smooth out the cycles in the economy towards its long-term growth path. They are designed to expand or contract the economy, not to differentiate and restructure it. Conventional monetary policy is thus too broad-based to green; if the central bank is trying to boost the economy, it will push towards higher production, causing an even faster decay of the environment (Boneva et al., 2021). The second reason research does not focus on conventional monetary tools is that they have been refrained from working as they should since the Global Financial Crisis in 2008. At the beginning of the economic crisis, financial institutions faced liquidity and solvency threats, leading to market participants not wanting to provide funds to the banking sector. Central banks started to reduce short-term policy interest rates to address the dry spell on the interbank market to prevent the economy's slowdown (Bowdler & Radia, 2012). But interest rates were fast to reach the zero lower bound, and inflation was in peril of undershooting the 2% target for a long time. Thus, central banks started implementing unconventional monetary policy measures (Andrade et al., 2016). The principal tool central banks used within this unconventional toolkit is *quantitative easing* (QE). Through substantial asset pur-

chases, central banks expanded their balance sheet to a large extent, which pumped liquidity into the economy and prevented a deeper recession (Cerclé et al., 2021). The other widely used instruments in unconventional monetary tools include long-term repo operations and forward guidance (Bowdler & Radia, 2012). Figure 1 offers a graphical representation of the monetary tools and the possibility of greening them.

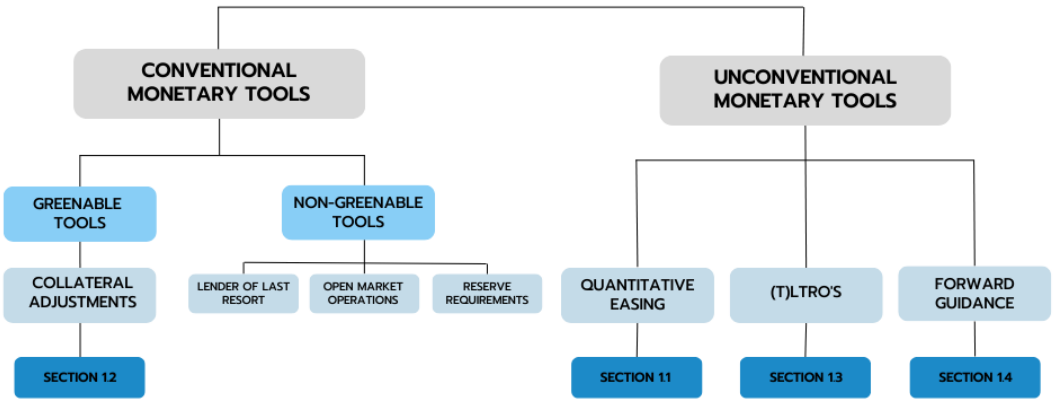


Figure 1: ECB's monetary tools

This research will focus on green monetary policy within the European Central Bank (ECB). The president of the ECB, Christine Lagarde, has raised attention to the necessity of including climate risks when making monetary policy decisions (European Central Bank, 2022d). In July 2021, the ECB presented its latest *Monetary Policy Strategy Review*, introducing climate change into its unconventional monetary policies (European Central Bank, 2021c). Firstly, the ECB has started considering climate criteria in their corporate bond Purchase Programmes, as detailed in section 1.1. Climate risks will also be included when assessing assets mobilised as collateral by borrowing counterparties of the Eurosystem credit operations, further explained in section 1.2. Although it has not been implemented, some experts researched the possibility of green-targeted longer-term refinancing operations (TLTRO) in cooperation with the ECB. Detailed information on these green TLTROs and how they could be set up is available in section 1.3. The last monetary policy tool worth mentioning is forward guidance. With proper communication, the ECB signals the financial world about their priorities for the following years. As explained in section 1.4., these signals affect the real economy and have the power to enable the green transition further.

1.1 Asset Purchase Programmes

1.1.1 APP and PEPP

When the conventional monetary tools were proven insufficient to boost the real economy in the wake of the Great Financial Crisis, the ECB joined other central banks in implementing quantitative easing (European Central Bank, 2015). Over the previous decade, they purchased approximately €5.1 trillion worth of assets, including corporate, government, asset-backed, and covered bonds. These asset purchases more than quadrupled the ECB's balance sheet and pumped liquidity in the real economy (European Central Bank, 2023d). What follows is an overview of the two extensive Purchase Programmes of the ECB since 2014; the Asset Purchase Programme (APP) and the Pandemic Emergency Purchase Programme (PEPP). These two programmes represent about 75% of the ECB's current portfolio. Changing their composition is often referred to in the literature as the primary way the ECB could improve the green transition, which is why it is crucial for further understanding of this paper to understand their configuration.

1. In October 2014, the ECB announced its Asset Purchase Program (APP) (European Central Bank, 2023e). The APP consists of four different bond Purchase Programmes listed below - the Corporate Sector Purchase Programme (CSPP), the Public Sector Purchase Programme (PSPP), the Asset-backed Purchase Programme (ABSPP) and the Covered Bond Purchase Programme (CBPP3). All four bond Purchase Programmes ran until the end of 2018. Throughout 2019, the ECB decided to only reinvest the payments from maturing securities from their portfolio. At the end of 2019, they restarted the Purchase Programmes and kept them on until June 2022. In June 2022, the ECB recently decided to slow down and once again only reinvest the principal payments from maturing securities. In February 2023, the APP accumulated to a total purchased amount of €3.4 trillion. That month, the ECB announced the decrease of their APP portfolio by €15 billion per month from March to June 2023 because of the persisting inflation. This decision will be fully elaborated in section 1.1.2. (European Central Bank, 2023d).

   The first part of the APP is the Public Sector Purchase Programme (PSPP), launched in 2015. It was aimed to reduce market differentiation between countries which refrained the price mechanisms from working correctly (European Central Bank, 2023a). The bonds represent about 80% of the ECB's asset portfolio (Schoenmaker, 2021). The included bonds are nominal and inflation-linked central government bonds and bonds issued by recognised agencies, regional and local governments, international organisations and multilateral development banks in the euro area. The second part, the Corporate Sector Purchase Programme (CSPP), started in June 2016, allowing six national central banks in the Eurozone to purchase corporate bonds. Currently, about 7% of the ECB's asset holdings are corporate bonds (Schoenmaker, 2021). Through these purchases, the ECB decreased the price of credit to firms eligible under the programme. Thus, commercial

banks made fewer profits from their loans. Consequently, they became more willing to lend to SMEs, which boosted the economy (Grosse-Rueschkamp, 2019). This means the ECB did not only influence firms eligible under the programme but was also able to decrease the price of credit to non-eligible firms as investors looked for alternative investments. Lastly, the APP includes the Covered Bond Purchase 3 (CBPP3) and the Asset-Backed Securities Purchase Programme (ABSPP). Both were based on pre-existing Purchase Programmes (Gambetti & Musso, 2017). In 2019, the covered bonds represented about 10% of the portfolio's assets, and the asset-backed securities only constituted about 1% of the ECB's assets (Schoenmaker, 2021).

2. In 2020, massive disruptions occurred globally because of the COVID-19 pandemic and the subsequent lockdowns. The resulting economic shock required additional liquidity pumps from the ECB to ensure price stability. In March 2020, they announced another purchase program, the Pandemic Emergency Purchase Programme (PEPP). The eligible bonds were almost identical to the ones from the previous APP. The PEPP was maintained until March 2022 and totalled €1.7 trillion (Böninghausen et al., 2023).

1.1.2 Purchase Programmes as a tool for the green transition

One way the ECB could support the green transition is by holding a significantly higher share of green bonds in its portfolio. Bhutta et al. (2022) define green bonds as a financial instrument used to finance environmentally friendly projects. When issuing this type of bond, a firm uses its proceeds to finance sustainable investments. The European Commission has recently, in March 2023, reached an agreement to set a universal standard for green bonds (European Commission, 2023). Every issuer of an EU Green Bond will need to ensure that at least 85% of the raised funds through the issued bonds are used for sustainable activities[1], as specified in the EU Taxonomy. Thus far, entities could claim their bonds were green but were not held accountable if they did not use the raised capital for sustainable activities. Although the policy is not entirely in place yet, soon enough, firms will have to meet specific, voluntary criteria to obtain the label of an EU Green Bond (European Commission, 2023). Once this framework is implemented, it will make it easier for investment entities to ensure that their funds are being directed towards sustainable companies.

[1]The EU Taxonomy established six environmental objectives; climate change mitigation, climate change adaptation, the sustainable use and protection of water and marine resources, the transition to a circular economy, pollution prevention and control, the protection and restoration of biodiversity and ecosystems. To be declared sustainable, an economic activity has to support at least one of the objectives without causing significant harm to any other objective. Electricity generation from wind power is an example of an eligible activity, but a full list is still in the works (European Commission, 2023).

According to current research, the ECB does not prioritize the green bond market when making asset purchase decisions. In fact, until recently, did not take any sustainability criteria into account and instead prioritized other risk factors over climate change. Cojoianu et al. (2020) show that a bond of an energy company located in the Eurozone is more likely to be purchased as a part of the ECB's programme if the firm's greenhouse gas intensity is higher. In 2021, Isabel Schnabel, a board member of the ECB, held a speech urging the ECB to step away from their *market neutrality* principle (European Central Bank, 2021b). This idea poses that if green bonds represent x percentage of the bond market, the ECB can at most hold the same x percentage of green bonds in their portfolio (Demary & Hüther, 2020). But Schnabel disagrees as she thinks that the ECB has thus far pushed more carbon-intensive sectors and is falsely claiming they are acting as a neutral financial supervisor. She moves forward with the idea of what she calls *market efficiency*. This new way of examining monetary policy acknowledges market failures, such as omitted climate risk and negative externalities. Despite her statements, 11.9% of the ECB's current corporate bond holdings were issued by fossil fuel companies, which are the most polluting and are responsible for merely 1.1% of the gross added value in the EU, as shown in table 1. As they represent 7.8% of the overall Eurozone corporate bond market, they are thus over-represented in the asset holdings of the ECB. Dafermos et al. (2022) refer to this phenomenon as the *QE's carbon bias*. Of the assets purchased within the CSPP, 62.7% were bought from firms active in the highest polluting sector. As shown in table 1, the authors identified four carbon-intensive sectors; the fossil-fuel sector, energy-intensive sectors (most of which undertake manufacturing activities), the non-renewables sector involved in the production and distribution of electricity and carbon-intensive transportation sectors that are engaging in activities related to cars, air and sea transport (Dafermos et al., 2020). Combined, these sectors make up 45.5% of the Eurozone bond market and contribute 29.1% to the Eurozone's gross added value. As such, they are over-represented in the ECB's portfolio. Only 7% of the assets acquired through the CSPP align with climate objectives, which include green bonds and bonds purchased from companies involved in the railway industry (Jourdan & Kalinowski, 2019).

	All euro non-bank corporate bonds (%)	ECB list of bonds (%)	Share of euro area gross added value (%)
Fossil fuel	7.8	11.9	1.1
Energy-intensive	15.8	17.3	13.5
Non-renewable utilities	7.3	14.5	2
Carbon-intensive transportation	14.5	18.9	12.6
Carbon-intensive sectors	45.5	62.7	29.1

Table 1: Presence of carbon-intensive sectors in the asset portfolio of the ECB

Source: Dafermos et al (2020)

According to a study by Jourdan and Kalinowski (2019), bonds from companies involved in the fossil fuel, car manufacturing, and energy-intensive sectors will remain a significant part of the ECB's portfolios for the next decade due to their longer maturities. On the other hand, green bonds, defined by Bhutta (2022) as bonds that fund environmentally friendly projects, have shorter maturities compared to the average. This again proves that the ECB's asset holdings exhibit a carbon bias, which not only fuels climate change but also poses a potential risk to the Eurosystem. According to Senni et al. (2022), the ECB currently holds assets that fail to meet its own risk standards due to the absence of climate risk considerations in its purchase decisions. A credit rating analysis was conducted in 2018 on 73% of the assets in the CSPP portfolio (Monin, 2018). The results revealed that certain companies are more susceptible to default due to the impact of climate change on both transition and physical risks. This is concerning as the ECB continues to hold onto these assets without proper risk evaluation, which could pose a significant danger when climate change risks become more apparent.

De Santis et al. (2018) show that by purchasing green bonds, as defined by Buttha (2021), central banks could influence the market in two ways. On the one hand, a green bonds purchase programme could increase firms' issued green bonds. Hilmi et al. (2022) argue consistently, *"Although corporate bonds represent around 7% of total ECB asset holdings, these purchases could render climate-friendly if the ECB chooses to fund investments that help the transition to low fuel production methods."* The researchers found a positive impact between their measure of liquidity and the total volume of green bonds. They did not quantify the effect, but the positive sign implies that increased liquidity through quantitative easing could expand the number of issued green bonds. At first, asset purchases only impact the monetary base. Only when the effect of the asset purchases is felt in the real economy and the amount of credit grows in the green sector, will the amount of issued green bonds increase. Hence, by launching a greener purchase programme, the ECB would increase the number of issued green bonds. Such an increase is significant as it directly impacts corporate emission levels. Fatica and Panzica (2021) found that non-financial companies issuing green bonds decreased their carbon emissions following the issuance. This shows that if the Purchase Programmes were to aim for greener bonds and therefore push firms to issue more green bonds, the ECB would assist companies to decrease their emissions. The second way the Purchase Programmes influence the bond market is by swaying the yields of the eligible bonds under the purchase programme (De Santis, 2018). When there is a higher demand for a bond, its price increases, resulting in a decrease in the bond's yield[2].Accordingly, the firm that issued the bond will now have access to cheaper funding, as newly issued bonds by this

[2]

$$\text{current yield} = \frac{\text{annual coupon}}{\text{bond's market price}}$$

This equation shows the negative relationship between a bond's market price and yield. Suppose your US Treasury bond with \$1000 face value and 4% coupon rate gets corporate emissions would decrease old for \$800. The current yield would be $\frac{40}{800} = 5\%$. As it got sold under the face value, the bond was undervalued. If the bond is overvalued and sold for \$1200, the current yield would be $\frac{40}{1200} = 3.33\%$. This example clarifies that a drop in the current bond yield is good for the bond owner, as the bond is more sought after and will render more profit.

firm will be in higher demand and will therefore be sold faster. Bremus et al. (2021) show that bonds eligible under ECB Purchase Programmes enjoy a reduction in yield compared to non-eligible bonds. The authors analysed the effect of the CSPP and the PEPP on eligible green bonds compared to non-eligible green bonds. Their results show that the CSPP decreased the yields of the eligible green bonds on average between 18 and 33 basis points compared to the non-eligible green bonds. Thus, after the CSPP, the green bonds eligible under the purchase programme were more sought after. A bond owner selling an eligible green bond will profit more than a non-eligible green bond. It was discovered that the PEPP had a similar outcome, but its effect varied across various categories of green bonds. The program led to a greater yield spread of 135 basis points between qualifying green bonds and non-qualifying green corporate bonds, while only causing a 15 basis points yield decrease on Swedish crown-issued bonds. It had minimal impact on green bonds issued by financial institutions in the Eurozone. Nonetheless, these results demonstrate that the purchase programs successfully enhanced financing terms for eligible asset issuers. If climate criteria were to be considered for eligibility, the Purchase Programs could further improve the financial conditions of environmentally friendly businesses and ultimately boost the economy's sustainability.

1.1.3 Monetary tightening, asset purchases and the green transition

Because of the continuous high inflation, the ECB announced in February 2023 that they would reduce their asset portfolio by €15 billion per month between March and June 2023 (Eurostat (2023) and European Central Bank (2023c)). After a period of monetary expansion since 2008, we currently experience a period of monetary tightening (European Central Bank, 2023b). It is, therefore, not helpful to dwell on the idea of a climate-related quantitative easing scheme shortly, as additional bond purchases would pump even more liquidity into the economy and create further inflation. Thus, the relevant future policy around asset purchases and climate change concerns asset tilting. An asset tilt means overweighting the value of assets of certain firms in the central bank's asset holdings, in this case, based on climate criteria. Bonds from the most carbon-intensive firms will, in turn, be underweighted (Schoenmaker, 2021).

The ECB announced the decarbonization of its portfolio on July 4$^{\text{th}}$ 2022 (European Central Bank, 2022a). This is equivalent to an asset tilt based on carbon criteria. Carbon-intensive firms will be less eligible for purchase than more carbon-neutral firms. This is done by assigning a climate score to each eligible firm in the CSPP and PEPP universe. The climate score is measured on three dimensions; the current level of emissions of the firm[3], the future climate targets of the firm and the quality of the disclosed climate-related information. These three sub-scores are then aggregated towards an overall climate performance (European Central Bank, 2022b). Firms with a better climate score will represent

[3]The emission sub-score evaluates the issuer's scope 1 and 2 emissions, along with the sectoral level scope 3 emissions. It uses the best-in-class method to compare the firm with its peers in the same sector while also assessing its emissions across the entire corporate universe.

a more significant share of the ECB's purchased assets. The ECB did a first analysis of this policy and reported that the asset tilting framework reduced the Weighted Average Carbon Intensity (WACI) by 65% for the purchase flows executed in the last quarter of 2022 compared to the first nine months of that year. The calculation of WACI involves assigning weights to the carbon intensity score of each issuer based on their share of holdings in the portfolio. This metric determines how much a portfolio is exposed to an issuer's carbon intensity and can act as an indicator of the portfolio's vulnerability to climate transition risks. Their report also shows that the carbon intensity, carbon footprint and total carbon emissions decreased between 2018 and 2022 for corporate bond holdings. However, the carbon emissions over the whole portfolio nearly doubled. The ECB notes that this is merely a result of the increase in purchased securities because of the pandemic (European Central Bank, 2023f). Critics believe the ECB is moving too slowly to be on track with the 1.5°C warming scenario. Phillips (2023) states that the rate at which the portfolio reduces carbon intensity is slowing down instead of accelerating. Dafermos et al. (2022) also call the current asset tilting scheme unambitious. The policy that the ECB recently announced only applies the climate criteria when reinvesting the amounts of maturing corporate bonds. Thus, out of their €350 billion corporate bond holdings, only €30 billion will be reinvested annually. In other words, only 10% of the ECB's portfolio of corporate bonds will go through an asset tilt each year (Dafermos et al., 2022). Corporate bonds only represent 7% of the full ECB's portfolio, so their decision represents less than 1% of their total asset holdings (Schoenmaker, 2022). Dafermos et al. (2022) therefore believe the asset tilt should be applied to the whole portfolio, not merely to the reinvestments. In that scenario, bonds of carbon-intensive firms would be sold and replaced with bonds of less polluting firms.

Dafermos et al. (2018) already explored the idea of an asset tilt of the whole portfolio. The authors warned that their starting point was very optimistic about green investment responsiveness. However, they found a temperature decrease of 0.5 degrees Celsius by 2100 compared to a counterfactual scenario without an asset tilt. This is a significant difference, but the policy would not be sufficient to reverse climate change fully. It could, however, be in complementary use with other climate policies. Dafermos et al. (2018), therefore, argue that asset tilting should be part of the central banks' toolkit towards a greener economy. Schoenmaker (2021) also looked at the results of an asset tilt on the whole portfolio of the ECB. He decomposes the ECB's portfolio; only 18.5% of the portfolio would be applicable for an asset tilt, as the remaining 80% of the bond holdings are government bonds. Schoenmaker (2021) argues that an asset tilt on the collateral system would be more effective as this framework allows way more asset holdings to be tilted and would have a more significant impact. The technicalities of collateral asset tilting will be further discussed in section 1.2. However, it is essential to note that some countries have issued green government bonds since 2017 to finance public sustainability projects. Thus, it is not ruled out to perform an asset tilt on their public sector bond holdings, contrary to what Schoenmaker (2021) suggests (De Santis et al., 2018).

Overall, the estimations of the impact of a hypothetical full asset tilt vary. Ferrari & Nispi Landi (2023) argue that an asset tilt could help reduce emissions. The authors explore a hypothetical scenario where a central bank tilts its assets and look at its effect on two sectors; a green sector that does not and a brown sector that does pollute. While only having a limited impact on the stock of pollution, they find the asset tilt could effectively reduce emissions. Ultimately, they plead for central banks to act strongly early in the green transition for a shorter period rather than purchasing green bonds at a slower rate over a more extended period. Abiry et al. (2022) disagree. When analyzing the effects of a hypothetical asset tilt directly on climate change, they only report a slight reduction in temperature. They state that even if a central bank replaced all the assets in their portfolio towards green bonds, it would save us a 0.04 degrees Celsius rise by 2100. Compared to a well-implemented carbon tax by the government, this temperature decrease is four times less effective.

The varying results make it difficult to quantify the effects of an asset tilt. It makes sense that the findings are diverse, as a full climate-related asset tilt has never been implemented, and all research is based on hypotheses. Researchers agree that by buying more green bonds or bonds from less carbon-intensive firms, central banks could stimulate firms to issue more green bonds or pay more attention to their climate impact, as this would impact the firm's financial conditions. The effect of the holdings of central banks on the bond market and how much the issuance of green bonds affects the behaviour of the issuing firm is debatable. Although most studies show a positive effect of green bonds on a firm's climate performance, the quantitative impact is still under discussion. Consequently, it is almost impossible to extrapolate these findings to the entire Eurozone. Let alone accurately estimating how strongly an asset tilt would push firms to be greener and to which extent this would directly impact the environment. What can be concluded is that the central bank's Purchase Programmes improve the financial conditions of the firms issuing the eligible bonds under the programme. Researchers believe this motivates firms to adapt their behaviour toward the eligibility criteria.

1.2 Collateral adjustments

Another way central banks can support the transition towards a greener economy is by adjusting collateral requirements. Collaterals are a conventional tool of central banks' monetary policy. National and commercial banks lend from the central bank against specific collateral, shielding the central bank against financial damage if the borrowing bank cannot pay back its debt. Usually, these collaterals are financial securities, such as bonds or other financial assets. Central banks then apply what is called a haircut on each asset used as collateral.[4] As of now, these collaterals are primarily based on credit risk and loan duration, but literature is increasingly arguing in favour of including climate risks in the central bank's assessment too.

[4]When a financial asset is posted as collateral, for example, with a market value of €10 million and the ECB assigns a 5% haircut, the borrowing bank only receives a loan of €9.5 million even though their collateral was worth more. In other words, the higher the ECB sets the haircut, the lesser a bank's access to funding.

The current ECB framework does the opposite. Many carbon-intensive companies receive implicit subsidies because climate risk is not considered. This can be seen in the table 2, which shows that 59% of the bonds accepted by the ECB as collateral are issued by carbon-intensive entities. However, these companies only account for 24% of EU employment and 29% of the EU's gross added value, making this disproportionate. Similarly to the last section, the carbon-intensive sectors are defined as fossil fuel, energy-intensive, non-renewable utilities, and carbon-intensive transportation. From the same study, it is apparent that four large fossil fuel companies even rely on more than half of their financing on bonds that the ECB subsidizes through its collateral framework.

	All euro non-bank corporate bonds	ECB list of eligible bonds as collateral	Share of euro area gross added value
Carbon-intensive sectors	45.5%	59%	29%

Table 2: Presence of carbon-intensive sectors in the collateral framework of the ECB
Source: Dafermos et al (2021)

Not only do the eligibility criteria exhibit a bias towards carbon, but the applied haircuts also show a similar trend. Table 3 highlights that the average haircut in carbon-intensive sectors is 11.99%, considerably lower than the average in non-carbon-intensive sectors, which is 13.93%. It's worth noting that the applied haircut is influenced by the credit rating of the issuing entity, the repayment timeframe, and its interest rate. However, the lack of consideration of climate criteria by the ECB tends to result in an overly optimistic credit rating for carbon-intensive firms. This sends a signal to financial markets that dirty assets are less risky. Consequently, the financial conditions of carbon-intensive sectors are better than those of clean ones (Dafermos et al., 2021).

	Average haircut
Fossil fuel	13.33%
Energy-intensive	11.03%
Non-renewable utilities	13.36%
Carbon-intensive transportation	10.27%
Carbon-intensive sectors	11.99%
Non-carbon-intensive sectors	13.93%

Table 3: Average haircut in the ECB's collateral framework
Source: Dafermos et al (2021)

Dafermos et al. (2021) looked at solutions to reverse the carbon bias. Only changing the haircuts seems insufficient to change the carbon intensity of the collateral list. To make a significant difference, the eligibility criteria must also be revisited by replacing dirty bonds with greener bonds. As mentioned earlier, Schoenmaker (2021) also favours this measure. He carried out a hypothetical extra haircut applied on collaterals at 0.1 for medium-carbon assets and 0.2 for high-carbon assets. This in combination with an asset tilt of the asset purchase portfolio would reduce the carbon emissions in ECB's portfolio by 55%. In line with these findings, the ECB pledged in July 2022 to include climate risks in their collateral framework and thus counteract the existing carbon bias (Dafermos, 2022). In their announcement, they state they will exclude eligible high-emitting firms to be used as collateral before 2024. By the end of 2023, they will include climate risks in their assessment for the haircut they impose on each lending (European Central Bank, 2022a).

It is interesting to examine the effects of a climate-related reform of the collateral system taken by the People's Bank of China (PBoC) in 2018 (Macaire & Naef, 2021). The PBoC decided to expand the type of assets eligible as collateral by including green bonds and giving them preferential treatment over other financial assets. Macaire & Naef (2021) compared the yields of green bonds, that became eligible as collateral following this decision, to non-green bonds with similar characteristics from the same firm. They found that the PBoC's measure increased the yield spread between similar green and non-green bonds from 32 to 46 basis points in favour of the green bonds. Other research, although unrelated to climate change, also finds that the eligibility of an asset as collateral by the ECB decreases the yield of the eligible bonds. Mésonnier et al. (2022) analyzed an unexpected extension of the ECB's eligible collaterals in 2012 and its effect on corporate loans in France. Their results show the policy resulted in a yield spread of 7 basis points when comparing eligible bonds to non-eligible bonds. A Chinese study (Chen et al., 2019) looks at the opposite policy: excluding certain bonds as collateral. In 2014, AA+ and AA bonds were prohibited from being used as collateral from the PBoC's repurchase agreements. The yields of the excluded bonds increased on average between 40 and 83 basis points. This research proves a reform of the collateral framework could support the green transition. Depending on the level of haircuts and which bonds are eligible, the central banks directly influence the credit flow of each borrowing entity.

1.3 Green TLTRO

As part of their unconventional monetary policy package in 2014, the ECB introduced targeted longer-term refinancing operations (TLTRO). These were launched next to the long-existing primary refinancing operations (MRO) and longer-term refinancing operations (LTRO). The MRO and LTRO, with maturities of respectively one week and three months, are the primary credit that banks can get from the ECB. Its interest rate fluctuated somewhere between the interbank rate and the ECB's overnight loans in case of emergency. As the interbank market was running dry, the transmission of their conventional policies towards the real economy was broken, and inflation was still way below its target, the ECB launched the TLTRO programme to provide more advantageous funding to the banking sector. The TLTROs were the cheapest credit banks could find, but the budget could only be used to provide direct credit to firms and households. It worked and incited the banks to lend more to the rest of the economy (van 't Klooster, 2021). The last programme, TLTRO III, ran between June 2020 and June 2022 following the COVID-19 pandemic (European Central Bank, 2022e).

According to a recent study by Alogoskoufis et al. (2021), many banks do not have a framework to consider the EU's climate agenda when making lending decisions. This means that the LTRO program may not be adequately funding companies focused on environmentally-friendly initiatives, while those investing in non-sustainable projects are receiving more support. The same issue applies to the now-concluded TLTROs, which did not consider a bank's level of "greenness". Non-financial corporations and non-mortgage loans were eligible for these loans, with exceptionally low-interest rates of up to -1%. van 't Klooster (2022) believes the ECB needs to target particular sectors and markets: *"By setting the cost of investment, unavoidably it has a profound impact on the long-term orientation of economic development"*. In this context, van 't Klooster (2021) studied the possibilities of a "*Green TLTRO*". He believes central banks could have stimulated a green recovery following the pandemic by targeting green bank loans through this channel. The author argues the TLTROs were the monetary tool with the most direct impact on the real economy.

Recently, van 't Klooster (2022) has reworked his proposal now that inflation is brewing. The TLTROs were designed to boost inflation through very cheap consumer credit, which increased spending on manufactured goods. Therefore, in the current inflationary economy, the ECB has decided, as of November 2022, to index the interest rates of the TLTRO operation to the average applicable ECB interest rate until the maturity date (European Central Bank, 2022c). Schnabl (2023) suggests that a more differentiated investment tool, such as the Green TLTRO proposed by van 't Klooster (2022), could still be beneficial. Under this approach, banks would continue to borrow from the ECB at regular LTRO rates. At the same time, a Green TLTRO would be introduced to provide discounted interest payments for banks adhering to the EU's Green Taxonomy. In this framework, the interest rates of the TLTROs would be based on the percentage of loans from the borrowing bank that comply with the EU

Taxonomy. The Taxonomy classification system lists environmentally sustainable economic activities (European Union, 2020). If the borrowing bank has a lot of loans complying with the Taxonomy, they could receive a lower interest rate on their loan from the central bank. Whether a loan complies with the Green Taxonomy is not set in stone yet, but it will soon be legally required by banks to provide enough climate-related information to do so. Therefore, once the Green Taxonomy and its regulations are completed, implementing and communicating differentiated interest rates for the TLTRO will be easy. van 't Klooster (2022) compares the still-existing LTRO program to a new green TLTRO. The main difference is that a green TLTRO would allow differentiated long-term investment, while the LTROs only serve as a way to reach the inflation target without differentiation. The TLTRO could, therefore, still be helpful, as a transition towards a green economy is financed through longer-term investment. Although we find ourselves in a period of high inflation, the author believes cheap and differentiated longer-term credit remains necessary for investments. Unlike the ECB's Purchase Programs and collateral adjustments, there are currently no plans to relaunch the TLTRO to support environmentally-friendly projects.

1.4 Forward guidance

A last way of using monetary policy tools to steer the green transition is by using proper communication to direct the financial markets. Although it might not be the monetary tool with the most substantial impact, it is widely accepted and implemented in the central bank's policies (Șimandan et al., 2023). Central banks communicate their forecasts and influence future market expectations and current market behaviour. There are many examples of central banks using this tool for topics unrelated to climate change, especially following the Great Financial Crisis in 2008. One of them is a statement of the ECB in July 2013; *"The Governing Council expects the key ECB interest rates to remain at present or lower levels for an extended period."* By using *for an extended period*, the ECB changed the expectations of financial actors. The goal is for banks to lower their interest rates too when lending to the real economy, as they believe they can borrow at a cheaper rate from the ECB for an extended period (Praet, 2013). This precedent shows what could be possible for green financial markets.

Christine Lagarde, the current President of the ECB, has added a green touch to the communication of the ECB. Since her inauguration as President, ecology has been central to her speeches. Following the COVID-19 pandemic, the ECB started advocating for a green recovery under the slogan "Never waste a crisis". They argued that releasing funds required by the pandemic was an opportunity to fund green technology (Șimandan et al., 2023). Boneva et al. (2022) mention that climate communication could encounter criticism, as the urge for greener policies could be perceived as a way to gain more power. Some critics feel that communication on ecology removes the ECB from its primary financial stability mandate. Preunkert (2022) finds that 12% of economists over 33 surveyed central banks believe climate change is only a political challenge. This is because the ECB's mandate states it should

primarily focus on price stability and only secondarily support the EU's agenda. But Ehrmann et al. (2023) tested through a survey that climate change considerations and communications do not affect the credibility of the inflation objective, neither positively nor negatively. This would mean that the central bankers thinking the ECB is drifting away from their neutrality at the stake of price stability, are unnecessarily worried. Research even shows that we could benefit from more transparent climate change communication. Annicchiarico et al. (2021) find that reducing uncertainties in climate policy can ensure better climate action. Uncertain economic agents form uncertain expectations and add extra difficulty in implementing climate policies, as it increases risks regarding financial stability.

An increase in climate-related communication impacts green financial markets positively. In July 2021, the ECB presented their latest *Monetary Policy Strategy Review* that introduced climate change into its monetary policies. It was anticipated that the central bank would mention climate change, but it was unexpected that it would be one of the major themes of the announcement. The new strategy sent a signal to the rest of the economy (European Central Bank, 2021c). Eliet-Doillet & Maino (2022) analyzed the effect of this message on the green bonds market. On the demand side for green bonds, the authors found a significant decrease of 4 basis points in the Yield-to-Maturities of the green bonds that are eligible for the ECB's Purchase Programmes compared to conventional bonds that are eligible for the Purchase Programmes. As this effect is up to one-fourth of the impact of the yields of eligible bonds when the CSPP was announced, it can be considered sizable. Additionally, Eliet-Doillet & Maino found that the stock of green firms experienced a positive shock following the ECB announcement. They found that, on average, stocks from the 25% greenest firms of their analyzed sample enjoyed an average 0.8% excess return around the announcement days. When looking at the effect on the supply side of the green bond market, they found that issuers in the Eurozone increased their issuance of green bonds after the ECB's signal, compared to issuers elsewhere. Overall the paper sees positive effects when considering only the announcement's impact before actual policy changes were even made. This shows the importance of forward guidance and the power of central bank announcements on the green financial markets.

2 Sustainable finance and greenwashing

In 2022, the green bond market was worth more than €2.2 trillion, merely 15 years after the launch of the first green bond. Its success proves that a significant part of the financial world is considering climate change when investing (Sertore, 2023). Investors are willing to receive lower returns if their investment is positive for the environment (Baldi & Pandimiglio, 2022). But as sustainable finance spreads like wildfire, it is important to develop a common framework to prevent corporations from jumping on the green bandwagon without further obligations. This phenomenon is defined as *greenwashing:"The intersection of two firm behaviours: poor environmental performance and positive communication about environmental performance"* (Delmas & Burbano, 2011). One example is that out of the twenty largest corporate green bond issuers in the Eurozone, only eleven kept reporting targets and measures to quantify the impact of their issued bonds. This proves the disconnect between actual climate goals and green bond financing (Tukhanen & Vulturius, 2022). As green monetary policy evolves, it is important for the financial world to agree on measurements of sustainable economic activities and definitions of climate risks. Without a clear framework, the central bank cannot guide investors and corporations towards sustainable practices. It is also important to have proper benchmarks and controls in place to ensure that companies make tangible changes in their operations and that funds from green bonds are allocated towards sustainable activities. Simply increasing the ECB's purchase of sustainable assets or green bonds will not have a significant impact unless these factors are addressed.

Currently, the most prevalent way of assessing the sustainability of a firm is through Environmental, Social and Governance scores (ESG). These are scores provided by rating agencies based on each firm's economic performance in the three mentioned categories. Although various rating methods exist, most ESG scores should be seen as a risk measurement of a firm rather than a climate performance rating. Similarly to traditional credit rating, a firm enjoys positive stock market returns when it gets a better rating (Kumar et al. (2021), Chen & Xie (2022)). Many researchers have brought up the fact that there is wide heterogeneity in these ESG scores, as each agency uses its own framework. Gibson Brandon et al. (2021) find that ESG scores of the same company by different rating agencies correlate with 44.7%, compared to credit risk ratings that are correlated with 99%. Berg et al. (2021) raise three reasons to justify this divergence. First, the fact that each agency uses different categories to assess ESG performance. Second, the measurement divergence between agencies, which refers to the fact that the agencies are free to use different measures to calculate the sub-scores. Lastly, each agency weighs the sub-scores to their best knowledge to reach an aggregated score, which can add to the heterogeneity of the ESG scores. Some, for example, foreground climate disclosure. As more profitable firms can afford such research and reporting within their company, this focus on disclosure leads to a bias in the scores in favour of bigger firms (Dimson et al. (2020), Dorfleitner et al. (2015), Drempetic et al. (2020)). To limit such bias in ESG scores, a clear framework is necessary to assess a

firm's climate risk and performance. If this is not done in the right manner, risks of greenwashing may even rise as firms are trapped in a context of great focus on decarbonization without much follow-up assessment (Dafermos et al., 2021).

Dafermos et al. (2021) pleaded for the financial sector to shift its focus to a more proactive approach. Instead of focusing on a corporation's level of disclosure and climate risks, measurable climate alignment criteria should be the backbone of sustainable finance. They stated that disclosure, although necessary, will not solve climate change alone. The EU started in 2020 to set up a framework to legitimise sustainable activities, the EU Taxonomy. Significant financial and non-financial companies must disclose to what extent their economic activity meets the set criteria. This implies that a sustainable company has to contribute to one of the six objectives of the framework — climate change mitigation, climate change adaptation, sustainable use and protection of water and marine resources, transition to a circular economy, pollution prevention and control and protection or restoration of biodiversity and ecosystems. The economic activity in which the firm is active is also required to cause no significant harm to any of the other objectives. Additionally, each firm gets inspected on minimum safeguarding of human rights and undergoes a technical screening by an expert group (Envoria, n.d.). Smaller firms can voluntarily disclose their information to be recognised by the Taxonomy framework. This framework will, for example, be used in the previously explained EU Green Bond Standard (European Commission, 2023). As soon as the framework setup progresses, the ECB may consider incorporating the EU taxonomy into its climate assessments.

An important point has been raised here— the difference between the climate risks and the performance regarding climate mitigation of a firm. This is a thin line between which the ECB's green monetary policy balances. Its primary mandate is to sustain financial stability, which implies the importance of adequately assessing climate risk in the Eurozone's financial sector. These policies, such as stress tests, complement the idea of market neutrality, where the ECB ensures that its operations do not lead to preferential treatment of certain asset classes. Opponents of green monetary policy often present market neutrality as a legal obligation of the central bank (Jourdan & Del Vasto, 2021). However, the ECB has confirmed that there is no such principle in EU law (European Central Bank, 2021a), and Lagarde wrote to a member of the European Parliament that this solely stems from the principle of an open market economy with free competition (European Central Bank, 2019). Additionally, as noted in section 1, the ECB, in its nature, is not entirely neutral as it always intervenes to influence market outcomes (Jourdan & Del Vasto, 2021). The evidence from the literature in section 1 exhibits the carbon bias of the Purchase Programmes, for example. The recently implemented policies of the ECB, as announced on September 19th, introduce backwards-looking emission levels and forward-looking criteria on top of their assessment of climate disclosure in the reinvestments of their assets (European Central Bank, 2022b). This implies that the ECB distanced itself for the first time from the market neutrality principle (European Central Bank, 2021b).

3 Stock market reactions

The hypothesis of this research pertains to the three climate change policy announcements made by the ECB in the past year. With the increasing focus on green central banking, it is crucial to quantify the impact of these announcements and policies. To understand investor perception of monetary policy decisions, stock market returns serve as the clearest measure. Therefore, it is important to comprehend how stock markets typically respond to the ECB's announcements for a comprehensive analysis of green monetary policy. This section serves as a reference point for the outcomes of the investigation undertaken in the next chapters.

3.1 ECB announcements and the stock market

For decades, economists have been discussing to which extent and through which channels monetary policy affects stock prices. Based on the discounted cash flow model, stock prices are equal to the present value of expected future net cash flows. Thus, monetary policy affects stock prices either by changing the interest rate or by successfully altering market participants' expectations of the future economy. When monetary policy is expansive, this generally brings a period of low-interest rates, higher economic activity and higher profits for firms. Monetary tightening, on the other hand, is seen as bad news, as it implies lower future economic activity. Empirical studies show that expansive monetary policy increases stock prices while restrictive monetary policy decreases them (Ioannidis & Kontonikas, 2008).

3.1.1 Interest rate announcements

A change in interest rates has widely been proven to affect stock prices. Kuttner (2001) tested this theory on the US stock market. He could distinguish a strong effect of the interest rate when the target rate was unexpectedly shifted. At the same time, the interest rate only slightly impacted the stock market when market participants expected a change of the target rate. This corresponds to a concept from the 1970s from Fama (1970), stating that only unexpected changes in monetary policy could impact stock prices, as expected changes are integrated into an investor's train of thought prior to the announcement or implementation of the policy. Expected changes are, therefore, already included in the current valuation of the stocks. When analyzing the effect of a certain announcement or policy on stock prices, the total effect can thus be divided into the expected component and the unexpected component. Only the unexpected component alters the current and future stock prices.

Empirically, Hussain (2011) finds that a surprise increase of the interest rate by 25 basis points by the ECB generally decreases index returns. He measured a decrease in stock returns on the French stock market by 0.5%, by 0.34% on the German stock market, and it even reduced the returns on the Swiss stock market by 0.14%, although they are not part of the Eurozone. Fausch & Sigonius (2018) tested this same hypothesis of a 25 basis point surprise increase in the interest rate. This resulted in a 1.64% decrease in German stock returns, an even stronger impact than Hussain's findings.

3.1.2 Unconventional communication

Communication has a different impact during crises. Fausch & Sigonius (2018) prove that the effect of a surprise change in the interest rate was non-significant. This shows that conventional transmission channels stop working during crises. However, Haitsma et al. (2016) show in their research on ECB announcements that unconventional policy surprise announcements seem to have an even stronger positive effect on stock returns than conventional policy surprise announcements. Similarly, Chebbi (2019) observed a significant impact of unconventional monetary policy surprises on stock prices.

In his paper, Chebbi (2019) describes four channels through which unconventional policy impacts stock returns. First, the confidence channel refers to an increase of confidence and reduced uncertainty in the financial system as the ECB announces expansive unconventional policy. In turn, it boosts the stock returns. Secondly, stock prices may also react positively because of what Chebbi (2019) calls the bank credit risk channel. It implies that by increasing liquidity through unconventional monetary policy, banks are less concerned with potentially defaulting. This reduces the risk level associated with a bank's lending. The value of assets may therefore increase due to lower risk premiums. Third, as the ECB buys a big share of assets, for example, a smaller amount of those assets will be available for private investors. Investors are now displaced towards other securities on financial markets, which will boost asset prices overall. At last, the ECB channels a signal to the financial world. Different from the three other channels, this can work positively or negatively on asset prices. On the one hand, big asset purchases, for example, signal that the economic conditions are worse than the ECB initially thought. Investors could therefore choose safer investments, causing a decline in stock prices. On the other hand, an unconventional policy can signal that the ECB will keep interest rates low for a longer period of time in the future. All four channels are interesting as they can be related to climate change announcements. By participating in climate change mitigation, the ECB also sends signals to financial markets and reduces the risk components for the whole financial market.

3.2 Climate change and the stock market

To understand the impact of announcements of climate mitigation by the ECB, it is essential to consider the literature on how green firm stocks behave. The definition of a green firm is ambiguous. Some authors adopt a narrow definition, meaning a green firm only produces green output (Brown & Ratledge, 2012). Most studies, however, compare firms' carbon intensities and divide the firms into a group of green firms and a group of brown firms. A firm's carbon intensity is calculated as the amount of CO2-equivalent greenhouse gas emissions necessary for a firm to generate $1 million (Ardia et al., 2022). Whether green firms' stocks generally outperform, brown firms' stocks is still under discussion. As researchers treat different time periods, use different empirical models and assess the greenness of a company differently, results are unclear. Matsumura et al. (2014) show that for every 1000 metric tons of additional emitted carbon, a firm's value decreases by $212,000. Bauer et al. (2022) indicate that green stocks in the G7 have generally provided higher returns than brown stocks since 2012. Bolton &

Kacperczyk (2021, 2022) also find results proving the existence of a *"carbon premium"*; compensation investors receive for investing in brown firms, as holding brown stocks comes with a higher risk. On the contrary, Alessi et al. (2021) find that by not disclosing any information on climate performance, a firm performs better on financial markets than a firm that reveals its low emission level. Bauer et al. (2022), mentioned above, argue that these various results might be due to the aversion towards polluting firms increasing over the past decades. If the sample period is older, the aversion towards brown firms seems smaller.

Researchers do agree that climate distress betters green firms' performance. In times where disturbances other than climate change are more prevalent, different investment decision factors may play a bigger role. During the energy crisis, for example, brown firms outperformed green firms. As sufficient energy supply was the principal worry, investors may have been more optimistic that brown firms were better positioned to meet the high demand for energy (Bauer et al., 2022). But as distress about climate change grows, investors tend to shift to investing in green firms, which causes the green stocks to outperform the brown stocks (Bouri et al., 2021). Pastor et al. (2021) described two mechanisms explaining how climate change preferences influence stock prices. The first mechanism regards investors' expectations. As concerns for the environment grow, policies that harm brown firms are likely to be implemented. Investors' expectations shift, and green firms will seem less risky to invest in. The second mechanism assumes that as the climate change preferences change, investors will also be more eager to invest in sustainable firms as these firms are more in line with their personal beliefs. Ardia et al. (2022) tested this hypothesis. They find that in periods of great climate change distress, stocks from green firms generate more returns than stocks of brown firms. Their calculations bring evidence of a discount channel, meaning that the green firms enjoy a decrease in equity cost when the worries in regard to climate change are deeper, which implies their stock returns are higher compared to brown firms. Engle et al. (2020) find that when an essential global climate treaty is signed or a global climate convention is held, stocks from green firms perform better. Similarly, Faccini et al. (2021) find that when there are expectations of the US government to intervene to fight climate change, markets react in favour of green firms.

4 Methodology

On July 8th 2021, the ECB presented their *Monetary Policy Strategy Review* with a strong general undertone that they will soon be undertaking action regarding climate change. They, however, did not specify precise measures (European Central Bank, 2021c). The impact of this announcement on the stock return of green firms has been analyzed by Eliet-Doillet & Maino (2022). They found that, on average, stocks from the 25% greenest firms of the EU STOXX 600 enjoyed an average 0.8% excess return around the days of the announcement compared to the 25% highest emitting firms in the EU STOXX 600. A year later, the ECB announced on July 4th 2022 that they would include climate change considerations in their corporate bond holdings starting in October 2022. This will be done gradually, as they will only conduct an asset tilt on reinvestments of their maturing securities. That day, they also announced that they would change the collateral framework by considering climate considerations when applying haircuts on corporate bonds used as collateral, starting before the end of 2023. They will also reduce the number of assets eligible as collateral issued by high-emitting firms by the end of 2024 (European Central Bank, 2022a). On September 19th 2022, they disclosed more information regarding the upcoming asset tilt. Namely, that issuers will receive an overall climate score based on three sub-scores. The first sub-score is based on the firm's past emissions, the second on the firm's objectives to reduce its emissions, and the third sub-score will rate the firm's climate disclosure (European Central Bank, 2022b). Recently, on February 2nd 2023, the ECB announced a stronger tilt of their corporate bond purchases as of March 2023 (European Central Bank, 2023c). Until May 2023, these are the only three climate-related policy announcements the ECB has disclosed; therefore, it is important to understand their impact.

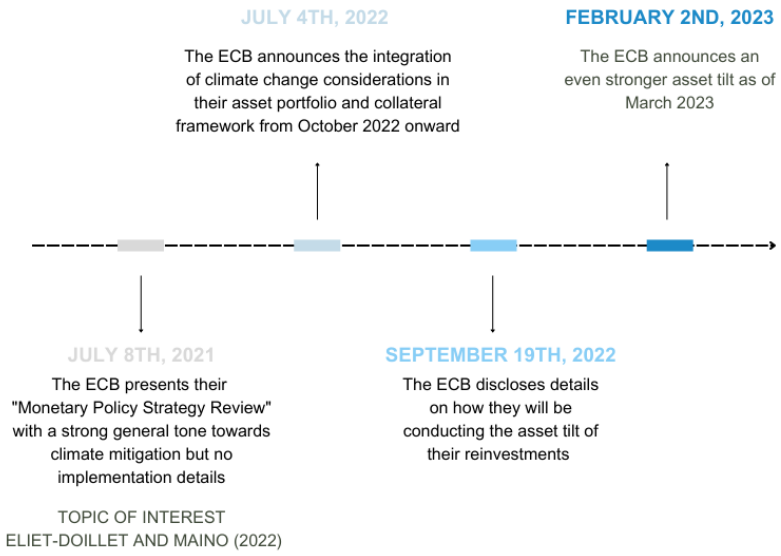


Figure 2: Timeline of ECB's climate mitigation announcements

4.1 Hypothesis development

As mentioned in section 1.1.3, the reinvestments of corporate bond holdings only represent a small share of the ECB's portfolio. The undertaken policy will, therefore, not drastically impact the future of climate change or directly reduce greenhouse gas emissions. But it is clear from previous research that the ECB impacts stock markets by managing investors' expectations. As the ECB starts implementing climate mitigation policies, it is essential to estimate to which extent they can influence the financial world. First, I will compare the stock returns of green firms compared to brown firms following these three announcements; on July 4^{th} 2022, on September 19^{th} 2022 and on February 2^{nd} 2023, to see whether the ECB announcements successfully managed to send a signal to investors in Europe.

Hypothesis 1: When the ECB announces a climate mitigation policy, this sends a signal to investors, and the stocks of the European green firms outperform the stocks of brown firms on the days around these announcements.

By announcing an asset tilt on the reinvestments of their corporate bond holdings, one could expect the ECB mostly impacts stocks of eligible firms under the programme. As the ECB predominantly purchases bonds from firms located in the Eurozone, this would imply that the announcement more strongly impacted the performance of Eurozone firms than non-Eurozone firms. However, it is clear from previously mentioned research that announcements of the ECB create spillover effects for non-Eurozone stock markets. This brings us to the second hypothesis of this research, which could clarify the mechanisms behind the effects following an ECB announcement.

Hypothesis 2: A stronger effect of the ECB announcements is expected for green firms in the Eurozone, as these could become eligible for purchase, compared to green firms not located in the Eurozone.

4.2 Data

4.2.1 Defining green and brown firms

The dataset was compiled by looking at all the firms from the EU STOXX 600. With this index, it will be feasible to assess the impact of announcements on European companies, both within and outside the Eurozone. The index contains small-cap, mid-cap, and big-cap firms in 17 European countries. Its primary goal is to be representative of the whole European stock market. Through Refinitiv, each firm was categorized within a sector (Refinitiv, n.d.). Based on data from Our World in Data (Ritchie, 2020) and Howell (2023), the most-polluting sectors were labelled as brown; Oil & Gas (Related Equipment and Services), Natural Gas utilities, Freight and logistics, Metal & Mining and Construction Materials. The Renewables sector was labelled as green. Each firm belonging to a brown sector automatically got labelled as a *brown firm*, while each firm in the renewables sector got the *green firm* label.

Next, each firm that had not received a label was given a score based on Refinitiv's environmental scores (Refinitiv, n.d.). Each firm is given a score out of 100 based on their emitted emissions, resource use and an innovation criterion. Looking at the environmental scores of all the firms in the dataset, a benchmark was set for the firms that belonged to the worst-performing 25% quartile of the sample and the same was done for the best-performing 25%. All the firms with a score lower or equal to 56 got labelled as a *brown firm*, and each firm in the best 25%, with a score above or equal to 86, got labelled as a *green firm*. Out of the 561 firms analyzed, 130 green and 184 brown firms are left. For the second part of the paper, I looked at the difference in performance between Eurozone and non-Eurozone firms. After only selecting the firms within the Eurozone, 79 green firms and 81 brown firms remain. This will be compared to the 51 non-Eurozone green firms and the 103 non-Eurozone brown firms.

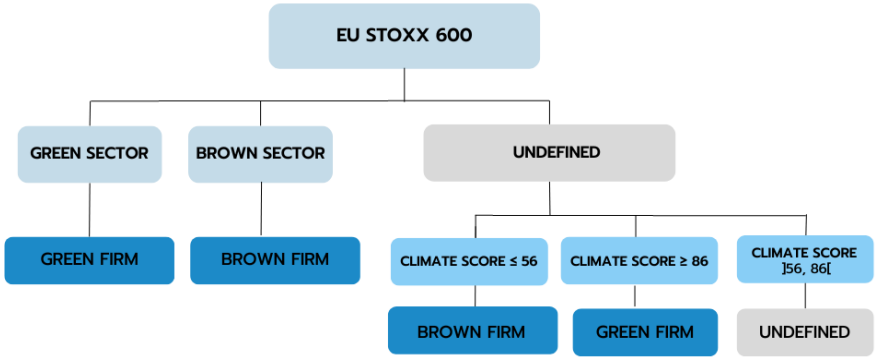
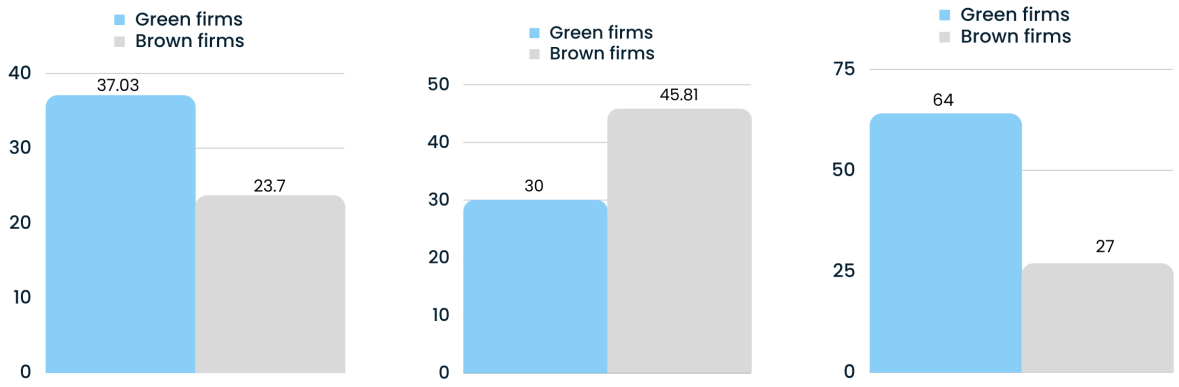


Figure 3: Defining green firms and brown firms

The reason for a sectoral division, instead of simply looking at the environmental scores, is to straighten out the bias in the environmental scores of rating agencies. As a consistent framework to assess firms' sustainability does not exist yet, some highly-polluting firms receive high environmental scores because of their often unrealistic prospects and the quality of their disclosure. Studies show that the environmental scores are biased through location, firm size and industry. This implies that larger firms are more visible and have a bigger incentive to greenwash their climate performance; therefore, they often get overrated by rating agencies (Aouadi & Ma (2023), Gregory (2022)). Even after the sectoral division performed here, a size bias remains between the firms. Figure 4 displays three ways of measuring firm size; revenue, total assets and the number of employees. The green firms have a higher mean revenue and more than double the average number of employees compared to the brown firms. As to total assets, the brown firms take the upper hand. Regarding the location bias, the number of firms within the Eurozone and outside the Eurozone is similar in both groups after the sectoral division. Until an objective standard is set for sustainability, ESG rating agencies will keep trying to overdo their competitors by taking extra measures into account and therefore adding to the heterogeneity of the environmental scores. Currently, the ESG scores are the most objective measure as the reported data is verified by an official rating agency and, therefore, at least partially prevents greenwashing, but it is far from perfect.



(a) Mean revenue (in billion) (b) Mean total assets (in billion) (c) Employees (in thousands)

Figure 4: Size differences between green and brown firms

4.2.2 Stock returns

Through Refinitiv, the required daily stock returns of the green and brown firms were collected, as explained further below. I used the *Return Index* variable, as this represents best how much each stock is worth at that moment. It takes price, stock splits, dividends etc., into account. This altogether formed a dataset of stocks of the green firms that could be compared to the stocks of the brown firms.

4.3 Empirical design

The effect of the announcements will be estimated through an event study, following the global three-factor model of Fama & French (1992). This framework can explain up to 90% of investment returns. In their model, Fama & French estimate the expected rate of return on equity based on its three market components. The difference between the expected rates of return and the actual returns is then calculated and called the abnormal returns. Comparing these abnormal returns between green and brown firms will tell us whether each announcement of the ECB had a different impact on firms based on their climate performance.

Step 1) The first step consists of setting up an estimation window, which will provide information on the "normal" return of each stock prior to any announcement. In figure 5, the estimation window is displayed as the purple rectangle. Studies prove that results do not vary based on the length of the estimation window as long as it exceeds 100 days (Armitage, 1995). I will therefore use an estimation window of 150 trading days, ending ten trading days before the first announcement on July 4$^{\text{th}}$ 2022. This means weekends are not accounted for, as no data is available these days. The estimation window, therefore, runs between November 23$^{\text{rd}}$ 2021 and 20$^{\text{th}}$ of June 2022. When removing all Saturdays and Sundays, 150 days of stock return data remain for each firm.

$$R_{ft} = \alpha_f + \beta_{1f} R_{m_t} + \beta_{2f} R_{SMB_t} + \beta_{3f} R_{HML_t} + \epsilon_{ft} \tag{1}$$

In equation 1, R_{ft} is the stock return of firm f on day t. The market components, R_{m_t}, R_{SMB_t} and R_{HML_t} are found on the website of K. French (2023) for each market, in our case Europe. R_{m_t} represents the excess return on the market at time t, R_{SMB_t} is the performance of small firms compared to big firms at time t, and R_{HML_t} represents the performance of high book to market firms compared to low book to market firms at time t. Filling in and regressing the formula makes it possible to calculate the firm-specific coefficients β_1, β_2 and β_3 for each firm in the dataset.

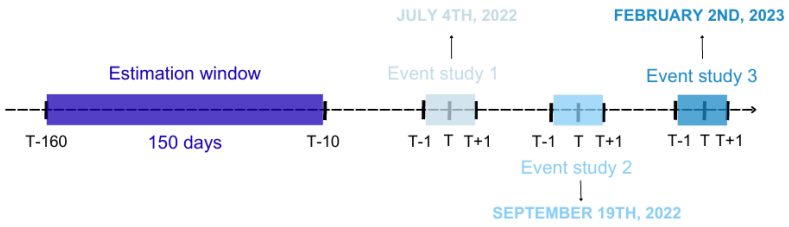


Figure 5: Graphical representation of the empirical design

Step 2) The next step uses the stock returns of the day prior to the announcement, the day of the announcement, and the day following the announcement. This is the event window, in this case, a total of three days, displayed in figure 5 as the blue rectangles. It is important to note that the first two announcements were on a Monday, meaning there is no stock return data on the Sunday before the announcement. I, therefore, use the stock return on the Friday beforehand instead of the day before. The difference between these actual stock returns (RR_t) and the "normal" returns (R_{ft}) calculated in step 1 is called the abnormal returns (AR) of firm f at day t. These ARs will be computed for each firm over the 3-day event window for every announcement.

$$AR_{ft} = R_{ft} - RR_t \tag{2}$$

Step 3) For each firm, I sum the AR values over the three days of the event window. This means I sum AR_{-1}, AR_0 and AR_{+1} for each firm in our dataset to obtain the Cumulative Abnormal Return (CAR). The CARs for the green firms will be used later on to compare them to the CARs of the brown firms by looking at the mean and median CAR of both types of firms.

$$CAR_f = \sum_{t=-1}^{T} AR_{ft} \qquad T = [-1, 1] \tag{3}$$

$$mean \quad CAR_{GreenFirms} = \frac{1}{F} \sum_{f=1}^{F} CAR_f \qquad F = 130 \tag{4}$$

$$mean \quad CAR_{BrownFirms} = \frac{1}{F} \sum_{f=1}^{F} CAR_f \qquad F = 184 \tag{5}$$

5 Results

5.1 Analysis of the effects on Eurozone and non-Eurozone firms combined

5.1.1 Event one: July 4th 2022

On this day, the ECB announced an asset tilt on their maturing corporate bond holdings, starting October 1st 2022. Bonds from better-performing firms regarding climate will receive preferential treatment compared to higher-emitting firms. They also announced that before the end of 2023, their collateral framework will be adapted. Climate change considerations will be considered when applying haircuts on corporate bonds used as collateral. By 2024, some assets of high-emitting firms will be banned from being used as collateral.

a) Structure of the event study

The following structure was used for this first event study. In figure 6, the purple rectangle represents the estimation window used to measure each stock's "normal" returns. Based on these returns, the Fama and French model can calculate if and how abnormal the stocks behaved during the event window, the light blue rectangle on the graph.

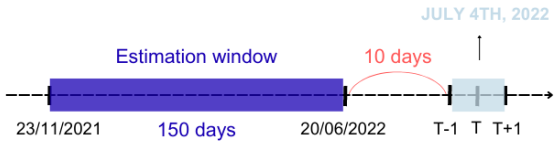


Figure 6: Graphical representation of the first event study

b) Comparing cumulative abnormal returns

As mentioned, the cumulative abnormal return (CAR) is the value obtained for each firm by adding up its abnormal return over the event window. Calculating the average and the median of the CARs for both types of firms returns the values displayed in table 4. The third column shows the difference between green and brown firms. The average CAR of the stocks of the green firms was 0.61 percentage points higher during the event window compared to the brown firms. When looking at the median CAR, the result is slightly larger, as the median CAR of the green firms was 0.92 percentage points higher than the median CAR of the brown firms. This indicates that investors perceived the announcement of the ECB as more favourable for the green firms than the brown firms. The results are comparable to those of Eliet-Doillet & Maino (2022). They found that after the ECB announced their Monetary Policy Strategy Review, the 25% lowest-emitting firms enjoyed a CAR that was, on average, 0.8 percentage points higher than the brown firms. When looking at the median, they found a higher return for the green firms by 0.6 percentage points, which is similar but slightly smaller than here.

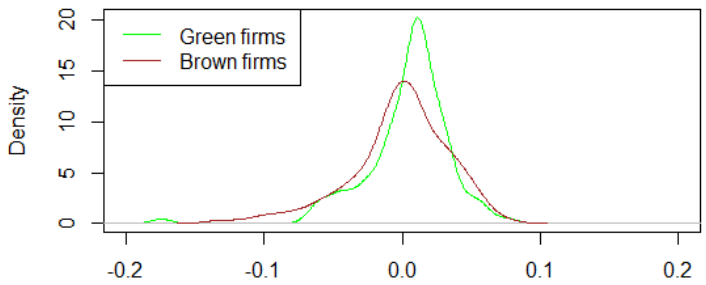
	Green firms	Brown firms	Difference
Mean CAR	0.0042	-0.0019	0.0061
Median CAR	0.0099	0.0007	0.0092

Table 4: CAR values following the first announcement

A difference in mean CAR of 0.61 percentage points is relatively big for an ECB announcement. A study analyzing the impact of 157 ECB conventional monetary policy announcements between 1999 and 2008 found an average CAR following these announcements of 0.33 percentage points on the Eurozone stock markets (Filbien & Labondance, 2013). Ferreira & Serra (2022) examined 120 unconventional monetary policy announcements between 2008 and 2018. Although non-significant, they found a CAR of 0.69 percentage points of the effects of ECB announcements on the EU STOXX 600 index. For the EU STOXX 50, they found a significant result of 1.17 percentage points in CAR. Antoniuk and Leirvik (2021) studied different climate events and their effects on the stock market. On the day of the nuclear disaster in Fukushima, it was expected that dirtier ways of generating electricity, such as fossil fuels, would be undesirable compared to cleaner energy production. In line with the hypothesis, the difference in CAR was 0.68 percentage points higher for the clean energy sectors compared to the fossil fuels sector. The authors also performed a similar analysis by looking at the day the former president of the United States, Donald Trump, was elected. During his election campaign, Trump stated he planned to leave the Paris Agreement and revive the coal industry in the US. This would have repercussions for the US and make it harder for other countries to decrease emissions. That event study is, therefore, comparable to an opposite event compared to the events studied in this paper. On an event window of one day before the elections until one day after, fossil fuel firms' stocks had a negative CAR of -2.15 percentage points, while the clean energy sector experienced a negative CAR of -4.51.

c) Statistical significance tests

The Kernel densities of the CARs of the green firms and the brown firms following the first announcement are displayed in figure 7. The x-axis represents the values the CAR variables can take on, while the y-axis shows the probability densities. The peak of each distribution represents the most probable CAR value within that type of firm. As the height of the green line lies more on the right, a green firm is more likely to have experienced a more positive CAR during the studied event window than a brown firm. Furthermore, figure 7 tells us there is a low probability of extreme results for the CAR of the green firms, as the tails of the distribution are steep between approximately -0.05 and 0.05. The tails of the distribution of the brown firms are slightly wider, especially on the left side, meaning there is a higher probability of more extreme negative CAR values for stocks of the brown firms.



N_G=130 N_B=184

Figure 7: Kernel density plot of the CARs around the first announcement

In the first two columns of table 5, are the results of significance tests looking at the CARs of the green and brown firms separately. As computed in table 16 in Appendix A, we can reject at a 1% significance level that the CARs of both groups are normally distributed through a Shapiro-Wilk test. A t-test is, therefore, not adequate to test the significance of the results. Similarly to Eliet-Doillet & Maino (2022), a Wilcoxon test is computed on the median CAR values as it is a non-parametric test and therefore does not assume normality. The test does require independence between the two datasets, and that the distributions are similar in shape, although it is robust to moderate deviations from this assumption. As this is the case, the Wilcoxon test is appropriate to test the significance of the priorly computed results. The p-value in the first column is smaller than 0.01, which means the hypothesis that the green firms did not react to the announcement can be rejected at a 1% significance level. This can not be rejected for the brown firms. The null hypothesis that the brown firms did not react to the announcement can, therefore, not be rejected.

The third column of table 5 displays the results of significance tests on the difference in median CARs between green and brown firms. Once again, the value under the median CAR represents the p-value obtained through a Wilcoxon test. As the p-value equals 0.0792, we can reject an equal reaction between the different types of firms at a 10% significance level. This shows that investors perceived the announcement of the ECB as more favourable for green firms.

	Green firms	Brown firms	Green firms vs brown firms
Median CAR	0.0099***	0.0007	0.0092*
	(0.004)	(0.7922)	(0.0792)

p-value in parentheses

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$

Table 5: Wilcoxon-test on the results of the first announcement

5.1.2 Event two: September 19th 2022

On the 19th of September 2022, the ECB released a statement with more information on the asset tilt that would soon be performed on all purchases of their maturing corporate bonds. As explained before, they disclosed how they would give all firms an environmental score based on three sub-scores. The quality of disclosure, the carbon emissions, and a firm's climate mitigation plans will be considered in eligibility decisions. The firms with a higher overall score will be more eligible for purchase than others.

a) Structure of the event study

As the effects of the first announcement should not influence the normal returns used for the second event study, the estimation window was set before the first announcement. We chose the same estimation window as the first event study discussed in section 5.1.1, again totalling 150 days, ending 65 non-trading days before the second event study. The event window goes from one trading day before the announcement, which, just like the first event, is the Friday before until the day after the announcement.

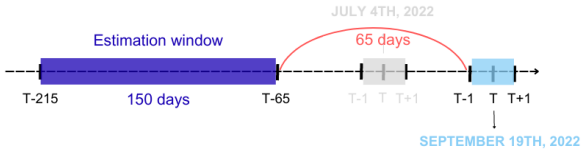


Figure 8: Graphical representation of the second event study

b) Comparing cumulative abnormal returns

As can be read from the third column of table 6, the mean CARs differ by 1.18 percentage points in favour of the green firms. This means that, on average, a green firm enjoyed a 1.18 percentage points higher CAR over the studied event window than a brown firm. The median values differ by 1.5 percentage points. This is a more substantial effect than what was computed in the first event study, possibly due to the policy implementation drawing near. These results are also higher than the previously mentioned results of Eliet-Doillet & Maino (2022), where the green firms enjoyed a higher average CAR of 0.8 percentage points compared to the brown firms.

	Green firms	Brown firms	Difference
Mean CAR	0.0090	-0.0028	0.0118
Median CAR	0.0102	-0.0048	0.015

Table 6: CAR values following the second announcement

According to Ferreira & Serra (2022), the average CAR of 120 unconventional monetary policy announcements between 2008 and 2018 on the STOXX 600 added up to 0.69. An event study by Antoniuk and Leirvik (2021) examined the abnormal returns of clean and fossil-fuel exchange-traded funds following the Paris Agreement. They found that when looking at an event window of one day before the agreement until one day after, the clean funds had a CAR of 2.09 percentage points, while the fossil-fuel funds had a negative CAR of -0.77 percentage points. However, it should be noted that the results on a seven-day event window were significantly larger than those shown in this analysis on a longer-term basis. But considering the smaller extent of this announcement compared to the Paris Agreement, a positive mean CAR of 0.9 percentage points for the green firms and a mean CAR for the brown firms of -0.28 percentage points is considerable.

c) Statistical significance tests

Figure 9 shows the Kernel densities of the distribution of the CAR-values for the green and the brown firm for the event window of the second announcement. The graph is very similar to figure 7. Again, the peak of the green line reveals that a green firm is more likely to have enjoyed a more positive CAR than a brown firm following this announcement. Here too, the tails of the green firms are pretty steep, while the tails of the brown firms are wider, making extreme values more probable.

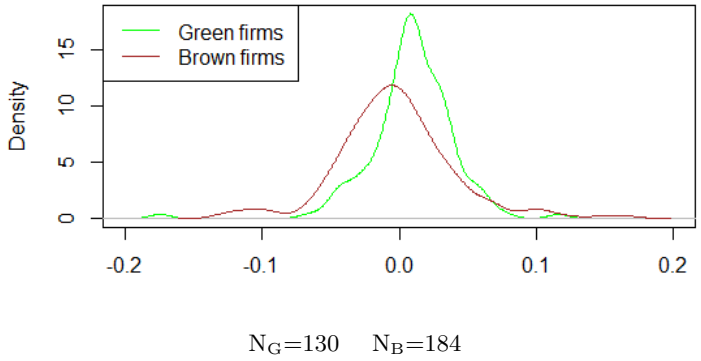


Figure 9: Kernel density plot of the CARs around the second announcement

The results of the Shapiro-Wilk test in table 16 in Appendix A reject the hypothesis of a normal distribution for both types of firms at a 1% significance level. Therefore once again, the Wilcoxon test will be used to check the significance of the computed results as displayed in table 7. The null hypothesis that the green firms did not react to the announcement can be rejected at a 1% significance level. In contrast, the results of the brown firms are not found to be significant. When comparing the green firms to the brown firms in the third column, the difference in median CARs is significant at a 1% significance level. Similarly to the first event study, we can conclude that investors perceived the announcement of the ECB as more favourable for green firms.

	Green firms	Brown firms	Green firms vs brown firms
Median CAR	0.0102***	-0.0048	0.015***
	(0.00002)	(0.1196)	(0.0001)

p-value in parentheses

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$

Table 7: Wilcoxon-test on results of the second announcement

5.1.3 Event three: February 2nd 2023

On the 2nd of February 2023, the ECB announced a more substantial asset tilt of their repurchases of maturing corporate bonds starting March 1st 2023. Important to note that they also announced the decline of their portfolio by €15 billion per month between March and June 2023, with the possibility of further extensions. On the same day, they announced raising three key interest rates by 50 basis points six days later. This implies that the effects of the climate announcement could be blurred by the other policy changes, especially compared to the first two event studies performed above, as these were solely climate-related.

a) Structure of the event study

Similar to the second announcement, we used the same fixed estimation window as in the first event study. The estimation window thus ends 163 non-trading days before February 2nd 2023 and totals 150 days. Once again, the event window starts the day before the announcement and ends the day after.

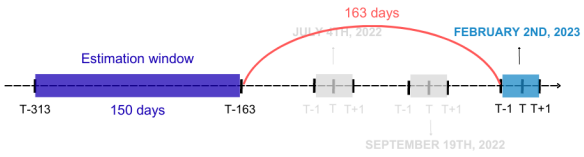


Figure 10: Graphical representation of the third event study

b) Comparing cumulative abnormal returns

Following the third announcement, the green and brown firms both enjoyed a positive CAR. This could be explained by the fact that the ECB also announced other policies unrelated to climate change that day. The interest rate announcement, for example, could blur the difference between the green and brown firms as their inherent characteristics may react differently to these types of announcements. The announcement was also less radical compared to the first two. Typically, when interest rates go up, the stock market goes down. However, in this case, as shown in the 8 tables, the CARs are positive instead of negative. De Tijd (2023) explains that investors expected the ECB's interest rate to rise after the FED's interest rate increase, such that the interest rate increase was already integrated into

the stock market before the actual announcement. Additionally, the president of the ECB, Lagarde, expressed more optimism about inflation in her communication than expected, which left a positive impression on investors. As a result, the European stock market rose by an average of 1.6%. The STOXX 600 index closed higher than the day before on February 2nd, which is unusual for an interest rate increase.

Surprisingly, the mean CAR of the green firms is lower than the one of the brown firms, while the median CAR is higher. The mean values display a difference of -0.14 between both types of firms. When looking at the median CAR values, the green firms' median CAR remains higher by 0.78 percentage points compared to the brown firms. As the median difference is much higher than the mean difference, there could be some outliers in the CARs distribution, causing the mean values to be unrepresentative. This will become clear when performing statistical significance tests.

	Green firms	Brown firms	Difference
Mean CAR	0.0139	0.0153	-0.0014
Median CAR	0.0195	0.0117	0.0078

Table 8: CAR values following the third announcement

c) Statistical significance tests

When looking at the Kernel density plots of the CARs, as shown in figure 8, the CAR values of the brown firms are symmetrical around the 0.0 value on the x-axis, while the peak of the green line is more on the right. The peak represents the most probable value of the distribution. Therefore, green firms had a higher probability of having a more positive CAR following the announcement. The two bumps in the graph indicate the median CAR values are more representative than the mean CARs. This implies a more positive effect on green firms than brown firms.

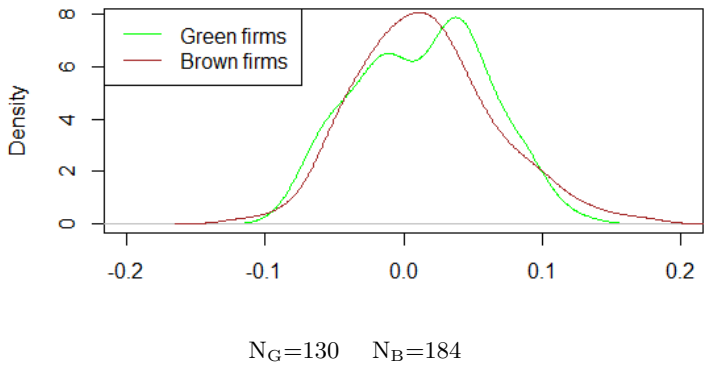


Figure 11: Kernel density plot of the CARs around the third announcement

As shown in table 16 of Appendix A, the normality of the green firms can be rejected at a 10% significance, which means it is again more representative to look at the results of the Wilcoxon test than computing a t-test. For the brown firms, normality is not rejected, and a t-test is performed too on the mean CAR to test the result's significance. It is clear from the first two columns of table 9 that both types of firms reacted significantly to this announcement. Both p-values in the first two columns reject the null hypothesis at a 1% significance level. This differs from the priorly performed event studies, where the effect on the brown firms' stocks was insignificant. There is very little evidence to reject the null hypothesis when comparing the green firms with the brown firms. There is no sufficient proof to state that the CARs significantly differ from one another. This event study's results vary from the first two because of the cluster of policies announced on the 2nd of February 2023. The interest rate announcement will likely have had a stronger impact on the stock returns that day than the announcement of a stronger asset tilt.

	Green firms	Brown firms	Green firms vs brown firms
Mean CAR	0.0139	0.0153* * *	-0.0014
		(<0.01)[1]	
Median CAR	0.0195* * *	0.0117* * *	0.0078
	(0.0018)[2]	(0.0004)[2]	(0.8761)[2]

p-value in parentheses

*$p < 0.1$, **$p < 0.05$, * * *$p < 0.01$

[1] t-test,[2]Wilcoxon-test

Table 9: Wilcoxon-test on results of the third announcement

5.2 Analysis of the effects on Eurozone and non-Eurozone firms separately

The second part of this research will analyse whether the climate mitigation announcements of the ECB studied in section 5.1 had a more substantial effect on firms within the Eurozone compared to firms located outside the Eurozone. If so, it would mean the ECB mainly impacts the performance of firms that could become eligible under their Purchase Programmes. If not, it implies the ECB sends signals to European investors, regardless of whether the firms' assets could become eligible.

5.2.1 Event studies on Eurozone firms only

The three event studies computed in section 5.1 were performed in precisely the same manner for the 79 green firms and 81 brown firms located in the Eurozone. The results are shown in table 10. The Shapiro-Wilk test results in table 17 of appendix A do not provide sufficient evidence to reject the normality of the distribution of the CARs of the green and brown firms for the first event. Therefore, a t-test was conducted to compare the mean CAR values between both types of firms and a Welch test that does not require an equal variance. The computed values are found with superscript [1] and [2], respectively. Similarly to section 5.1, a Wilcoxon test on the median CARs was also performed to confirm the findings, displayed with a superscript [3]. For the second and third events, the Shapiro-Wilk tests in table 17 in appendix A provide enough evidence to reject the normality of the distributions of the CARs. Therefore, only a Wilcoxon test was computed to compare the median CAR values.

		Green firms vs brown firms
First event	Mean CAR	-0.007
		$(0.557)^1$ & $(0.556)^2$
	Median CAR	-0.0109
		$(0.4517)^3$
Second event	Median CAR	0.0372
		$(0.2558)^3$
Third event	Median CAR	0.0031
		$(0.4215)^3$

p-value in parentheses

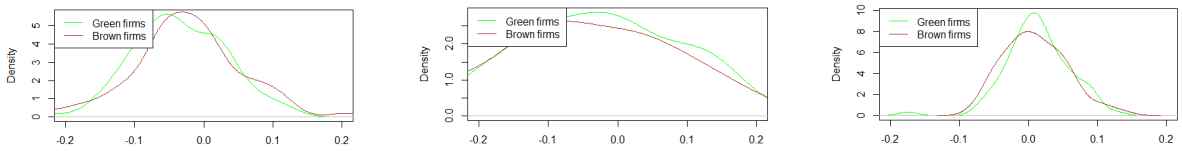
$^*p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

[1] t-test, [2] Welch-test,[3]Wilcoxon-test

Table 10: Significance tests of the event studies on Eurozone firms only

The first event study returned a slightly more negative mean and a slightly bigger median CAR difference for green firms than brown firms. The negative difference does not mean the CAR of the green firms was negative; it simply points out that the CARs of the green firms are less positive than the CARs of the brown firms. The second event study found a difference of more than three percentage points in the median CAR in favour of the stocks of the green firms. The difference is smaller but still positive for the third event study, with a difference of around 0.3 percentage points. However, none of the statistical tests came to a significant result. Therefore one can not conclude that the announcements of the ECB had a different effect on the green firms in the slightly compared to the brown firms in the Eurozone. The small dataset and the distributions of the results may be blurring the findings, for which I refer to the next paragraph.

Figure 12 shows the Kernel density plots of the CARs of the green and brown firms in the Eurozone for the three event studies performed. The left panel shows the CARs following the announcement on the 4^{th} of July 2022, and the middle panel represents the Kernel densities of the second event study looking at the announcement on 19^{th} of September 2022. The right panel displays the Kernel density plot of the CARs around the announcement on 2^{nd} of February 2023. In the first two panels, especially the middle one, the distributions take on more extreme values compared to section 5.1, where the firms located outside the Eurozone were taken into account too. Extreme values mean that the stocks reacted very strongly to these announcements, regardless of being brown or green. The fact that the sample is smaller could explain why the difference in mean and median values are insignificant while being larger than in section 5.1. A better comprehension of these results is possible when comparing them directly to the results of the non-Eurozone firms in section 5.3.



N_G=79 N_B=81

Figure 12: Kernel distributions of the CARs of the event studies on Eurozone firms only

5.2.2 Event studies on non-Eurozone firms only

The three event studies were performed on the 51 non-Eurozone green firms and the 103 non-Eurozone brown firms. These firms are in the United Kingdom, Switzerland, Norway, Denmark and Sweden. They are, therefore, not directly impacted by the ECB's policy. But it is possible, mainly because the firms are still located in Europe, that the ECB still indirectly affects them as their sales market is likely to be focused on Europe, and their investors might be following up on ECB's policies. Additionally, the central banks of these non-Eurozone countries may adopt policies implemented by the ECB.

The results are displayed in table 11. The Shapiro-Wilk tests in table 18 of appendix A reject the hypothesis that the distributions are normally distributed for each announcement for at least one of the two groups. Therefore, a t-test on the difference in mean CARs is not adequate. As a Wilcoxon test does not require normality of the distributions, this was computed for all three differences of median CARs. The p-values that were computed are found in parentheses.

		Green firms vs brown firms
First event	Median CAR	0.0101* * *
		(0.0048)
Second event	Median CAR	0.002
		(0.4681)
Third event	Median CAR	0.0036
		(0.2965)

p-value in parentheses

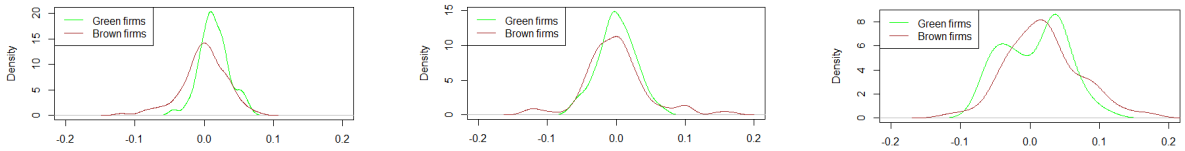
$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 11: Significance tests of the event studies on non-Eurozone firms only

The green firms had a median CAR higher by 1.01 percentage points following the first announcement. Only for this event study were there significant results computed. The null hypothesis that the values are equal when comparing green and brown firms can thus be rejected at a 1% significance level. This makes sense as the first announcement was the most unexpected and drastic of the three. A study by Korus (2019) looks at the spillover effect of unconventional monetary policy on the stock market in Denmark, Norway and Sweden. For the announcement of the CSPP, the results are significant for Denmark and Norway, with an effect of -0.03 and -0.77 percentage points, respectively. The effect of forward guidance also seems highly significant, with effects up to 1.2 percentage points in all three countries. Fausch & Sutter (2022) also prove the existence of a spillover effect of both conventional and unconventional policy on Swiss stock markets. A decrease of the ECB policy rate by 25 basis points boosts the Swiss stock market by 1.45 percentage points. The literature thus proves that the

ECB impacts the stock market of European, non-Eurozone firms, which is confirmed by these results. The literature refers to the impact of the ECB on investors through the confidence and signalling channels. The confidence channel indicates that the ECB reduces uncertainty in the European market by implementing policies affecting expectations and reducing investors' uncertainty in non-Eurozone countries. On the other hand, the signalling channel suggests that ECB signals future expectations, potentially impacting the stock market more than the actual policy itself if successfully done. The ECB's policies also affect non-Eurozone countries' economies through exchange rates and government bonds, among other ways (Antal & Kaszab, 2021). For the second and third announcements, the differences are bigger but insignificant. The tests did not provide sufficient proof to reject the hypothesis that the stocks of the green firms reacted differently to these announcements than the brown firms. As the second announcement is significant when putting the Eurozone and non-Eurozone firms together but insignificant when analyzed separately, it could be that the smaller sample is the reason for the insignificant results. The third event brings insignificant results whether the samples are combined, confirming that other effects were at play that day besides the additional asset tilt.

The Kernel density plots in figure 13 represent the CAR distributions of the three event studies on the non-Eurozone firms only. The left panel shows that the CAR of the green firms had a higher probability of being positive compared to the CAR of the brown firms following the first announcement of the ECB. The middle panel shows similar distributions for both types of firms. The right panel reveals that the CARs of the green firms have a higher chance of being positive, but the difference is not as clear. Compared to the analysis on the Eurozone firms only in section 5.2.1, the distributions have steeper tails, meaning that the effects of the announcement on the CAR are less extreme for non-Eurozone firms than Eurozone firms alone.



N_G=79 N_B=81

Figure 13: Kernel distributions of the CARs of the event studies on non-Eurozone firms only

To conclude, it seems like the smaller dataset, especially for the green firms, could be blurring the effects of the announcements, similar to the findings for the Eurozone firms. Especially as quite strong effects were found for the second announcement when the Eurozone and non-Eurozone firms were combined in a dataset, but insignificant results were found when analyzed separately. It could also be that there are two movements at play here; one, where more sustainable investors shift their investments towards greener firms, while another group, alarmed by the proactive approach of the ECB, shifts its investments outside the Eurozone. This could explain the wide densities of the Eurozone CARs and

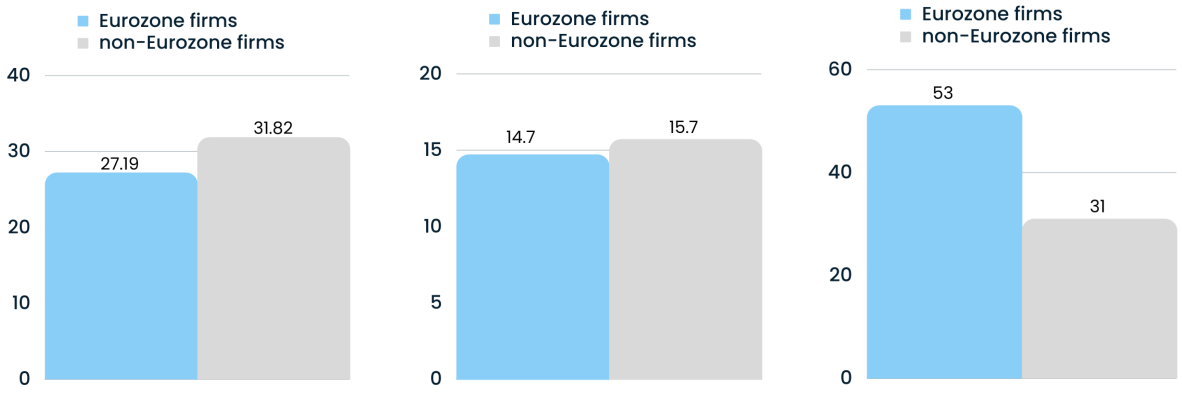
the more evident results for the non-Eurozone firms. An additional analysis examining this hypothesis is available in the next section. The third announcement did not bring significant results when combined, so it is not surprising that this was not the case when looked at separately. As mentioned before, other factors seemed to play a more prominent role in the stock market that day.

5.3 Computing the differences between the Eurozone and non-Eurozone firms

This section delves into the differences in CAR between firms of the same type in the Eurozone and those outside it. The objective is to understand better how ECB announcements impact investors' perceptions. Especially as the analysis looking at the Eurozone and non-Eurozone firms separately did not bring conclusive results. Surprisingly, the effects of the first announcement were larger for the non-Eurozone firms than the Eurozone firms, which is typically not the case for ECB announcements. Although there are spillover effects to non-Eurozone stock markets, the effect usually does not surpass the effects on the stock market in the Eurozone.

5.3.1 Dataset comparison

To assess the difference in effects between Eurozone and non-Eurozone firms, it is essential to ensure the two datasets only differ in whether they are located in the Eurozone. To ensure the firms do not vary in size, the mean revenue, the mean total assets and the mean total number of employees are looked into in figure 14 for both groups. The mean revenue and the mean total assets of the non-Eurozone firms are slightly larger than the Eurozone firms, while the mean number of employees of the Eurozone firms is larger compared to the non-Eurozone firms. However, the differences are relatively small and, therefore, negligible.



(a) Mean revenue (in billion) (b) Mean total assets (in billion) (c) Employees (in thousands)

Figure 14: Size differences between Eurozone and non-Eurozone firms

5.3.2 Differences in CAR and statistical tests

The normality of the distributions was rejected by the Shapiro-Wilk test in tables 17 and 18 in Appendix A, for all the CARs analyzed, except for the green firms following the first announcement and the brown firms following the third announcement. On all the other comparisons except these two, only Wilcoxon tests were used to test the significance of the effects. For the two comparisons where normality could not be rejected, a t-test and Welch-test were also computed. The results are displayed in table 12.

		Green firms Eurozone vs non-Eurozone	Brown firms Eurozone vs non-Eurozone
First event	Mean CAR	-0.0496***	/
		(<0.01)[1] & (<0.01)[2]	
	Median CAR	-0.0508***	-0.031***
		(0.000002)[3]	(0.0007)[3]
Second event	Median CAR	-0.0211*	-0.0586**
		(0.0956)[3]	(0.0102)[3]
Third event	Mean CAR	/	-0.0098
			(0.1866)[1] & (0.1808)[2]
	Median CAR	-0.0089	-0.0082
		(0.5369)[3]	(0.1996)[3]

p-value in parentheses

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$

[1] t-test, [2] Welch-test,[3]Wilcoxon-test

Table 12: Event studies and significance tests comparing Eurozone and non-Eurozone firms

It is striking that the non-Eurozone stocks reacted far more positively to the announcements than Eurozone firms, for both the green firms and the brown firms, when analyzing each of the three announcements. For the first event, the green firms outside the Eurozone had a median CAR higher by 5.08 percentage points than those in the Eurozone. For the brown firms, the difference is 3.1 percentage points in favour of the non-Eurozone firms. These results are significant at a 1% significance level. Similarly, for the second announcement, the median CARs of the stocks of the green non-Eurozone firms were 2.11 percentage points higher than the green Eurozone firms. For the third event, the results are not significant, although still negative. But as mentioned before, many other factors were at play with this announcement which explains why the results differ from those of the first two announcements. However, the results for the two first announcements are substantial. On the day of the Brexit referendum, the stock market of Norway and Switzerland, which Brexit did not directly impact, had

abnormal returns of 1.48 and 1.11 percentage points, respectively. In contrast, the UK stock markets experienced negative abnormal returns of -4.22 percentage points. Comparing these figures shows a significant difference of 5.7 and 5.33 percentage points (Burdekin et al., 2018), similar to the difference between the brown firms of the Eurozone and the non-Eurozone for the second announcement. Although the impact on the UK, Norway, and Switzerland was less severe than on weaker EU countries like Greece or Italy, the difference of 5 percentage points in abnormal returns highlights its significance.

The study's findings shed light on why there was no significant difference between green and brown firms in the Eurozone sample, while the non-Eurozone results were more precise. It appears that two distinct effects occurred following the climate announcements. Firstly, investors perceived the announcements to have a more negative impact on the Eurozone economy. This was evidenced by the results in table 12, which showed that European investors did not view the ECB's climate mitigation announcements favourably. Consequently, they chose to invest more outside the Eurozone, unaffected by the new climate mitigation policies. Secondly, overall in Europe, investors perceived the announcements to be more favourable for more sustainable firms, with spill-over effects in non-Eurozone countries. To conclude, the differences between the Eurozone and non-Eurozone firms were more pronounced than those between green and brown firms in section 5.1. This indicates that during the analyzed event windows, investors primarily chose to invest in firms outside the Eurozone, with a relatively minor preference for more sustainable firms. However, this was not the primary determining factor.

6 Robustness checks

6.1 Robustness checks for Eurozone and non-Eurozone firms combined

6.1.1 Event window of three hours

Research conducted by Hussain in 2011 revealed that the impact of ECB announcements on the stock market is only temporary. A three-hour event window was established to ensure accurate measurement of the unfiltered effects. For example, for the first announcement on July 4th 2022, posted at 11:00 AM, the analyzed the stock returns ran from an hour and a half before until an hour and a half after the announcement. The same methodology was used for the second and third announcements, released at 10:00 AM and 2:45 PM, respectively. To analyze the impact of ECB policies on stock returns, similar to Aguilar et al. (2020) and Rogers et al. (2014), the closing trade price was used for subsequent analysis since the return index is only available per day.

		Green firms	Brown firms	Green firms vs brown firms
First event	Median CAR	0.0008	-0.0429	0.0437**
		(0.7132)	(0.412)	(0.0214)
Second event	Median CAR	0.0034	-0.0277***	0.0311***
		(0.6495)	(0.0002)	(0.00005)
Third event	Median CAR	0.032***	0.0205***	0.0115***
		(0.00001)	(0.0018)	(<0.01)

p-value in parentheses

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$

Table 13: Wilcoxon-test on results with a shorter event window

Shapiro-Wilk tests were performed to check the normality of the distributions of the CAR values in table 19 in Appendix A. As normality was rejected for all the events, only Wilcoxon-tests were computed to test the significance of the results. For the first time, the results of all three events are positive and highly significant in favour of the green firms of the dataset. The results are also bigger than over a three-day event window, with differences in median CAR or 4.37, 3.11 and 1.15 percentage points for the three events, respectively. This confirms the computed findings in the original analysis that investors perceived the ECB announcements as better for green firms.

6.1.2 Event window of eleven days

To ensure accurate results, the event window was expanded to five days before and after the announcement to provide accurate results instead of just one day before and after. An eleven-day symmetrical event window, often written as [-5,5], is the most common event window used in research, according to Oler et al. (2007). However, such a lengthy window is not ideal for ECB announcements and stock returns. In fact, the majority of studies on monetary policy announcements only utilize a maximum of a three-day event window, as was done here in the original analysis (Eliet-Doillet & Maino (2022), Aguilar et al. (2020), Rogers et al. (2014)). When analyzing climate change announcements, the impact on stock markets increases with a longer studied event window. Antoniuk and Leirvik studied four climate events and found that the difference in CARs between fossil fuel stocks and clean energy stocks was higher at a [-1,5] event window than a [-1,1] window. Since the announcements studied involve both monetary policy and climate change, it is essential to consider a longer event window.

		Green firms	Brown firms	Green firms vs brown firms
First event	Median CAR	0.0095	0.002	0.0075
		$(0.165)^3$	$(0.9262)^3$	$(0.3905)^3$
Second event	Mean CAR	0.0068	-0.009	0.0158
		$(0.431)^1$	$(0.2126)^1$	$(0.1596)^1$ & $(0.1602)^2$
	Median CAR	0.0137	-0.0129	0.0266
		$(0.5312)^3$	$(0.1804)^3$	$(0.1989)^3$
Third event	Median CAR	0.0201**	0.0202**	0.0228
		$(0.0447)^3$	$(0.0112)^3$	$(0.9768)^3$

p-value in parentheses

$^*p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

[1] t-test, [2] Welch-test,[3]Wilcoxon-test

Table 14: Wilcoxon-test on results with a longer event window

The results of the event studies and tests are in table 14. For the first and third events, normality was rejected, as shown in table 20 in Appendix A. Thus, only a Wilcoxon test was performed on CARs to compare the results. The green firms had a slightly higher median CAR by 0.75 percentage points for the first announcement, but it is insignificant. For the second event, the Shapiro-Wilk test did not reject normality. Therefore the mean CARs were also compared with a t-test and a Welch test. Once again, a relatively big positive difference was found for the second announcement in favour of the green firms, but this was insignificant. For the third event, it was apparent that both types of firms reacted to the ECB's announcement, but not significantly different. Overall, the effects did not wholly fade after a few days but did not remain significant for long.

6.1.3 Narrow definition of green and brown firms

To check the robustness of the results in the section 5.1, I will use the top and bottom 10% instead of taking the 25% best-rated and the 25% worst-rated firms in terms of the environment to make sure the results are consistent. This is a more narrow definition of green and brown firms. As previously done in the section 5.1, all firms operating in the renewables sector will be designated as green. In contrast, those in the Oil & Gas (Related Equipment and Services), Natural Gas utilities, Freight and logistics, Metal & Mining, and Construction Materials sectors will be labelled brown. Additionally, firms with an environmental score less than or equal to 39 will be categorized as brown, whereas those with a score of 93 or higher will be classified as green. This approach yields 60 green and 101 brown firms within and outside the Eurozone. The amount of firms in each category is uneven as some of the brown firms have a score higher than 93, which would put them in the green firm category. Nevertheless, since they operate in highly polluting sectors, they are automatically classified as brown regardless of their environmental score. Similarly to the original analysis, the event study was performed on a three-day event window. For each event, a Shapiro-Wilk test was performed to check the normality of the distributions as shown in table 21 of appendix A. Only for the third event the hypothesis of normality was not rejected. Therefore t-tests and a Welch test were used to check the significance of the results of the mean CARs. For the first and second events, the normality hypothesis was rejected. Thus, only a Wilcoxon test was used, as shown in table 15.

		Green firms	Brown firms	Green firms vs brown firms
First event	Median CAR	0.0105	0.0029	0.0076
		$(0.1275)^3$	$(0.4005)^3$	$(0.1309)^3$
Second event	Median CAR	0.007**	-0.0039	0.0109**
		$(0.0126)^3$	$(0.5936)^3$	$(0.0377)^3$
Third event	Mean CAR	0.0199***	0.0149***	-0.005
		$(0.0013)^1$	$(0.005)^1$	$(0.5371)^1$ & $(0.5237)^2$
	Median CAR	0.0209***	0.0165**	0.0044
		$(0.0025)^3$	$(0.012)^3$	$(0.4143)^3$

p-value in parentheses

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$

[1] t-test, [2] Welch-test,[3]Wilcoxon-test

Table 15: Wilcoxon-test with a narrow definition of green and brown firms

For the first event, the green firms had a median CAR of 1.05 percentage points, while brown firms only had a median CAR of 0.29 percentage points. Although the difference is similar to using the 25% benchmark, it was not found to be significant. However, the results for green firms and the contrast between the two types of firms were almost significant at a 10% level. It is possible that the sample size of 60 green firms influenced these results. For the second event, the results were similar to those in section 5.1, as green firms experienced a positive and significant median CAR of 0.7 percentage points. In contrast, results for brown firms are again insignificant but negative. The significant and positive value in the third column suggests that investors perceived this announcement as more favourable for green firms. For the third announcement, both types of firms showed a strongly positive and significant result, but the difference was inconclusive, consistent with the findings in section 5.1.

6.2 Robustness checks for Eurozone firms only

6.2.1 Event window of three hours

The event window was set to three hours to ensure the results on the Eurozone firms only are robust. The results of this event study can be found in table 31 in Appendix B. To check the normality of the distributions of the CARs, Shapiro-Wilk tests were performed, as displayed in table 22 in Appendix A. The normality assumption could be rejected for at least one of the types of firms for the second and third announcements. Thus, only a Wilcoxon test was performed to compare the median values. For the first announcement, a t-test, a Welch-test and a Wilocoxon test were computed.

The first announcement returns a mean difference in CARs between the green and brown firms of 1.33 percentage points and a median difference of 1.05 percentage points, both significant at a 5% significance level. The second announcement also returns a positive difference, although insignificant. These results align with the original analysis performed on a three-day event window. For the third announcement, a positive and significant difference was computed too. The result is quite extensive, with a 3.4% difference, which is surprising as the original analysis did not return significant differences between the firms in the Eurozone alone or combined with the non-Eurozone firms. It seems like on a shorter event window, the results are more precise, and all point towards a clear positive interpretation of the announcements by investors.

6.2.2 Event window of eleven days

The results of the events studies performed on the Eurozone firms only, but with an event window of 5 days before the event until five days after, are displayed in table 32 in Appendix B. The Shapiro-Wilk tests are in table 23 in Appendix A. As a normal distribution was rejected for the first event, only a Wilcoxon test was used to check the difference in the median values.

For the first event, the results are equal for the green and brown firms. However, the differences are sizeable and significant for the second and third events. This is interesting as both effects were insignificant when looking at a three-day event window solely for the Eurozone. While investors initially showed reluctance towards the European Central Bank's move to adopt climate change mitigation measures, causing them to invest more outside the Eurozone, these results suggest that the emphasis on sustainability may have a more enduring impact after a few days.

6.2.3 Narrow definition of green and brown firms

The results of the events studies performed on the Eurozone firms only, but with a higher benchmark for the green and brown firms, are displayed in table 33 in Appendix B. The Shapiro-Wilk tests are in table 24 in Appendix A. As a normal distribution was rejected for the first event, only a Wilcoxon test was used to check the difference in the median values.

After analyzing three events, it was found that the stocks of green firms in the Eurozone performed better than those of brown firms when only selecting firms at a 10% benchmark. The first event showed a slight difference of 0.03 percentage points, while the second and third events had much larger differences of 1.61 percentage points and 1.94 percentage points, respectively. All three robustness checks confirm the original analysis, implying that the impact of the announcements in the Eurozone, was positive in favour of the green firms.

6.3 Robustness check for non-Eurozone firms only

6.3.1 Event window of three hours

The results of the Shapiro-Wilk tests of the event studies performed on a shorter event window for the non-Eurozone firms are displayed in table 25 in Appendix A. Following these results, only Wilcoxon tests were performed on the median values for the first and the third event, while the second event was also analyzed with a t-test and Welch-test. The results of the event studies can be found in table 34 in Appendix B.

For all three events, positive differences in median CAR were computed. However, the first and third announcements were found to be insignificant. For the second event, a positive difference in mean CAR was calculated at 0.37 percentage points and a difference in median CAR of 0.99 percent-

age points when comparing the green firms to the brown firms. Both the mean and median differences turned out to be significant at a 5% level. The results align with the original analysis, which also found three positive differences in favour of green firms, although not all significant.

6.3.2 Event window of eleven days

The results of the events studies performed on the non-Eurozone firms only, but with an event window of 5 days before the event until five days after, are displayed in table 35 in Appendix B. The Shapiro-Wilk tests are in table 26 in Appendix A. As a normal distribution was rejected for the first and third events, only a Wilcoxon test was used to check the difference in the median values.

The discrepancies between green and brown firms operating outside the Eurozone are insignificant when analyzed on a more prolonged event window for all three events. This finding is not unexpected since previous analyses of Eurozone and non-Eurozone events also showed insignificant results over a longer duration. These outcomes suggest that the spillover effects of heightened attention towards a company's sustainability were merely a temporary effect.

6.3.3 Narrow definition of green and brown firms

The results of the events studies performed on the non-Eurozone firms only, but with a higher benchmark, are displayed in table 36 in Appendix B. The Shapiro-Wilk tests are in table 27 in Appendix A. As a normal distribution was rejected for the second, only a Wilcoxon test was used to check the difference in the median values.

None of the analyzed announcements yielded significant results. Surprisingly, the mean and median CARs for the first and third events were even in favour of the brown firms, contradicting the original analysis, although with low statistical significance. One possible explanation could be the smaller size of the benchmark datasets used in this study, which was only 10%. Conducting a larger-scale event study could provide more clarity on the matter, and it would be interesting to explore this avenue further.

6.4 Robustness checks on the difference between Eurozone and non-Eurozone firms

6.4.1 Event window of three hours

The results of a comparison between Eurozone and non-Eurozone firms on a shorter event window of three hours can be found in table 37 in Appendix B alongside the Shapiro-Wilk tests computed, in table 28 in Appendix A. Due to the results of the Shapiro-Wilk tests, only Wilcoxon-tests were performed when comparing certain groups.

For the first two announcements, all groups experienced a lower CAR in the Eurozone than outside the Eurozone. This aligns with the findings of the original analysis. Insignificant results were computed on the original three-day event window for the third event. This is not the case here. For the green firms, significant and positive differences are seen in the Eurozone compared to the non-Eurozone firms. For the brown firms, the opposite is true, as the results are negative and significant, which implies brown firms outside the Eurozone had a better CAR that day.

6.4.2 Event window of eleven days

The events studies' results on the differences between Eurozone and non-Eurozone firms, but with an event window of 5 days before the event until five days after, are displayed in table 38 in Appendix B. The Shapiro-Wilk tests are in table 29 in Appendix A. As a normal distribution was rejected for the first event, only a Wilcoxon test was used to check the difference in the median values.

The only significant comparisons are for the first event, and the brown firms on the third event. These all show negative signs, indicating that investing in Eurozone firms remains less favourable for multiple days after these events. Specifically, the results show that after the first event, the median CAR was 2.75 and 2.36 percentage points lower for the green and brown firms in the Eurozone, respectively. For the third event, the median CAR of the brown firms remains significant and negative, 1.88 percentage points lower for those in the Eurozone. As measured on the shorter event window, the positive effect for the green firms within the Eurozone did not stay. These differences still suggest a significant adverse reaction towards climate mitigation, although somewhat smaller than the benefit of the green firms in the Eurozone on a more prolonged event window.

6.4.3 Narrow definition of green and brown firms

The events studies' results on the differences between Eurozone and non-Eurozone firms, but with stricter benchmarks, are displayed in table 39 in Appendix B. The Shapiro-Wilk tests are in table 30 in Appendix A. As a normal distribution was rejected for the first and second events, only Wilcoxon-tests were used to check the difference in the median values for these two events.

None of the results are significant, except for the difference between the green firms in the Eurozone and those outside the Eurozone after the third event. However, it is essential to consider that there were other factors in play that day, so this should be approached with caution. In most other comparisons, the median CARs for the Eurozone were negative. As previously mentioned, the small sample sizes on these 10% benchmarks may be the reason for the lack of significant results.

7 Discussion and limitations

After analyzing the impact of three ECB announcements about climate mitigation on the combined dataset of Eurozone and non-Eurozone firms, it was discovered that investors had a more favourable perception of the two first announcements for green firms than brown firms. A significant difference in median CARs of 0.92 and 1.5 percentage points was computed for the first and second announcements, respectively. This is noteworthy, given that the Paris Agreement resulted in a 2.86 difference in CARs between clean and dirty assets when analyzed on a three-day event window, as Antoniuk and Leirvik (2021) reported. A study similar to the analysis conducted in this paper, by Eliet-Doillet & Maino (2022), examined the announcement of the Monetary Policy Strategy Review by the ECB. It discovered a median difference of 0.6 CAR between firms with high and low emissions. When it comes to unconventional monetary policy, other studies have found that there is an average impact of 0.69 percentage points on CAR when analyzing 120 different policies (Ferreira & Serra, 2022). This is comparable, although smaller, with the results computed here. Overall, the results suggest that the ECB effectively influenced investors' perceptions regarding the increased significance of a company's sustainability. Since the third announcement covered a group of policies, it is understandable that the outcomes were not significant. Nevertheless, the median difference in CARs still leans towards benefiting green firms. After conducting various robustness checks, it is evident that the outcomes are indeed stable. Notably, on a shorter event window, even the third announcement shows a positive and significant result when comparing the green and brown companies. As could be expected from related literature, the effects of the first two announcements are even stronger when analyzed on a shorter event window. However, when extending the event window to eleven days, the contrast remains positive but loses statistical significance. This suggests that the effect of an ECB announcement is not long-lasting, which is consistent with what has been found in the literature. Furthermore, with a more specific classification of green and brown companies, the differences in median CAR values are positive for all three announcements, although only significant for the second one. This is most likely due to the small dataset caused by the higher benchmark.

The findings of the first phase of the research suggest that implementing more environmentally-friendly measures in the ECB's monetary policy is a viable option. Nevertheless, the second phase, which involved comparing the performance of Eurozone and non-Eurozone companies, did not yield the expected positive results. When looking at the findings for the Eurozone firms only, no significant results were found. It is possible that the mixed perceptions of investors caused the effects to be unclear. While the announcements were perceived as more favourable for green firms, they were also considered unfavourable for the Eurozone. When looking at Eurozone firms versus those outside the Eurozone within the same category, significant negative differences in median CARs are observed in the first two announcements - which hold the most relevance - at 3.1 and 5.86 percentage points, respectively. This holds for both categories of companies. In fact, the impact is even greater than the contrast observed

between green and brown companies, indicating that the negative perception of the Eurozone on that particular day is more powerful than the growing emphasis on sustainability. These results are important, as they demonstrate a comparable magnitude of impact to that observed in a study analyzing the effects of Brexit on the UK versus unaffected European countries (Burdekin et al., 2018). Borghesi et al. (2022) examined the behaviour of green and brown portfolios following green-policy announcements in different European countries. They found that when a government takes such a policy, on average, international investors perceive this as positive and boost the short-run stock market. Based on these findings, it appears that the adverse outcomes experienced by Eurozone companies in this paper are not directly linked to their implementation of climate action. Instead, the problem may lie with the ECB intervening and way of communicating.

After conducting thorough robustness checks on the Eurozone exclusively, it has become evident that the impact is more pronounced. Specifically, when examining the top and bottom 10% of firms in the Eurozone, all three events have surfaced as significant and positive for environmentally conscious firms. On a shorter event widow, the first and third announcements also yield favourable results for the green firms. Moreover, when extending the event window, the last two announcements indicate a positive and significant effect in favour of green firms. The results for non-Eurozone firms appear insignificant in most robustness checks, especially on a more prolonged event window. On a short event window and when looking at the top and bottom 10% of green and brown firms, the results are consistent with the original findings, although often insignificant. The robustness checks conducted to compare the Eurozone and non-Eurozone, confirm that the impact on the Eurozone remains negative, although somewhat less significant.

The findings are consistent with the outcomes reported in other research papers regarding the influence of climate change (mitigation) on stocks, such as those by Eliet-Doillet & Maino (2022) and Antoniuk & Leivik (2021). As far as I am aware, no literature is available as a reference regarding the spillover effects or impacts on non-Eurozone stock markets resulting from climate policies implemented by the ECB or EU.

The presented hypotheses were successfully addressed using the Fama and French (1992) event study model. Nevertheless, limitations exist within the study. Firstly, extending the analysis to a larger dataset would be worthwhile. Furthermore, as previously stated, the environmental scores generated by rating agencies are far from perfect. Examining the climate mitigation policies of fully sustainable and extremely polluting firms that are comparable and free from biases would be compelling. Even with all the data available on emissions and outsourcing within production, it is senseless that biases persist and greenwashing continues to be prevalent among large companies. The wealthiest companies can hire experts to fulfil the rating agencies' criteria for higher scores. An illustrative case is Shell, the oil & gas enterprise, which received an environmental score of 91 despite being highly polluting

(Refinitiv, n.d.). This is the reason the sectoral division was done first. The conducted event study may still have some bias as there is no assurance that the green firms are entirely sustainable. During the analysis of the original dataset, it was noted that there was still a bias towards larger firms in the green firm subset, as observed in both revenue and number of employees. Upon reviewing the literature, there appears to be a negative correlation between firm size and the impact of unconventional monetary policy. This suggests that if any bias exists in the results, it would paint an even more positive picture for green firms (Henseler & Rapp, 2018). However, it should be noted that some older studies have indicated that the impact of monetary policy on smaller firms is simply stronger than for bigger firms, rather than being entirely positive or negative (Guo (2004), Thorbecke (1997)). Since there is no definitive conclusion regarding the impact of firm size on monetary policy, it would be beneficial to utilize more impartial environmental scores to reinforce the results.

8 Conclusion

This study evaluated the effectiveness of the ECB's initial efforts in addressing climate change. Three announcements of the past year were analysed regarding the greening of the ECB's asset portfolio and collateral framework. Since October 2022, the central bank has prioritised companies with higher environmental performance when reinvesting their maturing assets. The size of these reinvestments is relatively small compared to the total portfolio, which means that the policies set forth by the ECB will not directly change emission levels. Instead, the announcements served as a signal to investors and businesses that sustainability is now important for the central bank. Therefore, it was crucial to assess whether the message has been effectively communicated to the financial sector to set the future of the ECB's climate decisions. The effectiveness of these signals was evaluated on the stock market, which serves as a suitable platform for this purpose.

The paper effectively addressed the previously stated hypotheses:

Hypothesis 1: When the ECB announces a climate mitigation policy, this sends a signal to investors, and the stocks of the European green firms outperform the stocks of the European brown firms on the days around these announcements.

This hypothesis has been thoroughly confirmed, at least in cases where no other significant monetary policy updates were released on the same day. The first two announcements, that only regarded climate policies, yielded favourable and significant results in favour of the green firms compared to the brown firms on the European stock market. When comparing median cumulative abnormal results, the difference between the green and brown firms added up to 0.92 and 1.5 percentage points for the first and second announcements, respectively. The difference between both types of firms for the third announcement was also positive, although insignificant. On a shorter event window of three hours, all three announcements had an even more positive and significant impact on the green firms, which confirms the original results. After a few days, however, the effect seems to have faded, as it usually does for ECB announcements. It can be concluded that the ECB effectively emphasised the significance of sustainability through their policies and communication.

Hypothesis 2: A stronger effect of the ECB announcements is expected for green firms in the Eurozone, as these could become eligible for purchase, compared to green firms not located in the Eurozone.

It has been confirmed that the hypothesis was incorrect, as the opposite has been proven. Interestingly, the three recent announcements had a more adverse effect on Eurozone firms than non-Eurozone firms, regardless of whether they are green or brown. Investors seem not to support the European Central Bank's efforts towards climate change mitigation. The measured effects are even stronger than the increased care for sustainability, with differences in median CAR between 2.11 and 5.8 percentage points between Eurozone and non-Eurozone firms. The reason for this disapproval is up for debate; it could

be due to the ECB's departure from neutrality and involvement in political matters, or it could be a fear of the potential effects of the overall strong climate mitigation actions in Europe. The literature generally finds that when a government takes climate action, the stocks experience a positive response, implying that the negative effect on the Eurozone in this study is due to the fear of the ECB stepping away from its neutrality principle. After conducting thorough robustness checks, it was observed that the results remained consistent. The effect on firms operating in the Eurozone returned stronger on the robustness checks than in the initial analysis. In contrast, the outcomes for non-Eurozone firms in the robustness checks were frequently inconclusive, contrasting with the original research.

Overall, investors are hesitant about the ECB getting involved in climate mitigation, as they are concerned about the potential loss of impartiality and focus on the primary objective. The ECB will have to assess if the impact of their policies on climate change and company behaviour towards better climate performance outweighs the temporary aversion of investors. If the policies have minimal effect, monetary policy may not be the best approach to address global warming. However, as the European Commission moves further into its path towards a sustainable European Union, it is likely that sustainable finance continues to grow while more polluting sectors lose market power. A shift towards a more sustainable financial world may therefore be inevitable, even if investors are not yet on board. While the ECB has made some commendable strides, they still have a ways to go in terms of reducing its carbon bias in its portfolio and collateral framework. This implies that while investors may be hesitant about the decisions, but if the ECB continues to hold a disproportionate amount of carbon-intensive assets in the future, it could lead to even greater aversion towards investing in the Eurozone down the line.

A Shapiro-Wilk tests

		Green firms	Brown firms
First event	W	0.8895	0.9578
	p-value	(0.00003)***	(<0.01)***
Second event	W	0.899	0.8896
	p-value	(<0.01)***	(0.00002)***
Third event	W	0.9817	0.988
	p-value	(0.0761)*	(0.1222)

p-value in parentheses

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$

Table 16: Shapiro-Wilk tests performed on CARs of Eurozone and non-Eurozone firms combined

		Green firms	Brown firms
First event	W	0.9912	0.9799
	p-value	(0.871)	(0.232)
Second event	W	0.9652	0.9326
	p-value	(0.0299)***	(0.0003)***
Third event	W	0.9621	0.9828
	p-value	(0.0192)**	(0.3493)

p-value in parentheses

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$

Table 17: Shapiro-Wilk tests performed CARs of Eurozone firms only

		Green firms	Brown firms
First event	W	0.9836	0.9686
	p-value	(0.7001)	(0.0149)**
Second event	W	0.9929	0.936
	p-value	(0.9898)	(0.0012)***
Third event	W	0.9494	0.9866
	p-value	(0.0298)**	(0.3893)

p-value in parentheses

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$

Table 18: Shapiro-Wilk tests performed CARs of non-Eurozone firms only

		Green firms	Brown firms
First event	W	0.9643	0.9633
	p-value	(0.0037)***	(0.00006)***
Second event	W	0.9504	0.9659
	p-value	(0.0013)**	(0.00002)**
Third event	W	0.9886	0.8748
	p-value	(0.4144)	(0.00001)***

p-value in parentheses

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$

Table 19: Shapiro-Wilk tests with a smaller event window

		Green firms	Brown firms
First event	W	0.9517	0.4229
	p-value	(<0.01)* * *	(0.00001)* * *
Second event	W	0.9858	0.9911
	p-value	(0.2004)	(0.3138)
Third event	W	0.9887	0.9892
	p-value	(0.3675)**	(0.1751)

p-value in parentheses

*$p < 0.1$, **$p < 0.05$, * * *$p < 0.01$

Table 20: Shapiro-Wilk tests with a bigger event window

		Green firms	Brown firms
First event	W	0.9218	0.9793
	p-value	(0.0009)* * *	(0.1129)
Second event	W	0.9711	0.9567
	p-value	(0.1658)	(0.0004)* * *
Third event	W	0.9831	0.9876
	p-value	(0.5712)	(0.4728)

p-value in parentheses

*$p < 0.1$, **$p < 0.05$, * * *$p < 0.01$

Table 21: Shapiro-Wilk tests with a narrow definition of green and brown firms

		Green firms	Brown firms
First event	W	0.9858	0.9681
	p-value	0.5844	0.1169
Second event	W	0.9871	0.9436
	p-value	(0.6649)	(0.0056)* * *
Third event	W	0.9836	0.876
	p-value	(0.4629)	(<0.01)* * *

p-value in parentheses

$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 22: Shapiro-Wilk tests on Eurozone firms only with a smaller event window

		Green firms	Brown firms
First event	W	0.9417	0.3611
	p-value	(0.001)* * *	(<0.01)* * *
Second event	W	0.9865	0.9828
	p-value	(0.5749)	(0.3488)
Third event	W	0.9893	0.9818
	p-value	(0.7596)	(0.3028)

p-value in parentheses

$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 23: Shapiro-Wilk tests on Eurozone firms only with a longer event window

		Green firms	Brown firms
First event	W	0.9373	0.9439
	p-value	(0.0008)***	(0.0358)**
Second event	W	0.9826	0.9487
	p-value	(0.0579)*	(0.834)
Third event	W	0.9783	0.9657
	p-value	(0.5979)	(0.2234)

p-value in parentheses

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$

Table 24: Shapiro-Wilk tests on Eurozone firms only with a narrow definition of green and brown firms

		Green firms	Brown firms
First event	W	0.8368	0.951
	p-value	(0.00002)***	(0.0021)***
Second event	W	0.986	0.9845
	p-value	(0.879)	(0.7925)
Third event	W	0.9772	0.9525***
	p-value	(0.5565)	(0.0018)

p-value in parentheses

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$

Table 25: Shapiro-Wilk tests on non-Eurozone firms only with a shorter event window

		Green firms	Brown firms
First event	W	0.9897	0.9523
	p-value	(0.9337)	(0.001)***
Second event	W	0.9839	0.9
	p-value	(0.7145)	(0.5707)
Third event	W	0.9736	0.9689**
	p-value	(0.3092)	(0.0157)

p-value in parentheses

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$

Table 26: Shapiro-Wilk tests on non-Eurozone firms only with a longer event window

		Green firms	Brown firms
First event	W	0.9516	0.9736
	p-value	(0.4821)	(0.4821)
Second event	W	0.9779	0.936
	p-value	(0.9352)	(0.0086)***
Third event	W	0.9131	0.9867
	p-value	(0.1128)	(0.835)

p-value in parentheses

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$

Table 27: Shapiro-Wilk tests on non-Eurozone firms only with a narrow definition of green and brown firms

		Green firms EU	Green firms non-EU	Brown firms EU	Brown firms non-EU
First event	W	0.9858	0.8368	0.9671	0.951
	p-value	(0.5844)	(0.00002)* * *	(0.1169)	(0.0021)* * *
Second event	W	0.9871	0.986	0.9435	0.9845
	p-value	(0.6649)	(0.879)	(0.0056)* * *	(0.7925)
Third event	W	0.9836	0.9772	0.876	0.9525
	p-value	(0.4629)	(0.5565)	(<0.01)* * *	(0.0018)* * *

p-value in parentheses

*$p < 0.1$, **$p < 0.05$, * * *$p < 0.01$

Table 28: Shapiro-Wilk tests on the difference between EU and non-EU with a shorter event window

		Green firms EU	Green firms non-EU	Brown firms EU	Brown firms non-EU
First event	W	0.9417	0.9897	0.3611	0.9523
	p-value	(0.0013)***	(0.9337)	(<0.01)***	(0.0009)***
Second event	W	0.9865	0.9839	0.9829	0.989
	p-value	(0.5749)	(0.7145)	(0.3488)	(0.5707)
Third event	W	0.7596	0.3092	0.9818	0.9689
	p-value	(0.7596)	(0.3092)	(0.3028)	(0.0157)**

p-value in parentheses

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$

Table 29: Shapiro-Wilk tests on the difference between EU and non-EU with a longer event window

		Green firms EU	Green firms non-EU	Brown firms EU	Brown firms non-EU
First event	W	0.9103	0.9516	0.9439	0.9736
	p-value	(0.003)***	(0.4821)	(0.0358)**	(0.3092)
Second event	W	0.9487	0.9779	0.9849	0.936
	p-value	(0.0579)**	(0.9352)	(0.834)	(0.008)***
Third event	W	0.9783	0.9131	0.9657	0.9867
	p-value	(0.5979)	(0.1128)	(0.2234)	(0.835)

p-value in parentheses

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$

Table 30: Shapiro-Wilk tests on the difference between EU and non-EU with a narrow definition of green and brown firms

B Robustness checks for Eurozone and non-Eurozone separately

B.1 Eurozone only

B.1.1 Shorter event window

		Green firms	Brown firms	Green firms vs brown firms
First event	Mean CAR	0.0076**	-0.0057	0.0133**
		(0.0332)[1]	(0.1364)[1]	(0.0127)[1]& (0.0108)[2]
	Median CAR	0.0092**	-0.0013	0.0105**
		(0.0124)[3]	(0.1231)[3]	(0.0104)[3]
Second event	Median CAR	-0.0047	-0.0101	0.0054
		(0.107)[3]	(0.1907)[3]	(0.426)[3]
Third event	Median CAR	0.0376***	0.0036	0.034***
		(0.00001)[3]	(0.6188)[3]	(0.00001)[3]

p-value in parentheses

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$

[1] t-test, [2] Welch-test,[3]Wilcoxon-test

Table 31: Significance tests on Eurozone firms only with a shorter event window

B.1.2 Longer event window

		Green firms	Brown firms	Green firms vs brown firms
First event	Median CAR	-0.0044	-0.0044**	0
		(0.3764)[3]	(0.0434)[3]	(0.3823)[3]
Second event	Mean CAR	0.0178	-0.0198*	0.0368**
		(0.1197)[1]	(0.09)[1]	(0.0214)[1] & (0.0214)[2]
	Median CAR	0.0129	-0.0219*	0.0348**
		(0.1846)[3]	(0.0791)[3]	(0.043)[3]
Third event	Mean CAR	0.0362**	0.0039	0.0323*
		(0.011)[1]	(0.7524)[1]	(0.0879)[1] & (0.0882)[2]
	Median CAR	0.0327**	0.0093**	0.0234
		(0.0195)[3]	(0.7382)[3]	(0.1102)[3]

p-value in parentheses

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$

[1] t-test, [2] Welch-test,[3]Wilcoxon-test

Table 32: Significance tests on Eurozone firms only with a longer event window

B.1.3 Narrow definition of green and brown firms

		Green firms	Brown firms	Green firms vs brown firms
First event	Median CAR	0.0016	0.0013	0.0003*
		(0.1256)[3]	(0.4569)[3]	(0.1)[3]
Second event	Median CAR	0.0087***	-0.0074	0.0161**
		(0.007)[3]	(0.4541)[3]	(0.0187)[3]
Third event	Mean CAR	0.0279***	0.0085	0.0194*
		(0.0003)[1]	(0.2206)[1]	(0.0528)[1] & (0.0529)[2]
	Median CAR	0.0264***	0.0121	0.0143*
		(0.001)[3]	(0.2563)[3]	(0.0656)[3]

p-value in parentheses

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$

[1] t-test, [2] Welch-test,[3]Wilcoxon-test

Table 33: Significance tests on Eurozone firms only with a narrow definition of green and brown firms

B.2 Non-Eurozone only

B.2.1 Shorter event window

		Green firms	Brown firms	Green firms vs brown firms
First event	Median CAR	0.0051**	0.0096***	0.0039
		(0.0104)[3]	(0.0001)[3]	(0.6254)[3]
Second event	Mean CAR	0.0103*	-0.0066	0.0037**
		(0.0838)[1]	(0.1498)[1]	(0.0227)[1] & (0.0242)[2]
	Median CAR	0.0064*	-0.0035	0.0099**
		(0.0585)[3]	(0.1601)[3]	(0.0187)[3]
Third event	Median CAR	0.0193	0.0099***	0.0094
		(0.1225)[3]	(0.00004)[3]	(0.588)[3]

p-value in parentheses

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$

[1] t-test, [2] Welch-test,[3]Wilcoxon-test

Table 34: Significance tests on non-Eurozone firms only with a shorter event window

B.2.2 Longer event window

		Green firms	Brown firms	Green firms vs brown firms
First event	Median CAR	0.0231***	0.0192*	0.0039
		(0.0005)[3]	(0.0754)[3]	(0.21)[3]
Second event	Mean CAR	-0.0069	-0.0005	-0.0064
		(0.5954)[1]	(0.953)[1]	(0.6877)[1] & (0.6879)[2]
	Median CAR	-0.012	0.0008	-0.0128
		(0.5964)[3]	(0.8797)[3]	(0.7239)[3]
Third event	Median CAR	0.0164	0.0281***	-0.0117
		(0.8038)[3]	(0.0019)[3]	(0.1124)[3]

p-value in parentheses

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$

[1] t-test, [2] Welch-test,[3]Wilcoxon-test

Table 35: Significance tests on non-Eurozone firms only with a longer event window

B.2.3 Narrow definition of green and brown firms

		Green firms	Brown firms	Green firms vs brown firms
First event	Mean CAR	0.0105*	0.0043	-0.0064
		(0.0627)[1]	(0.7786)[1]	(0.8177)[1] & (0.7028)[2]
	Median CAR	0.0112**	0.0164	-0.0052
		(0.0305)[3]	(0.8038)[3]	(0.9435)[3]
Second event	Median CAR	0.0007	0.0002	0.0005
		(0.571)[3]	(0.9067)[3]	(0.571)[3]
Third event	Mean CAR	0.004	0.0213**	-0.0173
		(0.6731)[1]	(0.013)[1]	(0.2638)[1] & (0.173)[2]
	Median CAR	0.0107	0.0189**	-0.0082
		(0.6441)[3]	(0.0225)[3]	(0.436)[3]

p-value in parentheses

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$

[1] t-test, [2] Welch-test,[3]Wilcoxon-test

Table 36: Significance tests on non-Eurozone firms only with a narrow definition of green and brown firms

B.3 Difference

B.3.1 Shorter event window

		Green firms Eurozone vs non-Eurozone	Brown firms Eurozone vs non-Eurozone
First event	Median CAR	-0.0041***	-0.0109
		$(0.0074)^3$	$(0.4818)^3$
Second event	Mean CAR	-0.0063	/
		$(0.2966)^1$& $(0.3457)^2$	
	Median CAR	-0.0011	-0.0066**
		$(0.2735)^3$	$(0.0196)^3$
Third event	Mean CAR	0.0226**	/
		$(0.051)^1$& $(0.048)^2$	
	Median CAR	0.0183**	-0.0064**
		$(0.0552)^3$	$(0.0274)^3$

p-value in parentheses

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$

Table 37: Event studies and significance tests comparing Eurozone and non-Eurozone firms with a shorter event window

B.3.2 Longer event window

		Green firms Eurozone vs non-Eurozone	Brown firms Eurozone vs non-Eurozone
First event	Median CAR	-0.0275* * *	-0.0236* * *
		$(0.0017)^3$	$(0.0074)^3$
Second event	Mean CAR	0.0247	-0.0193
		$(0.153)^1$& $(0.1604)^2$	$(0.1854)^1$& $(0.192)^2$
	Median CAR	0.0249	-0.0227
		$(0.203)^3$	$(0.01781)^3$
Third event	Mean CAR	0.0198	/
		$(0.1346)^1$& $(0.1242)^2$	
	Median CAR	0.0163	-0.0188*
		$(0.1445)^3$	$(0.0785)^3$

p-value in parentheses

*$p < 0.1$, **$p < 0.05$, * * *$p < 0.01$

Table 38: Event studies and significance tests comparing Eurozone and non-Eurozone firms with a longer event window

B.3.3 Narrow definition of green and brown firms

		Green firms Eurozone vs non-Eurozone	Brown firms Eurozone vs non-Eurozone
First event	Median CAR	-0.0096	-0.0151
		$(0.1833)^3$	$(0.7213)^3$
Second event	Median CAR	0.008	-0.0076
		$(0.3529)^3$	$(0.6626)^3$
Third event	Mean CAR	0.0239^*	-0.0128
		$(0.066)^1$& $(0.0497)^2$	. $(0.246)^1$& $(0.2351)^2$
	Median CAR	0.0157^*	-0.0068
		$(0.08)^3$	$(0.3351)^3$

p-value in parentheses

$^*p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 39: Event studies and significance tests comparing Eurozone and non-Eurozone firms with a narrow definition of green and brown firms

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