GREEN MONETARY POLICY:

Analysing the impact of ECB green policy announcements on the performance of green bonds.

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Preface

Writing this dissertation marks the end of my studies in economics. It is clear that I could not have completed this dissertation without the encouragement of some key people. Therefore, this is a good moment to express my gratitude towards them.

I would like to thank Professor De Schryder for the opportunity to write this master's thesis. I want to thank her for her assistance throughout the writing process. Her valuable insights and comments were crucial in bringing this master's thesis to a successful conclusion.

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Michiel Depoorter

Ghent, June , 2024

Contents

List of abbreviations

ABS   Asset-backed security

ABSPP   Asset-Backed Security Purchase Programme

APP   Asset Purchase Programme

BoE   Bank of England

BoJ   Bank of Japan

CBI   Climate Bond Initiative

CBPP3 Covered Bond Purchase Programme

CISS   Composite Indicator of Systemic Stress

CSPP   Corporate Sector Purchase Program

CSRD   Corporate Sustainability Reporting Directive

DiD   Difference-in-Differences

DRC   Democratic Republic of Congo

DSGE   Dynamic Stochastic General Equilibrium

ECB   European Central Bank

EU   European Union

GBP   Green Bond Principles

GVA   Gross Value Added

IAM   Integrated Assessment Model

MRO   Main Refinancing Operations

NGFS   Network for Greening the Financial System

PBoC   People's Bank of China

PEPP   Pandemic Emergency Purchase Programme

PSPP   Public Sector Purchase Programme

TLTRO Targeted Longer-Term Refinancing Operations

WGI   Worldwide Governance Indicators

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Introduction

Climate change stands out as perhaps the most pressing challenge confronting humanity in the 21st century. The science is unequivocal. Global emissions of greenhouse gases must end within years to avoid catastrophic climate instability. Through the Paris Agreement, countries have agreed on a target of limiting global heating to well below 2°C, and preferably to 1.5°C by the end of the century (United Nations, 2015).

Although governments and legislators have the primary responsibility for driving and supporting this transition, the European Central Bank (ECB) believes that they must do their part by promoting sustainable finance and greening monetary policy operations, without prejudice to the ECB's primary objective of price stability. An orderly transition to a green economy would, in the longer run, reduce climate-related risks for the entire economy and financial system, as well as for the inflation outlook and the assets on the Euro system balance sheet.

This paper examines how financial markets react to green ECB policy announcements. More specifically, the effect of five different green ECB announcements on the greenium (the premium investors are willing to pay for green bonds) is examined in this paper.

The first part discusses the avenues in which climate change can influence macroeconomic outcomes. The second part of the papers gives an extended overview of green central banking. It explores different green monetary policy tools. It dives deeper into the possibility to green the ECB's main refinancing operations, targeted longer-term refinancing operations, collateral framework, quantitative easing and forward guidance. The third part of the paper explores green ECB speeches and their possible impact on financial markets is given. Then, the fourth chapter discusses the green bond market and the concept of the greenium. In the fifth chapter, the empirical approach and the hypotheses are presented. The sixth chapter discusses the overall impact on these five events. The seventh chapter discusses an overall impact of the five events. Following this, chapter eight addresses the limitations and possibilities for further research are given. The last chapter includes an overall conclusion of this paper.

1 Climate change and monetary policy

In line with the Treaty on the Functioning of the European Union, the ECB has the obligation, within its mandate and without prejudice to the primary objective of price stability, to support general economic policies in the European Union (EU). In that way, the ECB can contribute to the transition to a carbon-neutral economy and to protecting the environment.

In addition to the obligation to support the general economic policies of the EU within its mandate the ECB's efforts to contribute to the transition to a carbon-neutral economy and to protect the environment can also influence their primary objective. Because climate change impacts macroeconomic outcomes, financial markets, and institutions primarily through two avenues: physical risk and transition risk (European Central Bank, 2021a). Physical risks arise from the interaction of heightened average temperatures, increased occurrences of extreme weather events, and the vulnerability of societal and economic systems to these hazards. These risks encompass gradual global warming and its resultant physical changes, such as rising sea levels or alterations in precipitation patterns, as well as natural disasters like hurricanes, floods, and heatwaves. Transition risk, on the other hand, pertains to the impact and challenges associated with transitioning to a green economy, including transition costs and investment needs.

1.1 Physical risk

Climate change is expected to increase the occurrence and intensity of extreme weather events, further amplifying the ongoing global warming trend. This heightened physical risk is anticipated to alter both the nature and frequency of economic shocks. Extreme weather events can be primarily thought of as supply shocks, which tend to increase prices and lower output, posing a challenge for central banks. Central banks respond based on the shock's duration and the impact on inflation. If this is only short-lived, central banks may tolerate temporary inflation to avoid output and employment volatility, as emphasized by former Bank of England (BoE) governor Mervyn King's statement about "inflation nutters" (King, 1997). Monetary policy action may be warranted only if the shock is more persistent and there are risks of dis-anchoring inflation expectations. As climate change amplifies the frequency and severity of supply shocks, central banks may find it increasingly challenging to overlook or disregard these shocks (Batten et al., 2016; Batten, 2018; Rudebusch, 2019).

The literature confirms that there are also demand-side adjustments, both in the short-term and long-term. These adjustments stem from disruptions to income, shifts in consumption patterns, alterations in investments, changes in export dynamics, impact on infrastructure, and shifts in consumer behaviour, which could be linked to migration trends and increasing climate awareness. As climate change is anticipated to exacerbate not only the frequency and severity of natural disaster but also the gradual degradation of the environment, including issues like air and water pollution, global warming, acid rain and wildfires. These changes may result in premature deaths and injuries, compelling individuals to flee their homes and relocate temporarily or permanently to other regions, thereby affecting overall well-begin and welfare (Ciccarelli & Marotta, 2021). On top of this, as discussed by Andersson et al. (2020), uncertainty surrounding future conditions may prompt businesses and investors to adopt a more cautious approach and reduce their willingness to invest in long-term projects.

1.2 Transition risk

As mentioned above, physical risk is not the only avenue on which climate change impacts macroeconomic outcomes, financial markets, and institutions. Transition risk is also a significant consideration, representing the challenges associated with the shift to a greener economy. The green transition is likely to have substantial effects on economic and financial activities, relative prices and inflation, output growth and productivity and hence on the optimal response from monetary policy. Schnabel, member of the ECB's executive board, states that we will face a new age of energy inflation with three interconnected shocks. First, she mentions *'climateflation'* referring to the supply shocks we previously discussed in the part on physical risk (European Central Bank, 2022a).

The second shock, named *'fossiliflation'* refers to the trend of rising fossil fuel prices due to efforts to combat climate change. Many institutional investors have started to reduce their exposures to fossil fuel energy producers. Because fewer investors are willing to provide capital to fossil fuel producers, the cost of loans and other forms of financing for these companies are increasing. Higher capital costs make new investments less attractive and raise the threshold for companies to start new projects or expand existing operations. This contributes to the sluggish response of crude oil production in large parts of the world. On top of that, energy producers try to steer supply in the oligopolistic energy market, pushing up prices at the expense of energy importers, such as

the euro area (European Central Bank, 2022a). In 2023, the fossil fuel sector once again lost ground to the market as a whole. Oil majors reported a 30% decline in annual profits and the sector posted an annual loss in return of almost 5% (Chung and Cohn, 2024).

According to the report of the Institute of Energy Economics and Financial Analysis (Chung and Cohn, 2024), fossil fuel stocks have dragged down stock market returns over the last 10 years. This pattern broadly holds, despite the fossil fuel sector's profits in the wake of the COVID-19 pandemic and the war in Ukraine. As the long-term outlook for fossil fuels remains negative, we can expect exposure to fossil fuel energy producers to decrease even further.

The last shock is called *'greenflation.'* Green technologies require significant amounts of metals and minerals, such as copper, lithium and cobalt. Green technologies are set to account for most of the growth in demand for most metals and minerals in the near future (Valcx et al., 2021). However, supply of these metals and minerals is constrained in the short and medium term since it takes five to ten years to develop new mines. The imbalance between rising demand and constrained supply is why the prices of many commodities have increased over the last years (European Central Bank, 2022a).

In addition to the imbalance caused by the slow development of new mines, there is also the danger of supply chain disruptions from geopolitically sensitive countries. For instance, the Democratic Republic of Congo (DRC), where 73% of cobalt mines were situated in 2022 (Cobalt Institute, 2022), ranks in the bottom 10 percent of countries on the Worldwide Governance Indicators (WGI). This indicator measures the quality of governance in over 200 countries, assessing factors such as political stability, absence of violence, government effectiveness, regulatory quality, rule of law and control of corruption (Kaufmann and Kraay, 2023).

Cavallero (2021) examined the impact of different conflicts in the Democratic Republic of Congo on the price of cobalt. Civil war and regional conflicts have disrupted or eliminated several times in de DRC and resulted in fierce price fluctuations. Given the importance of cobalt in the green transition, these geopolitical tensions can also impact inflation and consequently the primary objective of the ECB. Through this geopolitical channel, 'greenflation' can thus also come into play.

2 Green monetary policy tools

On the one hand, a warming planet causes damages that will make resources scarcer and prices higher. On the other hand, the fight against climate change will make fossil fuels and raw materials more expensive. How should central banks conduct monetary policy in this new landscape?

The Network for Greening the Financial System (NGFS) reported a growing consensus among its members for the idea that, at the very least, central banks must assess, and where appropriate adopt, appropriate risk management measures to protect their balance sheets against emerging climate related financial risks. Climate-related financial risks may damage market confidence, output and financial stability, and thus affect both the counterparties and financial assets that are used in monetary policy operations. Assets held by central banks can lose value due to various climate-related risks. This would generate losses for central banks. While a central bank's objective is not to generate profits but to fulfil a broader mandate, financial losses can nevertheless pose risks to the reputation, credibility and financial independence of a central bank (NGFS, 2021). However, it is still not clear what adjustments would be optimal, given the large uncertainty surrounding climate change and the transition policies, as well as the possible losses these may cause.

Central banks can use instruments that they already have, by greening them. In the following sections, I will go deeper on the different possibilities central banks have to green their monetary policy framework.

2.1 Green the banks' main refinancing operation

Adjusting the key interest rate on main refinancing operations (MROs) is the first way in which monetary policy could green up. Central banks could adjust the main refinancing operation rate applied to a bank by a premium (positive or negative) determined based on the average degree of climate risk associated with the credits that this bank grants to its customers. Kempf (2020) formulated this proposal and stated that this would make commercial banks aware of the climate implications of their lending activity. The introduction of this climate premium on the interest rate on MROs would add a positive opportunity cost to the granting of carbon credits, whereas this cost is currently non-existing. This scheme would be applied to private commercial banks but also public, national, or regional banks. If they target their activity towards the financing of green projects, they could obtain refinancing at lower rates.

Roy (2024) has looked into the effects of this green policy measure. He employs the modern monetary macroeconomics model, known as the 3-equation model. In particular, the IS curve, Phillips curve and interest rate-based monetary policy rule (IS-PC-MR) model, as proposed by Clarida et al. (1999) and later elaborated by Carlin and Soskice (2015) serves as analytical framework. To calibrate the model, the author uses a Mathematical Programming Language (AMPL).

As we can see in figure 1, this new policy framework would work through two different channels. The production channel (1,2) and the consumption channel (3). A green interest rate will increase the credit flow, as a percentage of total credit flows in the economy, to industries working to reduce carbon emissions. A fall in the credit flows to high carbon-intensive industries will diminish their capital formation and productivity, while low-carbon intensive industries will experience increased capital formation and productivity. As a result, the production of high-carbon intensive goods drops and so do the carbon emissions. On the other hand, as the production of high-carbon intensive inputs like oil and coal decreases, their supply and subsequent consumption also diminish, leading to a reduction in emissions through the consumption channel. Simultaneously, the production of low-carbon intensive goods increases, resulting in a higher supply and consumption of these products, which further reduces emission levels (Roy, 2024).
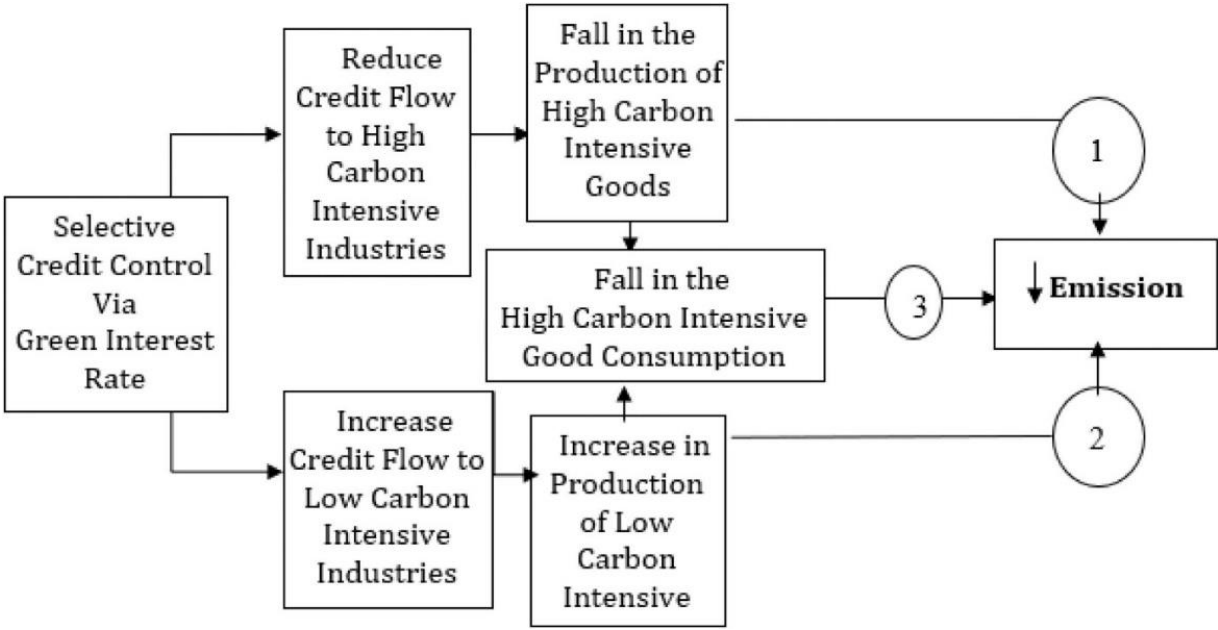

Figure 1: Transmission mechanism of green interest rates.

Source: Roy, A. (2024). Green monetary policy to combat climate change: Theory and evidence of selective credit control. Journal of Climate Finance, 6, 100035.

The calibration of the model used in the paper, reveals that green credit flow will increase over time. Output will first decline due to the fall in output in the carbon-intensive industries and then reverses as output increases in the low-carbon industries driven by the innovation effect. Carbon emissions decline steadily as green credit flows increases over time. In their model, equilibrium output is the level of output associated with constant inflation. Initially, inflation decreases as aggregate demand falls due to output reduction. However, it stabilizes at a new steady state as output rebounds. The key insight of this paper is that by implementing green interest rates, a central bank can simultaneously achieve two critical goals: minimizing both inflation and emissions.

2.2 Green targeted longer-term refinancing operations

Targeted longer-term refinancing operations (TLTROs) are Eurosystem operations that provide financing to credit institutions. Banks receive long-term funding at attractive conditions, helping to preserve favourable borrowing conditions for banks and stimulate bank lending to the real economy, at least when monetary policy is accommodative (European Central Bank, 2021b).

It is argued that TLTROs are the ECB instrument with the most direct real economic impact. Other monetary policy instruments focus on the price of short-term credit or the quantity in the financial system, while TLTROs seek to incentivize lending to the real economy. The problem with standard TLTROs is that banks are enticed to ramp up their unsustainable lending practices. By providing cheap funding without applying any environmental criteria, the ECB accelerates a set of market practices that may be unsustainable (van 't Klooster & van Tilburg, 2020).

van 't Klooster and van Tilburg (2020) insist that green TLTROs would tackle this problem. Green TLTROs are like all LTROs targeted, they do not just provide banks with one refinancing rate, but rather incentivize a specific allocation of capital towards green investment. So how would the Green TLTRO programme work in practice? Instead of providing credit at a unitary refinancing rate, the interest rate on Green TLTRO credit is determined by the volume of bank lending that complies with the EU's Green Taxonomy. The taxonomy is a classification system that defines criteria for economic activities that are aligned with a net zero trajectory by 2050 and the broader environmental goals other than climate (European Commission, 2020).

Operational aspects of green TLTROs have to be taken into account. An effective green TLTRO program should be designed to (i) evaluate to what extent bank lending is green as well as (ii) verify whether information provided by banks is accurate and "ensure that the fungible funds provided by banks are correctly and effectively used by individual borrowers to finance green projects" (Drudi et al., 2021) Colesanti Senni, Pagliari & van 't Klooster (2023) came up with three design options:

- **EU policy-based design**: The most simple model for Green TLTROs would be to rely on EU Taxonomy regulation. With clear criteria in place, verification of reported lending patterns could be left to the bank's external auditor.

- **Bank-based design:** The selection of what counts as a green investment could be left to systems developed by banks and evaluated by the central bank. As a part of the Bank of Japan's (BoJ's) Climate Response Financing Operations, eligible counterparties are required to develop internal systems to screen bank loans based on "targets and actual results for their investment or loans" (BoJ, 2022). If the ECB would opt for this design, the ECB's role would be to evaluate the adequacy of bank screening criteria, while the external auditor could be asked to certify reported lending.

- **Supervisory expectations-based design:** Green TLTROs could be used to support existing financial stability policies in which supervisors scrutinize banks internal risk management capacities for climate and environmental risk screening. Eligibility in the program could be made available for lending by banks that meet the expectations set out in the ECB's Guide on climate-related and environmental risks (European Central Bank, 2020). However, most banks lack adequate systems to incorporate climate and environmental risks into their lending decisions (European Central Bank, 2022b).

Green TLTROs could be powerful instruments to steer the climate transition in case the ECB would offer lower rates for loans under the commitment that they use the proceeds of the longer-term operations for green lending. Excess liquidity in the financial system could impact the effectiveness of Green TLTROs. If banks already have excess liquidity the impact of offering cheaper funding for green purposes might be limited. The additional funds provided by green TLTROs may be less attractive when there is excess liquidity in the system. Banks may not see a significant need to utilize these specific funding source, because they already have ample liquidity.

2.3 Green the composition of assets accepted as collateral in refinancing operations

To implement a sound monetary policy, central banks lend money only against adequate collateral. The Eurosystem collateral framework includes a wide range of collateral types to ensure sufficient collateral availability for a wide range of counterparties with different business models, operating in different markets (Adler et al., 2023).

The value of the collateral is based on four different risk control measures. First of all, counterparty and collateral eligibility criteria are considered, this to make sure that operations are conducted with financially sound banks and lent against adequate collateral. Secondly, there is the valuation of the collateral, which occur on a daily basis for marketable assets. Finally, valuation haircuts, depending on the asset's credit and market risk, as well as liquidity are applied (Bindseil et al., 2017).

Even though the collateral framework of a central bank is not a direct monetary policy tool, it can aid in its implementation. During the COVID-19 crisis, the collateral framework was used to provide market liquidity. The ECB approved a general 20% reduction in the haircuts, this increased the amount of money that banks can borrow from the ECB, since they could borrow more with the same colleteral. It is argued that this was the first instance in which the ECB used haircuts as a monetary policy instrument (Adler et al., 2023).

The European Central Bank (2022c) announced the greening of its collateral framework in July 2022. The Eurosystem will limit the share of collateral from high carbon footprint entities for borrowing. The aim is to reduce climate-related financial risks in Eurosystem credit operations. In that same announcement, the ECB promised to consider climate change risks when reviewing haircuts applied to corporate bonds used as collateral. On top of that, the Eurosystem will only accept marketable assets and credit claims from companies and debtors that comply with the Corporate Sustainability Reporting Directive (CSRD) as collateral in its credit operations. These CSRD-compliance requirements are applicable as of 2026 (European Council, 2022). In December 2022, the European Central Bank (2022d), however, reversed its earlier decision and said they will not incorporate climate change considerations in its haircut schedule.

When examining the literature, there is an increasing consensus of including climate risk considerations into the collateral framework of central banks. McConnel, Yanovski and Lessman (2022) see "brown" collateral haircuts based on carbon exposure as a promising instrument, since it can help the economy to stay below a certain emission target with a lower carbon price. They state that collateral should be treated differently, since the "brown" collateral is associated with additional transition risk. This treatment in in line with the market neutrality principle, in this case collateral haircuts are based on transition risk assessments. Another remarkable finding of their study shows that when monetary policy adopts this approach, the optimal size of carbon taxes, decided by fiscal authorities, can decrease. In this way, differentiated collateral valuations and conventional carbon pricing can be considered complementary instruments for achieving emission reduction, which means that, in the presence of a brown collateral haircut, the economy can stay below a certain emission target with a lower carbon price. This can potentially make a timely transition to a carbon neutral economy more politically feasible.

Dafermos et al. (2021) specified three policy scenarios for the greening of the collateral framework. In the first scenario, the list of eligible bonds remain the same, but the haircuts of the bonds are adjusted according to their climate footprint. In the second scenario, fossil fuel companies' bonds (except for bonds with a 'green' label) are excluded from the list of eligible bonds and other bonds with relatively low climate footprints are added instead. In the third scenario bonds issued by other carbon-intensive companies are excluded and replaced with other bonds that are not carbon-intensive and satisfy fully or partly the eligibility criteria. In all of these scenarios, the carbon intensity of eligible bond list declines. There is a higher decline in the second and third scenario, suggesting that these scenarios are more consistent with tackling climate emergency.

The People's Bank of China (PBoC) already introduced a green collateral framework. The PBoC included green financial bonds into the pool of eligible assets. Also giving those bonds a first-among-equals status, meaning these bonds have priority over other financial bonds. Macaire and Naef (2023) revealed a notable impact of the policy change on the yield spread between green and non-green bonds. Using a difference-in-difference approach, they show that the policy increased the spread by 46 basis points.

One major concern with these proposals is that issues arise for the following eligible asset classes, which made up 79% of the collateral used in the Eurosystem in the first quarter of 2024 (Oustry et al., 2020; European Central Bank, 2024b):

- **Non-marketable assets**: such a credit claims, face challenges in carbon footprint assessment due to insufficient data availability. Credit claims involve many micro-debtors for whom detailed data is not available. An accurate assessment of their carbon impact hence poses a significant challenge. While sectoral averages can be used, these may not provide precise insights.

- **Asset-backed securities (ABS):** an ABS is a security whose income payments are derived from a specified pool of underlying assets such as residential mortgages or public sector or auto loans. From a climate analysis perspective, assessing the ABS means assessing the underlying assets. While there is an evolution of regulation on the disclosure of information such that more and more data on the debtors is accessible for authorities, this data is often not climate specific and debtors, micro-debtors included, are not covered by carbon databases.

- **Covered bonds:** Like an ABS, a covered bond is a security refinancing a pool of non-marketable assets. It is difficult to access the data of the underlying asset from a covered bond which poses challenges for assessing climate risks.

The greening of the collateral framework is promising. By adjusting haircuts or eligibility criteria, a decrease in carbon emissions and lower yields for green bonds can be observed. However, a significant part of Eurosystem collateral is difficult to assess due to insufficient climate specific data.

2.4   Green quantitative easing

In normal economic circumstances, the ECB influences financial conditions and hence, macroeconomic developments and inflation by setting the short-term key interest rates. However, following the global financial crisis of 2008 and shifts in the way our economy works, key interest rates neared their effective lower bound. The ECB adopted alternative measures to address the risk that inflation could be too low for too long (European Central Bank, 2022e).

The Asset Purchase Programme (APP) was one of those alternative measures. It was one of the two extensive purchase programmes of the ECB. It was initiated in mid-2014 to support the monetary policy transmission mechanism and provide the amount of policy accommodation needed to ensure price stability. The APP consisted of four different programmes: Corporate sector purchase programme (CSPP), public sector purchase programme (PSPP), asset-backed securities purchase programme (ABSPP) and third covered bond purchase programme (CBPP3). The ECB decided not to reinvest redemptions as of July 2023. Although the ECB is currently not reinvesting in the APP, a significant amount of assets remain on its balance sheet. The stock of Eurosystem APP bonds still stood at €3098 billion at the end of April 2024 (European Central Bank, 2024a)..

The second extensive purchase programme of the ECB was the Pandemic Emergency Purchase Programme (PEPP). To counter the impact on the euro area economy of the coronavirus pandemic, the PEPP allowed the ECB to purchase different types of assets in financial markets. Prices of those assets went up, and by extension market interest rates went down, by doing this. This helped to maintain borrowing, spending and investment despite the pandemic crisis (European Central Bank, 2021c).

On 16 December 2021 the Governing Council decided to discontinue net asset purchases under the PEPP at the end of March 2022 and to reinvest the principal payments from maturing securities purchased under the PEPP until at least the end of 2024. On 14 December 2023 the Governing Council announced that it intends to continue to reinvest, in full, the principal payments from maturing securities purchased under the PEPP during the first half of 2024 and to reduce the PEPP portfolio by €7.5 billion per month on average over the second half of the year. At the same time, the Governing Council announced that it intends to discontinue reinvestments under the PEPP at the end of 2024 (European Central Bank, 2024c).

Matikainen, Campiglio, and Zenghelis (2017) conducted a closer examination of the assets purchased. They found that emission-intensive sectors such as manufacturing and utilities make up a disproportionate share of estimated purchases relative to their contribution to gross value added (GVA) and the European bond market as a whole.

Many central banks such as the ECB, the Bank of England, and the Sverige Riksbank have started to study how to decarbonize their balance sheets and in particular their monetary policy portfolios. Motivated by this, Ferrari and Nispi Landi (2023) conducted research on Green QE (The purchase of green bonds).

Through the lens of a dynamic stochastic general equilibrium (DSGE) model, Ferrari and Nispi Landi (2023) answered the question whether green QE is useful in further reducing the flow of emissions and the stock of atmospheric carbon along the transition, and how it could be better designed to maximize its effectiveness. The model features two production sectors: a green sector, where firms do not pollute and a brown sector, where production generates CO_2 emissions. Brown firms are also taxed for each unit of emissions.

Ferrari and Nispi Landi (2023) showed that green QE is able to curb emissions by shifting demand from the brown to the green sector. However, the effect on the stock of euro-area and global pollution is small. Green QE can lead to a 0.6% reduction in emissions, but this reduction is only temporary as it returns to its steady-state level in the medium term. The intuitive explanation is that the large CO_2 stock in the atmosphere and the associated projected decline occur very slowly, making it difficult to influence through green QE. Climate change and pollutions are structural issues, whereas green QE primarily addresses cyclical fluctuations (Ferrari and Nispi Landi, 2023).

The findings of Ferrari and Nispi Landi (2023) had some relevant implications for the design of the policy. They find that green QE is more effective on climate in the short run, while their effectiveness decreases over time as the carbon tax kicks in. So it is better to act more aggressively immediately and then progressively reach market neutrality. Ferrari and Nispi Landi (2023) discovered that an important factor in assessing the policy's effectiveness is the elasticity of substitution between brown and green goods. When central banks invest in green bonds, they should determine what is green and what is brown in order to maximize this elasticity of substitution. This implies that a "best-in-class" (favouring firms with the cleanest technology) is more appropriate than the "best-in-universe" (discriminating between sectors) approach.

Dafermos et al. (2018) also conducted research on the impact of green QE. The authors found, after modelling an ecological macroeconomic model, that Green Quantitative Easing leads to a rise in the prices of green corporate bonds, resulting in a decrease in yields. This reduction in yields, they argue, leads to lower borrowing costs for all companies and reduced reliance on bank credit. Consequently, this leads to an increase in (sustainable) investments. It is through these investments that there is an increased use of renewable energy, thereby reducing CO2 emissions. However, similar to Ferrari and Nispi Landi (2023), they find a modest effect on CO2 emissions and temperature rise. Even with green QE, global warming is not significantly lower than 4°C by the end of the century according to their model.

A proposal by Abiry et al. (2022) is to implement a carbon tax, alongside green QE as a supplementary measure. Using an integrated assessment model (IAM), they determine that a carbon tax of $13.6 per tonne of carbon (This is low compared with for example the carbon price peaking at USD 98 per tonne of CO_2 under the EU Emissions Trading System in mid-August 2022), could potentially reduce global temperatures by 0.17 degrees Celsius. This reduction surpasses the maximum impact achievable through green QE alone by fourfold. Despite the modest effectiveness of green QE alone, it could still play a valuable role when combined with a well-structured fiscal policy.

An important remark, made by Abiry et al. (2022) is that international cooperation and agreements for the successful implementation of an effective carbon tax have an important role. The authors acknowledge that this might be challenging. In the case of failure of international cooperation, they suggest that green QE could be implemented at the regional level, such as within the European Union, serving as a complementary strategy to address climate change.

2.5 Green forward guidance

Forward guidance refers to the communications issued by the ECB Governing Council about its future monetary policy plans, be it in terms of key interest rates or asset purchase programmes. The ECB Governing Council began employing forward guidance in July 2013, and since then, it has periodically adjusted its approach. By managing the expectations of economic actors and reducing uncertainty surrounding monetary policy actions, forward guidance helps ensure the effective transmission of monetary policy (European Central Bank, 2022f).

A large literature is showing that central bank communication significantly influences asset markets. For instance, Gurkynak, Sack, and Swanson (2004) show that a big part of the surprise news about monetary policy at the time of FOMC announcements arise from signals about the central bank's intentions about future monetary policy. Similarly, Altavilla et al. (2019) conducted an event study on the ECB's monetary policy communication. They also confirm that communication by central banks can significantly influence asset markets.

The ECB could green this monetary policy tool. By taking an active role in raising awareness about climate, the ECB could influence green asset markets. To provide a better understanding of this communication, I refer to section six of this paper, where five green announcements from the ECB are discussed, each accompanied by a brief explanation of the content of the announcement. Central banks doing this are likely to face diverse constraints and criticisms. For example, public communication by central banks emphasizing the urgency to green the financial system could be perceived as an attempt to expand the responsibilities and increase their authority (Boneva et al., 2022). Hence, central banks undertaking such actions are likely to encounter criticism.

Ehremann, Georgarakos and Kenny (2023) however, conducted an information experiment in September 2021. A random subset of respondents received different pieces of information about the ECB's inflation target and its new monetary policy strategy, and a control group received no information. This setup allowed the authors to determine causal effects of communicating the strategy review decisions on the perceived credibility of the ECB's target. They found out that providing additional information, such as climate change considerations of the central bank, implies no additional credibility gains, but does not negatively affect credibility either.

In what follows, the effect of green ECB announcements on the greenium is examined. First, a discussion on green ECB speeches will be presented. Next, this paper provides an extensive overview of the green bond market. Finally, in the last section, these elements are combined in an event study to analyse the impact of green ECB speeches on the greenium.

3 Green ECB speeches

The first ECB speech concerning climate change was delivered by Sabine Lautenschläger in 2018 (European Central Bank, 2018). Since then, there are 78 speeches on the topic of climate change available in the public available ECB speech database (European Central Bank, 2024d). Notably, 25 of the 78 speeches on climate change by the ECB are from president Christine Lagarde

As mentioned before, central bank communication can influence asset markets. Neszveda and Siket (2023) tried to examine the impact of green ECB speeches on assets markets. The authors find that green speeches by the ECB have a substantial and statistically significant impact on financial markets and can help to further green goals. The authors used a green sentiment index to evaluate the greenness of ECB speeches between 2010 and 2020. They then looked at their impact on stock returns of portfolios with differing emission reduction records. They defined green speeches as a speech with a primary green focus, and the title must contain one green-related term. The results show that the stock performance of the most polluting portfolios lags far behind greener portfolios. They also found that the strongest effects emerge following the ECB speeches with a greener tone.

Eliet-Doillet and Maino (2022) shed light on the role central banks can play in fostering the transition to a low-carbon economy. They delved into the impact of the monetary policy strategy review of the ECB in July 2021 on green bonds. They found that there was a statistically and economically significant reduction in Yield-to-Maturities of eligible green bonds compared to eligible conventional bonds. Overall their findings provide evidence of the positive effects on green bond issuance of including green considerations within monetary policy operations.

Sangiorgi and Sopohl (2021) used survey evidence from European asset managers, the authors provide insights into their green bond investment activities and the factors that affect their investment decisions. Their survey revealed that European asset managers would invest more in the green bond market if policy makers would do more on the policy side to incentivise investments in green bonds. Preferential capital treatments of low carbon assets and minimum standards of green definitions receive strong investor support.

From the survey by Sangiorgi and Sophol (2021), it is clear that policy makers can influence the green bond market, European asset managers would invest more in the green bond market if policy

makers incentivise investments in green bonds. Furthermore, Nezszveda and Siket (2023) and Eliet-Doillet and Maino (2022) demonstrate that the ECB can influence green assets through their green announcements. Following a discussion of the green bond market and calculating the greenium, this paper aims to test if the ECB can influence the greenium. In section 6, the impact of five green ECB announcements on the greenium is examined.

4 Overview of green bonds

Green bonds are sustainable finance instruments that aim at financing environmentally sustainable projects and the transition to a low-carbon economy. According to the International Capital Market Association (2021), a green bond is any type of bond instrument where the proceeds or an equivalent amount will be exclusively applied to finance or re-finance, in part or in full, new and/or existing eligible green projects which are aligned with the four core components of the Green Bond Principles (GBP). A bond is classified as a green bond if the *Use of Proceeds* principle is satisfied. This is the case if the issuer allocates the bond proceeds specifically to finance qualifying green projects, as outlined in the bond's legal documentation. The second component, *the Process for Project Evaluation and Selection principle*, is met when the issuer effectively communicates: (i) the objectives of the green project, (ii) the criteria that render the project eligible and (iii) the environmental and social risk associated with it. The third principle, the *Management of Proceeds*, necessitates that bond proceeds are diligently managed and monitored within the company's financial structure. This may involve establishing a dedicated sub-account to segregate the proceeds. Lastly, according to the *Reporting principle,* a company should provide comprehensive reports on the utilization of green bond proceeds and the specific project to which funds have been allocated in the final report (International Capital Market Association, 2021).

Since the GBP are voluntary, many investors are sceptical about Green marketing and "Greenwashing", i.e., misleading claims regarding Green credentials (Kapraun et al., 2021). Here's where the Climate Bonds Initiative (CBI) certification steps in to enhance the credibility of green bonds. CBI issued its standard (Climate Bond Standard). This document established the requirements for green bond certifications. It is built on the broad integrity principles contained in the ICMA's GBP. It allows investors, governments and other stakeholders to identify and prioritize low carbon and climate-resilient investments and avoid "greenwashing" (Climate Bonds Initiative, 2024).

Incorporating the CBI certification into the evaluation of green bonds adds a layer of credibility, ensuring that only projects with tangible environmental benefits are financed. This is particularly significant in the context of this thesis, as focusing on CBI-certified green bonds provides a more robust and reliable basis for analysing the impact of green monetary policy announcements on green bond performance.

4.1 The green bond market

Green bonds are becoming more and more popular. The European Investment Bank was the first green bond issuer on the market in 2007. Their "climate awareness bond" was widely seen as the first bond with a green label (European Investment Bank, 2021). The World Bank quickly followed in 2008. The first sovereign European country that issued green bonds was Poland in 2016. The world's largest issuer of green bonds is the European Union. In order to fund the EU Next Generation Program, they will raise up to 30% of the funds needed for the plan with green bonds. Governments play a significant role in the issuances of green bonds. When looking at the top three issuers of green bonds, we can find the French and German republics, alongside the European Union.

As depicted in Figure 2, the green bond market has experienced rapid expansion since 2015, surpassing 250 issued green bonds with a total value exceeding 200 billion euros. However, there was a notable decrease in the issuance of green bonds in 2023, attributed to the challenging macroeconomic environment during that period.
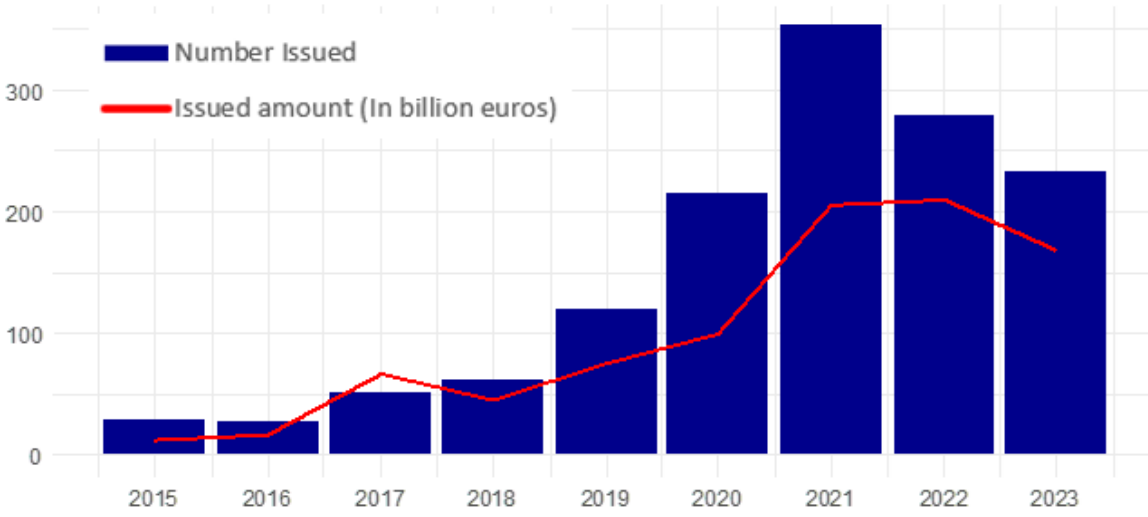

Figure 2: Green Bonds in the Eurozone: Number Issued and Issued Amount in Billion Euros

Source: Refinitiv

4.2 Greenium

The greenium of a green bond is defined as the additional spread a green bond pays when compared with an equivalent non-green bond of matching maturity, seniority and currency. There is some debate as to whether a greenium exists. Methodological heterogeneity among different studies has resulted in general ambiguity regarding a consensus over the existence of the green premium (MacAskill et al., 2021; Kedia & Joshipura, 2023).

Ma et al. (2020) provide us with key qualitative arguments in favour of a negative greenium (i.e. a green bond should yield less than an equivalent non-green bond):

1. Investors derive added benefits from green bonds due to their positive environmental impact and psychological appeal.

2. Growing demand for green bonds may outpace supply, driven by investors seeking to enhance ESG credentials.

3. A key aim of green bonds is to allow green projects to be financed at a lower cost than would be usually associated with bond issuance, and hence encourage more green projects to be taken on by corporations. This should help to transition away from projects which are less environmentally friendly. In this case, one would expect a negative greenium.

4. Arguably, green bonds may be part of a more buy-and-hold long-term strategy, reflecting their commitment to sustainability and patience in realizing environmental outcomes. This should lead to lower volatility in market sell-offs.

5. There are more costs involved for an issuer to bring a green bond, in form of third party verification or greater disclosure requirements. The extra costs potentially leads to lower coupon rates.

On the other hand, Ma et al. (2020) also come up with two arguments which dispute that a greenium should exist. Firstly, the growth of green bonds has far outstripped the growth of green bond funds. This indicates that many green bonds are held by non-dedicated investors, and that green bond investors have a more limited influence on the pricing of these instruments in secondary markets. The growth of green bonds that outstrips the growth of green bond funds can be the case when traditional bond investor, who may not prioritize environmental concerns in their investment strategies, are also buying green bonds. As a result, the influence of dedicated green bond investors may be diluted by the larger pool of bond investors.

Secondly, the quantitative aspect cannot be disregarded. Fixed income investors are assessing attractiveness based on the underlying credit risk and the risk premium offered by the bond. In the event of an issuer default, green bonds are treated exactly the same as non-green bonds. They have equal claim in default. Additionally, the issuer covers the coupon payments and notional repayment on the bond, not the relevant green project. Hence, the investor must consider the financial risk of the issuer. So purely examining from a quantitative viewpoint will always point to no greenium existing.

4.3 Matching

In this paper the greenium is calculated by matching bonds from the Green Bond Guide of Refinitiv (n.d.) with their non-green counterparts. This allows for a direct comparison between the financial performance of green bonds and their non-green counterparts. By matching bonds with similar characteristics, the analysis helps in determining whether investors are willing to accept lower returns for green bonds compared to non-green bonds with similar risk profiles. In this thesis, the following criteria, similar to Zerbib (2019) and Kapraun et al. (2021), when matching green bonds and non-green bonds are

1. Bonds are issued by the same company.
2. Bonds are denominated in the same currency.
3. Issue date of matched bonds is no longer than two years apart.
4. Maturity date of matched bonds is no longer than two years apart.
5. Issue size of the bond is not less than half of the issue size and not more than two times the issue size of the matched bond.
6. Bonds have the same credit rating.
7. Bonds have the same bond structure.
8. Bonds have the same coupon type.
9. Bonds are exclusively issued within the Euro Zone.

All green bonds included in the Refinitiv database, have the green bond label of the Climate Bonds Initiative. An overview of matched bonds can be found in Appendix A. The sample that is used, consists of 32 matched bond pairs of unique issuers. In this way, issuers having too much influence on the results is avoided. If an issuer has more than one pair, the pair that is the longest running is chosen. In this way, more data point are available. The issue date of the earliest bond is 05/11/2015, and the longest-dated bond in the sample matures on 26-11-2051.

The financial sector is a major player of the euro-denominated green bond market. In the sample, 16 out of the 32 pairs are from issuers in the financial sector. The second largest sector in the sample is real estate with 5 out of the 32 pairs. It is also noteworthy that France has issued a significant portion of green bonds denominated in euros. Out of the 32 pairs in the sample, 18 originate from French issuers.

4.4   Option-Adjusted Spread

Investors use option-adjusted spread (OAS) analysis to first measure the value inherent in a bond's cash flows and embedded options and then to compare the results to market reference levels. OAS analysis, when used consistently, provides an apples-to-apples basis for measuring value (Miller, 2010).

In figure 3, we see the evolution of the greenium. This greenium was calculated based on the matched bond pairs, explained in section 4.3. In particular, the difference between OAS between green bonds and their non-green counterparts is presented. Throughout the majority of the period from August 2020 to March 2024, we take this period, since it will help us to do the analysis of the impact on green monetary policy announcement on the greenium, we note a negative greenium, indicating a higher demand for green bonds relative to non-green bonds. The greenium falls within the range of 0 to 5 basis points. This observation aligns with the finding of MacAskill et al. (2021), who conducted a systematic literature review on the green bond premium. Their research identified a greenium ranging between 1 and 9 basis points.
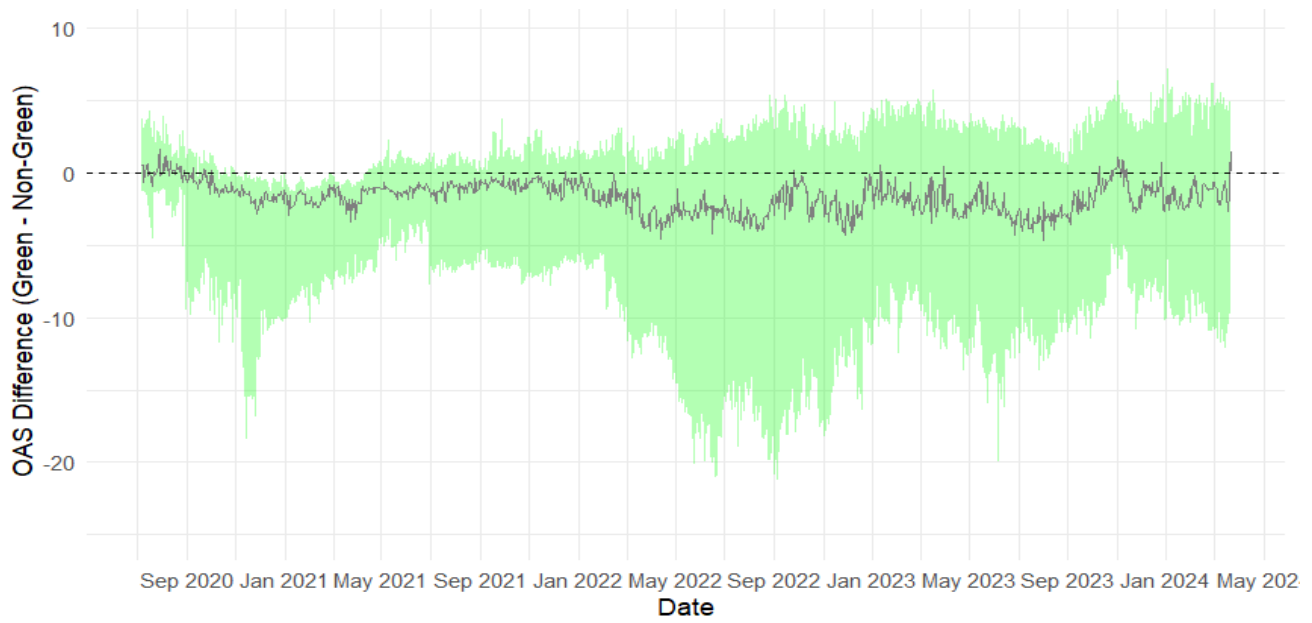
Figure 3: The greenium

Source: Own calculations, based on the matched bonds from Appendix A

5 Impact of green monetary policy announcements on the performance of green bonds

5.1 Hypothesis Development

This paper investigates whether green ECB announcements led to a decrease in the cost of bond financing for green projects and green firms. In particular, the effect of green ECB announcements on the Option Adjusted Spreads of green and conventional bonds. This analysis builds on prior studies focusing on the effects of the creation of the CSPP and PEPP on Yield-to-Maturities of green corporate bonds on secondary market transactions (Bremus et al., 2021), and the impact of the monetary policy strategy review on the Yield-to-Maturities of green bonds (Eliet-Doillet & Maino, 2022).

Based on the evidence of section 3, a drop in the Option Adjusted Spreads of green bonds relative to conventional bonds is expected after green ECB announcements.

> *Hypothesis 1: Following the green ECB announcements, it is expected that the OAS of green bonds decrease relative to the OAS of conventional bonds.*

As stated in section 4.1 green projects have faced challenges stemming from elevated interest rates, rising component costs, and disruptions in the supply chain, resulting in penalties for such initiatives. That is why this paper also wants to include the impact of the yield curve spot rate with a 10-year maturity on nominal government bonds issued by all issuers with a AAA rating (European Central Bank Data Portal, 2024c). This factor is incorporated to investigate whether the differences in OAS between green and non-green bonds can potentially be explained by higher interest rates. By taking this variable into account, a deeper understanding of the dynamics of the bond market and the factors influencing the valuation of green versus non-green bonds is obtained.

> *Hypothesis 2: Higher long-term interest rates lead to greater penalties for green projects, thus we can expect that higher long-term interest rates will increase the OAS of green bonds more than the OAS of conventional bonds.*

Section 4.2 provides us with possible arguments in favour of a negative green bond premium. Ma et al. (2020) argue that green bonds may be part of a more buy-and-hold long-term strategy, reflecting their commitment to sustainability and patience in realizing environmental outcomes. This should then lead to lower volatility in market sell-offs. To test for this argument, this study incorporates the Composite Indicator of Systematic Stress (CISS), a metric designed to gauge financial stability across various market segments (European Central Bank Data Portal, 2024a). The CISS combines data from 15 financial stress indicators from five market segments, including banking and non-banking financial intermediaries, the money market, securities markets, and currency markets. Holló, Kremer and Duca (2012) state that the CISS is the most suitable measure of systemic stress due to its emphasis on simultaneous instability across multiple market segments.

Hypothesis 3: Green bonds may be part of a buy-and-hold strategy. This suggests that green bonds may exhibit greater resilience and lower volatility during market sell-offs. So, during periods of high systemic stress, the OAS of both green and conventional bonds are expected to increase, but the increase in OAS for green bonds should be less pronounced compared to conventional bonds

5.2 Empirical Design

In order to evaluate the impact of green ECB announcements on the performance of green bonds, a difference-in-differences approach is used. Differences-in-Differences (DiD) estimation has become an increasingly popular method for estimating causal relationships. This approach involves identifying a specific intervention or treatment, such as green ECB announcements in this paper. The next step is to compare the change in outcomes before and after the intervention for the affected group, green bonds in this paper, to the change in outcomes for the unaffected group, conventional bonds in this paper (Bertrand et al., 2004). The parallel trend assumption is a crucial condition for the validity of the difference-in-differences estimation. It means that in the absence of the intervention, the difference in outcomes between the treated and untreaded groups would have remained constant over time. Thus, the treated and control groups should have followed similar trends before the intervention (Marx et al., 2024).

The following regression specification is employed:

$$OAS_{it} = \alpha + \beta_1 \text{ Green}_i + \beta_2 \text{ After}_t + \beta_3 (\text{Green}_i * \text{After}_t) + \gamma FE + \varepsilon_{it}$$

OAS_{it} is the Option Adjusted Spread of bond i, at time t. $Green_i$, is a treatment dummy taking the value 1 for all green bonds and 0 for all non-green bonds. $After_t$ is a treatment dummy taking the value 1 after the green ECB announcement, 0 before. γFE are company fixed effects. The coefficient of interest is β_3, this coefficient measures the impact of the green speech on the green bonds. Standard errors are clustered at the bond level to robustify against serial correlation in the outcome (Bertrand et al., 2004).

Additionally, this study assesses the impact of long-term interest rates, and the CISS indicator on the performance of green bonds. For this purpose the following regression specification is employed:

$$OAS_{it} = \alpha + \beta_1 \text{ Green}_i + \beta_2 \text{ After}_t + \beta_3 (\text{Green}_i * \text{After}_t) + \beta_4 (\text{Green}_i * \text{Bond.Yield}_t) + \beta_5 (\text{Green}_i * \text{CISS}_t) + \gamma FE + \varepsilon_{it}$$

In this equation, β_4 is the coefficient of the interaction term between Bond Yield and Green, while β_5 is the coefficient of the interaction term between CISS and Green. These terms allow for the assessment of how the bond yield and the CISS indicator can influence the option adjusted spread of green bonds relative to non-green bonds. As in the first regression, standard errors are clustered at the bond level to robustify against serial correlation in the outcome (Bertrand et al., 2004).

The empirical part of this paper builds upon the work of Eliet-Doillet and Maino (2022), who provided a timeline of green ECB announcements. They identified five specific green ECB speeches regarding the incorporation of climate change considerations into its monetary policy strategy. These five green ECB speeches are discussed in section six of this paper. The research by Eliet-Doillet and Maino (2022) focuses on the impact of the Monetary Policy Strategy Review of the ECB. This research extends this, and aims to determine the impact of all five green ECB announcements on green bond performance. By examining these additional events, an assessment of the broader impact of green ECB announcements can be made. This broader analysis helps identify patterns and evaluate the overall effectiveness of green ECB announcements.

Three different time windows, for each event are employed: 1) One month before and after the announcement, 2) three months before and after the announcement and 3) six months before and after the announcement. For each time window within each event, regressions are conducted both with and without controls for bond yield and the CISS indicator. This approach ensures robustness in the results. Macaire & Naef (2023), in their study on the impact of green monetary policy in China, utilized a six-month time window, which is why a six-month window is also employed here. Additionally, Eliet-Doillet and Maino (2022) used a time window of four months before and two months after their events, leading to the choice of a three-month window to balance these approaches. One month was added to check for any immediate short-term impacts.

6   Results

In section one, we discussed why it is necessary for monetary policy to also consider the green transition in its framework. In section two, we explored how this could be achieved, with one of the methods being green forward guidance. Section three then discussed the impact of green forward guidance on financial markets. In section four, we examined the greenium, the yield difference between green and non-green bonds. Section five brought everything together and established our aim to assess the impact of green forward guidance on the greenium. The following sections analyse five different green ECB announcements, evaluating the impact of each on the greenium. A graphical representation of each event can be found in appendix B.

6.1   January 25th 2021: Climate change and central banking

Christine Lagarde concludes in this speech that the ECB will contribute in incorporating climate change within its mandate. Lagarde also calls for a greater role for sustainable investment an innovation. On this day, the ECB also decided to set up a climate change centre, to bring together the work on climate issues in different parts of the bank (European Central Bank, 2021d).

However, as expected, the bond yield increases the green OAS more relative to the OAS of non-green bonds, but only in the time window of six months before and after the announcement. This suggests that higher longer-term interest rates impact green project more severely in the longer-term.

Contrary to our hypothesis, the CISS index seems to increase the green OAS relative to the OAS of non-green bonds, but again, this effect is only observed in the long term. This may indicate that during this event, we might not be dealing with buy-and-hold investors who refrain from selling their green bonds during market sell-offs while selling their non-green ones.

Before drawing stronger conclusions, we will first discuss the results of the other events. This will be done prior to providing a general discussion and conclusion in section 7.

	Dependent variable: OAS					
	One month		Three months		Six months	
	(1)	(2)	(3)	(4)	(5)	(6)
Green	-8.560***	-3.775	-8.476***	-5.800	-4.640***	-4.822
	(1.244)	(8.621)	(1.127)	(6.855)	(0.973)	(4.646)
After	-8.831***	-3.127*	-27.411***	-7.576***	-43.024***	-20.727***
	(1.250)	(1.742)	(1.148)	(2.254)	(0.982)	(1.925)
Bond.Yield		-40.053***		-32.165***		22.366***
		(10.046)		(8.447)		(5.126)
CISS		137.127***		264.645***		338.970***
		(39.013)		(19.999)		(13.325)
Green:After	1.737	0.883	2.254	1.264	-0.922	0.363
	(1.768)	(2.463)	(1.607)	(3.185)	(1.348)	(2.716)
Green:Bond.Yield		5.904		6.293		14.899**
		(14.208)		(11.894)		(7.218)
Green:CISS		-22.993		7.677		59.604***
		(55.159)		(28.243)		(18.788)
Observations	1,816	1,816	5,204	5,204	9,996	9,996
R2	0.081	0.105	0.177	0.239	0.274	0.376
Adjusted R2	0.072	0.095	0.174	0.235	0.272	0.374
F Statistic	52.708*** (df = 3; 1798)	30.161*** (df = 7; 1794)	371.421*** (df = 3; 5181)	232.057*** (df = 7; 5177)	1,253.860*** (df = 3; 9969)	856.641*** (df = 7; 9965)
Note					*p<0.1; **p<0.05; ***p<0.01	

Table 1: Regression results of the announcement on January 25th 2021

6.2 June 14th 2021: From market neutrality to market efficiency

Executive board member of the ECB, Isabel Schnabel, hints at 'market efficiency' as guiding principle for greening monetary policy. She also states that governments should have the leading role in the global fight against climate change, but that the ECB cannot remain idle (European Central Bank, 2021e).

	Dependent variable: OAS					
	One month		Three months		Six months	
	(1)	(2)	(3)	(4)	(5)	(6)
Green	-4.875***	-4.164***	-5.284***	-5.309***	-6.426***	-4.590***
	(0.436)	(1.024)	(0.292)	(0.703)	(0.457)	(1.018)
After	-1.983***	-1.073**	-5.053***	-3.732***	-12.056***	-10.805***
	(0.419)	(0.531)	(0.282)	(0.351)	(0.447)	(0.441)
Bond.Yield		10.566**		9.539***		-23.655***
		(4.204)		(1.533)		(1.743)
CISS		-7.689		-0.344		77.884***
		(16.765)		(10.005)		(11.834)
Green:After	-0.459	-0.022	0.242	0.248	1.716***	1.460**
	(0.594)	(0.759)	(0.393)	(0.495)	(0.608)	(0.603)
Green:Bond.Yield		6.941		0.153		5.210**
		(5.976)		(2.168)		(2.459)
Green:CISS		9.850		1.839		-1.889
		(23.665)		(14.148)		(16.647)
Observations	1,755	1,755	5,555	5,555	11,813	11,813
R2	0.169	0.182	0.188	0.200	0.113	0.158
Adjusted R2	0.157	0.168	0.184	0.195	0.110	0.156
F Statistic	117.317*** (df = 3; 1729)	54.766*** (df = 7; 1725)	426.120*** (df = 3; 5526)	196.743*** (df = 7; 5522)	498.925*** (df = 3; 11778)	316.337*** (df = 7; 11774)
Note					*p<0.1;	**p<0.05; ***p<0.01

Table 2: Regression results of the announcement on June 14th 2021

In this event, we observe a negative greenium across all regressions, even with control variables included. Notably, the OAS of green bonds increases more than that of non-green bonds in the long term after this specific green ECB announcement. This is in contrast with our hypothesis. It is important to note that the next event occurs less than a month after this one, which may result in overlapping periods that influence the long-term outlook.

Similar to Event 1, green bonds are more adversely affected by higher long-term interest rates, causing their OAS to rise more significantly than that of non-green bonds. We do not find significant results regarding the CISS indicator, indicating that systematic stress in the system does not impact the relative performance of green versus non-green bonds.

6.3   July 8th 2021: Monetary policy strategy review

In the ECB's monetary policy strategy review, a roadmap to adapt the corporate bond purchase scheme to include climate considerations was given. The general tone was strong, but no implementation details were given. It was unexpected that so much importance would be given to climate issues (European Central Bank (2021f).

In this event, we see that even in the three month window, the green coefficient is significant and positive, indicating that the green OAS increases more, relative to the OAS of non-green bonds. This increased green OAS relative to the non-green OAS can also be seen in the time window of six months before and after this green ECB announcement. Additionally, in the longest time window, the six months' time window, the bond yield increases the OAS of green bonds more than that of non-green bonds.

	Dependent variable: OAS					
	One month		Three months		Six months	
	(1)	(2)	(3)	(4)	(5)	(6)
Green	-5.495***	-6.590***	-5.123***	-4.365***	-5.920***	-4.929***
	(0.438)	(1.704)	(0.278)	(0.738)	(0.269)	(0.570)
After	-3.967***	1.446		-5.389***	-9.433***	-9.699***
	(0.427)	(1.115)		(0.405)	(0.259)	(0.259)
Bond.Yield		23.293***		-0.305		-17.504***
		(4.197)		(1.587)		(1.037)
CISS		-31.152*		-2.198		17.299***
		(17.024)		(9.420)		(6.349)
Green:After	0.574	-0.443	0.607	1.288**	1.474***	1.429***
	(0.603)	(1.577)	(0.372)	(0.566)	(0.354)	(0.355)
Green:Bond.Yield		-3.862		4.077*		4.607***
		(5.924)		(2.233)		(1.460)
Green:CISS		8.213		0.451		6.499
		(24.110)		(13.331)		(8.899)
Observations	1,945	1,945	5,745	5,745	12,308	12,308
R2	0.189	0.211	0.108	0.194	0.194	0.229
Adjusted R2	0.178	0.198	0.083	0.190	0.191	0.226
F Statistic	149.037*** (df = 3; 1918)	73.037*** (df = 7; 1914)	337.542*** (df = 3; 5587)	196.471*** (df = 7; 5712)	981.692*** (df = 3; 12273)	519.678*** (df = 7; 12269)
Note					*p<0.1; **p<0.05; ***p<0.01	

Table 3: Regression results of the announcement on July 8th 2021

6.4 July 4th 2022: ECB climate agenda

The ECB confirmed on this date that they will take further steps to green its corporate bonds holding, citing October 2022 as starting date. The ECB announces that it will tilt their portfolio based on issuer 'climate performance' score, but no details were revealed about how this score will be constructed (European Central Bank, 2022g).

In the analysis of this event, no significant results were found for any of the hypotheses we aimed to test. Despite this, it is noteworthy that the greenium remains significantly negative for 5 out of 6 regressions conducted. This consistency in the negative greenium aligns with our earlier findings and suggest a persistent trend.

	One month		Three months		Six months	
	(1)	(2)	(3)	(4)	(5)	(6)
Green	-9.527***	-3.588	-7.996***	-4.941**	-6.771***	-4.763***
	(0.954)	(7.930)	(0.615)	(2.035)	(0.563)	(1.163)
After	0.213	10.156***	5.818***	-0.757	13.492***	1.849**
	(0.922)	(1.508)	(0.613)	(0.792)	(0.559)	(0.843)
Bond.Yield		20.827***		6.397***		6.885***
		(2.651)		(0.999)		(0.637)
CISS		-19.181**		46.841***		22.107***
		(9.637)		(5.842)		(4.003)
Green:After	1.462	-0.274	0.371	1.235	-0.191	1.692
	(1.304)	(2.132)	(0.866)	(1.119)	(0.791)	(1.192)
Green:Bond.Yield		-3.879		-1.518		-0.537
		(3.749)		(1.412)		(0.901)
Green:CISS		0.922		-4.563		-7.366
		(13.629)		(8.260)		(5.661)
Observations	2,752	2,752	8,376	8,376	16,673	16,673
R2	0.063	0.101	0.058	0.102	0.080	0.111
Adjusted R2	0.052	0.089	0.055	0.098	0.078	0.109
F Statistic	61.387*** (df = 3; 2717)	43.705*** (df = 7; 2713)	172.428*** (df = 3; 8341)	135.260*** (df = 7; 8337)	482.674*** (df = 3; 16638)	296.620*** (df = 7; 16634)
Note					*p<0.1; **p<0.05; ***p<0.01	

Dependent variable: OAS

Table 4: Regression results of the announcement on July 4th 2022

6.5 September 19th 2022: ECB provides details on how it aims to decarbonise its corporate bond holdings

On this day, the ECB gave further details regarding components of the 'climate performance' score. This score will include: (i) a backward-looking component, based on past GHG emissions and emissions intensities, (ii) a forward-looking component, based on the ambitions and the credibility of firm's climate objectives, and (iii) a disclosure component. The ECB also confirms that a favourable treatment is given to externally reviewed green bonds in its primary market bidding behaviour (European Central Bank, 2022h).

When interpreting the results of the final event, a similar conclusion as with event 4 can be found. The only difference is that a positive significant result is found at the period six month after the announcement on green bonds OAS relative to non-green bonds OAS, but it is only at the 90 percent confidence level. This suggest a potential impact, but it is important to note that this significance level falls slightly short of conventional thresholds, preventing us from drawing conclusions based on this result.

	Dependent variable: OAS					
	One month		Three months		Six months	
	(1)	(2)	(3)	(4)	(5)	(6)
Green	-7.669***	-7.664	-8.017***	-4.348	-7.707***	-4.595**
	(1.011)	(8.347)	(0.750)	(3.878)	(0.610)	(2.248)
After	6.136***	5.855***	5.306***	-0.298	7.607***	-1.628
	(1.000)	(2.068)	(0.750)	(1.434)	(0.610)	(1.273)
Bond.Yield		5.067		7.396***		6.667***
		(3.282)		(1.558)		(1.028)
CISS		-28.914*		-6.498		46.049***
		(16.035)		(5.903)		(3.547)
Green:After	0.779	0.901	1.653	3.623*	1.295	3.247*
	(1.414)	(2.925)	(1.061)	(2.027)	(0.863)	(1.801)
Green:Bond.Yield		-0.672		-2.378		-1.637
		(4.642)		(2.202)		(1.454)
Green:CISS		2.910		-1.221		-3.715
		(22.677)		(8.347)		(5.016)
Observations	2,751	2,751	8,317	8,317	16,626	16,626
R2	0.066	0.068	0.037	0.041	0.037	0.061
Adjusted R2	0.054	0.055	0.033	0.037	0.035	0.059
F Statistic	63.748*** (df = 3; 2716)	28.354*** (df = 7; 2712)	106.663*** (df = 3; 8282)	50.640*** (df = 7; 8278)	212.005*** (df = 3; 16591)	154.091*** (df = 7; 16587)
Note					*p<0.1; **p<0.05; ***p<0.01	

Table 5: Regression results of the announcement on September 19th 2022

7 Discussion and limitations

An increase in the greenium for the second and third event, on the 14th of June and the 8th of July 2021 respectively was found. For the third event, we found an increase in the three-month window with control variables. For both events, we found an increase in the greenium in both the model with and without control variables for the six month window. There appears to be no significant impact on the greenium for the other three events. The obtained results were surprising, given that the discussion in section 3 showed that green ECB announcements were positive for green assets. And that European asset managers wanted to invest more in the green bond market when policy makers take action.

It is important to note that there is only one month between event 2 and event 3. Thus, there is a significant overlap in the periods we examined for those two events. In addition, the ECB also announced changes to the inflation target in the Monetary Policy Strategy Review (European Central Bank (2021f). There might be confounding effects due to the announcement of the changes to the inflation target of the ECB.

Eliet-Doillet and Maino (2022) isolated the effect related to the "greening" component in the ECB announcement. This by taking conventional and green bonds with similar credit worthiness. This approach is based on the assumption that bonds with similar credit worthiness should react similarly to any changes in the ECB's inflation target. Therefore, identifying the specific aspect of the ECB announcements that constitute the greening component, and examining the impact of this green component on the greenium would provide a deeper understanding of the impact of green ECB announcements on the greenium.

An examination of the effect of the impact of the Monetary Policy Strategy review on externally reviewed green bonds, was also done by Eliet-Doillet and Maino (2022). Interestingly, their analysis of these bonds showed an increase in the greenium after the announcement on the 8th of July 2021. This findings aligns with the results obtained in this paper, since in this paper only externally reviewed bonds are examined.

Based on the analysis of five events, with only two events showing significant results, it cannot be concluded that green ECB announcements have a consistent impact on the greenium.

In the first three of the five events examined, the bond yield increased the OAS of green bonds more relative to conventional counterparts. However, this effect was only evident within the six-month time window following the green ECB announcements.

Based on the analysis, the CISS indicator was found to be statistically significant in only one out of the five events examined, only for the six month window of event 1, the coefficient of the CISS indicator was positive and significant. This limited evidence suggest that general market stress does not have a consistent and significant impact on the relative OAS of green bonds compared to conventional bonds.

A limitation of this study is the limited sample size. This study only includes 32 matched bond pairs for which the OAS was available on a daily basis in the Refinitiv Database. Despite this limitation, this sample can still provide valuable information, as the greenium in this paper and its evolution is in line with estimates in the literature of green bonds, such as the systematic literature review of MacAskill et al. (2021). Due to limited sample size, an analysis at the level of subsamples could not be conducted in this paper.

Another limitation is that this study focused on analysing five specific green ECB announcements out of the 78 green ECB speeches on their website. Further research into the effects of the other green ECB announcements would give better insights into the impact of green ECB announcements on the greenium.

8 Conclusion

This study investigated the impact of green ECB announcements on the performance of green bonds. While an increase of the greenium following the announcements were expected, the results were mixed. Green ECB announcements led to a significant increase in the greenium only for two out of the five events examined. This events also had a notable degree of overlap, since there is only one month between event 2 and event 3.

The bond yield did increase the OAS of green bonds more relative to their conventional counterparts. However, this effect was only found in the first three of the five examined events, and only for the time window of six months. In addition, systematic market stress, as measured by the CISS indicator did not consistently influence the greenium. It only appeared to be significant in the first event, for the time window of six months.

The green bond market remains a relatively young market and experienced a rapid development over the past decade. It is crucial for the ECB to continue its efforts to support the green transition. The next Monetary Policy Strategy Review presents a unique opportunity to strengthen the role of green monetary policy.

The findings of this study shows that the ECB have minimal effect on the green bond market. That is why in parallel to central bank actions, the European Commission must continue to implement green policies in order to achieve a successful green transition. Achieving this successful green transition requires effective collaboration between the ECB and the European Commission. Only through effective collaboration and a shared vision between these institutions can the full potential of green finance be realized, ensuring a just and equitable transition to a low-carbon economy.

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A   Overview of matched green bonds

A.1   Green bonds

Issuer	ISIN	Sector	Country of issue	Issue Date	Maturity	Amount Issued
Atenor	BE0002739192	Real Estate	Belgium	23-10-2020	23-10-2024	35.000.000
Bankinter SA	ES0213679HN2	Financial Sector	Spain	8-7-2019	8-7-2026	750.000.000
Banque Federative du Credit Mutuel SA	FR0014001I68	Financial Sector	France	19-1-2021	19-7-2028	1.000.000.000
Bayerische Landesbank	DE000BLB80F9	Financial Sector	Germany	9-4-2020	9-4-2027	50.000.000
BPCE SFH	FR0014005E35	Financial Sector	France	16-9-2021	16-10-2028	1.000.000.000
BPIFRANCE	FR0013510724	Financial Sector	France	6-5-2020	26-2-2027	1.500.000.000
CAISSE FSE FINANCEMENT LOCAL	FR00140033E4	Financial Sector	France	27-4-2021	27-4-2029	750.000.000
CNP ASSURANCES	FR0013521630	Financial Sector	France	30-6-2020	30-6-2051	750.000.000
GROUPAMA ASSURANCES MUTUELLES	FR0013447125	Financial Sector	France	16-9-2019	16-9-2029	500.000.000
CODIC INTERNATIONAL	BE0002710912	Real Estate	Belgium	15-6-2020	15-6-2025	20.000.000
COFINIMMO	BE0002267368	Real Estate	Belgium	26-10-2016	26-10-2026	70.000.000
COVIVIO	FR0013262698	Real Estate	France	21-6-2017	21-6-2027	595.000.000
CREDIT AGRICOLE HOME LOAN SFH	FR0013393899	Financial Sector	France	16-1-2019	16-1-2029	1.500.000.000
ENGIE	FR0013365285	Energy	France	19-9-2018	19-9-2025	500.000.000
FLUVIUS SYSTEM OPERATOR	BE0002831122	Energy	Belgium	24-11-2021	24-11-2031	600.000.000
HESSEN, STATE OF	DE000A1RQD92	Government	Germany	2-11-2021	10-10-2031	500.000.000
ICADE	FR0013320058	Real Estate	France	28-2-2018	28-2-2028	600.000.000
ILE-DE-FRANCE MOBILITES	FR0014000KN6	Transportation	France	16-11-2020	16-11-2035	500.000.000
IRELAND	IE00BKFVC899	Government	Ireland	16-6-2020	18-10-2030	8.087.550.000
KBC GROEP	BE0002766476	Financial Sector	Belgium	14-1-2021	14-1-2029	750.000.000
LA BANQUE POSTALE	FR0013349099	Financial Sector	France	13-7-2018	13-7-2028	750.000.000
LA POSTE SA	FR0013447604	Postal	France	17-9-2019	17-9-2027	1.000.000.000
Landesbank Hessen-Thüringe	DE000HLB24S7	Financial Sector	Germany	23-7-2021	23-7-2030	100.000.000
Landesbank Saar	DE000SLB8395	Financial Sector	Germany	24-1-2020	24-1-2033	10.000.000
Madrid community	ES0000101875	Government	Spain	23-2-2018	30-4-2028	1.000.000.000
NRW BANK	DE000NWB17L1	Financial Sector	Germany	17-8-2016	17-2-2025	700.000.000
Oberbank AG	AT0000A2CN04	Financial Sector	Germany	28-1-2020	28-1-2030	250.000.000
VILLE DE PARIS	FR0013144052	Government	France	6-4-2016	12-1-2032	300.000.000
REGION PAYS DE LA LOIRE	FR0013467859	Government	France	17-12-2019	17-12-2031	25.000.000
SFIL	FR0014003S98	Financial Sector	France	4-6-2021	4-6-2029	1.000.000.000
SOCIETE DES GRANDS PROJETS	FR0014006OB0	Transportation	France	26-11-2021	26-11-2051	1.250.000.000
VINCI	FR0013397452	Construction	France	18-1-2019	18-1-2029	1.200.000.000

Table 6: Green bonds

A.2 Conventional bonds

Issuer	ISIN	Sector	Country of issue	Issue Date	Maturity	Amount Issued
Atenor	BE0002776574	Real Estate	Belgium	19-3-2021	19-3-2025	25.000.000
Bankinter SA	ES0213679JR9	Financial Sector	Spain	6-2-2020	6-10-2027	750.000.000
Banque Federative du Credit Mutuel SA	FR0014004750	Financial Sector	France	29-6-2021	29-6-2028	750.000.000
Bayerische Landesbank	DE000BLB8063	Financial Sector	Germany	30-4-2020	30-4-2027	50.000.000
BPCE SFH	FR0013514502	Financial Sector	France	27-5-2020	27-5-2030	1.250.000.000
BPIFRANCE	FR0014003C70	Financial Sector	France	6-5-2021	25-5-2028	2.000.000.000
CAISSE FSE FINANCEMENT LOCAL	FR0013459757	Financial Sector	France	13-11-2019	13-11-2029	750.000.000
CNP ASSURANCES	FR0013463775	Financial Sector	France	27-11-2019	27-7-2050	750.000.000
GROUPAMA ASSURANCES MUTUELLES	FR0014004EF7	Financial Sector	France	7-7-2021	7-7-2028	500.000.000
CODIC INTERNATIONAL	BE0002825066	Real Estate	Belgium	20-10-2021	20-10-2026	20.000.000
COFINIMMO	BE0002269380	Real Estate	Belgium	9-12-2016	9-12-2024	55.000.000
COVIVIO	FR0013170834	Real Estate	France	20-5-2016	20-5-2026	500.000.000
CREDIT AGRICOLE HOME LOAN SFH	FR0013465010	Financial Sector	France	6-12-2019	6-12-2029	1.250.000.000
ENGIE	FR0013245859	Energy	France	27-3-2017	27-3-2024	700.000.000
FLUVIUS SYSTEM OPERATOR	BE0002755362	Energy	Belgium	2-12-2020	2-12-2030	600.000.000
HESSEN, STATE OF	DE000A1RQD43	Government	Germany	18-6-2021	18-6-2031	600.000.000
ICADE	FR0013281755	Real Estate	France	13-9-2017	13-9-2027	600.000.000
ILE-DE-FRANCE MOBILITES	FR0014006PN2	Transportation	France	24-11-2021	24-11-2036	500.000.000
IRELAND	IE00BFZRQ242	Government	Ireland	17-10-2018	18-3-2031	6.848.090.000
KBC GROEP	BE0002832138	Financial Sector	Belgium	1-12-2021	1-3-2027	750.000.000
LA BANQUE POSTALE	FR0013415692	Financial Sector	France	24-4-2019	24-4-2029	750.000.000
LA POSTE SA	FR0013384567	Postal	France	30-11-2018	30-11-2028	500.000.000
Landesbank Hessen-Thüringe	DE000HLB2417	Financial Sector	Germany	22-7-2021	22-7-2030	100.000.000
Landesbank Saar	DE000SLB0GC5	Financial Sector	Germany	18-11-2020	18-11-2033	10.000.000
Madrid community	ES0000101909	Government	Spain	24-2-2019	30-4-2029	1.250.000.000
NRW BANK	DE000NWB0AC0	Financial Sector	Germany	5-11-2015	10-11-2025	500.000.000
Oberbank AG	AT0000A2RZH2	Financial Sector	Germany	2-7-2021	2-7-2031	250.000.000
VILLE DE PARIS	FR0013054897	Government	France	18-11-2015	25-5-2031	300.000.000
REGION PAYS DE LA LOIRE	FR0013370871	Government	France	12-10-2018	12-10-2030	50.000.000
SFIL	FR0014000MX1	Financial Sector	France	23-11-2020	23-11-2028	500.000.000
SOCIETE DES GRANDS PROJETS	FR0013422383	Transportation	France	3-6-2019	25-5-2050	2.500.000.000
VINCI	FR0014000PF1	Construction	France	27-11-2020	27-11-2028	500.000.000

Table 7: Conventional bonds
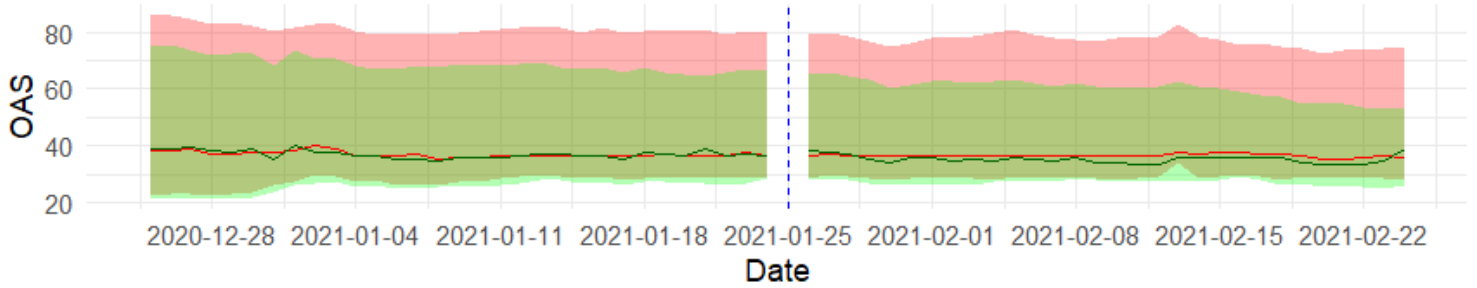
Figure 4: Graphical representation of the event on January 25th 2021

B.2   June 14th 2021

Median OAS of Green and Non-Green Bonds with 25th and 75th Percentiles

Figure 5: Graphical representation of the event on June 14th 2021
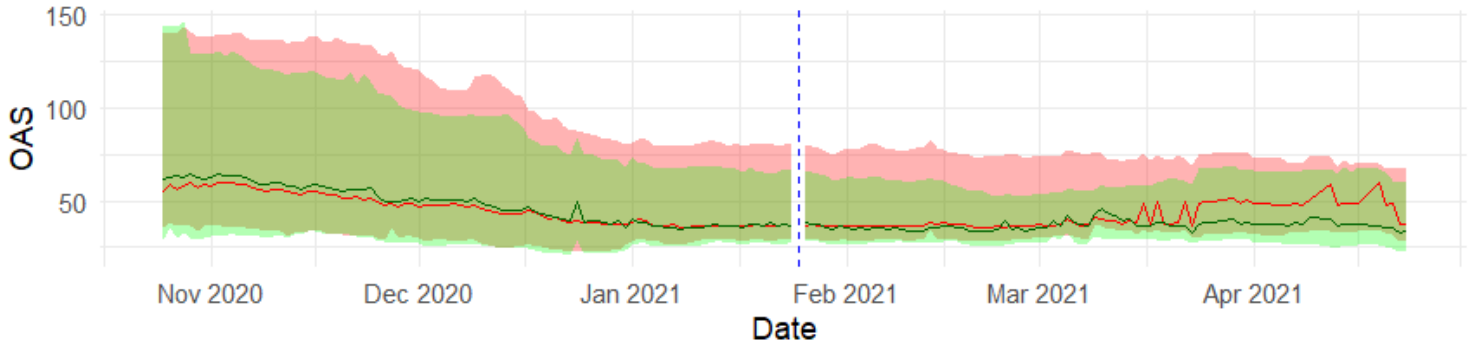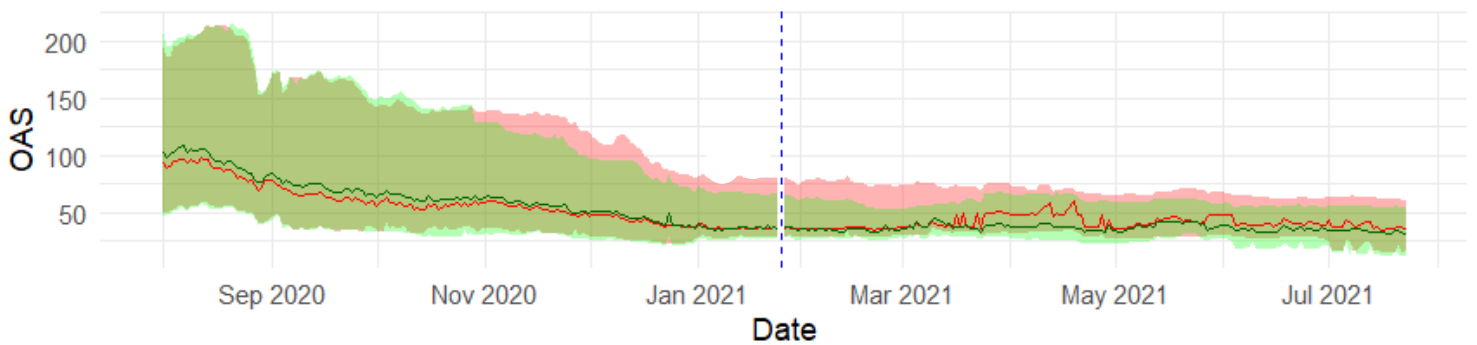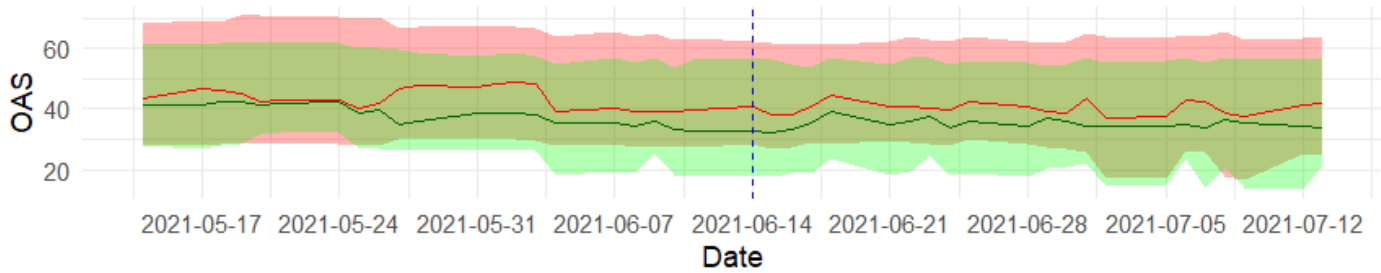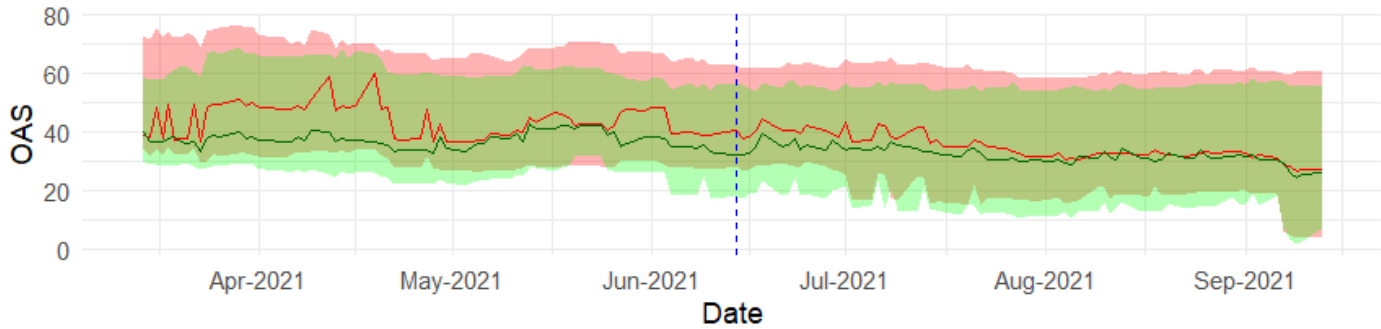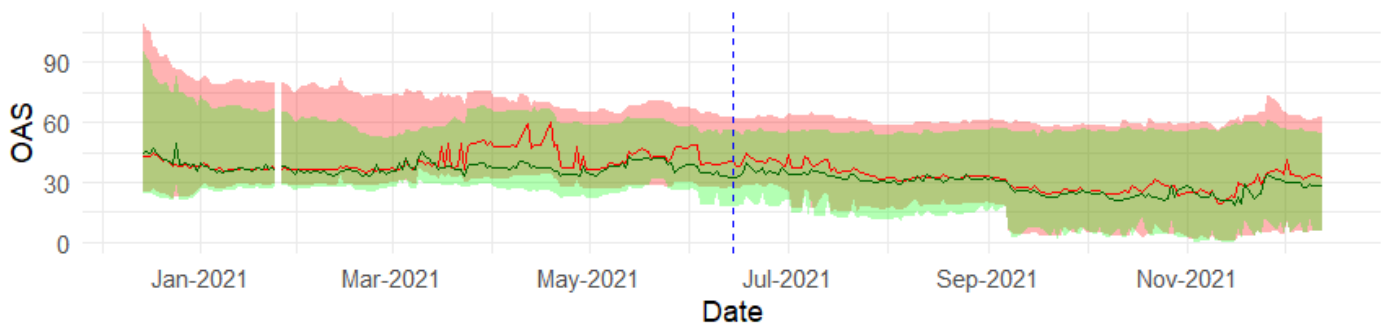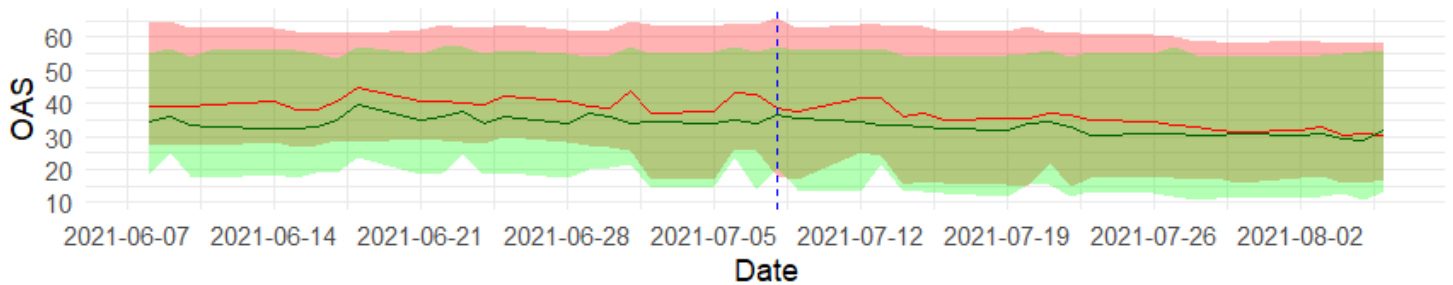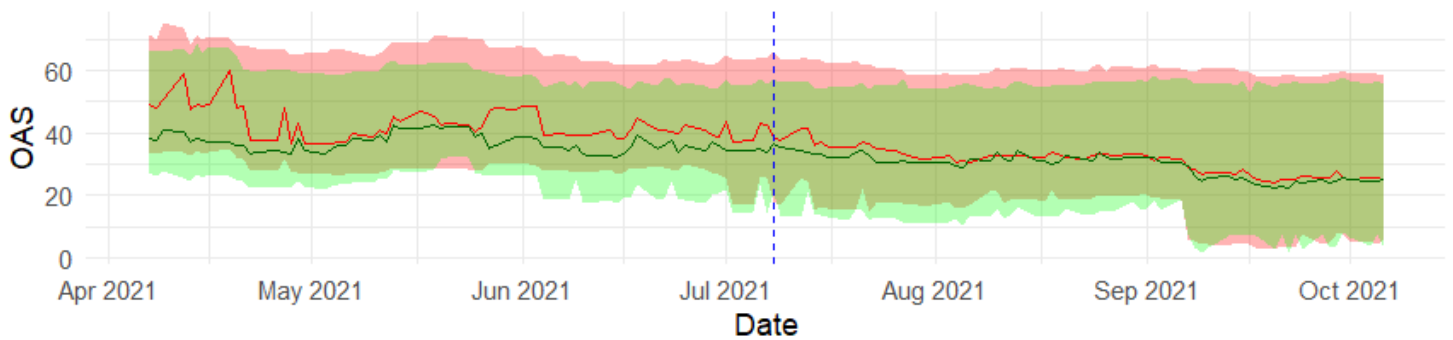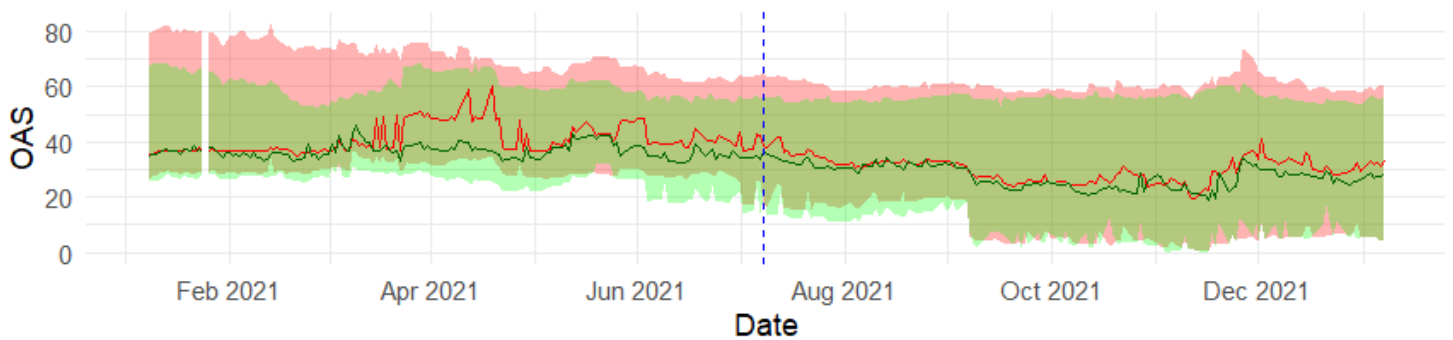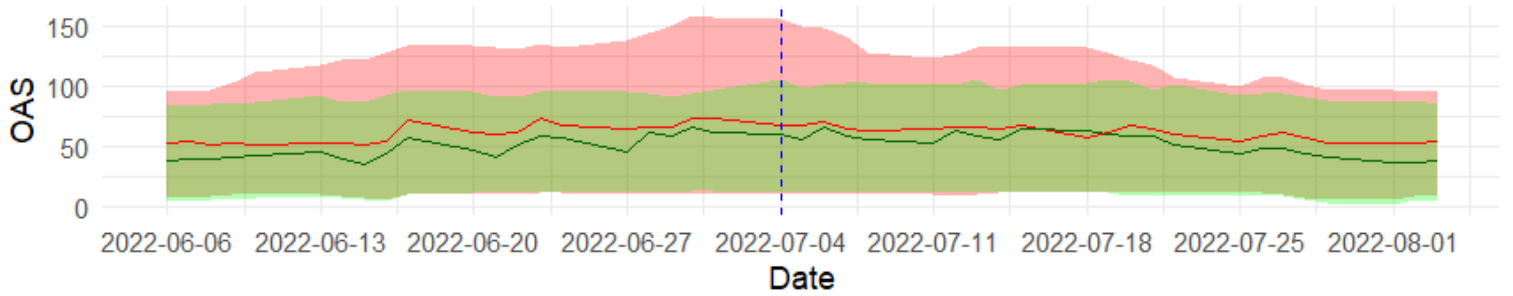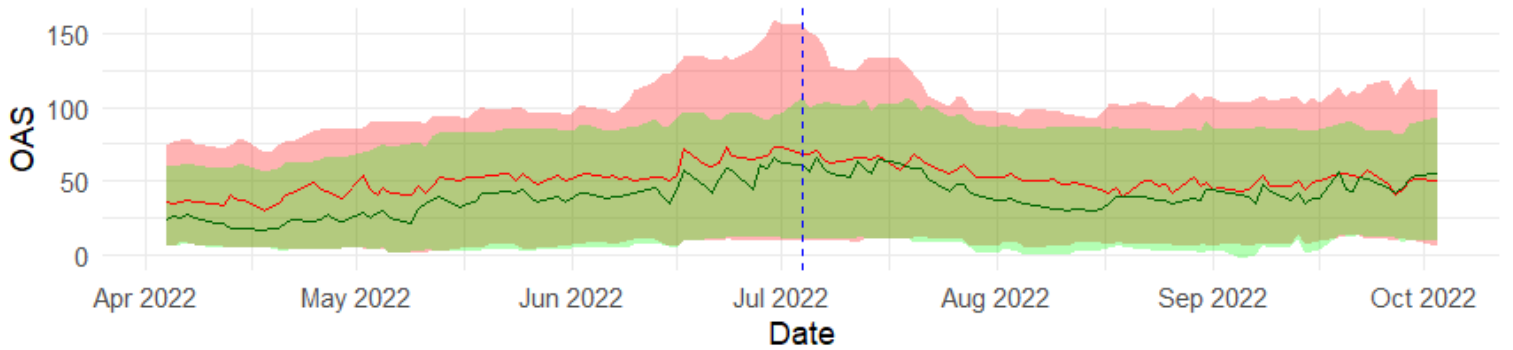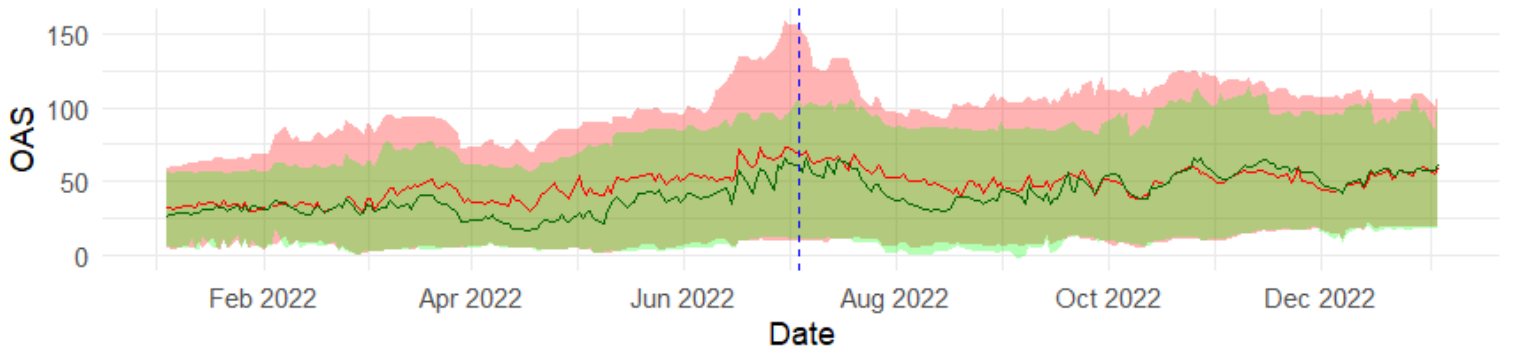
Median OAS of Green and Non-Green Bonds with 25th and 75th Percentiles

Time window: One month before and after the announcement

Time window: Three months before and after the announcement

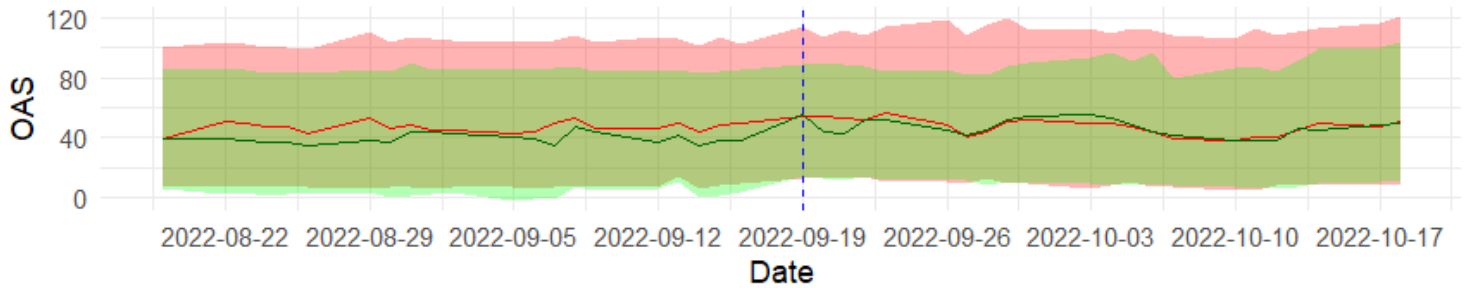### Time window: Six months before and after the announcement

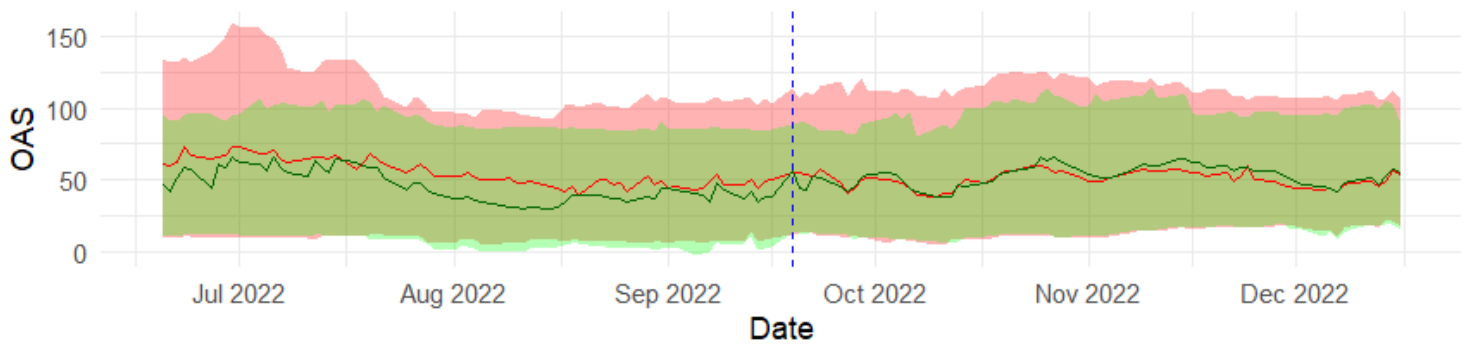Figure 6: Graphical representation of the event on July 8th 2021

Median OAS of Green and Non-Green Bonds with 25th and 75th Percentiles
Time window: One month before and after the announcement

Time window: Three months before and after the announcement

Time window: Six months before and after the announcement

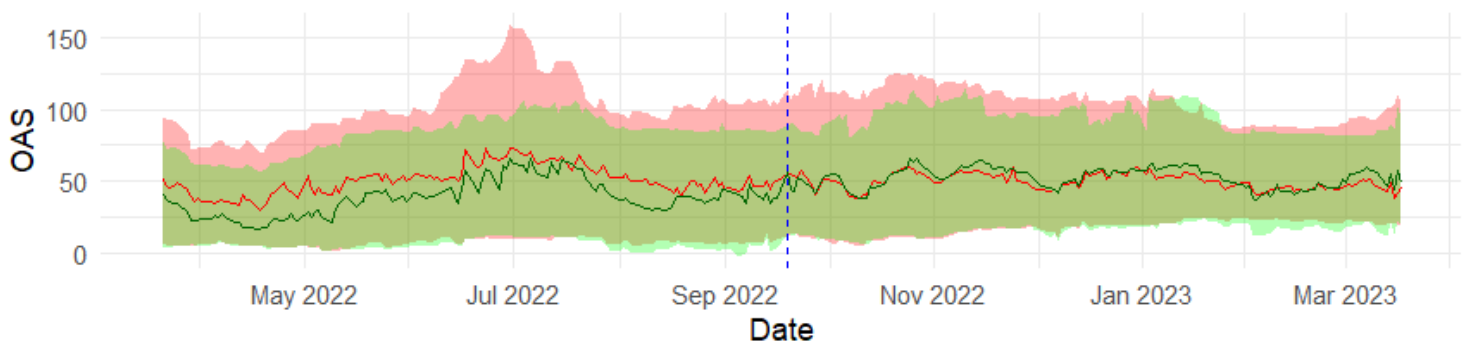Figure 7: Graphical representation of the event on July 4th 2022

Figure 8: Graphical representation of the event on September 19th 2022