INVESTIGATION OF THE GREENIUM IN COMMERCIAL MORTGAGE-BACKED SECURITIES

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ABSTRACT

INVESTIGATION OF THE GREENIUM IN COMMERCIAL MORTGAGE-BACKED SECURITIES

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In recent years, environmental factors seem to play an important role in financial decisions, particularly due to the increasing popularity of sustainable investing strategies. One of the investment alternatives in this field is green commercial mortgage-backed securities (CMBS), complex financial products supported by loans on commercial properties with environmental certifications or sustainable characteristics. This thesis investigates the presence of a "greenium" in CMBS by comparing note rates of green-labeled and traditional mortgage loans, as well as the pass-through rates (PTR) of their corresponding CMBS. Findings indicate that green-labeled multifamily properties secure mortgage rates 12-20 basis points lower than non-green properties, while the evidence for PTR is mixed. Notably, green certification from independent third parties doesn't significantly affect mortgage note rates but does lower the PTR of CMBS by 48.46 basis points, suggesting secondary market participants value these certifications. Policy changes in September 2019 and the Covid-19 pandemic influenced note rates and PTR of green-labeled and green-certified CMBS dıfferently. Overall, the research underscores the existence of greenium in both commercial mortgage loans and CMBS markets, with certified green properties benefiting more significantly in the securitized market. The findings of this thesis add to the expanding knowledge of sustainable finance, and the pricing of commercial mortgages and CMBS. Furthermore, the findings have significant consequences for investors, policymakers, and

market participants interested in comprehending the connection between environmental conditions and the valuation of commercial mortgage-backed securities.

Keywords: SRI, Green Bonds, Green Commercial Mortgage Backed Securities, ESG, Greenium

ÖZ

İPOTEĞE DAYALI TİCARİ MENKUL KIYMETLERDE YEŞİL PRİMİN ARAŞTIRILMASI

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Son yıllarda, özellikle sürdürülebilir yatırım stratejilerinin artan popülaritesinden dolayı çevresel faktörlerin finansal kararlarda önemli bir rol oynadığı görülmektedir. Bu alandaki yatırım alternatiflerinden biri de çevre sertifikalı veya sürdürülebilir özelliklere sahip ticari mülklere ilişkin kredilerle desteklenen ve karmaşık finansal ürünler olan yeşil ticari konut kredilerine dayalı menkul kıymetlerdir (CMBS). Bu tez, yeşil etiketli ve geleneksel ticari konut kredilerinin faiz oranlarını ve bunları menkul kıymetleştiren CMBS'lerin ödemeyi taahhüt ettiği faiz oranlarını (pass-through rate, PTR) inceleyerek, ticari kont kredisine dayalı menkul kıymetlerde bir "greenium (yeşil prim)" varlığını araştırmaktadır. Bulgular, yeşil etiketli çok aileli mülklerin kredi oranlarının yeşil olmayan mülklere göre 12-20 baz puan daha düşük olduğunu gösterirken, PTR oranına ilişkin kanıtlar karışıktır. Çalışma bulguları, bağımsız üçüncü taraflardan alınan yeşil sertifikaların ticari konut kredisi faiz oranlarını önemli ölçüde etkilemediğini ancak CMBS'nin PTR'sini 48,46 baz puan düşürdüğünü göstermektedir. Bu da ikincil piyasa katılımcılarının bu sertifikalara değer verdiğinin bir işaretidir. Eylül 2019'daki politika değişiklikleri ve Covid-19 salgını, ticari konut kredisi faiz oranları ile yeşil etiketli ve yeşil sertifikalı CMBS'lerin PTR'sini farklı etkilemektedir. Bu tez, yeşil sertifikalı mülkler üzerindeki ticari konut kredileri menkul kıymetleştirildiğinde daha avantajlı fiyatlandığını göstermekte ve hem ticari konut kredilerinde hem de CMBS piyasalarında greenium'un varlığının altını çizmektedir.

Bu tezin bulguları, sürdürülebilir finansın genişleyen bilgi kütlesi ile ticari konut kredisi ve CMBS'nin fiyatlandırılması konularına katkıda bulunmaktadır. Ayrıca bulgular, çevresel koşullar ile ticari konut kredisine dayalı menkul kıymetlerin değerlemesi arasındaki bağlantıyı anlamakla ilgilenen yatırımcılar, politika yapıcılar ve piyasa katılımcıları için önemli sonuçlar içermektedir.

Anahtar Kelimeler: Sosyal Sorumluluk Yatırımları, Yeşil Tahvil, Yeşil Ticari Konut Kredilerine Dayalı Menkul Kıymet (CMBS), ESG, Yeşil Prim

To My Beloved Mother...

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I want to thank my dear father, Cahit Kahveci, my beloved sisters Şebnem, Melek, and Nur, my dear nephews, and my brothers for never giving up on me, believing in me and making me feel that they are always with me. Having a family like them is a person's greatest blessing.

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LIST OF ABBREVIATIONS

AB	Amortizing/Balloon
CDO	Collateralized Debt Obligations
CMBS	Commercial Mortgage-Backed Security
CRT	Credit Risk Transfer
CSR	Corporate Social Responsibility
DID	Differences-in-Differences
DSCR	Debt Service Coverage Ratio
DUS	Delegated Underwriting and Servicing
ESG	Environmental, Social and Governance
FHFA	Federal Housing Finance Agency
Fannie Mae	Federal National Mortgage Association
Freddie Mac	Federal Home Loan Mortgage Corporation
Ginnie Mae	Government National Mortgage Association
G	Green
GSE	Government Sponsored Enterprises
ICMA	International Capital Market Association
IOAB	Interest Only/Amortizing/Balloon
IOB	Interest Only/Balloon
LEED	Leadership in Energy and Environmental Design
LTV	Loan to Value
MBS	Mortgage-Backed Security
NG	Non Green
NGBS	National Green Building Standard
NR	Note Rate
PTR	Pass-Through Rate
RMBS	Residential Mortgage-Backed Securities
TBond	Treasury Bond
UPB	Unpaid Principal Balance
VIF	Variance Inflation Factor

CHAPTER 1

INTRODUCTION

Climate change has become an existential problem manifested by catastrophic weather events, rising sea levels, and environmental changes that have profound consequences for ecosystems, economies, and communities around the world. Due to increasing climate problems, there is a growing understanding of the critical need for novel financial instruments to meet the numerous difficulties caused by the global ecological crisis.

Sustainable investment is emerging as a powerful way to reduce these climate crises' environmental, economic, and social impacts. This investment strategy aims to integrate environmental, social, and governance (ESG) criteria into financial and organizational decisions, with the goal of promoting the well-being of the planet. By doing so, it seeks to achieve long-term sustainability while providing financial returns. The sustainable investment approach, which directs capital to companies that attach importance to ESG criteria and are as sensitive to environmental issues as investors, and to projects designed in line with these concerns, not only reduces the risks of the climate crisis but also catalyzes social change.

As the role of sustainable investment in combating the climate crises increases, innovative financial instruments have begun to emerge. Green bonds, among these various financial products, have become an essential financing tool for directing capital to environmentally beneficial projects. Green bonds, issued by governments, municipalities, companies, and government-supported organizations, are used in financing environmentally friendly projects such as renewable energy, energy efficiency, sustainable agriculture, clean transportation, waste management, and energy-efficient

housing.

Green mortgage-backed securities (MBS) are securitizing mortgages on residential or commercial real estate built in an environmentally responsible manner. Green mortgages underlying green MBS are designed to channel funds into sustainable real estate projects. These projects may include energy-efficient upgrades, renewable energy installations (such as solar panels), water conservation measures, sustainable construction practices, or other environmentally friendly initiatives in residential or commercial properties. Properties financed with mortgages underlying green MBS must meet several environmental requirements, which vary depending on the institutions and organizations overseeing the process. These may include energy efficiency ratings, green building standards such as Leadership in Energy and Environmental Design (LEED) certifications, environmentally friendly materials, and sustainable energy systems. Participation in certification programs of recognized organizations is required to ensure that securitized mortgages meet the required environmental standards.

Green MBS, whose investors include many large investors such as institutional investors, pension funds, and insurance companies, have grown as interest in sustainable investments increased and governments have enacted policies to encourage green financing. However, like any investment, they carry risks, including credit risk, interest rate risk, prepayment risk, and the risk of environmental factors affecting property and securitized loan values. This is where the debate in academic literature comes into play: is there a difference in the pricing of green and traditional mortgage loans, and green and conventional MBS?

Pricing differential, based on the logic that socially responsible investors are willing to pay extra or to earn lower returns on green investments compared to conventional ones in exchange for their environmental impact, is called greenium in academic literature. There have been several papers analyzing the "greenium" in the municipal and corporate bond markets. Hinsche [19] found evidence of a significant greenium for euro-denominated fixed coupon rate green bonds issued by sovereigns, government agencies, government development banks, and supranational. Furthermore, there are several papers analyzing the "greenium" in the municipal and corporate bond mar-

kets. Hacıömeroğlu et al. [18] compared the yield to maturity of green and brown (conventional bonds without green attributes) corporate bonds at their issuance dates and concluded that green bonds do not necessarily offer cost advantages over brown bonds when differences in their risk characteristics are controlled for. Intonti [20] investigated the determinants of greenium in more detail. Intonti suggested that the COVID-19 pandemic may have increased the greenium. Hacıömeroğlu et al. [17] documented a 32 basis point greenium in primary market yields of corporate bonds during the pandemic. The secondary market analysis of Hacıömeroğlu et al. [17] revealed a larger decline in the returns of conventional corporate bonds compared to green ones, consistent with increased investor awareness of environmental issues and stronger demand for green bonds during the pandemic. Löffler [26] and Caramichael and Rapp [6] presented empirical evidence for the existence of a greenium, and Caramichael attributed it to the demand pressure and bond index participation of green bonds.

Although there are studies on green corporate and municipal bonds in the literature, as far as we know, there are very few studies investigating greenium in green mortgage-backed securities. It is important to examine this issue to see what effect green approaches have on the housing market, which has a large share in major areas that trigger the climate crisis such as carbon emissions, greenhouse gas production, and energy consumption. In this study, the differences between the interest rates on green commercial mortgage loans and green commercial mortgage-backed securities (CMBS) with their non-green counterparts were examined while controlling for market and issue-related characteristics. To increase the homogeneity of the sample of CMBS analyzed in this thesis, we limited our sample to commercial mortgage pass-through pools containing only one loan. This type of CMBS account for 25% of all commercial mortgage pass-through securities available in the market.The CMBS examined in this thesis are the securities issued by the Federal National Mortgage Association, also known as Fannie Mae. The sample consists of fixed-rate CMBS issued between 2017 and 2023 by this association.

In September 2019, the Federal Housing Finance Agency (FHFA) canceled the favorable status it has given to green MBS issued by Fannie Mae and Federal Home Loan Mortgage Corporation (Freddie Mac). In addition, FHFA increased the cap on

the total mortgage loans that these two organizations can purchase in a year from $35 billion to $100 billion. To investigate the impact of this policy change, a differences-in-differences (DiD) analysis was performed on green and non-green CMBS before and after September 2019.

The findings show that mortgages for green-labeled multifamily homes have note rates that are 12–20 basis points lower than those for equivalent non-green properties. The pass-through rates (PTR) for Green CMBS are 5 to 7 basis points lower than those for equivalent non-green CMBS. Furthermore, mortgages on properties with green certification have note rates that are 6.7 to 49 basis points lower than those on comparable non-certified green and non-green properties. These findings confirm the existence of a greenium in the commercial mortgage loan and CMBS markets.

The results of DiD show that FHFA intervention has no significant effect on the differences between green mortgage loan note rates and their non-green counterparts. On the other hand, policy change results in a decline of 0.1773 percentage points in the PTR of green MBS compared to non-green ones. The DiD model on green-labeled and green-certified mortgage loans shows that mortgage loans that have green certification had a note rate decrease of 0.2294 percentage points more than green-labeled mortgage loans after the policy change in September 2019. The findings for the PTR of green-certified and green-labeled CMBS are opposite of those for the note rate. PTR of green-labeled CMBS decrease by 0.2467 percentage points more than that of green-certified CMBS after the policy change. These results indicate that green-certified projects obtained more favorable financing rates and when securitized, these mortgages offered higher PTR to investors after the policy change.

The remainder of this thesis is organized as follows. In Chapter 2, the general properties of green bonds, MBS, CMBS, and green CMBS are explained. The literature on green bonds and green CMBS is summarized from the perspectives of investors and issuers while revealing their benefits and drawbacks in Chapter 3. Chapter 4 explains the structure of the data and the empirical methods employed in this thesis. The results of the analyses are presented and discussed in Chapter 5, and our conclusions are presented in Chapter 6.

CHAPTER 2

GREEN BONDS, MBS, GREEN MBS AND POLICY CHANGES

2.1 Green Bonds

With the signing of the Paris Agreement by 196 countries in 2015, an important step was taken for global cooperation in the fight against climate change. In the action plan published by the European Commission in 2018, growth strategies that would reduce greenhouse gas emissions by 55% were put forward. Sustainable finance plays an important role in achieving these goals.

Green bond issuers borrow money from the general public by selling bonds to investors and promise to repay the principal amount along with periodic interest payments, as in the case of traditional bonds. Where they differ from conventional bonds is their "green" designation, which requires transparency and accountability regarding the use of funds raised by issuing these bonds. Issuers must provide detailed information to investors about the environmental benefits and adherence to green standards of projects financed with green bonds. For this reason, through verification and certification services, independent organizations ensure that the funds obtained through green bonds are used in projects within the framework of determined environmental standards. At this point, institutions such as the Climate Bonds Initiative and the International Capital Market Association (ICMA) play an essential role in developing green bond standards. They establish appropriate criteria, reporting standards, and guidelines to ensure transparency and reliability of the green financing market.

In ICMA's Green Bond Principles document dated 2021, the definition of green bonds is given as follows: "Green Bonds are any type of bond instrument where the proceeds

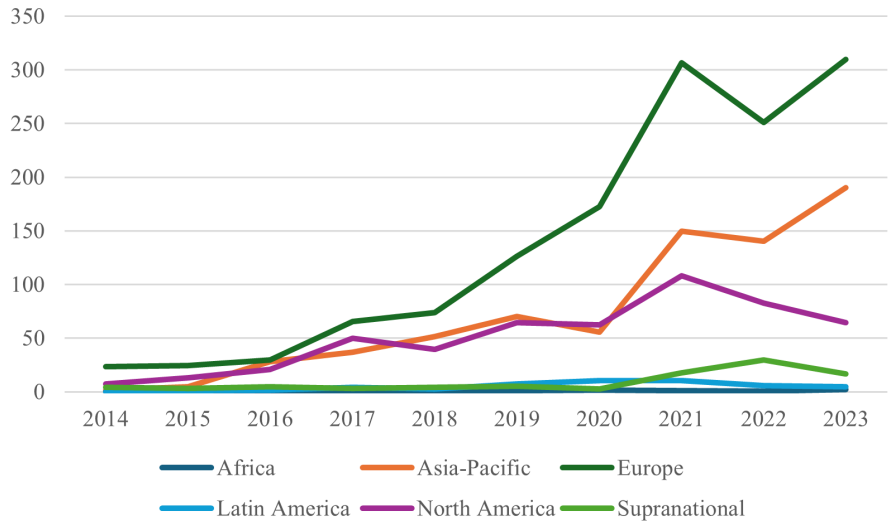


Figure 2.1: Total Green Bond Amount Issued by Region

or an equivalent amount will be exclusively applied to finance or re-finance, in part or full, new and/or existing eligible Green Projects and which are aligned with the four core components of the Green Bond Principles". ICMA is the institution that creates a set of standards and rules to minimize the problem of greenwashing, which means making false or misleading statements regarding the environmental benefits of projects financed with green bonds.

According to the report of the Climate Bond Initiative, green bond issuance reached its highest level globally in 2021. Furthermore, it increased by 15.23% compared to the previous year and reached $587.6 billion in 2023. As we can see in Figure 2.1, Europe dominated the green bond market with a volume of $309.6 billion. The largest individual issuer in Europe was the United Kingdom with an issue amount of GBP18.3bn. Europe is followed by the Asia-Pacific region and North America. Unlike Europe and Asia-Pacific, green bond insurance in North America decreased in 2023. We see the change in green bond issuance according to market type over the years in Figure 2.2 Since 2014, on average 65% of the green bonds are issued by developed countries. In addition, although there are fluctuations over the years, we see that emerging markets have increased their share in the green bond market since 2021. In Figure 2.3 we see the classification of green bonds according to the use of their proceeds. As expected, most of the funds were used in energy, building, and transportation-related projects, which have the highest carbon emissions.

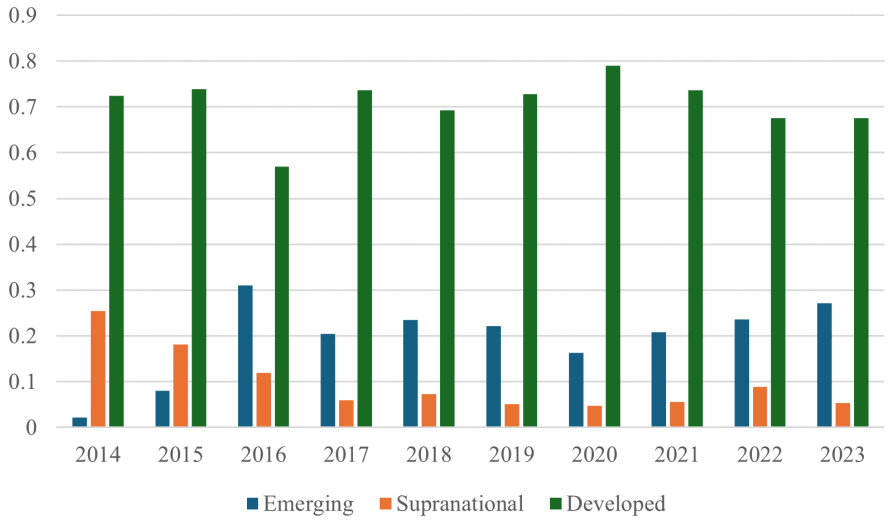


Figure 2.2: Percentage of Green Bond Issued by Market Type

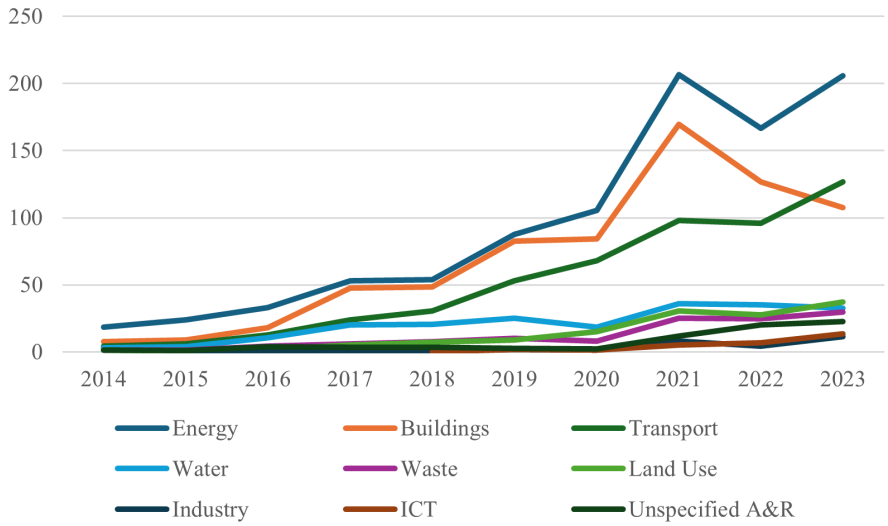


Figure 2.3: Total Green Bond Amount Issued by Use of Proceeds

2.2 Mortgage-Backed Securities

MBS are financial instruments that grant an ownership interest in a pool of mortgage loans. These securities are created when banks and mortgage lenders bundle together many individual mortgage loans or a single jumbo mortgage loan and sell shares or bonds backed by cash flows generated by interest and principal payments on those mortgage loans in the pool. MBS are financial products designed to increase the liquidity of mortgage loans, and the origins of the modern US MBS market are traditionally traced back to the issuance of the first agency MBS pool by the Government National Mortgage Association known as Ginnie Mae in 1970 (Fuster et al. 2022). Mortgage loans are grouped, securitized, and sold to investors as an investment tool. By securitizing their mortgage portfolios, financial institutions created additional funds to be loaned out to those wanting to buy a house.

In the MBS origination process, first, lenders make individual mortgage loans to home buyers. The next step after these loans are originated is for banks to sell these loans to government-sponsored enterprises (GSE) such as Ginnie Mae, Federal National Mortgage Association (Fannie Mae), Federal Home Loan Mortgage Corporation (Freddie Mac), or private institutions. These institutions pool loans purchased from loan originators to form a mortgage-backed security. This security is divided into smaller units, such as bonds or shares, and then sold to investors.

MBS can be issued or guaranteed by government-sponsored organizations such as Fannie Mae, Freddie Mac, or Ginnie Mae. Non-agency MBSs are not guaranteed by the state and are issued by private financial institutions. MBS can be issued as “Pass-throughs” where investors receive a proportionate share of the principal and interest payments from the underlying mortgage pool or Collateralized Mortgage Obligations (CMOs). CMOs, also known as "pay-through bonds", are issued in tranches with each tranche having a distinct priority when it comes to principal payments from the underlying mortgage pool. As a result, the risk and reward associated with each tranche varies among the structures. The lower-priority and higher-interest tranches of an MBS are frequently repackaged and sold as Collateralized Debt Obligations (CDOs).

A CMBS securitizes mortgage pools on multifamily and commercial properties, including dormitories, retail or office buildings, hotels, schools, industrial sites, and other commercial buildings, whereas residential mortgage-backed securities (RMBS) securitize mortgage pools on single-family properties. A CMBS often has a distinct structure compared to an RMBS such as severe prepayment penalties and balloon payments.

An MBS is a popular investment for various entities. Information regarding investors holding the agency and GSE-issued securities is available in the Financial Accounts of the United States. As of mid-2021, depository institutions constitute the largest group of investors, holding 32% of the total MBS. They are followed by the Federal Reserve at 23%, international investors at 11%, mutual funds at 7%, and money market funds at 5% [14]. Since they are the liquid version of illiquid mortgage loans, they are considered a good investment alternative for diversifying a fixed-income portfolio. Investors in an MBS receive cash flows from the underlying mortgage loans, primarily through regularly distributed interest and principal payments.

An MBS entails several risks for investors. Duration risk is noteworthy due to its correlation with the volatility and sensitivity of an MBS's value to changes in interest rates. Prepayment risk is the possibility of early repayment of an MBS due to deliberate activities of borrowers, such as refinancing, or involuntary occurrences, like defaults. This risk affects the term of the MBS and is characterized by "negative convexity." The credit risk associated with an agency MBS is quite low as agencies provide a guarantee against this risk, whereas a nonagency MBS exposes investors to potential credit losses. To transfer some of the credit risk to the private sector, Credit Risk Transfer (CRT) bonds, also launched by Fannie Mae, were put into practice. [11]. Therefore, achieving success in MBS investment necessitates carefully evaluating and controlling these complex risks.

As can be seen in Figures 2.4 and 2.5, MBS issuance increased until 2020 and stabilized or started decreasing after 2020. Mortgages originated in 2020 amounted to $4 trillion due to a record wave of refinancing fueled by a rise in house prices. According to Fuster et al. [14], 42% of the unpaid balance of the pools in 2021 is less than a year old because of this wave of refinancing in 2020. This is an unusually high

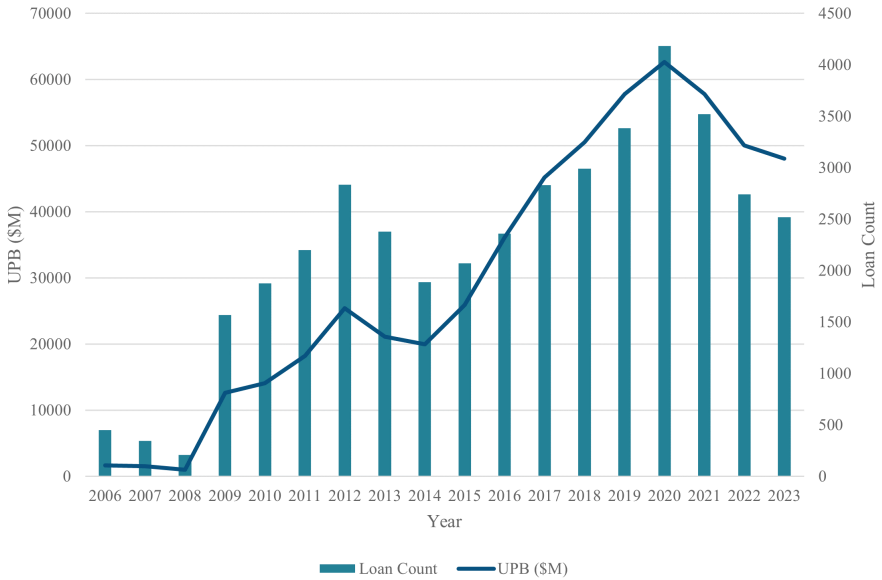


Figure 2.4: Fannie Mae Multifamily DUS Fixed MBS Issuances

percentage. Additionally, as seen in Figure 2.6, there has been an overall decrease in MBS trading volume since 2020.

2.3 Green Mortgage Loans and Green Mortgage-Backed Securities

Green Mortgage-Backed Securities (MBS) are a subset of Mortgage-Backed Securities that emerged as a financial instrument designed to promote environmentally sustainable and energy-efficient housing. Today, as the importance of sustainable investment increases, Green MBS play a vital role in this trend due to its potential to align the housing market with environmental goals, create financial incentives for sustainable housing, and contribute to the fight against climate change. As the world seeks ways to reduce carbon emissions, housing and buildings, which account for a significant share of emissions, have come under scrutiny. The adoption of mortgage-backed securities, an essential tool for the continuity of the mortgage market, into the green context has also been fueled by the spread of environmentally friendly houses and increased demand for these types of houses. Additionally, as governments and financial regulators increasingly recognize the need to take action against the climate change crisis, various initiatives and standards, such as green building codes and certification schemes, have been introduced to promote sustainability in housing and finance [30].

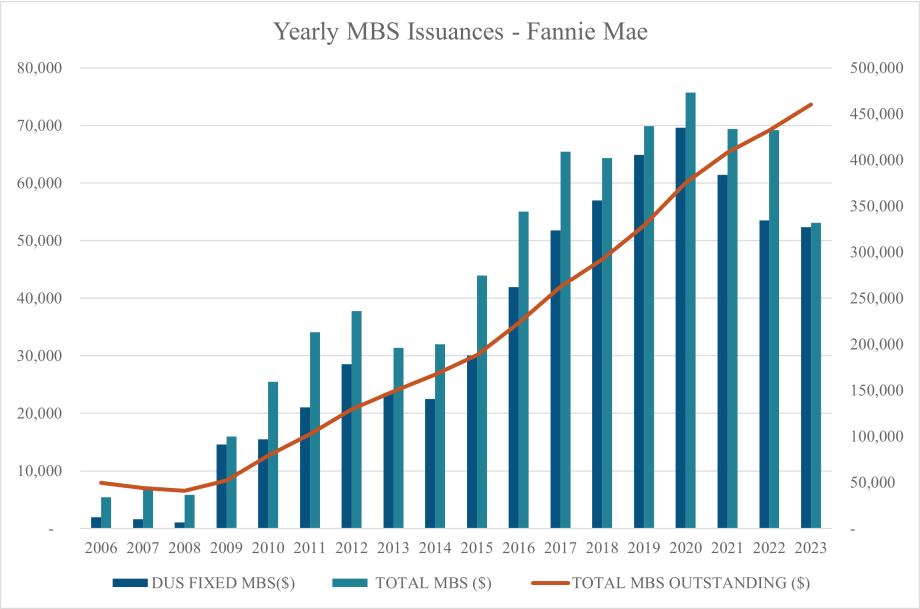


Figure 2.5: Fannie Mae Yearly MBS Issuances

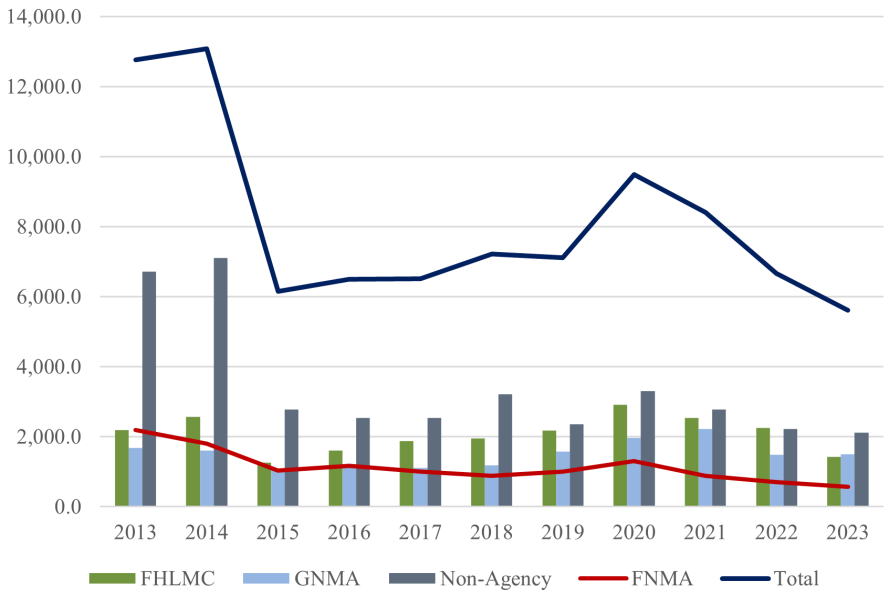
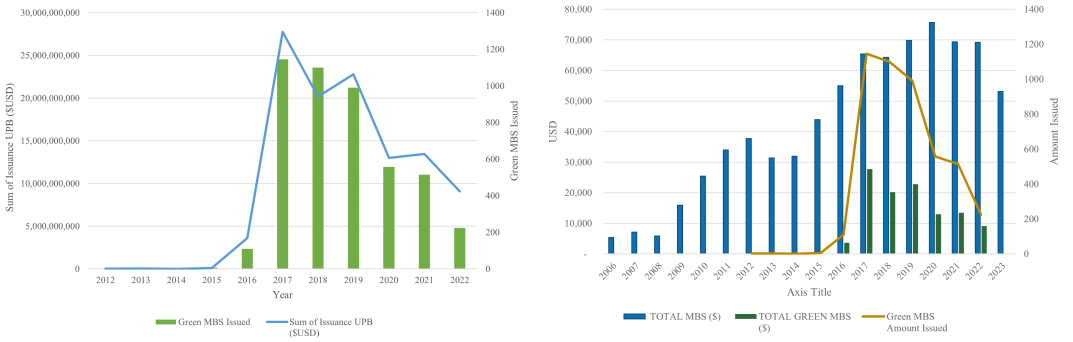


Figure 2.6: US MBS Trading Volume

We can list many benefits of green mortgage loans for the environment, investors, companies, and financial markets. Green mortgage loans encourage homeowners and developers to embrace sustainable and energy-efficient building construction. By contributing to the spread of energy-saving houses that consume less energy and produce fewer carbon emissions, green mortgage loans can reduce the carbon footprint of the housing sector, which would be an important development in the fight against climate change. Furthermore, green mortgage loans lead to a more sustainable and resilient housing sector by encouraging the development of green building practices, technologies, and materials. By securitizing these green mortgages, green MBS offer environmentally conscious investors an investment opportunity that complies with their ESG concerns and at the same time diversifies their portfolios with assets that carry lower environmental risks. As real estate's environmental and social impact becomes more critical, the mortgage market and traditional mortgage-backed securities are increasingly likely to face reputational and financial challenges [3]. Green MBS play a significant role in dealing with these challenges of traditional mortgage products by addressing the environmental concerns of investors and potentially reducing these risks. In addition, developing a green finance market and transitioning to green housing can create jobs in the green construction and renewable energy sectors and stimulate economic growth.

Fannie Mae through a national network of Delegated Underwriting and Servicing (DUS) lenders, either finances or guarantees the mortgages on multifamily projects. Fannie Mae also pioneered the issuance of green agency MBS. The green MBS program aims to improve the energy and water efficiency of multifamily (rental) housing in the United States.

Fannie Mae's green MBS are usually backed by a single green loan that is produced by one of its DUS lenders according to its publicly available DUS origination and servicing requirements. After the lenders finish the loan closing process, they transfer it to Fannie Mae. Fannie Mae then secures the loan with their guarantee and delivers it to investors as a Fannie Mae MBS. This approach guarantees that borrowers obtain the most favorable interest rate for their mortgage loan and establishes pricing transparency for the investment community. For loans to be securitized as Fannie Mae green MBS, they must undergo either an energy and water audit or obtain a



(a) Multifamily Green MBS (b) Green MBS Issuance vs. Total MBS

Figure 2.7: Green MBS Issuances

Green Building Certification from a third party approved by Fannie Mae before being submitted to Fannie Mae.

Figures 2.7 and 2.8 show Fannie Mae's Multifamily green MBS issuance across years. There has been a significant increase in the issuance of green MBS in 2017 which could be related to the green bond policy implemented by the FHFA between 2016 and 2019 [9]. In 2014, FHFA placed a $35 billion cap on the multifamily loans Fannie Mae and Freddie Mac could purchase and securitize in any given year. In 2016, mortgages on green properties were excluded from this cap by FHFA. The exclusion of green mortgages from this cap caused a significant increase in the issuance of green mortgages and green MBS by Fannie Mae and Freddie Mac. This resulted in a significant increase in the market share of these two entities. As a result, FHFA issued a new policy in September 2019 that increased the multifamily lending cap to $100 billion and removed the privilege given to green property loans.

Fannie Mae's Multifamily DUS business offers two types of green mortgage loans: green building certification and green rewards. A property must have received a Fannie Mae recognized third-party certification to qualify for a Green Building Certification loan. There are thirty-five distinct certifications recognized and issued by twelve distinct organizations. The Green Rewards program is an internal program of Fannie Mae and it recognizes an owner's efforts to improve the energy and water efficiency of an existing multifamily building (for more information on green rewards and green certifications, please visit: https://capitalmarkets.fanniemae.com/sustainable-bonds/green-bonds/multifamily-green-mbs).

2.3.1 Green Rewards Program of Fannie Mae and Green Certification

To be included in Fannie Mae's Green Building Certification loan program, properties must have one of the 35 certifications recognized by Fannie Mae from 12 different organizations. Every year, these certifications are checked to make sure they are still valid. A separate consulting company makes groups based on the requirements for each certification, such as Towards Zero, Group 1, Group 2, and Group 3. The current requirements for these groups are as follows:

Towards zero: A cut of more than 50% in water or energy use from the national average.

Group 1: A cut of at least 20% in water or energy use from the national average and ventilation standard requirements from new buildings.

Group 2: A drop in energy use of more than 15% from the national average.

Group 3: A drop in energy use of more than 10% from the national average.

As the requirements of the market change, these groups may need to satisfy stricter rules. For example, ventilation requirements were added to Group 1 and Towards Zero ratings recently to make sure that improvements in energy efficiency don't hurt people's health.

The Green Rewards program, an internal assessment of Fannie Mae, incentivizes owners to enhance an existing Multifamily property's energy and water efficiency. Currently, to qualify for a Green Rewards Mortgage Loan, the owner of the property must agree to implement energy and water efficiency measures that are expected to decrease the property's overall energy and water usage by at least 30%, with a minimum reduction of 15% in energy consumption.Requirements for eligibility in the Green Rewards program are becoming stricter over time as well. To qualify for the Green Rewards program before January 1, 2019, the owner had to implement efficiency measures that were expected to decrease the entire property's overall energy or water usage by at least 25%. Before December 18, 2017, a decrease of at least 20% in the overall energy or water usage of the entire property was enough to be eligible.

2.4 Risk Factors

MBS, created by pooling mortgages and selling them as shares or bonds, have an essential place in the financial market. These financial instruments, which provide liquidity to the mortgage industry and make investors partners in the real estate market, are tools that have been studied in detail in academic literature. We can examine the historical development of MBS in four main sections. From the launch of the first agency MBS in 1970 to 2008 as the early period, MBS were seen as a safe investment tools. Homeowners who took out mortgage loans were making their payments, and these payments were providing MBS investors with a reliable and regular income stream. The housing market was booming then, and mortgage default rates were low. In addition, the high ratings given to MBS by credit rating agencies contributed to the popularization of this instrument. The reason for the rapid rise in the nonagency MBS market after 2000 is the introduction of "subprime" and "alt-A" MBS, whose underlying assets are mortgage loans with very high credit risk. During the 2007-2008 global financial crisis, many homeowners were unable to make their payments, leading to an increase in defaults and foreclosures. This increase in defaults caused housing prices to decrease as the supply of houses on the market increased due to foreclosed properties. This decline in house prices led to more defaults on residential mortgages and created a spiraling effect.

In the post-crisis period, some regulations were enacted to reduce the risk and opacity in the mortgage market. In September 2008, the FHFA announced that it would acquire ownership in the Federal National Mortgage Association (Fannie Mae) and the Federal Home Loan Mortgage Corporation (Freddie Mac) in order to prevent them from going bankrupt. To mitigate losses from the 2008 global financial crisis and develop a new operating structure that would allow for a return to self-management, FHFA established conservatorships in which the management of each business worked under FHFA's direction. Dodd-Frank Wall Street Reform and Consumer Protection Act placed strict regulations on MBS issuers and required more transparency in their operations. The Federal Reserve has developed programs to purchase MBS and stabilize the housing market. Today, the majority of MBS are launched by Fannie Mae and Freddie Mac, government-sponsored enterprises. The increase in mortgage credit

quality in the market and the rise in insurance standards make MBS attractive again for investors looking for returns.

CHAPTER 3

LITERATURE REVIEW

Green bonds, a financial tool for funding green and climate projects, have grown significantly recently. The market for green bonds is expected to continue thriving, with potential for further research and development. These bonds have been found to impact corporate performance and social responsibility positively [34], and can serve as a model for mobilizing private capital to provide financing to climate change projects [28]. According to Banga [4], the lack of proper institutional mechanisms for green bond administration is an important obstacle to the growth of the green bond sector in developing countries. Additional factors blocking the growth of the green bond industry are the different views on the financial advantages, an absence of standardized methods for the management of proceeds, and challenges in impact reporting and measuring. Some suggestions for removing these obstacles for developing countries are standardization of issuance processes, increased transparency, and setting the green bond market apart from other instruments and tools to support environmentally friendly investments. [8]

When we look at green bonds from the issuer's perspective, we can see that they have many advantages. According to Roslen et al. [29] and Flammer [12], investors react favorably to green bond issuance announcements and this positive reaction is stronger for the issuance of green bonds for the first time and issuance of bonds certified as green by third parties. These papers document an improvement in the environmental performance of issuers (reduced CO2 emissions and improved environmental ratings), indicating that green bonds are successful in enhancing companies' ecological impact. Furthermore, these is an increase in the ownership of long-term and environ-

mentally conscious investors after the issuance of green bonds. These findings only apply to green bonds certified by independent third parties, implying that certification is a key governance instrument in the green bond market.

Kuchin et al's [22] findings confirm that green and climate-aligned bonds receive a positive market reaction and result in an increase in a company's value. However, Lebelle et al. [23] report an adverse market reaction to announcements of green bond issuances, similar to that of conventional or convertible bonds due to signaling of damaging information about the issuers. This negative market response is more evident in developed markets and at the time of the first Green Bond issuance. After issuing green bonds, a corporation's cost of capital decreases by 24.9 basis points, and the value of the company increases [32]. Caramichael and Rapp [6] also state that green bonds have an 8 basis point advantage over conventional bonds in terms of borrowing costs. Furthermore, Alonso-Conde and Rojo-Suárez [1] employ a methodology that involves a comprehensive scenario analysis to assess the effects of green bond financing on the solvency and profitability of a company. Their results indicate that green bond financing improves internal rates of return (IRR) for shareholders and increases average debt service coverage ratios.

There are studies showing that benefits from green finance vary depending on the type of company, its reliability, and certification status of the bonds. According to Bachelet et al. [3], to minimize informational asymmetries, reduce concerns for greenwashing, and provide favorable financing conditions, the issuer's reputation or third-party verifications of the issue's greenness are crucial. Issuing green bonds signals company's commitment to corporate social responsibility (CSR), and bonds with green certification have lower interest rates [24].

Green bonds issued by supranational entities and corporations carry a premium, whereas financial institutions do not [10]. Green bonds in Asia often provide greater returns, but bonds issued by Asian banks give consistently lower returns [31]. In another study on the green bond market in Asia, Wang et al. [32] show that corporate green bonds in China have a pricing premium compared to conventional bonds, and the economic magnitude of this pricing premium is much larger than that previously reported in the literature for an international green bond.

Green bonds have become popular investment alternatives that attract the attention of mainstream investors because of their potential environmental benefits. Some research has indicated that there is not a significant performance difference between conventional and green bonds [16]; yet, other studies have emphasized the financial advantages of green bonds, including lower financing costs and positive stock market responses [21] [15]. Green bonds also typically exhibit lower volatility and higher Sharpe ratios than non-green bonds, indicating better risk-adjusted returns [25]. However, Buttin [6] notes that green bond market also poses risks, including greenwashing and additional costs compared to standard bond issuance such as green certification and reporting. Despite these challenges, green bonds are regarded as a critical financing tool for the energy transition [5], and their positive externalities can benefit the economy in the long run [25].

Zerbib [33] completed one of the first research regarding green premiums in the secondary bond market. 110 green bonds issued by corporations, supranationals, subsovereigns, municipalities, and financial institutions are included in the sample. Each green bond is matched with two synthetic conventional bonds with the same attributes as the green bond—currency, rating, bond structure, seniority, collateral, coupon type, and closest maturity. Using a two-step regression analysis, he documents an average green bond premium of -2 basis points.

Conflicting findings regarding greenium indicate that, while comparing green and non-green bonds, it is important to work between bonds that are as similar as possible in order to prevent the results being affected from other bond characteristics. Löffler et al. [26] also identify green and non-green bonds with similar characteristics in their study. A subsample of the original data, which is comprised of 180,000 non-green and 2,000 green bonds, is created using propensity score matching and coarsened exact matching techniques to find similar bonds in terms of issuers corporate structure, issue volume, bond seniority, and time-to-maturity. Their findings indicate that, in both the primary and secondary markets, yields on green bonds are 15 to 20 basis points lower than those on comparable conventional bonds. Furthermore, although there is a greenium in the secondary market in 2018 and 2019, the results are only significant after 2018.

Hacıömeroğlu et al. [18] conduct a study using the matching method to examine the influence of various factors on bond rates. They also explored the presence of a "greenium" during bond issuance and compared the initial yields of green and non-green (brown) corporate bonds. The study focuses on evaluation of the risk and return performance of brown (for-profit) versus green (blended-value) bonds. They also compare green bond yields to those of conventional (brown) bonds to analyze the "greenium". Their final sample consists of 12,197 non-green and 563 green bonds issued by 265 corporations between 2013 and 2019. They identified a group of green and brown bonds that match exactly in terms of coupon type, principal currency, and country of issue. As the second group, they identified the bonds that were the nearest match regarding issue date and maturities. The efficient frontiers of the 2013-2016 and 2017-2019 subperiods indicate that green bonds trade at lower returns in the secondary market. In their analysis of the primary market yields, they discover that green bonds give a greenium of 23-26 basis points (bps) over their brown equivalents while controlling for market, firm, bond, and currency factors.

Hacıömeroğlu et al. [17] examine the effects of the COVID-19 epidemic on the performance of green bonds compared to conventional (brown) bonds of the same issuer, both in the primary and secondary markets. They analyze green and brown bonds of corporations, agencies, governments, municipalities, and supranational institutions issued before and during the pandemic. The initial yields of green and brown bonds issued over the subperiods of January 2019–March 2020 and March 2020–February 2021 are compared. They discover that during the pandemic, primary market yields on brown and green bonds decreased, with a more significant decrease for green corporate bonds. Only green and brown bonds issued by the same issuer before January 2019 and are still outstanding as of February 2021 are included for secondary market analysis. In the end, 262 green and 4,271 brown bonds from 163 different issuers made up their dataset for secondary market study. According to their findings, green corporate bonds generated higher daily returns during the pandemic than brown bonds on the secondary market. They note the increased demand for green bonds in primary and secondary markets after the pandemic as one of the explanations for their findings.

One of the most recent publications regarding green bonds is the paper published in

2024 by Caramichael and Rapp [6]. A comprehensive worldwide panel dataset comprising of 1,169 green corporate bonds and 129,043 conventional corporate bonds issued between 2014 and 2021, as well as information from international primary bond markets, are used for the study. The research leverages a broad global panel dataset to examine the borrowing cost advantage for green bond issuers using matched sample regressions and fixed-effects regression. The findings indicate that, on average, the borrowing cost advantage (greenium) of green corporate bonds is 3 to 8 basis points compared to conventional bonds. In 2019, the greenium showed a notable increase to approximately 15 basis points, and it then declined in the following years. Strong investor demand largely explains why green bonds have a lower borrowing cost.

Partridge and Medda [27] examine how US green municipal bonds that are climate-aligned and labelled as green perform in comparison to ordinary municipal bonds issued between 2009 and 2016. Green municipal bond index is created from their dataset using S&P methodology to compare the performance of conventional and green municipal bonds. Furthermore, they analyze the differences in yields of green and brown municipal bonds both in the primary and secondary markets. From 2014 to 2018, the green municipal bond index showed a statistically significant green premium in the secondary market, outperforming the nearest S&P index. According to their initial yield study, there was a noticeable increase in greenium across their sample period. Compared to market benchmarks, the climate and green indexes showed better risk-adjusted returns and annual growth rates.

In their discussion of the concentration effect in the mortgage market, Connolly and Echeverry [7] argue that local concentration fosters a kind of learning-by-owning, which in turn influences lenders' decisions about which loans to green next. In other words, lenders with higher market shares issue more green loans in particular areas, leading to higher interest rate spreads but better property cash flows over time. When looking at the creation of green assets in the housing market, the study shows how important market structure at the local level is. The study's dataset, from Fannie Mae's DUS disclosure portal, focuses on single-property, multifamily loan originations made by lenders with more than 100 loans in total between 2017 and 2021. The dataset contains details on seller and servicer names, issuance characteristics, property qualities, and mortgage terms. They show that lenders with larger market shares

than those with smaller market shares provide more green multifamily mortgages. Higher interest rate spreads are associated with green mortgages in concentrated markets, but the properties have better cash flows for the first three years after the loan is issued. Furthermore, banks experience a greater impact from increased green lending than nonbanks do, suggesting that banks benefit from proximity in terms of information exchange.

An and Pivo [2] examine the effect of green building certification on default risk and loan terms in the CMBS market. They show that green building loans provide better terms at the time of loan origination, including a 15 basis point interest rate reduction. They also document a 34% lower chance of default for CMBS loans when green buildings are involved. They also analyze potential reasons for the decreased default risk in green buildings using data they obtained from Trepp and the U.S. Green Building Council. The existence of green rent premiums, which can raise the debt service coverage ratio (DSCR) for mortgages on green buildings and hence reduce default risk, is one argument. Equity premiums coming from the increased income and lower risk associated with green buildings provide an additional explanation. These premiums probably strengthen the owners' equity position and decrease the loan-to-value ratio (LTV), which further decrease the chance of default for mortgages on green properties.

Devine and McCollum [9] is the only work in the literature focusing on Fannie Mae multifamily green mortgage-backed security issuances, making it the only study to examine this specific type of security. They analyze Fannie Mae's multifamily single asset mortgage-backed security issuance data between 2016 and 2018 to investigate the correlation between the green MBS program's adoption and the loans' terms at the time of issuance. The paper also examines the policy implications for Fannie Mae and other debt issuers considering the adoption of green bond regulations. It also incorporates certification data from certifying bodies, economic and demographic control data from the U.S. Census and American Community Survey, and heating and cooling degree day data from the National Oceanic and Atmospheric Administration. They find that loans on green multifamily properties have lower interest rates, lower debt service coverage ratios, and larger leverage ratios than their brown equivalents. These favorable conditions extend to properties eligible for green programs even if they do

not participate in the program.

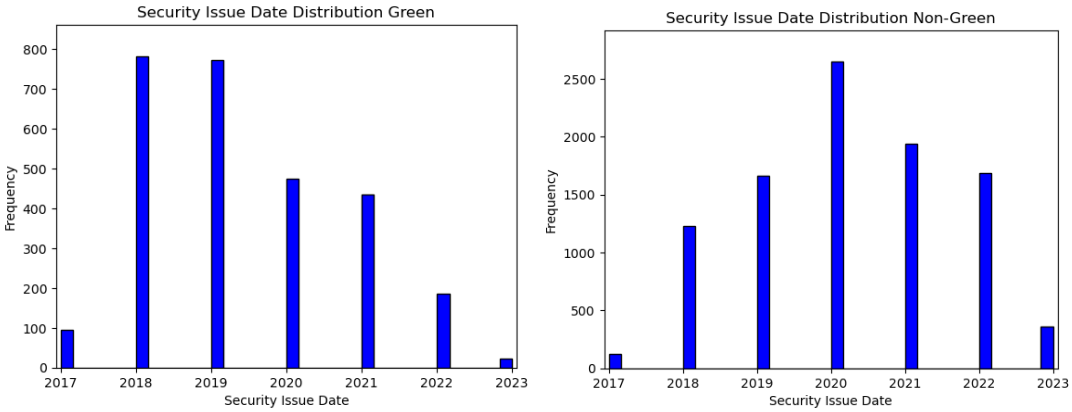
Eventhough residential, commercial mortgages and mortgage-backed securities are researched extensively, the greenium in note rates of mortgages and pass-through rates of MBS is not. By filling this gap in the literature, this thesis contributes to both the greenium and the MBS literatures.

CHAPTER 4

DATA AND METHODOLOGY

4.1 Data

We obtain the primary market data from Fannie Mae's publicly available Delegated Underwriting and Servicing (DUS) disclosure website. We collect data on all green and non-green commercial mortgage pass-through securities until February 2023 without making any restrictions other than security type. We are going to refer to these securities as CMBS as well. Initially, we have 49,726 FannieMae CMBS of which 9% are green CMBS. Our data contains a total of 283 distinct attributes related to security, the underlying mortgage loan, and the property for each CMBS. To create a sample of green and brown CMBS with similar characteristics, first, we limit our sample to CMBS with the security product type of DUS and the security interest type of fixed rate. These restrictions reduce our sample of securities by half. Later, we restrict the number of loans and properties in the securitized pools to one. In addition, we limit the loan lien position to the first lien because the loan with the highest claim on the property indicates more secure lending. After these restrictions, the number of CMBS included in our sample decreases to 19,969. In the next stage, we choose general and specific property types as multifamily as it may cause differences in the loan and securitization stages, and this reduces our sample to 17,758 CMBS. After eliminating observations with missing data points, we have a total of 12,407 CMBS in our sample. Of these, 9,643 are non-green and 2,765 are green ones.



(a) Green (b) Non-Green

Figure 4.1: Issue Date Distribution

In the original dataset, there are non-green CMBS issued between 1998 and 2023 and green CMBS issued between 2014 and 2023. After our filters, green and non-green CMBS included in our sample are the ones issued between 2017 and 2023. In the final sample, the green CMBS account for 28% of observations.

Figures 4.1 show the issuance of green and non-green CMBS remaining in sample across years. The majority of the non-green CMBS are issued in 2020 consistent with findings in Fuster et al. (2021). However, the issuance of green CMBS is higher in 2018 and 2019 reflecting the changes in the FHFA's treatment of green mortgage loans during this period.

In order to eliminate the effect of outliers in the unpaid principal balances in our data, we winsorize the data at 1% and 99%.

We collect the 5-year, 10-year, and 20-year Treasury bond rates from the "Federal Reserve Bank of St. Louis" database. To control for market conditions, we add the bond rates we obtained to our data according to the date when mortgage loans are created, when these loans are pooled and securitized, and the time to maturity of the loan and security. To explain with an example, we first check the remaining term of the loan underlying the CMBS. If we take a MBS with a 20-year term for which the underlying mortgage loan is created on 1/1/2019, we take the 20-year Treasury bond rate on

(a) Sample Distribution

(b) Green Financing Types

Figure 4.2: Green and Non-Green Distribution and Green Financing Types

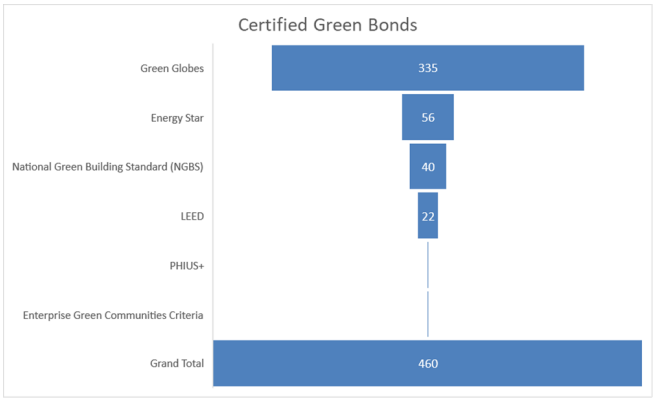
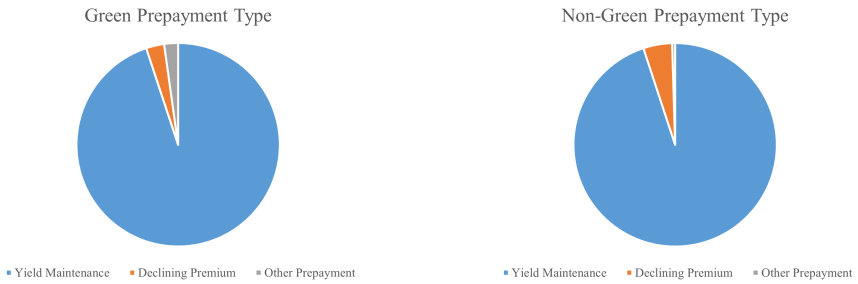


Figure 4.3: Green Bond Certifications in Sample

1/1/2019 as the Loan T-Bond variable. For the Security T-Bond variable, we look at the day when the MBS is issued and create this variable by writing the corresponding Treasury bond's rate with the same maturity as the MBS on the securitization date.

As can be seen in Figure 4.2a, approximately 30% of our sample consists of green CMBS. Figure 4.2b shows that 80% of these 2,765 green CMBS are in Fannie Mae's Green Rewards program. The remaining 20% consists of CMBS with underlying mortgages on properties with Green Building certification.

Figure 4.3 shows the distribution of the green building certificates for our sample of green CMBS. The majority of CMBS with Green Building Certification have Green Globes Certification. It is followed by ENERGY STAR and National Green Building Standard (NGBS) certification



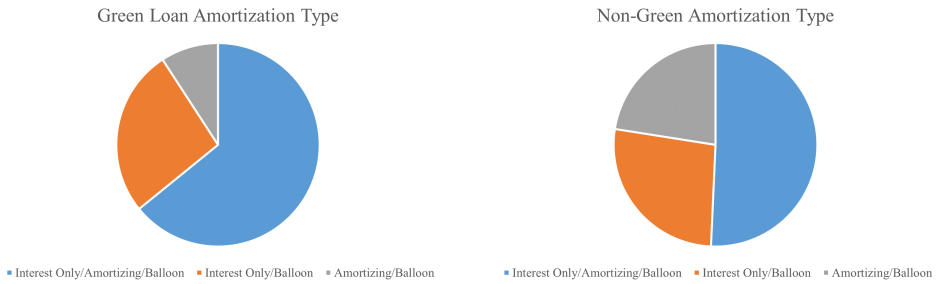
(a) Green (b) Non-Green

Figure 4.4: Prepayment Type Distribution

When we look at the distribution of prepayment restrictions for our green and non-green samples, we see that the yield maintenance type is the most common prepayment penalty for both samples. If we look at Figures 4.4, 94.4% of the green sample and 94.8% of the non-green sample have yield maintenance type as their prepayment restriction. For the remaining mortgages, the declining premium prepayment is the second most common penalty type.

Yield Maintenance, the most popular type of prepayment protection, permits complete voluntary prepayments when the borrower pays a yield maintenance fee, as stated by Fannie Mae in its DUS program document. The prepayment premium for each mortgage loan is to be paid during the yield maintenance period. When a borrower chooses to pay off a mortgage loan before the yield maintenance period ends, the prepayment premium is determined using a standardized calculation. Fannie Mae passes the yield maintenance prepayment premium to investors after deducting the company's total portion of the remaining premiums collected. If a borrower pays off a mortgage loan on or after the day the yield maintenance period ends, the borrower is not required to pay a prepayment penalty to the investors.

Another option for prepayment premiums is a variable premium schedule, also referred to as a declining or fixed premium. A proportion of the current outstanding principal balance is the basis for the declining premium, which decreases throughout the loan's term. Loans with declining premiums usually include a prepayment



(a) Green (b) Non-Green

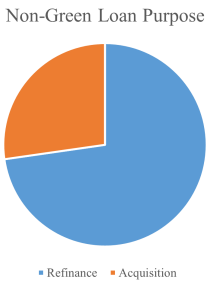
Figure 4.5: Amortization Type Distribution

lockup period that lasts for the initial 12 months of the loan term. Prepayment lockouts restrict the borrower from making voluntary early payments on a loan unless the payments are due to unexpected events like damage or government property acquisition. Because of these prepayment penalties, prepayment risk is not a major concern for commercial mortgages and CMBS.

In the Interest Only/Amortizing/Balloon (IOAB) type, which is the majority of loans in both our green and non-green samples (see Figure 4.5), the borrower initially makes just interest payments for a specified term. Once the interest-only period is over, the monthly mortgage payments are updated to include the repayment of the principal. In the Interest Only/Balloon (IOB) type, which is the second most common security type in our sample, the payment schedule comprises only interest payments, while the principal payment is made on the maturity date of the mortgage loan. The Amortizing/Balloon (AB) type is less than the others in our green sample, but it is at the same level as IOB in the non-green sample. Monthly installments of AB mortgage-backed securities immediately include a component for principal and interest.

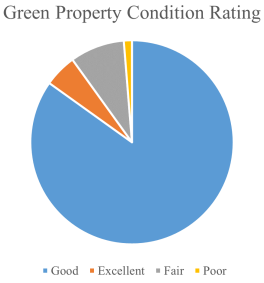
Figures 4.6 give information about the purposes of the loans in the sample. In our sample, we see that the percentage of CMBS that are issued with the purpose of refinancing is slightly higher. The incentives given to green MBS and green bonds in general may have encouraged people to benefit from these incentives by making green arrangements for their existing residences, and therefore the number of green

(a) Green

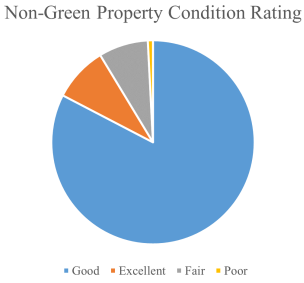


(b) Non-Green

Figure 4.6: Loan Purpose



(a) Green



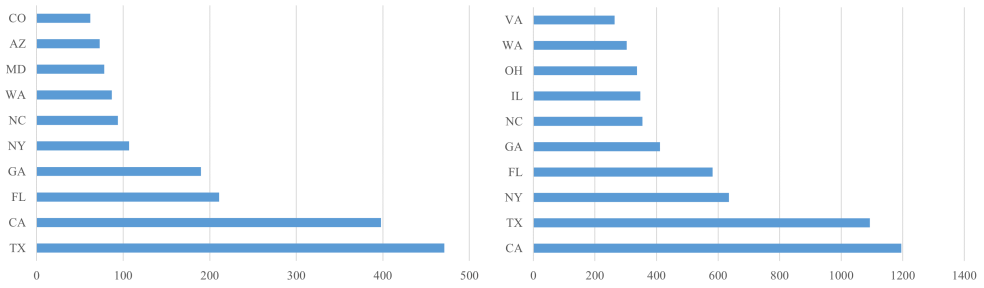
(b) Non-Green

Figure 4.7: Property Condition Rating

refinanced loans may have increased. Close to 75% of the non-green mortgages have the purpose of refinancing consistent with the wave of refinancing in 2020. [13] When we look at the conditions of the properties included in our sample, we see that most of them are in "good" status for both groups. (Figures 4.7)

When we look at the top 10 states in the issuance of green and non-green mortgages in Figures 4.8, we see that Texas and California lead the CMBS issuances. These two states, which are in the first two places in Green Issuance, are not in the first places when we take the ratio of green CMBS to non-greens. We see Nevada as the state with the highest percentage of green to non-green ratio, and Georgia is in second place (Figure 4.9). We see that Texas, which is the leader in the amount of Green CMBS issuance, has fallen to the 4th place based on the green to non-green ratio.

In Table 2, we see the summary statistics for our sample. Security UPB-Issuance and Loan UPB-Issuance variables denote the outstanding principal balance, expressed in



(a) Green (b) Non-Green

Figure 4.8: Top 10 CMBS Issuer States

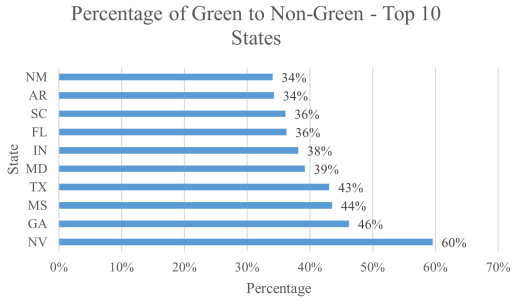


Figure 4.9: Percentage of Green to Non-Green – Top 10 CMBS Issuer States

millions of dollars. The average unpaid principal balance (UPB) for non-green (NG) CMBS is $14.1 million, with a standard deviation of $14.6 million. The average unpaid principal balance (UPB) for green (G) CMBS in our sample is $21.2 million, with a standard deviation of $16.9 million. Green CMBS have a UPB range of $0.9 million to $92.7 million. These comparisons indicate that G loans have higher loan balances. The Security PTR variable represents the interest rate for the pass-through security, expressed as a percentage. The average PTR is slightly higher for G securities (2.69%) in comparison to NG securities (2.62%) indicating a lack of greenium. The standard deviation for G securities is considerably smaller, suggesting that there is less variability in pass-through rates among G securities in comparison to NG securities. The average loan note rate for NG securities is slightly higher at 3.95% compared to G securities, which have an average interest rate of 3.86% indicating a presence of greenium in loan rates. However, G and NG securities have significantly different characteristics therefore, it is impossible to conclude the existence or lack of greenium without controlling for these differences. Both forms of securities

Table 4.1: Summary Statistics

Note: The mean, standard deviation, minimum, and maximum values for mortgage loan note rate and CMBS pass-through rate along with some characteristics of green and non-green CMBS are reported in this table. Variable definitions are given in Table 4.2 G and NG stand for green and non-green CMBS, respectively.

	Obs.		**Mean**		**Std. Dev.**		**Min**		**Max**	
	NG	**G**	**NG**	**G**	**NG**	**G**	**NG**	**G**	**NG**	**G**
UPB	9643	2767	14.13	21.17	14.63	16.84	0.90	1.00	92.34	92.70
Security PTR	9643	2767	2.62	2.69	1.04	0.95	0.84	0.76	6.12	5.28
Loan Note Rate	9643	2767	3.95	3.86	0.84	0.82	1.91	1.92	7.27	6.22
Term	9643	2767	128.82	130.67	31.19	28.92	60.00	60.00	480.00	360.00
LTV	9643	2767	63.62	67.32	11.92	10.02	11.00	17.90	92.20	90.00
DSCR	9643	2767	1.68	1.62	0.72	0.58	1.05	1.05	17.70	7.10

exhibit a similar standard deviation, suggesting that their note rates have a comparable level of variability. The mean term for G securities is slightly longer at 130.67 months, compared to NG securities, which have an average term of 128.82 months. G securities have a lower standard deviation, suggesting there is less variation in the maturity terms of G securities than NG securities. The loan-to-value (LTV) variable shows the proportion between the loan amount and the property's assessed value. In comparison to NG securities (63.62%), the mean LTV for G securities is higher at 67.32%. In comparison to NG securities, G securities have a lower standard deviation, which suggests less variation in LTV ratios of G secrities. Debt service coverage ratio (DSCR), which shows how much of the property's payments for debt is covered by its net operating income. NG equities have a slightly higher mean DSCR (1.68) than G securities (1.62). In addition, NG securities have a higher standard deviation than G securities, suggesting that NG securities have greater variability in DSCR.

Table 4.2: Variable Definitions

Note: Definitions of dependent, main explanatory, and control variables used in the cross-sectional analysis of this thesis are given in this table. The construction of the dummy variables is also explained here.

Variable Names	Definitions
Dependent Variables	
Note Rate (NR)	Security weighted average note rate at loan origination.
Pass-Through Rate (PTR)	Security paying pass-through rate at security issuance.
Main Explanatory Variables	
Green	Dummy variable that equals 1 for mortgage-backed securities labelled as green in Fannie Mae DUS Disclosure.
Green Certification	Dummy variable that equals 1 for mortgage loans which have green certification from independent organizations.
AfterSeptember2019	A dummy variable that equals 1 for CMBS issued after September 2019
Control Variables	
UPBPerUnit	Underlying mortgage loan's unpaid principal balance at the time of loan origination divided by the number of units in the property.
UPBPerUnitSquare	Square of the underlying mortgage loan's unpaid principal balance at the time of securitization divided by the number of units in the property
SecurityTBond	Relevant market Treasury bond rate on the date the loan pool is securitized.
LoanTBond	Relevant market Treasury bond rate on the date the loan pool is created
Term	Time to maturity of the loan.
LTV	Loan-to-value ratio of the loan.
LTVerrorterm	Taking the difference between the predicted value and actual values of the loans average loan to value entered into the regression with debt service coverage ratio.
DSCR	Underlying mortgage loans weighted average net cash flow debt service coverage ratio.
AfterSeptember2019	Dummy variable that equals 1 for VMBS issued after September 2019.
CovidErrorTerm	Taking the difference between the predicted value and actual values of the Covid dummy at loan issuance entered into the regression with after September 2019 dummy.
Seller/Servicer	Dummy variable that equals 1 for CMBS that have same seller and servicer.
Commercial Bank	A dummy variable that equals 1 for mortgage loans that seller is a commercial bank.
PrepaymentType	A dummy variable that equals 1 for CMBS that Prepayment type is yield maintenance.
AmortizationType	A dummy variable that equals 1 for CMBS that amortization type is Interest Only/Balloon.
Sunbelt	A dummy variable that equals 1 for CMBS that include property located sunbelt states of the US.
EastCoast	A dummy variable that equals 1 for CMBS that include property located east coast of the US.
WestCoast	A dummy variable that equals 1 for CMBS that include property located west coast of the US.
Property Total Units	Total number of units in the property.
LargeProperty	A dummy variable that equals 1 for CMBS that properties with more than 250 units.

4.2 Difference-in-Differences Analysis

When adding other control variables to the regression model, we aim to account for additional factors that might influence the outcome variable. Let us denote these control variables by X_{it}, where X_{it} is a vector of control variables for individual i at time t.

$$Y_{it} = \beta_0 + \beta_1 D_i + \beta_2 \text{Post}_t + \beta_3 (D_i \times \text{Post}_t) + \gamma' X_{it} + \epsilon_{it}$$

Where:

$\mathbf{Y_{it}}$: Outcome variable for individual i at time t.

$\mathbf{D_i}$: Binary indicator for treatment group ($D_i = 1$ if individual i is in the treatment group, 0 if in control).

$\mathbf{Post}_t$: Binary indicator for post-treatment period ($\text{Post}_t = 1$ if time t is in the post-treatment period, 0 if in pre-treatment period).

$\mathbf{D_i} \times \mathbf{Post_t}$: Interaction term representing the treatment effect.

$\mathbf{X_{it}}$: Vector of control variables for individual i at time t.

γ : Vector of coefficients for the control variables.

$\epsilon_{\mathbf{it}}$: Error term.

$\beta_{\mathbf{0}}$: Intercept term (average outcome for control group in the pre-treatment period, after adjusting for control variables).

$\beta_{\mathbf{1}}$: Difference between treatment and control groups in the pre-treatment period, after adjusting for control variables.

$\beta_{\mathbf{2}}$: Difference in outcomes between the pre-treatment and post-treatment periods for the control group, after adjusting for control variables.

$\beta_{\mathbf{3}}$: DiD estimator (the causal effect of the treatment,after adjusting for . control variables)

$$\text{DID} = (Y_{T1} - Y_{T0}) - (Y_{C1} - Y_{C0})$$

The Difference-in-Differences (DID) estimator quantifies the disparity in outcome changes between the treatment group (green MBS) and the control group (non-green MBS) before and after the treatment period (September 2019 in our scenario). It helps control time-invariant disparities between the groups and shared temporal patterns that impact both groups. If a treatment effect exists, it is reflected in the difference in changes between the treatment and control groups over time.

4.3 Cross Sectional Regression Models

In this thesis, the aim is to investigate the existence of "greenium" in commercial mortgage loan note rates and commercial mortgage pass-through rates. In this context, the note rate is modelled as a function of several property, loan and market characteristics using Equations 1.1, 2.1 and 1.2, 2.2. Similarly, the property, loan and market related determinants of the PTR are analyzed using Equations 1.3, 2.3 and 1.4, 2.4. The "Green" variable in these models indicates whether the underlying property has a green label or not, and the “Green Certification” indicates whether a green property has a green certification from an independent third party or not. These variables are the main variables of interest. While examining the difference between note rate and PTR of green and non-green securities, we control for other loan and CMBS characteristics, market conditions, and dummy variables for different time periods that might affect these rates. These control variables allow us to examine the impact of green label and green certification on note rate and PTR after isolating the effects of all other potential influencing factors. Equations 1.1, 1.3, 2.1 and 2.3 allow for a different intercept for green (green-labelled and green-certified) and non-green securities.

It is conceivable for an independent variable in equations 1.1, 1.3, 2.1 and 2.3 to have a differential impact on green and non-green securities. In this case, we need to allow for not only a different intercept for green and non-green securities but also different slope coefficients for these securities. Equations 1.2 and 2.2 (1.4 and 2.4) are designed

as regression models with interactive terms to examine the differential impact of these control variables on the green commercial mortgage loan note rate (the green CMBS PTR rate) and non-green ones. The coefficients of interactive terms (e.g., PropertyTotalUnits×Green) show the differential impact of the variable interacted with the green dummy variable (i.e. PropertyTotalUnits) on green securities.

In addition, the spread between note rate and PTR is also modeled as a function of several property, loan and market characteristics using Equation 3.1, 3.2, 3.3 and 3.4. These equations allow us to analyze the issuer spreads for green and non-green commercial mortgage pass-through securities. Variable definitions are the same as before. Regression models for the difference between note rate and PTR for each CMBS have the same structure as models for the loan note rate and PTR. Since the difference between the note rate and the PTR is modelled with these equations, SecurityTBond and LoanTBond variables are excluded from the models. As before, equations 3.2 and 3.4 include interaction terms. These interaction variables are added to the models to allow for not only a different intercept but also different slope coefficients for green (green-labeled and green-certified) and non-green securities.

These models help us understand the determinants of loan note rates and PTRs for green, green-certified, and non-green securities. One variable can have a statistically significant effect on the non-green mortgage loan note rate (non-green MBS PTR rate) but does not affect the green mortgage loan note rate (green MBS PTR rate) or vice versa. We will be able to identify these variables using these 12 models.

4.3.1 Model Equations

Equation 1.1 - Note Rate – Green Dummy

$$\begin{aligned}\text{NR}_i = \alpha_0 &+ \beta_0\text{Green}_i + \alpha_1\text{UPBPerUnit}_i + \alpha_2\text{UPBPerUnitSquare}_i + \alpha_3\text{LoanTBond}_i \\ &+ \alpha_4\text{Term}_i + \alpha_5\text{LTV}_i + \alpha_6\text{DSCR}_i + \alpha_7\text{AfterSeptember2019}_i \\ &+ \alpha_8\text{Covid}_i + \alpha_9\text{CommercialBank}_i + \alpha_{10}\text{PrepaymentType}_i + \alpha_{11}\text{AmortizationType}_i \\ &+ \alpha_{12}\text{EastCoast}_i + \alpha_{13}\text{WestCoast}_i + \alpha_{14}\text{Sunbelt}_i + \alpha_{15}\text{LargeProperty}_i \\ &+ \alpha_{16}\text{PropertyTotalUnits}_i + u_i\end{aligned}$$

Equation 1.2 - Note Rate – Green and Interactives

$$\begin{aligned}\text{NR}_i = \alpha_0 &+ \beta_0\text{Green}_i + \alpha_1\text{UPBPerUnit}_i + \alpha_2\text{UPBPerUnitSquare}_i \\ &+ \alpha_3\text{LoanTBond}_i + \alpha_4\text{Term}_i + \alpha_5\text{LTV}_i + \alpha_6\text{DSCR}_i \\ &+ \alpha_7\text{AfterSeptember2019}_i + \alpha_8\text{Covid}_i + \alpha_9\text{CommercialBank}_i + \alpha_{10}\text{PrepaymentType}_i \\ &+ \alpha_{11}\text{AmortizationType}_i + \alpha_{12}\text{EastCoast}_i + \alpha_{13}\text{WestCoast}_i + \alpha_{14}\text{Sunbelt}_i \\ &+ \alpha_{15}\text{LargeProperty}_i + \alpha_{16}\text{PropertyTotalUnits}_i \\ &+ \alpha_{17}\text{UPBPerUnit} \times \text{Green}_i + \alpha_{18}\text{UPBPerUnitSquare} \times \text{Green}_i \\ &+ \alpha_{19}\text{LoanTBond} \times \text{Green}_i + \alpha_{20}\text{Term} \times \text{Green}_i \\ &+ \alpha_{21}\text{LTV} \times \text{Green}_i + \alpha_{22}\text{DSCR} \times \text{Green}_i \\ &+ \alpha_{23}\text{AfterSeptember2019} \times \text{Green}_i + \alpha_{24}\text{Covid} \times \text{Green}_i \\ &+ \alpha_{25}\text{CommercialBank} \times \text{Green}_i + \alpha_{26}\text{PrepaymentType} \times \text{Green}_i \\ &+ \alpha_{27}\text{AmortizationType} \times \text{Green}_i + \alpha_{28}\text{Sunbelt} \times \text{Green}_i \\ &+ \alpha_{29}\text{EastCoast} \times \text{Green}_i + \alpha_{30}\text{WestCoast} \times \text{Green}_i \\ &+ \alpha_{31}\text{LargeProperty} \times \text{Green}_i + \alpha_{32}\text{PropertyTotalUnits} \times \text{Green}_i + u_i\end{aligned}$$

Equation 1.3 – Pass-Through Rate – Green Dummy

$$\begin{aligned}\text{PTR}_i = \alpha_0 &+ \beta_0\text{Green}_i + \alpha_1\text{UPBPerUnit}_i + \alpha_2\text{UPBPerUnitSquare}_i \\ &+ \alpha_3\text{SecurityTBond}_i + \alpha_4\text{Term}_i + \alpha_5\text{LTV}_i + \alpha_6\text{DSCR}_i \\ &+ \alpha_7\text{AfterSeptember2019}_i + \alpha_8\text{Covid}_i + \alpha_9\text{SellerServicer}_i + \alpha_{10}\text{PrepaymentType}_i \\ &+ \alpha_{11}\text{AmortizationType}_i + \alpha_{12}\text{EastCoast}_i + \alpha_{13}\text{WestCoast}_i + \alpha_{14}\text{Sunbelt}_i \\ &+ \alpha_{15}\text{LargeProperty}_i + \alpha_{16}\text{PropertyTotalUnits}_i + u_i\end{aligned}$$

Equation 1.4 – Pass-Through Rate – Green and Interactives

$$\begin{aligned}\text{PTR}_i = \alpha_0 &+ \beta_0\text{Green}_i + \alpha_1\text{UPBPerUnit}_i + \alpha_2\text{UPBPerUnitSquare}_i \\ &+ \alpha_3\text{SecurityTBond}_i + \alpha_4\text{Term}_i + \alpha_5\text{LTV}_i + \alpha_6\text{DSCR}_i \\ &+ \alpha_7\text{AfterSeptember2019}_i + \alpha_8\text{Covid}_i + \alpha_9\text{SellerServicer}_i + \alpha_{10}\text{PrepaymentType}_i \\ &+ \alpha_{11}\text{AmortizationType}_i + \alpha_{12}\text{EastCoast}_i + \alpha_{13}\text{WestCoast}_i + \alpha_{14}\text{Sunbelt}_i \\ &+ \alpha_{15}\text{LargeProperty}_i + \alpha_{16}\text{PropertyTotalUnits}_i \\ &+ \alpha_{17}\text{UPBPerUnit} \times \text{Green}_i + \alpha_{18}\text{UPBPerUnitSquare} \times \text{Green}_i \\ &+ \alpha_{19}\text{SecurityTBond} \times \text{Green}_i + \alpha_{20}\text{Term} \times \text{Green}_i \\ &+ \alpha_{21}\text{LTV} \times \text{Green}_i + \alpha_{22}\text{DSCR} \times \text{Green}_i \\ &+ \alpha_{23}\text{AfterSeptember2019} \times \text{Green}_i + \alpha_{24}\text{Covid} \times \text{Green}_i \\ &+ \alpha_{25}\text{SellerServicer} \times \text{Green}_i + \alpha_{26}\text{PrepaymentType} \times \text{Green}_i \\ &+ \alpha_{27}\text{AmortizationType} \times \text{Green}_i + \alpha_{28}\text{Sunbelt} \times \text{Green}_i \\ &+ \alpha_{29}\text{EastCoast} \times \text{Green}_i + \alpha_{30}\text{WestCoast} \times \text{Green}_i \\ &+ \alpha_{31}\text{LargeProperty} \times \text{Green}_i + \alpha_{32}\text{PropertyTotalUnits} \times \text{Green}_i + u_i\end{aligned}$$

Equation 2.1 – Note Rate – Green and Green Certification Dummy

$$\begin{aligned}\text{NR}_i = {} & \alpha_0 + \beta_0 \text{Green}_i + \beta_1 \text{GreenCertification}_i + \alpha_1 \text{UPBPerUnit}_i + \alpha_2 \text{UPBPerUnitSquare}_i \\ & + \alpha_3 \text{LoanTBond}_i + \alpha_4 \text{Term}_i + \alpha_5 \text{LTV}_i + \alpha_6 \text{DSCR}_i \\ & + \alpha_7 \text{AfterSeptember2019}_i + \alpha_8 \text{Covid}_i + \alpha_9 \text{CommercialBank}_i + \alpha_{10} \text{PrepaymentType}_i \\ & + \alpha_{11} \text{AmortizationType}_i + \alpha_{12} \text{EastCoast}_i + \alpha_{13} \text{WestCoast}_i + \alpha_{14} \text{Sunbelt}_i \\ & + \alpha_{15} \text{LargeProperty}_i + \alpha_{16} \text{PropertyTotalUnits}_i + u_i\end{aligned}$$

Equation 2.2 – Note Rate – Green, Green Certification and Interactives

$$\begin{aligned}\text{NR}_i = {} & \alpha_0 + \beta_0 \text{Green}_i + \beta_1 \text{GreenCertification}_i + \alpha_1 \text{UPBPerUnit}_i + \alpha_2 \text{UPBPerUnitSquare}_i \\ & + \alpha_3 \text{LoanTBond}_i + \alpha_4 \text{Term}_i + \alpha_5 \text{LTV}_i + \alpha_6 \text{DSCR}_i \\ & + \alpha_7 \text{AfterSeptember2019}_i + \alpha_8 \text{Covid}_i + \alpha_9 \text{CommercialBank}_i + \alpha_{10} \text{PrepaymentType}_i \\ & + \alpha_{11} \text{AmortizationType}_i + \alpha_{12} \text{EastCoast}_i + \alpha_{13} \text{WestCoast}_i + \alpha_{14} \text{Sunbelt}_i \\ & + \alpha_{15} \text{LargeProperty}_i + \alpha_{16} \text{PropertyTotalUnits}_i + \alpha_{17} \text{UPBPerUnit} \times \text{Green}_i \\ & + \alpha_{18} \text{UPBPerUnitSquare} \times \text{Green}_i + \alpha_{19} \text{LoanTBond} \times \text{Green}_i \\ & + \alpha_{20} \text{Term} \times \text{Green}_i + \alpha_{21} \text{LTV} \times \text{Green}_i + \alpha_{22} \text{DSCR} \times \text{Green}_i \\ & + \alpha_{23} \text{AfterSeptember2019} \times \text{Green}_i + \alpha_{24} \text{Covid} \times \text{Green}_i + \alpha_{25} \text{CommercialBank} \times \text{Green}_i \\ & + \alpha_{26} \text{PrepaymentType} \times \text{Green}_i + \alpha_{27} \text{AmortizationType} \times \text{Green}_i + \alpha_{28} \text{Sunbelt} \times \text{Green}_i \\ & + \alpha_{29} \text{EastCoast} \times \text{Green}_i + \alpha_{30} \text{WestCoast} \times \text{Green}_i \\ & + \alpha_{31} \text{LargeProperty} \times \text{Green}_i + \alpha_{32} \text{PropertyTotalUnits} \times \text{Green}_i \\ & + \alpha_{33} \text{UPBPerUnit} \times \text{GreenCertification}_i + \alpha_{34} \text{UPBPerUnitSquare} \times \text{GreenCertification}_i \\ & + \alpha_{35} \text{LoanTBond} \times \text{GreenCertification}_i + \alpha_{36} \text{Term} \times \text{GreenCertification}_i \\ & + \alpha_{37} \text{LTV} \times \text{GreenCertification}_i + \alpha_{38} \text{DSCR} \times \text{GreenCertification}_i \\ & + \alpha_{39} \text{AfterSeptember2019} \times \text{GreenCertification}_i + \alpha_{40} \text{Covid} \times \text{GreenCertification}_i \\ & + \alpha_{41} \text{CommercialBank} \times \text{GreenCertification}_i + \alpha_{42} \text{PrepaymentType} \times \text{GreenCertification}_i \\ & + \alpha_{43} \text{AmortizationType} \times \text{GreenCertification}_i + \alpha_{44} \text{Sunbelt} \times \text{GreenCertification}_i \\ & + \alpha_{45} \text{EastCoast} \times \text{GreenCertification}_i + \alpha_{46} \text{WestCoast} \times \text{GreenCertification}_i \\ & + \alpha_{47} \text{LargeProperty} \times \text{GreenCertification}_i + \alpha_{48} \text{PropertyTotalUnits} \times \text{GreenCertification}_i + u_i\end{aligned}$$

Equation 2.3 – Pass-Through Rate – Green and Green Certification Dummy

$$\begin{aligned}\text{PTR}_i = {} & \alpha_0 + \beta_0 \text{Green}_i + \beta_1 \text{GreenCertification}_i + \alpha_1 \text{UPBPerUnit}_i + \alpha_2 \text{UPBPerUnitSquare}_i \\ & + \alpha_3 \text{SecurityTBond}_i + \alpha_4 \text{Term}_i + \alpha_5 \text{LTV}_i + \alpha_6 \text{DSCR}_i \\ & + \alpha_7 \text{AfterSeptember2019}_i + \alpha_8 \text{Covid}_i + \alpha_9 \text{SellerServicer}_i + \alpha_{10} \text{PrepaymentType}_i \\ & + \alpha_{11} \text{AmortizationType}_i + \alpha_{12} \text{EastCoast}_i + \alpha_{13} \text{WestCoast}_i + \alpha_{14} \text{Sunbelt}_i \\ & + \alpha_{15} \text{LargeProperty}_i + \alpha_{16} \text{PropertyTotalUnits}_i + u_i\end{aligned}$$

Equation 2.4 – Pass-Through Rate – Green, Green Certification and Interactives

$$
\begin{aligned}
\text{PTR}_i = {} & \alpha_0 + \beta_0 \text{Green}_i + \beta_1 \text{GreenCertification}_i + \alpha_1 \text{UPBPerUnit}_i + \alpha_2 \text{UPBPerUnitSquare}_i \\
& + \alpha_3 \text{SecurityTBond}_i + \alpha_4 \text{Term}_i + \alpha_5 \text{LTV}_i + \alpha_6 \text{DSCR}_i \\
& + \alpha_7 \text{AfterSeptember2019}_i + \alpha_8 \text{Covid}_i + \alpha_9 \text{SellerServicer}_i + \alpha_{10} \text{PrepaymentType}_i \\
& + \alpha_{11} \text{AmortizationType}_i + \alpha_{12} \text{EastCoast}_i + \alpha_{13} \text{WestCoast}_i + \alpha_{14} \text{Sunbelt}_i \\
& + \alpha_{15} \text{LargeProperty}_i + \alpha_{16} \text{PropertyTotalUnits}_i \\
& + \alpha_{17} \text{UPBPerUnit} \times \text{Green}_i + \alpha_{18} \text{UPBPerUnitSquare} \times \text{Green}_i + \alpha_{19} \text{SecurityTBond} \times \text{Green}_i \\
& + \alpha_{20} \text{Term} \times \text{Green}_i + \alpha_{21} \text{LTV} \times \text{Green}_i + \alpha_{22} \text{DSCR} \times \text{Green}_i \\
& + \alpha_{23} \text{AfterSeptember2019} \times \text{Green}_i + \alpha_{24} \text{Covid} \times \text{Green}_i + \alpha_{25} \text{SellerServicer} \times \text{Green}_i \\
& + \alpha_{26} \text{PrepaymentType} \times \text{Green}_i + \alpha_{27} \text{AmortizationType} \times \text{Green}_i + \alpha_{28} \text{Sunbelt} \times \text{Green}_i \\
& + \alpha_{29} \text{EastCoast} \times \text{Green}_i + \alpha_{30} \text{WestCoast} \times \text{Green}_i \\
& + \alpha_{31} \text{LargeProperty} \times \text{Green}_i + \alpha_{32} \text{PropertyTotalUnits} \times \text{Green}_i \\
& + \alpha_{33} \text{UPBPerUnit} \times \text{GreenCertification}_i + \alpha_{34} \text{UPBPerUnitSquare} \times \text{GreenCertification}_i \\
& + \alpha_{35} \text{SecurityTBond} \times \text{GreenCertification}_i + \alpha_{36} \text{Term} \times \text{GreenCertification}_i \\
& + \alpha_{37} \text{LTV} \times \text{GreenCertification}_i + \alpha_{38} \text{DSCR} \times \text{GreenCertification}_i \\
& + \alpha_{39} \text{AfterSeptember2019} \times \text{GreenCertification}_i + \alpha_{40} \text{Covid} \times \text{GreenCertification}_i \\
& + \alpha_{41} \text{SellerServicer} \times \text{GreenCertification}_i + \alpha_{42} \text{AmortizationType} \times \text{GreenCertification}_i \\
& + \alpha_{43} \text{Sunbelt}_i \times \text{GreenCertification}_i + \alpha_{44} \text{EastCoast} \times \text{GreenCertification}_i \\
& + \alpha_{45} \text{WestCoast} \times \text{GreenCertification}_i + \alpha_{46} \text{LargeProperty} \times \text{GreenCertification}_i \\
& + \alpha_{47} \text{PropertyTotalUnits} \times \text{GreenCertification}_i + u_i
\end{aligned}
$$

These models are estimated using the Ordinary Least Squares regression model. Estimation results are reported and discussed in Chapter 5.

CHAPTER 5

ANALYSES AND RESULTS

We use Python to analyze our primary market data consisting of 283 attributes for a total of 12,410 MBS. We choose Python because of its flexibility and ease of access to many libraries.

As we mentioned earlier, we winsorize the unpaid principal balance (UPB) variable to eliminate outliers. We remove UPB values below 1% and above 99% from our data. The distribution of UPB before and after winsorization is given in Figures 5.1 and 5.2.

5.1 Univariate Analysis

We calculate the average Pass-through rate (PTR) and Note rates for green and non-green MBS on an annual basis. As seen in the line chart in Figure 5.3, for the mortgage-backed securities we analyzed, the note rates (mortgage loan interest rate) are about 100 basis points higher than the pass-through rates (security coupon rate) for both green and non-green CMBS every year.

Furthermore, the average note rate (PTR) of green CMBS is always less than that of non-green securities every year. While the difference is very small in 2017, it started to widen in 2018, and green mortgage loans and green mortgage-backed securities are issued at lower rates until the end of 2022. The point we can draw attention to here is that the difference between green and non-green note rates between the first quarter of 2018 and the last quarter of 2022 is higher than the difference between green pass-through rates and non-green pass-through rates. In the overall picture, this

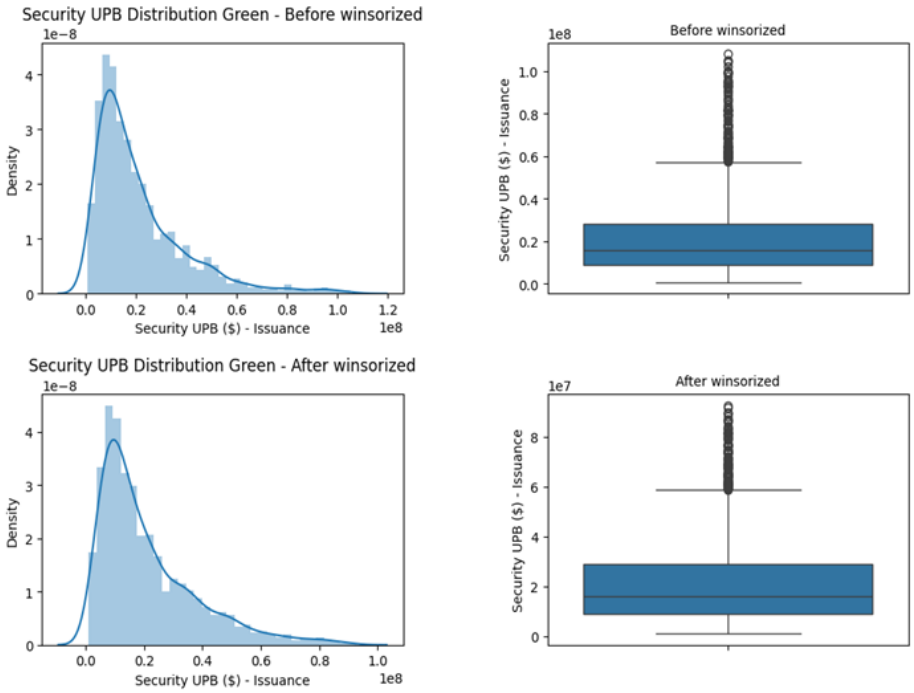


Figure 5.1: UPB Distribution Before and After Winsorization – Green

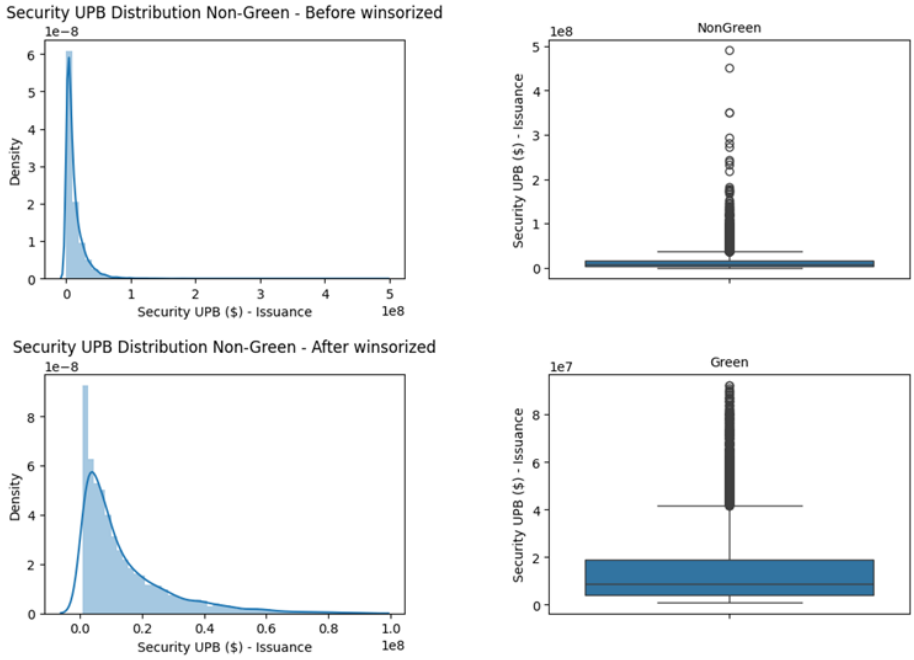


Figure 5.2: UPB Distribution Before and After Winsorization – Non-Green

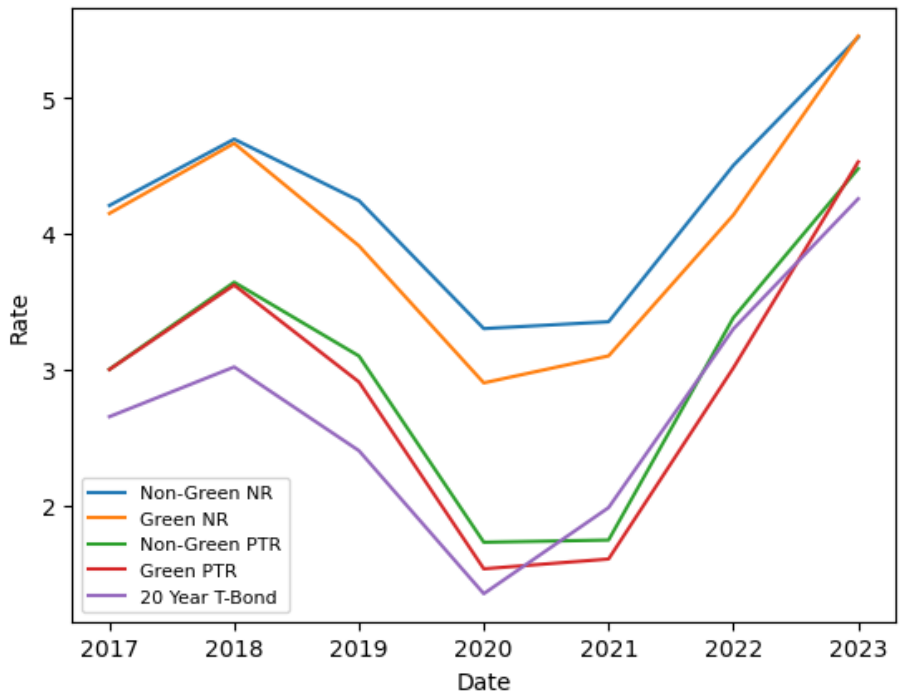


Figure 5.3: Average PTR, Note Rate for Green and Non-Green, 20-Year T-Bond

shows us that the property's green status is taken into consideration when creating a mortgage loan and determining the note rate for that loan. A lower pass-through rate is observed for securitized green mortgage loans, but the difference between PTRs of green and non-green MBS is lower than that between the note rates of green and non-green mortgage loans. Overall, this is a piece of initial evidence for the presence of a greenium in note rates and PTR of CMBS.

In Table 5.1, we see the result for t-tests of differences in mean values of dependent and independent variables in our cross-sectional regression models for green and non-green CMBS. The test results indicate a statistically significant difference in mean values of all dependent variables for green and non-green CMBS. The difference in mean security note rate for the green and non-green MBS is -0.09, indicating that green mortgage loans are offered to borrowers at 9 basis points lower rates than non-green loans. This univariate result is consistent with the existence of a greenium in the commercial mortgage loan market and conclusions from Figure 5.3. Based on these results, it can be concluded that the greenness of the properties has a notable impact on the interest rate of the mortgage loans provided for these properties. However, the mortgage-backed securities generated by securitizing these loans are released into the

market with PTR that is 7 basis points higher than that for non-green ones.

The test of means for independent variables included in our cross-sectional regressions shows a statistically significant difference in the mean value of all but PrepaymentType, Amortization Type, EastCoast, and WestCoast dummy variables. According to these univariate tests of means results, green CMBS have higher unpaid principal balances ($7.037 billion), longer terms (1.85 months), higher loan-to-value ratios (3.70), and lower debt service coverage ratios (-0.06) than non-green CMBS on average. Previous research indicates that mortgage loans with larger sums are anticipated to have higher note rates. Conversely, the opposite scenario is present here. Although the unpaid principal balances of green mortgages are higher, their note rates are lower. Higher average loan-to-value ratios combined with lower average debt service coverage ratios for green CMBS relative to non-green ones suggest that green mortgage loans could potentially be riskier investments compared to their non-green counterparts but they still have lower note rates. These univariate findings highlight the importance of accounting for these differences in the characteristics of green and non-green CMBS when examining the note rates and PTR for these securities.

Little more than half of the green CMBS (0.52) is issued after September 2019. However, 75% of the non-green mortgages and CMBS in our sample are issued after September 2019. This difference in green and non-green mortgage loans and CMBS issuances for green and non-green ones is again consistent with the wave of mortgage refinancing in 2020 (Fuster et al., 2021) [13] and the higher percentage of refinancing loans for non-green CMBS reported in Chapter 4 of this thesis. This finding can also be the result of changes in FHFA's treatment of green commercial mortgages when determining the caps for Fannie Mae and Freddie Mac, drawing attention to the importance of controlling for this variable in our cross-sectional analyses.

More of the non-green loans (-0.02) are issued by commercial banks. Having the same seller and servicer for CMBS is less common for green than non-green ones (-0.04). More of the green mortgage loans (0.13) are issued in Sunbelt states than non-green ones. Furthermore, multifamily properties financed with green mortgages not only have more units (54.13) but also more of them are large properties (0.11) with 250 or more units. The higher number of units in green multifamily properties

Table 5.1: Test of Means for Green and Non-Green CMBS

Note:In this table, the results of the differences in means of dependent and independent variables for green and non-green CMBS in the cross-sectional regression models are reported. Definitions of variables are given in Table 4.1. The p-value indicates the statistical significance of the t-test for the equality of means for green and non-green CMBS.

Variable	**Green**	**Non-Green**	**Green-Non Green**	**p-value**
Loan Note Rate (%)	3.86	3.95	-0.09	<0.0001
Security PTR (%)	2.69	2.62	0.07	<0.0001
UPB (Mil $)	21.1	14.1	7.0	<0.0001
Term	130.67	128.82	1.85	0.00518
LTV (%)	67.32	63.62	3.70	<0.0001
DSCR	1.62	1.68	-0.06	<0.0001
After September 2019	0.52	0.75	-0.23	<0.0001
Covid	0.38	0.65	-0.27	<0.0001
Commercial Bank	0.18	0.20	-0.02	0.0277
Seller/Servicer	0.80	0.84	-0.04	<0.0001
Prepayment Type	0.94	0.95	0.01	0.3464
Amortization Type	0.27	0.27	0.00	0.9060
Sunbelt	0.68	0.55	0.13	<0.0001
East Coast	0.32	0.33	0.01	0.5703
West Coast	0.19	0.18	0.01	0.4404
Property Total Units	196.32	142.19	54.13	<0.0001
Large Property	0.28	0.17	0.11	<0.0001

and larger property sizes for green mortgages are in line with the higher unpaid principal balance for these mortgages.

5.2 Results and Discussion of the Cross-sectional Regression Models

Before starting the regression analysis, we conduct the variance inflation factor (VIF) analysis to check whether any one of the independent variables can cause multicollinearity. In the equation below we can see the VIF formula. Regressing the i th independent variable on the other ones yields an unadjusted coefficient of determination (R_i^2).

$$VIF_i = \frac{1}{1-R_i^2}$$

VIF scores for independent variables included in cross-sectional regression models of this thesis are reported in Table 5.2. High VIF scores indicate the presence of multicollinearity. Even though none of the VIF scores are high enough to indicate multicollinearity, we also calculate the correlation coefficient between independent variables in our cross-sectional models. Independent variables with a high correlation with each other might be the reason for multicollinearity. To identify these variables that might cause multicollinearity, we construct the correlation table for independent variables and present it in Figure 5.3.

Table 5.2: VIF Scores of Independent Variables

Note:This table shows the variance inflation factor (VIF) scores for the independent variables included in our cross-sectional models. High VIF scores indicate the presence of multicollinearity in the models.

Variables	VIF
Constant	204.17
UPBPerUnit	2.8506
LoanTBond	1.7727
Term	1.0692
LTV	1.9801
DSCR	2.811
AfterSeptember2019	3.1011
Covid	2.9045
Seller/Servicer	1.0773
CommercialBank	1.0194
PrepaymentType	1.0322
AmortizingType	2.1265
EastCoast	1.1616
WestCoast	1.4318
Sunbelt	1.0599
LargeProperty	2.5461
PropertyTotalUnits	3.9539

The high positive and statistically significant correlation (0.06198) reported in Figure 5.4 between DSCR and LTV is not surprising given the requirements of commercial banks and mortgage originators. Similarly, Covid and AfterSeptember2019 dummy variables are positively and very highly correlated (0.7998) because they indicate more or less the same periods (after March 2020 when Covid-19 was declared as a pandemic by WHO, and after September 2019, respectively). These high correlations between these variables are a cause for concern. To eliminate the possibility of multicollinearity, we regress the LTV ratio on DSCR and take the error term of this regression as the part of the LTV ratio that is not correlated with DCSR. This variable is named as LTVErrorTerm. Similarly, we run a regression of the Covid dummy variable on the After September 2019 dummy variable and take the error term of this regression as the Covid dummy variable (CovidDummyErrorTerm) that does not contain the effect of AfterSeptember2019 dummy variable.

	UPB PerUnit	Loan TBond	Term	LTV	DSCR	After September 2019	NewCovid	Seller/ Servicer	Commercial Bank	Prepayment Type	Amortizing Type	EastCoast	WestCoast	Sunbelt	Large Property
LoanTBond	0.0691***														
Term	-0.0795***	-0.0094													
LTV	0.0039	-0.0604***	0.1329***												
DSCR	0.0178*	-0.209***	-0.1192***	-0.6198***											
AfterSeptember2019	-0.0092	-0.5144***	-0.0864***	-0.1092***	0.1261***										
NewCovid	-0.0005	-0.4397***	-0.106***	-0.1593***	0.1477***	0.7998***									
Seller/Servicer	0.0147	-0.0428***	-0.0619***	-0.0334***	0.0127	0.211***	0.2378***								
CommercialBank	0.0767***	0.0498***	0.0446***	-0.0271**	-0.0019	-0.0713***	-0.0686***	-0.0231*							
PrepaymentType	0.1182***	-0.0423***	0.0228*	-0.0742***	0.0543***	0.0571***	0.0654***	-0.0205*	0.0088						
AmortizingType	0.2013***	0.062***	-0.2022***	-0.467***	0.6413***	0.0588***	0.1037***	0.0232**	-0.0133	0.0738***					
EastCoast	0.0314***	-0.0202*	0.0022	0.1204***	-0.0959***	0.0209*	0.0254**	0.0435***	-0.0198*	-0.0576***	-0.1093***				
WestCoast	0.0085	-0.0873***	-0.0449***	-0.3054***	0.2241***	0.0071	0.0202*	-0.0204*	0.0415***	0.064***	0.2558***	-0.3284***			
Sunbelt	0.0676***	0.0419***	-0.0604***	-0.112***	0.0497***	-0.0765***	-0.0707***	-0.0682***	0.0246**	0.0207*	0.0818***	-0.1085***	0.1269***		
LargeProperty	0.6397***	0.0806***	-0.0325***	-0.0224*	0.0513***	-0.0568***	-0.0464***	0.0021	0.0559***	0.0632***	0.0917***	0.0142	-0.1347***	0.0851***	
PropertyTotalUnits	0.7562***	0.123***	-0.0142	-0.0108	0.0687***	-0.0847***	-0.0693***	-0.0211*	0.0773***	0.0785***	0.107***	-0.0104	-0.171***	0.1033***	0.7733***

Figure 5.4: Correlation Table for Independent Variables

Note:In this figure, Pearson correlation coefficients between independent variables included in the cross-sectional regression models are reported. ***, **, * indicate statistical significance of calculated correlation coefficients at 1

LTVErrorTerm Prewhitening Equation:

$$\text{LTV}_j = \alpha_0 + \beta_0 \text{DSCR}_j + u_j$$

$$\epsilon_j = \text{LTV}_j - (\hat{\text{LTV}}_j)$$

CovidErrorTerm Prewhitening Equation:

$$\text{Covid}_i = \alpha_0 + \beta_0 \text{AfterSeptember2019}_i + u_i$$

$$\epsilon_i = \text{Covid}_i - (\hat{\text{Covid}}_i)$$

Table 5.3: VIF Scores of the Independent Variable After Prewhitening

Note:This table shows the variance inflation factor (VIF) scores for the independent variables included in our cross-sectional models after prewhitening the LTV ratio and the Covid dummy variable. High VIF scores indicate the presence of multicollinearity in the models.

Variables	VIF
Constant	77.72
UPBPerUnit	2.8506
LoanTBond	1.7727
Term	1.0692
LTVErrorTerm	1.2195
DSCR	2.0654
AfterSeptember2019	1.5629
CovidErrorTerm	1.0466
Seller/Servicer	1.0773
CommercialBank	1.0194
PrepaymentType	1.0322
IO/Baloon	2.1265
EastCoast	1.1616
WestCoast	1.4318
Sunbelt	1.0599
LargeProperty	2.5461
PropertyTotalUnits	3.9539

Following the pre-whitening process, the model predictors showed reduced multicollinearity, hence improving the reliability of the regression analysis. Furthermore, The low correlation coefficients observed after pre-whitening provide evidence for the effectiveness of this strategy in minimizing undesirable correlations and enhancing the independence of the variables in the cross-sectional analysis.

	UPB PerUnit	Loan TBond	Term	LTV	DSCR	After September 2019	NewCovid	Seller/ Servicer	Commercial Bank	Prepayment Type	Amortizing Type	EastCoast	WestCoast	Sunbelt	Large Property
LoanTBond	0.0691***														
Term	-0.0795***	-0.0094													
LTV	0.0191*	-0.2421***	0.0752***												
DSCR	0.0178*	-0.209***	-0.1192***	0.00000											
AfterSeptember2019	-0.0092	-0.5144***	-0.0864***	-0.0396***	0.1261***										
NewCovid	0.0114	-0.0471***	-0.0614***	-0.0911***	0.0781***	0.0000									
Seller/Servicer	0.0147	-0.0428***	-0.0619***	-0.0326***	0.0127	0.211***	0.115***								
CommercialBank	0.0767***	0.0498***	0.0446***	-0.036***	-0.0019	-0.0713***	-0.0193*	-0.0231*							
PrepaymentType	0.1182***	-0.0423***	0.0228*	-0.0517***	0.0543***	0.0571***	0.033***	-0.0205*	0.0088						
AmortizingType	0.2013***	0.062***	-0.2022***	-0.0885***	0.6413***	0.0588***	0.0944***	0.0232**	-0.0133	0.0738***					
EastCoast	0.0314***	-0.0202*	0.0022	0.0777***	-0.0959***	0.0209*	0.0144	0.0435***	-0.0198*	-0.0576***	-0.1093***				
WestCoast	0.0085	-0.0873***	-0.0449***	-0.2122***	0.2241***	0.0071	0.0242**	-0.0204*	0.0415***	0.064***	0.2558***	-0.3284***			
Sunbelt	0.0676***	0.0419***	-0.0604***	-0.1034***	0.0497***	-0.0765***	-0.0159	-0.0682***	0.0246**	0.0207*	0.0818***	-0.1085***	0.1269***		
LargeProperty	0.6397***	0.0806***	-0.0325***	0.0120	0.0513***	-0.0568***	-0.0016	0.0021	0.0559***	0.0632***	0.0917***	0.0142	-0.1347***	0.0851***	
PropertyTotalUnits	0.7562***	0.123***	-0.0142	0.0406***	0.0687***	-0.0847***	-0.0026	-0.0211*	0.0773***	0.0785***	0.107***	-0.0104	-0.171***	0.1033***	0.7733***

Figure 5.5: Correlation Table for Independent Variables After Prewhitening

Note:In this Figure, Pearson correlation coefficients between independent variables after the prewhitening of LTV and Covid dummy variables included in the cross-sectional regression models are reported. ***, **, * indicate statistical significance of calculated correlation coefficients at 1

5.2.1 Discussion of Estimation Results for Equation 1.1 – Note Rate – Green Dummy

The estimation results for Equation 1.1 are shown in Table 5.4. The model can explain approximately 82.9% of the variation in note rates. The green bond indicator, the primary variable of interest, has a negative and statistically significant coefficient, suggesting that the yields on green mortgages are 12.4 basis points lower than those on comparable non-green mortgages. At the 5 percent level, the coefficients for almost all control variables are statistically significant. The AfterSeptember2019 and Sunbelt Dummy are exceptions.

The note rate on all mortgages riseswith the anticipated increase in the market interest rate proxied by the LoanTBond variable. The market interest rate and the note rate of MBS have a strong positive correlation, as shown by the variable's coefficient of roughly 0.75. The coefficient of our Term variable shows that a one-month increase in the term of the mortgage loan causes a 0.05 basis point increase in note rates. The positive and significant relation between note rate LoanTBond and Term variables are consistent with the term structure of interest rates theories. Similarly, the LTVerrorterm variable shows that a one percent increase in the error term of the loan-to-value ratio of a commercial mortgage is associated with an increase in note rate of 0.25 basis points. Since the increase in LTV will increase the default risk of a mortgage, it is expected to be reflected as an increase in the note rate.

Another factor is issue size (UPBPerUnit). The note rate on all mortgages falls as the issue size rises. This finding is counterintuitive. Economies of scale could be a potential explanation for this finding. Furthermore, the decline in closing costs as the amount of debt increases might be another reason why the note rate decreases as the UPBPerUnit increases. The square of UPBPerUnit has a positive and statistically significant coefficient indicating that as the per unit UPB increases, the note rate of mortgage loans decreases at a decreasing rate.[1]

Consistent with expectations, as the debt service coverage ratio (LoanDSCR) rises,

[1] Both UPBPerUnit and UPBPerUnitSquared have very small but statistically significant coefficient estimates. Therefore, coefficients of these variables are reported in Table 5.4 as -0.0000 and 0.0000, respectively to indicate the sign of the relationship between these variables and the mortgage loan note rates.

the note rate on the commercial mortgage loan falls. This variable is inversely proportional to the note rate because a higher debt service coverage ratio reduces the default risk associated with the mortgage loan. The coefficient of the prewhitened Covid dummy is -0.003 and statistically significant. This shows that the note rate of commercial mortgage loans is 3 basis points lower after March 2020. The note rate of MBS issued by Commercial Banks is 6.14 basis points lower than that of mortgage other originators signaling the informational advantage of commercial banks in evaluating the risk of mortgage recipients.

Note rates on CMBS with a yield maintenance prepayment type are 18.8 basis points lower than those with a decreasing premium, defeasance, prepayment lockout, and other prepayment penalties. Compared to mortgages with Interest Only/Amortizing/Balloon and Amortizing/Balloon, the note rate of mortgage loans with the amortization type of Interest Only/Balloon is 7.7 basis points lower. This result indicates that non-amortizing mortgages might be considered a lower-risk instrument.

It can be seen from our results that the mortgage loans taken for properties located on the West Coast (East Coast) of the US have note rates that are 3.73 (2.9) basis points lower (higher) than those in other regions. The number of units in the properties is another variable that affects the mortgage note rates. As the number of units in the properties increases by 1 unit, the note rate decreases by 0.13 basis points. This could be because of the higher income-generating ability of the property. However, for properties with more than 250 units, the note rate is 11.23 basis points higher than those on properties with less than 250 units.

5.2.2 Discussion of Estimation Results for Equation 1.2 – Note Rate – Green and Interactives

The findings in Table 5.4 demonstrate that the note rate on green bonds is lower than that of non-green bonds when all relevant variables are considered. The next crucial topic to examine is whether those attributes impact green and non-green mortgage rates differently. We interact all variables in equation 1.1 with the green dummy variable to answer this question. The estimation results for Equation 1.2 are shown in Table 5.4. With the inclusion of interactive variables, our Adjusted R square value

increases from 82.8% to 83.1%.

The coefficient estimates for explanatory factors and their statistical significances remain qualitatively unchanged from the results for equation 1.1 when we included the interactive variables. The Green Dummy variable is again negative and statistically significant in this revised model, which allows for different slope coefficients for green and non-green CMBS. The coefficient of the Green Dummy is -0.1939 indicating 19.4 basis points greenium in mortgage note rates.

The interaction terms with LoanTBond, DSCR, AmortizationType, EastCoast, Property Total Units, and LargeProperty have statistically significant coefficients indicating that the effect of these variables on green mortgage loan note rates is significantly different from that on non-green mortgages. The increase in the note rate of green MBS is 7.6 basis points more than that of non-green MBS when the market interest rate (Loan T Bond) increases. Note rates for green mortgages decline by 10 basis points more than non-green ones for every unit rise in the debt service coverage ratio (DSCR). The note rate for non-amortizing green mortgages is 8.53 basis points higher than that for their non-green counterparts. Mortgage loans originating for green properties on the East Coast have note rates that are 4.78 basis points lower than that for non-green ones. As Property Total Units increase, the green mortgage loan note rate decreases 8 basis points less than that of comparable non-green mortgages. Finally, there is no statistically significant difference in note rates of green mortgages on large versus small properties.

5.2.3 Discussion of Estimation Results for Equation 1.3 – Pass-Through Rate – Green Dummy

In our third and fourth models, we examined the determinants of the pass-through rates of CMBS on the date they are issued. The independent variables we use in models for pass-through rate are slightly different from those we use in the models for note rate. We replaced the LoanTBond variable with the SecurityTBond variable because of the difference between when a mortgage originates and when it is securitized. In the pass-through rate models, we include the Treasury bond rates, SecurityTBond, on the date the mortgage loan is securitized. Another important variable added to these

Table 5.4: Estimation Results for Equations 1.1 and 1.2 for Note Rate with Green and Green Interaction Variables

Note: Estimation results for equations 1.1 with green dummy variable and 1.2 with Green dummy and interactive variables for mortgage loan note rates are shown in this table. The variable definitions are presented in Table 4.1. The p-value is the significance of the t-test on individual coefficient estimates.

	Loan Note Rate Model 1.1		Interaction Model 1.2	
	coef	P>|z|	coef	P>|t|
Constant	**3.3120**	**0.0000**	**3.2976**	**0.0000**
UPBPerUnit	**-0.0000**	**0.0000**	**-0.0000**	**0.0000**
UPBPerUnitSquare	**0.0000**	**0.0000**	**0.0000**	**0.0000**
LoanTBond	**0.7461**	**0.0000**	**0.7373**	**0.0000**
DSCR	**-0.1489**	**0.0000**	**-0.1361**	**0.0000**
LTVerrorterm	**0.0025**	**0.0000**	**0.0023**	**0.0000**
Term	**0.0005**	**0.0000**	**0.0006**	**0.0000**
AfterSeptember2019	-0.0153	0.0700	0.0012	0.8980
CovidErrorTerm	**-0.0300**	**0.0050**	**-0.0315**	**0.0110**
CommercialBank	**-0.0614**	**0.0000**	**-0.0587**	**0.0000**
PrepaymentType	**-0.1882**	**0.0000**	**-0.1816**	**0.0000**
Amortization Type	**-0.0771**	**0.0000**	**-0.0828**	**0.0000**
Sunbelt	0.0027	0.6750	0.0012	0.8660
EastCoast	**0.0289**	**0.0000**	**0.0363**	**0.0000**
WestCoast	**-0.0373**	**0.0000**	**-0.0387**	**0.0010**
Property Total Units	**-0.0013**	**0.0000**	**-0.0015**	**0.0000**
LargeProperty	**0.1123**	**0.0000**	**0.1433**	**0.0000**
Green	**-0.1240**	**0.0000**	**-0.1939**	**0.0150**
UPBPerUnit x Green			-0.0000	0.1170
UPBPerUnitSquare x Green			0.0000	0.4640
LoanTBond x Green			**0.0759**	**0.0000**
Term x Green			-0.0002	0.4990
LTVerrorterm x Green			0.0009	0.4020
DSCR x Green			**-0.1003**	**0.0000**
AfterSeptember2019 x Green			0.0216	0.3620
CovidErrorTerm x Green			0.0173	0.4940
CommercialBank x Green			-0.0022	0.9110
PrepaymentType x Green			0.0023	0.9440
Amortization Type x Green			**0.0853**	**0.0040**
Sunbelt x Green			0.0114	0.4810
EastCoast x Green			**-0.0478**	**0.0050**
WestCoast x Green			0.0165	0.4980
Property Total Units x Green			**0.0008**	**0.0000**
LargeProperty x Green			**-0.1388**	**0.0000**
R-squared	0.829		0.832	
Adj. R-squared	0.828		0.831	
No. Observations	12407		12407	
F-statistic:	3523		1856	
Prob (F-statistic):	0.000		0.000	

models is the same Seller/Servicer dummy variable. This variable has a value of 1 for CMBS with the same loan seller and CMBS servicer. For CMBS with the same seller and servicer, information asymmetry is expected to be lower resulting in a lower pass-through rate. The CommercialBank dummy variable is also removed from models for pass-through rates because this is a security-level, not a mortgage-level analysis.

As seen in the regression results presented in Table 5.5, variables included in the model explain 88.3% of the variation in pass-through rates of CMBS. The coefficient of the Green dummy, the primary variable of interest, is negative and significant at the 5 percent confidence level, indicating that investors in the CMBS market accept 7.13 basis point lower pass-through rates if the securitized commercial mortgages are on green properties.

UPBPerUnit variable shows that PTR decreases as the unpaid principal balance per unit increases, as in note rate regressions. However, the square of UPBPerUnit has a positive and statistically significant coefficient indicating that as the per unit UPB increases, the PTR decreases at a decreasing rate.[2] The coefficient of the market interest rate (SecurityTBond) variable is 0.8819, as expected. This shows us that the pass-through rate of these mortgage-backed securities is in almost perfect correlation with the market interest rate. Another expected result is the relationship between time to maturity (Term) and the PTR of commercial mortgage-backed securities. As time to maturity increases, pass-through rates increase by 0.18 basis points. The increase in DSCR of the mortgages on which CMBS are based causes 6.81 basis point decrease in pass-through rates. The LTVerrorterm variable shows that a one percent increase in the error term of the loan-to-value ratio of a commercial mortgage is associated with a 0.35 basis points decrease in PTR. This counterintuitive coefficient estimate shows the effect of the LTV ratio independent from DCSR on the PTR of CMBS. Furthermore, CMBS with the same seller and servicer have pass-through rates that are 3.73 basis points lower than those with different seller and servicer, consistent with our expectations.

The policy change to remove the purchase cap in September 2019, which we men-

[2] Both UPBPerUnit and UPBPerUnitSquared have very small but statistically significant coefficient estimates. Therefore. Coefficients of these variables are reported in Table 5.5 as -0.0000 and 0.0000, respectively to indicate the sign of the relationship between these variables and the PTR of CMBS.

tioned before, is associated with a decrease of 34.13 basis points in pass-through rates. Increases in Fannie Mae's purchase cap might have an impact on pass-through rates by increasing the availability of MBS in the market. The increased supply of mortgage-backed securities may lead to a decrease in pass-through rates, as Fannie Mae has to offer reduced rates to attract investors to absorb the larger volume of MBS issued. After the Covid 19 pandemic, CMBS seems to be issued at a 22.54 basis point lower pass-through rate. This might be due to the increased awareness of investors of environmental issues and their desire to invest in securities with a positive impact on the environment. Our results show that the PTR of MBS with yield maintenance as the prepayment penalty type is 16.77 basis points less than MBS with other prepayment penalties.

According to our results, Interest Only/Balloon type CMBS, i.e. unamortizing MBS, have a 7.73 basis points higher pass-through rate than others. Unamortizing CMBS might be considered riskier than amortizing ones by the investors resulting in higher pass-through rates for them. When the mortgage loans with properties located on the West Coast of the US and the Sunbelt states are securitized, pass-through rates at the issuance are 2.06 and 2.18 basis points lower than those in other regions of the US. However, CMBS securitizing mortgage loans on properties located on the East Coast of the US have PTR that are 2.8 basis points higher than those in other locations. These results point out geographical differences in the pricing of CMBS. These differences could be explained by investor attitudes toward environmental issues or their socio-economic well-being. Finally, as in the models for note rate, a one-unit increase in total units in a multifamily property seems to be associated with 0.04 basis points lower PTR. However, securitized mortgages on large properties have 3.42 basis points higher PTR than those on small properties.

5.2.4 Discussion of Estimation Results for Equation 1.4 – Pass-Through Rate – Green and Interactives

In this model, we examine whether the variables in model 1.3 affect the PTR of green and non-green CMBS differently by adding the interactions of all independent variables except the prepayment type dummy, because all green commercial mortgages

Table 5.5: Estimation Results for Equations 1.3 and 1.4 for Pass-Through Rate with Green and Green Interaction Variables

Note: Estimation results for equations 1.3 with green dummy variable and 1.4 with Green dummy and interactive variables for the pass-through rate of CMBS are reported in this table. The variable definitions are presented in Table 4.1. The p-value is the significance of the t-test on individual coefficient estimates.

	Security PTR Model 1.3		Interaction Model 1.4	
	coef	P>|t|	coef	P>|t|
Constant	**1.4331**	**0.0000**	**1.4212**	**0.0000**
UPBPerUnit	**-0.0000**	**0.0000**	**-0.0000**	**0.0000**
UPBPerUnitSquare	**0.0000**	**0.0000**	**0.0000**	**0.0000**
SecurityTBond	**0.8819**	**0.0000**	**0.8918**	**0.0000**
DSCR	**-0.0681**	**0.0000**	**-0.0614**	**0.0000**
LTVerrorterm	**-0.0038**	**0.0000**	**-0.0035**	**0.0000**
Term	**0.0018**	**0.0000**	**0.0018**	**0.0000**
AfterSeptember2019	**-0.3413**	**0.0000**	**-0.3157**	**0.0000**
CovidErrorTerm	**-0.2254**	**0.0000**	**-0.1902**	**0.0000**
Seller/Servicer	**-0.0373**	**0.0000**	**-0.0521**	**0.0000**
PrepaymentType	**-0.1677**	**0.0000**	**-0.1764**	**0.0000**
Amortization Type	**0.0773**	**0.0000**	**0.0663**	**0.0000**
Sunbelt	**-0.0218**	**0.0010**	**-0.0207**	**0.0050**
EastCoast	**0.0280**	**0.0000**	**0.0277**	**0.0010**
WestCoast	-0.0206	0.0420	-0.0210	0.0660
Property Total Units	**-0.0004**	**0.0000**	**-0.0005**	**0.0000**
LargeProperty	**0.0342**	**0.0070**	**0.0528**	**0.0000**
Green	**-0.0713**	**0.0000**	0.0997	0.2150
UPBPerUnit x Green			-0.0000	0.2330
UPBPerUnitSquare x Green			0.0000	0.2230
SecurityTBond x Green			**-0.0928**	**0.0000**
Term x Green			0.0002	0.3950
LTVerrorterm x Green			**-0.0023**	**0.0350**
DSCR x Green			**-0.0688**	**0.0020**
AfterSeptember2019 x Green			**-0.1774**	**0.0000**
CovidErrorTerm x Green			**-0.1745**	**0.0000**
Seller/Servicer x Green			**0.0483**	**0.0150**
PrepaymentType x Green			0.0524	0.1270
Amortization Type x Green			**0.0952**	**0.0010**
Sunbelt x Green			-0.0032	0.8450
EastCoast x Green			-0.0027	0.8780
WestCoast x Green			-0.0108	0.6620
Property Total Units x Green			**0.0004**	**0.0000**
LargeProperty x Green			**-0.0676**	**0.0160**
R-squared	0.882		0.883	
Adj. R-squared	0.882		0.883	
No. Observations	12407		12407	
F-statistic	5441		2830	
Prob (F-statistic)	0.000		0.000	

have the same prepayment type, with the green indicator variable. Estimation results are reported in Table 5.5. Adjusted R square is 88.3% for this model. Unfortunately, the coefficient of green dummy variable is insignificant in this model. The remaining explanatory variables retain their significance levels as in equation 1.3 except West-Coast dummy.

SecurityTBond, LTVErrorTerm, Security DSCR, AfterSeptember2019, CovidError Term, Seller/Servicer, AmortizationType, PropertyTotalUnit, and LargeProperty interactive variables have statistically significant effects on PTR of green CMBS. The results show that green MBS are less sensitive to changes in the market interest rate than non-green ones. As the Treasury Bond rate increases, the PTR of green CMBS increase by 9.28 basis points less than that of non-green ones. An increase in DSCR of green mortgage loans is associated with a 6.88 basis points additional decline in their PTR compared to that on non-green ones. The coefficient of AfterSeptember interacted with green dummy variable shows us that the PTR of green CMBS are 17.7 basis points lower than that of non-green ones after the policy change in September 2019. This is an unexpected result indicating that the policy change did not hurt the green CMBS.

After the Covid pandemic, which started in March 2020, the PTR of green CMBS are 17.45 basis points lower than that of non-green ones. The PTR of green CMBS with the same seller servicer are 4.83 basis points higher than their non-green counterparts. Green unamortizing CMBS are considered riskier than their non-green counterpart, resulting in 9.52 basis points higher PTR for them than non-greens with the same features. Finally, the total number of units in properties and large property dummy variable do not have a statistically significant effect on the PTR of green CMBS.

5.2.5 Discussion of Estimation Results for Equation 2.1 – Note Rate – Green and Green Certification Dummy

Some of the green-labeled CMBS have third-party certifications accepted by Fannie Mae. Fannie Mae calls this group "Green Building Certification" in its literature. The remaining green-labeled CMBS have the green designation of Fannie Mae because they participate in its "Green Reward" program. To analyze the marginal effect of

third-party green certification on mortgage loan note rates using equation 2.1, a green certification dummy variable is added to the explanatory variables in equation 1.1. Estimation results for this model are presented in Table 5.6. The size, sign, and significance levels for coefficients of all control variables remained the same except AfterSeptember 2019. The coefficient of AfterSeptember2019 is still negative but statistically significant now. According the this, the note rate of commercial mortgage loans issued in or after September 2019 have note rates that are 1.79 basis points lower than those issued before September 2019. The coefficient of the Green dummy variable is still negative (-0.1309) and statistically significant. However, the Green Certification dummy variable does not have a statistically significant coefficient. This points out that when it comes to the note rate of mortgage loans being green decreases the note rates, but having a green certification from an independent third party does not have an additional effect on note rates.

5.2.6 Discussion of Estimation Results for Equation 2.2 – Note Rate – Green, Green Certification and Interactives

In equation 2.2, green certification interaction terms are added to equation 1.2 to understand how the effect of control variables on note rate varies in properties with green certification. No changes are observed in the size, sign, and significance levels for coefficients of control variables and green dummy interactions in equation 1.2. The coefficient of the green dummy variable indicates a 23.5 basis point lower note rate for green loans (Table 5.6). The Green Certification dummy variable does not have a statistically significant coefficient in this model. Green Certification interactive terms with UPBPerUnit, LoanTBond, AfterSeptember2019, and AmortizationType have statistically significant coefficient estimates at the 5% level. The results show that as per unit UPB increases, note rates of mortgages with green certification decrease less than the rest of the mortgage loans. Compared to the rest of the mortgage loans, those with green certification are affected 7.46 basis points less from changes in market interest rate. The policy change in September 2019 is associated with a 22.94 basis point decrease in the note rate of certified green mortgage loans. Furthermore, unamortizing mortgage loans with green certification have note rates that are 16.3 basis points higher than amortizing mortgage loans, consistent with findings from earlier

Table 5.6: Estimation Results for Equations 2.1 and 2.2 for Note Rate with Green and Green Certification Dummy, and Interactive Variables

Note: Estimation results for equations 2.1 with green and green certification dummy variables and 2.2 with green and green certification dummy variables and interactive terms for mortgage loan note rates are shown in this table. The variable definitions are presented in Table 4.1. The p-value is the significance of the t-test on individual coefficient estimates.

	Loan Note Rate Model 2.1		Interaction Model 2.2	
	coef	P>|t|	coef	P>|t|
Constant	**3.3165**	**0.0000**	**3.2976**	**0.0000**
UPBPerUnit	**-0.0000**	**0.0000**	**-0.0000**	**0.0000**
UPBPerUnitSquare	**0.0000**	**0.0000**	**0.0000**	**0.0000**
LoanTBond	**0.7459**	**0.0000**	**0.7373**	**0.0000**
DSCR	**-0.1492**	**0.0000**	**-0.1361**	**0.0000**
LTVerrorterm	**0.0025**	**0.0000**	**0.0023**	**0.0000**
Term	**0.0006**	**0.0000**	**0.0006**	**0.0000**
AfterSeptember2019	-0.0179	0.0360	0.0012	0.8990
Covid ErrorTerm	**-0.0325**	**0.0030**	**-0.0315**	**0.0110**
CommercialBank	**-0.0612**	**0.0000**	**-0.0587**	**0.0000**
PrepaymentType	**-0.1886**	**0.0000**	**-0.1816**	**0.0000**
Amortization Type	**-0.0774**	**0.0000**	**-0.0828**	**0.0000**
Sunbelt	0.0029	0.6600	0.0012	0.8650
EastCoast	**0.0298**	**0.0000**	**0.0363**	**0.0000**
WestCoast	**-0.0357**	**0.0000**	**-0.0387**	**0.0010**
Property Total Units	**-0.0013**	**0.0000**	**-0.0015**	**0.0000**
LargeProperty	**0.1112**	**0.0000**	**0.1433**	**0.0000**
Green	**-0.1309**	**0.0000**	**-0.2353**	**0.0090**
GreenCertification	0.0367	0.0500	0.1977	0.3730
UPBPerUnit x Green			**0.0000**	**0.0020**
UPBPerUnitSquare x Green			0.0000	0.0930
LoanTBond x Green			**0.0913**	**0.0000**
DSCR x Green			**-0.0765**	**0.0020**
LTVerrorterm x Green			0.0019	0.1030
Term x Green			-0.0002	0.5220
AfterSeptember2019 x Green			0.0330	0.2960
Covid ErrorTerm x Green			0.0094	0.7370
CommercialBank x Green			-0.0144	0.4850
PrepaymentType x Green			0.0125	0.7110
Amortizing Type x Green			0.0390	0.2470
Sunbelt x Green			-0.0030	0.8650
EastCoast x Green			-0.0409	0.0270
WestCoast x Green			0.0403	0.1370
Property Total Units x Green			**0.0009**	**0.0000**
LargeProperty x Green			**-0.1406**	**0.0000**
UPBPerUnit x GreenCertification			**0.0000**	**0.0180**
UPBPerUnitSquare x GreenCertification			-0.0000	0.0550
LoanTBond x GreenCertification			**-0.0746**	**0.0120**
Term x GreenCertification			0.0001	0.8830
LTVerrorterm x GreenCertification			-0.0045	0.1040
DSCR x GreenCertification			-0.0586	0.2130
AfterSeptember2019 x GreenCertification			**-0.2294**	**0.0060**
Covid ErrorTerm x GreenCertification			-0.1107	0.3910
CommercialBank x GreenCertification			0.0742	0.1720
Amortizing Type x GreenCertification			**0.1630**	**0.0130**
Sunbelt x GreenCertification			0.0667	0.0870
EastCoast x GreenCertification			0.0065	0.8780
WestCoast x GreenCertification			-0.0325	0.5590
Property Total Units x GreenCertification			-0.0001	0.6650
LargeProperty x GreenCertification			-0.0094	0.8820
R-squared	0.829		0.833	
Adj. R-squared	0.828		0.832	
No. Observations	12407		12407	
F-statistic	3328		1255	
Prob (F-statistic)	0.000		0.000	

models.

5.2.7 Discussion of Estimation Results for Equation 2.3 – Pass-Through Rate – Green and Green Certification Dummy

We add the green certification dummy variable to the explanatory variables of equation 1.3 to examine the marginal effect of third-party certification on the PTR of CMBS. Estimation results for this equation are reported in Table 5.7. The sign, size, and significance levels for coefficients of the control variables do not change from equation 1.3. In addition to Green dummy, Green Certification dummy variable also has a negative and statistically significant coefficient. According to the results, green-labeled CMBS are issued with 5.87 basis points lower PTR compared to non-green ones. Furthermore, CMBS created by securitizing mortgage loans on properties with green certification are issued with an additional 6.73 basis points lower PTR than green CMBS without certification. This result shows a higher greenium for CMBS certified by approved independent organizations.

5.2.8 Discussion of Estimation Results for Equation 2.4 – Pass-Through Rate – Green, Green Certification and Interactives

In order to see the differential effects of control variables on CMBS with green certification, we add variables obtained by interacting the green certification dummy variables with control variables other than Prepayment type to equation 2.3. The sign, size, and statistical significance of the majority of control variables remain the same as those obtained from estimating equation 1.4. Green-labeled CMBS are issued at 28.5 basis points higher PTR than non-green ones, while those with green certification are issued at a 48.5 basis points lower PTR. This result is consistent with our expectations and the empirical evidence in the literature. It shows that being labeled green is just not enough to claim a greenium, and green certificates received from independent institutions are associated with a serious decrease in PTR of green CMBS. In this model, green dummy interaction terms with DSCR and AmortizationType lose their statistical significance and Green×Term becomes statistically significant. Green

CMBS with longer term are issued with 3 basis points higher PTR than non-green ones.

SecurityTBond, LTVErrorTerm, AfterSeptember2019 and EastCoast variables that we interact with Green Certification are significant at the 5% level. According to the results, the change in market interest rates (SecurityTBond) affects the PTR of CMBS with green certification by 16.61 basis points more than CMBS without green certification. As the LTVErrorTerm of the third-party certified CMBS increases, a 0.5 basis point decrease is observed in their PTR. Although the policy change in September 2019 results in a decrease of 31.57 basis points in the PTR of all CMBS in general, CMBS with green certification are affected 24.67 basis points less from this change. Furthermore, CMBS securitizing mortgage loans on properties with green certification and located on the East Coast of the US have a PTR of 9.92 basis points higher than those in other regions of the US.

Table 5.7: Estimation Results for Equations 2.3 and 2.4 for Pass-Through Rate with Green and Green Certification Dummy, and Interactive Variables

Note: Estimation results for equations 2.3 with green and green certification dummy variables and 2.4 with green and green certification dummy variables and interactive terms for pass-through rate of CMBS are reported in this table. The variable definitions are presented in Table 4.1. The p-value is the significance of the t-test on individual coefficient estimates.

	Security PTR Model 2.3		Interaction Model 2.4	
	coef	P>|t|	coef	P>|t|
Constant	**1.4251**	**0.0000**	**1.4212**	**0.0000**
UPBPerUnit	**-0.0000**	**0.0000**	**-0.0000**	**0.0000**
UPBPerUnitSquare	**0.0000**	**0.0000**	**0.0000**	**0.0000**
SecurityTBond	**0.8824**	**0.0000**	**0.8918**	**0.0000**
DSCR	**-0.0676**	**0.0000**	**-0.0614**	**0.0000**
LTVerrorterm	**-0.0039**	**0.0000**	**-0.0035**	**0.0000**
Term	**0.0018**	**0.0000**	**0.0018**	**0.0000**
AfterSeptember2019	**-0.3365**	**0.0000**	**-0.3157**	**0.0000**
Covid ErrorTerm	**-0.2209**	**0.0000**	**-0.1902**	**0.0000**
Seller/Servicer	**-0.0377**	**0.0000**	**-0.0521**	**0.0000**
PrepaymentType	**-0.1670**	**0.0000**	**-0.1764**	**0.0000**
Amortization Type	**0.0778**	**0.0000**	**0.0663**	**0.0000**
Sunbelt	**-0.0221**	**0.0010**	-0.0207	0.0050
EastCoast	**0.0264**	**0.0000**	**0.0277**	**0.0010**
WestCoast	-0.0236	0.0200	-0.0210	0.0650
Property Total Units	**-0.0004**	**0.0000**	**-0.0005**	**0.0000**
LargeProperty	**0.0364**	**0.0040**	**0.0528**	**0.0000**
Green	**-0.0587**	**0.0000**	**0.2854**	**0.0010**
GreenCertification	**-0.0673**	**0.0000**	**-0.4846**	**0.0320**
UPBPerUnit x Green			-0.0000	0.1400
UPBPerUnitSquare x Green			0.0000	0.2490
SecurityTBond x Green			**-0.1715**	**0.0000**
DSCR x Green			-0.0523	0.2250
LTVerrorterm x Green			-0.0007	0.5480
Term x Green			**0.0003**	**0.0390**
AfterSeptember2019 x Green			**-0.2955**	**0.0000**
Covid ErrorTerm x Green			**-0.2236**	**0.0000**
Seller/Servicer x Green			**0.0516**	**0.0120**
PrepaymentType x Green			0.0385	0.2630
Amortization Type x Green			0.0529	0.1220
Sunbelt x Green			-0.0151	0.3980
EastCoast x Green			-0.0219	0.2430
WestCoast x Green			-0.0054	0.8450
Property Total Units x Green			**0.0004**	**0.0000**
LargeProperty x Green			**-0.0660**	**0.0290**
UPBPerUnit x GreenCertification			-0.0000	0.5300
UPBPerUnitSquare x GreenCertification			0.0000	0.9400
SecurityTBond x GreenCertification			**0.1661**	**0.0000**
Term x GreenCertification			0.0005	0.5600
LTVerrorterm x GreenCertification			**-0.0056**	**0.0440**
DSCR x GreenCertification			0.0107	0.8230
AfterSeptember2019 x GreenCertification			**0.2467**	**0.0050**
Covid ErrorTerm x GreenCertification			0.0756	0.5560
Seller/Servicer x GreenCertification			-0.0926	0.1480
Amortization Type x GreenCertification			0.0919	0.1640
Sunbelt x GreenCertification			0.0518	0.1910
EastCoast x GreenCertification			**0.0992**	**0.0220**
WestCoast x GreenCertification			0.0089	0.8750
Property Total Units x GreenCertification			-0.0001	0.7000
LargeProperty x GreenCertification			-0.0166	0.7980
R-squared	0.882		0.884	
Adj. R-squared	0.882		0.883	
No. Observations	12407		12407	
F-statistic	5144		1919	
Prob (F-statistic)	0.000		0.000	

5.3 Results and Discussion of DiD Analysis

As we mentioned before, in September 2019 FHFA raised the maximum amount of mortgage loans that FNMA could buy from $35 billion to $100 billion and eliminated the "carveout" application on green MBS. The diff-in-diff (DiD) analysis allows us to examine and evaluate changes in mortgage loan note rates and PTR of CMBS for both green and non-green categories before and after September 2019.

Cross-sectional regression models estimated in the previous sections provide the parameter estimates needed to conduct the DiD analysis while taking into account the effect of control variables. Using estimation results of equations 1.1 and 1.2, DiD analysis for note rates of green and non-green commercial mortgage loans can be conducted. These results are reported in Panel A of Table 5.8. This DiD analysis examines how the note rates of green and non-green commercial mortgage loans are affected by the policy change in September 2019.

The results show that the note rates of both green and non-green mortgage loans are higher after the policy change, however, these increases in the note rates are not statistically significant. This finding indicates that the policy change in September 2019 significantly affects the note rates of neither the green nor the non-greeen mortgage loans. The note rate of mortgages on Green properties is 0.19397 basis points lower than that of mortgages on non-green properties before the policy change. After the policy change, the difference between note rates of green and non-green mortgage loans is narrowed down to 0.17161 basis points. The estimate of the difference-in-differences term is 0.02165 and it is not statistically significant. This indicates that the policy change did not influence the difference in note rates of commercial mortgages on green and non-green properties.

Using estimation results of equations 1.3 and 1.4, DiD analysis for pass-through rates of green and non-green CMBS is conducted. These results are reported in Panel B of Table 5.8. The PTR of non-green CMBS decrease by 0.3157 basis points after the policy change, while this decrease is 0.4930 basis points for green CMBS. However, the differences in the PTR of green and non-green CMBS are not statistically significant both before and after September 2019. A significant DiD estimate of -0.1773

Table 5.8: Difference in Differences Analysis for Note and PTR of Green and Non-Green Commercial Mortgage Loans Before and After September 2019

Note: DiD analyses for note rates of green and non-green commercial mortgage loans are reported in Panel A of this table. Similarly, Panel B presents the DiD results for the PTR of green and non-green CMBS. ***, **, * indicate statistical significance of calculated coefficients at 1%, 5% and 10% levels, respectively.

Panel A – Mortgage Loan Note Rate			
	Non-Green	Green	Non-green - Green
Before	**3.2976*** **	**3.1036*** **	**-0.1939*** **
After	**3.2988*** **	**3.1265*** **	**-0.1716*** **
After - Before	0.0012	0.0228	0.0217

Panel B – CMBS Pass-Through Rate			
	Non-Green	Green	Non-Green - Green
Before	**1.4212*** **	**1.5209*** **	0.0997
After	**1.1055*** **	**1.0278*** **	-0.0318
After - Before	**-0.3157*** **	**0.4930*** **	**-0.1774*** **

shows that policy change in September 2019 reduced the PTR of green CMBS more than that of non-green ones.

The differences in the note rate and PTR of green-labeled and green-certified securities are also examined using the DiD analysis to see whether a third-party certification makes a difference. Using estimation results of equations 2.1 and 2.2, DiD analysis for the note rates of mortgage loans on green-labeled and green-certified properties is conducted. These results are shown in Panel A of Table 5.9. The differences in note rates of mortgage loans on Green and Green Certification properties are not statistically significant both before and after September 2019. After the policy change, a significant increase of 0.0342 basis points is observed in the note rates for green-labeled mortgage loans. The note rate of mortgage loans with green certification decrease by 0.1952 after September 2019. This result implies that the policy change in September 2019 affected the note rates of green-labeled and green-certified mortgage loans differently. A statistically significant DiD estimate of -0.2294 indicates a decrease in the difference between the note rates of mortgage loans on green-certified properties and green-labeled properties.

Using estimation results of equations 2.3 and 2.4, DiD analysis for the PTR of mortgage loans on green-labeled and green-certified properties is conducted. These results are presented in Panel B of Table 5.9. Before the policy change, the PTR of green-

Table 5.9: Difference in Differences Analysis for Note and PTR of Green and Green Certified Commercial Mortgage Loans Before and After September 2019

Note: DiD analyses for note rates of green and green-certified commercial mortgage loans are reported in Panel A of this table. Similarly, Panel B presents the DiD results for the PTR of green and green-certified CMBS. ***, **, * indicate statistical significance of calculated coefficients at 1%, 5% and 10% levels, respectively.

Panel A – Mortgage loan Note Rate			
	Green Certification	Green	Green Certification - Green
Before	**3.2599*** **	**3.0623*** **	0.1977
After	**3.0647*** **	**3.0964*** **	-0.0318
After - Before	**-0.1953*** **	**0.0118*** **	**-0.2294*** **

Panel B – CMBS Pass-Through Rate			
	Green Certification	Green	Green Certification - Green
Before	**1.2219*** **	**1.7066*** **	**-0.4846*** **
After	**0.8575*** **	**1.0954*** **	-0.2379
After - Before	**-0.3645*** **	**-0.6112*** **	**0.2467*** **

labeled CMBS is 0.4846 basis points higher than that of green-certified ones, while there is no significant difference between these two PTRs after the policy change. After the policy change while green-labeled CMBS are issued with a 0.6112 points lower pass-through rates, green-certified CMBS are issued with a 0.3644 basis points lower PTR. DiD estimate is positive and statistically significant. This indicates that the policy change had a differential impact on reducing PTR of green-labeled and green-certified CMBS. The difference between the PTR of green-certified and green-labeled CMBS is significantly lower after the policy change than before.

CHAPTER 6

CONCLUSION

Green commercial mortgage-backed securities (CMBS) are becoming an essential financial tool as sustainability-focused investments gain popularity and financial assessments of environmental impact of these investments become more common. Green CMBS might revolutionize how commercial real estate portfolios are financed for better environmental performance and long-term investor profits.

This thesis examines the presence of greenium in the note rates of green and traditional mortgage loans and the pass-through rates of green and traditional CMBS. According to the findings, green-labeled multifamily properties are financed with mortgages featuring note rates that are between 12 and 20 basis points less than those on comparable non-green properties. Evidence for the pass-through rates of green CMBS is mixed at best. There is a grenium of 7.13 basis points when the differential impact of control variables on green and non-green mortgage loans is not allowed. However, when interactive terms for control variables with the green dummy variable are included in the model, there is not a significant difference between the notes rates of green and non-green mortgage loans

There are different shades of greenness for commercial mortgage loans, green-label given by Fannie Mae based on planned improvements in the environmental impact of properties using the funds and green-certification obtained from independent third parties approved by Fannie Mae. The empirical evidence for green bonds highlights the importance of obtaining third-party green certifications to verify the green status of the bonds. Our cross-sectional regression results show 13 to 23 basis points lower note rates for green mortgage loans in general. Having a green certification from a

third party at best does not have any effect on the note rates of these mortgages at worst increases their note rates by 3.67 basis points implying that participation in Fannie Mae's Green Reward program is a credible signal of property's green status for mortgage originators. Hence, there is no incremental greenium coming from obtaining a green certification.

For the pass-through rates of CMBS, green certification seems to have additional value consistent with the evidence for green bonds. The PTR of both green-certified CMBS 6.73 basis points lower than those of green-labeled ones. However, when differential impacts of mortgage and property characteristics on the PTR of green-labeled and green-certified CMBS are accounted for, only green-certified CMBS has a greenium of 48.46 basis points signaling the higher value attached to these certificates in verifying the green status of underlying properties by the market participants. Properties with only a green-label from Fannie Mae have PTR that are 28.54 basis points higher than that of non-green and green-certified CMBS. This finding implies that investors in the securitized commercial mortgage loan market are willing to accept a lower pass-through rate when the property has a green certification from a third party justifying the expenses incurred for obtaining these certifications. These findings are consistent with the existence of greenium in both the commercial mortgage loan and CMBS markets. However, green certification does not make any difference in note rates of commercial mortgage loans while significantly reducing the PTR of CMBS.

After September 2019 dummy variable indicates a decline of 22.94 basis points in note rates of green-certified commercial mortgage loans only. However, the PTR of all CMBS decrease significantly after September 2019 and this decrease is higher for green CMBS. Policy change in September 2019 affects the PTR of green-labeled and green-certified CMBS differently. The PTR of green-labeled (green-certified) CMBS decrease significanty more (less) than non-green ones. Similarly, the Covid-19 dummy variable shows a significant decline in the note rates of all commercial mortgage loans and the PTR of all CMBS. While there is no significant effect of Covid-19 on note rates of green-labeled commercial mortgage loans, the note rates of green-certified commercial mortgage loans decrease even more after the pandemic. Conversely, the PTR of green-labeled CMBS declines more than that of green-certified

CMBS after Covid-19. Control variables in our regression equations for the note rate of commercial loans and the PTR of CMBS are mostly significant and have the expected signs.

The DiD analysis shows lower note rates for green commercial mortgage loans both before and after September 2019. However, the difference in note rates of green and non-green mortgages after September 2019 is statistically the same as that before. Furthermore, there is no statistically significant change in note rates of green and non-green commercial mortgage loans after the policy change. While the note rates of green-labeled commercial mortgage loans increase after September 2019, that for green-certified ones decrease widening the difference in their note rates and making it statistically significant. Even though, there is not a significant difference in note rates of green-labeled and green-certified commercial mortgage loans both before and after September 2019, the difference in note rates of green-certified and green-labeled commercial mortgage loans is lower after September 2019 than before. Higher note rates for green-labeled commercial mortgage loans after September 2019 can be consistent with the end of favorable treatment of green mortgages by the FHFA after this date. Similarly, lower note rates for green-certified mortgage loans after September 2019 might be due to the higher status attached to independent green certifications after September 2019 in this market.

Results of DiD analysis for the PTR of green and non-green CMBS document a decline for both groups after September 2019 where this decline is larger for green CMBS. There is not a statistically significant difference between the PTR of green and non-green CMBS both before and after September 2019. The PTR of green-certified CMBS is lower than that for green-labeled ones only before September 2019. The difference in PTR of green-certified and green-labeled CMBS decrease after September 2019 consistent with our conclusion of higher status attached to independent green-certifications before September 2019.

To summarize, in this thesis, we examine the note rates of commercial mortgage loans and PTR the of CMBS which are not examined extensively before. It was seen that mortgages taken for green properties are more advantageous than non-green ones. A significant greenium is observed in the mortgage loan market. The higher greenium is

observed in the securitized commercial mortgage market for CMBS with underlying mortgages on certified properties.

This thesis analyzes only the differences in pricing of green and traditional commercial mortgage loans, and green and traditional CMBS at the time of their issuance, i.e., in the primary market. Since yield to maturities for these assets at the time of their issue are not available, analyses are conducted in this thesis using the best alternatives to yield to maturity, note rates for commercial mortgage loans, and the PTR for CMBS. If these securities are priced at par at the time of their issuance, the note rate and the PTR are equal to the corresponding yield to maturities but they may not be priced at par. Furthermore, the lack of reliable period (daily, monthly, etc) returns for CMBS makes it impossible to extend the analyses to the secondary market and limits the contribution of this thesis to the academic literature.

Additional studies might investigate various approaches to comprehend further and improve the effectiveness of green finance methods in the commercial or residential real estate sector. A prospective study examining the long-term performance of properties designated as green versus those certified as green might provide valuable insights into the sustainability and financial feasibility of these investments in the long run. Examining the behavior and preferences of institutional investors in the secondary market might provide a valuable understanding of the level and determinants of interest in green as opposed to non-green CMBS. This involves understanding the standards investors use to assess environmentally friendly financial instruments, a desired equilibrium between risk and return, and the influence of green certifications on their investment choices. Examining the impact of regulatory changes and policy interventions on the secondary market for green CMBS may provide valuable insights into how government actions shape market dynamics and the adoption of green finance. An analysis of green CMBS with other forms of green bonds, such as corporate and municipal green bonds, may facilitate the identification of distinct attributes and performance indicators that are particular to green CMBS. This may facilitate comprehension of the broader framework of green financing in the fixed-income market. By concentrating on these specific areas, a deeper understanding of the variables that drive the success and difficulties of green CMBS can be attained. This, in turn, will aid in creating more efficient and sustainable financial instruments

within the commercial real estate industry.

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