GREEN BONDS: EFFECTIVENESS AND IMPLICATIONS FOR PUBLIC POLICY

Caroline Flammer*

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Abstract

This paper studies green bonds, a relatively new instrument in sustainable finance. I first describe the market for green bonds and characterize the "green bond boom" witnessed in recent years. Second, using firm-level data on green bonds issued by public companies, I examine companies' financial and environmental performance following the issuance of green bonds. I find that the stock market responds positively to the announcement of green bond issues. Moreover, I document a significant increase in environmental performance, suggesting that green bonds are effective in improving companies' environmental footprint. These findings are only significant for green bonds that are certified by independent third parties, suggesting that certification is an important governance mechanism in the green bond market. I conclude by discussing potential implications for public policy.

* Correspondence to: Caroline Flammer, Boston University, Questrom School of Business, 595 Commonwealth Avenue, Office 634A, Boston, MA 02215, U.S.A. E-mail: cflammer@bu.edu. This paper has been prepared for the NBER Conference on Environmental and Energy Policy and the Economy. I am grateful to Matthew Kotchen for helpful comments.

1. Introduction

Green bonds are a recent innovation in sustainable finance. Green bonds are debt instruments (i.e., "bonds"), whose proceeds are committed to the financing of low-carbon, climate-friendly projects (i.e., "green"). Issuers of green bonds include corporations, municipalities, government entities, and supranational institutions.

The first green bond was issued by the European Investment Bank (EIB) in 2007 to finance renewable energy and energy efficiency projects. Since then, green bonds have become increasingly popular. While the total issuance of green bonds was less than $1 billion in 2008, it soared to $143 billion in 2018. This trend—which practitioners often refer to as a "green bond boom" (Morgan Stanley, 2017)—is likely to continue in the years to come. Commentators often see green bonds as a promising tool to address climate change (e.g., Bloomberg, 2018).

Despite the growing popularity of green bonds, little is known about their effectiveness. Do green bonds benefit their issuers? And—importantly—do green bonds lead to improvements in environmental outcomes? The answers are not obvious, for two main reasons. First, issuers may engage in greenwashing by claiming that a bond is green (e.g., to cater to environmentally conscious investors) while it is not. In this vein, several examples of "green bonds that were not green" have been discussed in the media (e.g., Financial Times, 2015; Climate Bonds Initiative, 2017).

Second, there is no public regulation of green bonds, and hence the "greenness" of the bonds is not enforceable.[1] Instead, the governance of green bonds is decentralized and shaped by

[1] Exceptions include China and India. The Chinese green bond market is subject to public regulation pursuant to regulations enacted by the Chinese Central Bank (People's Bank of China) in 2015. Similarly, the Securities and Exchange Board of India regulated the Indian green bond market in 2016. Both sets of regulations are broadly consistent with global private governance standards.

private governance. Specifically, to circumvent the lack of enforceability, issuers rely on certification by independent third parties (e.g., those approved by the Climate Bond Standard Board). Yet, the criteria vary across certifiers, and the lack of unified standards may undermine the reliability of certification.[2]

The objective of this study is threefold. First, I characterize the market for green bonds over time, across countries, and across industries, highlighting the rapid development of this market (i.e., the "boom"). Second, using firm-level data on corporate green bonds issued by public companies, I examine the effectiveness of green bonds in terms of financial and environmental performance, and evaluate the role of third-party certification as a private governance regime. Third, I discuss potential implications for public policy.

I start by documenting the growing popularity of green bonds. In 2018 alone, the total issuance of green bonds was $141.3B worldwide. While green bonds only account for a small fraction of the overall bond market (the issuance of ordinary bonds was $32,341.7B in 2018), a striking feature of green bonds is their rapid growth in recent years. Indeed, while the issuance of green bonds was merely $0.8B in 2007, it grew by about 175 times by 2018 (in contrast, the issuance of ordinary bonds only grew by 1.6 times during the same period). There is considerable heterogeneity across countries and industries. The leading issuers of green bonds are based in China, France, and the U.S. In terms of industries, governments are the main issuers, followed by financials, utilities, industrials, and energy companies. I also document the emergence of a related asset class—the green "muni" bonds in the U.S. (i.e., green municipality bonds issued by U.S. states, counties, and cities). The issuance of green muni bonds has grown from $0.6B in 2010 to

[2] More broadly, in a recent article in the *Stanford Law Review*, Park (2018) notes that "[i]n comparison to public regulation, private governance is often faster to implement and more responsive to the needs of market participants but may suffer from a lack of legitimacy, accountability, and consistency and be susceptible to greenwashing" (p. 1).

$4.3B in 2018. New York, California, and Massachusetts are the main issuers.

I then examine the effectiveness of green bonds by focusing on the subset of green bonds issued by public companies. The benefit of studying public companies is that detailed firm-level data are available, which allows me to track the issuers' financial and environmental performance following the issuance of green bonds. I first conduct an event study that examines the stock market response to the announcement of green bond issues. I find a significant and positive stock market reaction. Specifically, in the two-day event window around the announcement, the cumulative abnormal return (CAR) is 0.67%. This suggests that green bonds are value-enhancing and hence beneficial to companies.

About two-thirds of green bonds are certified by independent third parties. When I split the green bonds depending on whether they are certified or not, I find that the stock market reaction is only significant for green bonds that are certified. This suggests that certification is an important governance tool in the green bond market.

I further examine how the issuance of green bonds affects long-term financial performance as measured by the return on assets (ROA) and the return on equity (ROE). I find that both ROA and ROE increase significantly in the long run (i.e., two and more years after the green bond issue), confirming that green bonds yield tangible benefits to companies. Finally, I examine how green bonds affect environmental performance. To proxy for environmental performance, I use the company's CO_2 emissions, as well as the environmental rating of Thomson Reuters' ASSET4.[3] I find that, following the issuance of green bonds, companies i) reduce their CO_2 emissions and ii) achieve a higher environmental rating. Again, these findings are only significant for green bonds that are certified by independent third parties.

[3] ASSET4 provides ratings of companies' environmental, social, and governance (ESG) performance based on 250+ key performance indicators. See Thomson Reuters (2019) for a description of this database.

One important concern with my analysis is that the issuance of green bonds is not random, and hence unobservables may drive a spurious correlation between the issuance of green bonds and, e.g., subsequent improvements in environmental performance. For example, it could be that some companies adopt environment-friendly business practices and, as a result, achieve higher environmental performance. At the same time, they may issue green bonds (in lieu of ordinary bonds) as they see an opportunity to cater to ESG (environmental, social, and governance) investors. To mitigate this and other potential (endogeneity) concerns, I use a matching approach. Specifically, I match each green bond issuer to another (non-green) bond issuer that is similar based on observables. While the matching mitigates the possibility that my results are driven by unobservables, I caveat that it does not fully rule out endogeneity concerns. Doing so would require an instrument for the issuance of green bonds, yet—given the voluntary nature of green bond issuance—it is difficult to come up with such an instrument.

Overall, the results of this study suggest that green bonds contribute to both financial and environmental performance, but only when they are certified. This suggests that the prevalent (certification-based) private governance regime is effective at ensuring that the green bond proceeds are invested into green projects. Naturally, this does not imply that it is *the* most effective governance regime. Indeed, various concerns have been raised by practitioners, including i) the lack of unified standards, ii) the lack of agreement as to what "green" truly means, and iii) the lack of "tiers" (e.g., a triple A rating for bonds with the largest environmental impact, etc.). In the last section of this paper, I discuss these considerations as well as potential implications for public policy.

This paper contributes to several strands of the literature. First, it adds to the literature that examines how climate finance can help address climate change and other grand challenges (e.g.,

Buntaine and Pizer, 2015; Kotchen and Costello, 2018; Kotchen and Negri, 2016; Markandya, Galarrage, Ruebbelke, 2017). Second, it contributes to the literature on impact investing that studies how financial instruments (such as SRI funds) can contribute to ESG objectives (e.g., Barber, Morse, and Yasuda, 2018; Flammer, 2015). Third, it contributes to the nascent literature that studies green bonds. The bulk of this literature focuses on the asset pricing properties of green bonds, and typically finds evidence that green bonds trade at a premium compared to plain-vanilla bonds (e.g., Baker, Bergstresser, Serafeim, and Wurgler, 2018; Zerbib, 2019).

The remainder of this paper is structured as follows. Section 2 describes the green bond market; Section 3 presents the analysis of green bonds issued by public companies; Section 4 discusses the policy implications and offers conclusions.

2. The green bond market

2.1 Data

The bond data are obtained from Bloomberg's fixed income database. Since the green bond market started in 2007, I extract all bonds issued between January 1, 2007 and December 31, 2018. I restrict the sample to the Bloomberg asset classes "corporate" and "governments".[4] This yields a total of 1,472,199 bonds. To distinguish between green and ordinary bonds, I use Bloomberg's *green bond indicator* that reports whether a bond is labelled as green. Out of the 1,472,199 bonds issued during the sample period, 1,855 are green bonds.

In addition to corporate and government bonds, Bloomberg also covers a separate asset class—the municipal bonds (so-called "munis" or "muni bonds") issued by U.S. states, counties,

[4] Bloomberg includes a series of other fixed income securities—such as certificates, loans (tranches), loans (deals), preferreds, mortgages (mortgage-backed securities (MBS) and structured), and mortgages (generics)—that can be marked as "green" as well. Since these are not bonds per se, I do not include them in the analysis.

and cities. Bloomberg does not maintain a *green bond indicator* variable for muni bonds. Instead, I rely on the variable *municipal bond purpose* to identify those that qualify as green muni bonds.[5] Since green muni bonds appear as of 2010, I extract the muni bond data from January 1, 2010 to December 31, 2018. This yields 1,224,773 muni bonds, out of which 4,794 are green.

In the following, I first describe the green bond market (excluding green munis). I then provide a separate characterization of the market for green muni bonds.

2.2 Green bonds over time

Table 1 provides statistic on the issuance of green bonds on a year-by-year basis. The first column reports the issuance of green bonds in billions of U.S. dollars (all foreign currencies are converted in U.S. dollars), while the second column reports the number of green bonds. The pattern is consistent with the "green bond boom" often noted in the financial press. Over a 10-year period, the issuance of green bonds soared from $0.8B in 2007 to $143.1B in 2018.

----- Insert Table 1 about here -----

The third and fourth columns of Table 1 provide the corresponding statistics for ordinary bonds.[6] The last two columns provide the share of green bonds (both in terms of dollar amount and number of bonds) relative to the overall bond market. As can be seen, green bonds represent only a small fraction of the bond market. In 2018, green bonds represent less than 0.5% of the overall market (the issuance of ordinary bonds was $32,342B, compared to $143.1B for green bonds). Importantly, the share of green bonds has been growing rapidly. While it was only 0.004%

[5] Specifically, I use the category "green bond." Bloomberg does not provide a more granular characterization of the use of proceeds.
[6] Throughout this paper, I refer to bonds as "ordinary" if they are not labelled as green in Bloomberg.

in 2007 (in dollar terms), it rose by about 100 times within the next 10 years, reaching an all-time high of 0.441% in 2018.[7]

2.2 Green bonds across countries

Table 2 provides summary statistics separately for each country.[8] As can be seen, the main issuers are China ($83.9B), France ($58.1B), and the U.S. ($56.9B). Following the top-three are mainly European countries, consistent with the view that Europe tends to be "greener" (e.g., Doh and Guay, 2006; Wall Street Journal, 2017).

----- Insert Table 2 about here -----

Figure 1 provides a visualization of the data from Table 2 (Panel A refers to the dollar amount, while Panel B refers to the number of green bonds). Darker-shaded areas represent higher issuance amounts and a higher number of green bonds, respectively. The general pattern in line with the above characterization: China, France, and the U.S. are the main issuers, followed by a large set of European countries.

----- Insert Figure 1 about here -----

Finally, Figure 2 plots the evolution of the green bond market across regions (Panel A refers again to the dollar amount, while Panel B refers to the number of green bonds). As can be seen, Europe dominates other regions. The large-scale issuance of green bonds started earlier (around 2013) and has grown continuously ever since. Also noteworthy is the sharp increase in

[7] The amount of green bond issuance (in dollars) has increased by about 175 times from 2010-2018, while the ratio of green bond issuance (compared to total bond issuance) has increased by about 100 times. This difference reflects the fact that the market for ordinary bonds has grown as well during this period.

[8] The countries used to characterize issuers are the countries of domicile (as opposed to the countries of incorporation) in Bloomberg.

green bond issuance in Asia in recent years: while green bonds were only marginal until 2015, Asia has been a major issuer as of 2016.[9]

----- Insert Figure 2 about here -----

2.3 Green bonds across sectors

Table 3 provides a characterization of green bond issuance across sectors. Sectors are defined according to BICS (Bloomberg Industry Classification Systems) codes. As is shown, governments (including supranational organizations) are the main issuers ($182.6B), followed by financials ($150.9B), utilities ($86.8B), industrials ($31.4B), and energy companies ($15.4B). The latter three are emission-intensive sectors.[10]

----- Insert Table 3 about here -----

Relatedly, Figure 3 plots the evolution of green bond issuance across sectors. The general pattern confirms the prevalence of green bonds among a set of key sectors, with the government sector being an earlier adopter of green bond financing.

----- Insert Figure 3 about here -----

2.4 Summary statistics

Table 4 provides summary statistics for several characteristics of green vs. ordinary bonds. As can be seen, green bonds tend to be larger (the average issuance amount is $264M compared to $242M for ordinary bonds) and have longer maturity (6.9 years compared to 3.4 years for ordinary bonds).

[9] The 2015 spike in North American issues in Panel B reflects the unusual case of the energy company SolarCity Corp that issued 130 green bonds in 2015 with a relatively small issuance amount ($5.5M on average). Accordingly, this spike in the number of green bonds (Panel B) does not appear in terms of the dollar amount of green bond issuance (Panel A).

[10] It is worth noting the significance of green bonds in the utilities sector. More than 2% of bonds issued by utilities are green (compared to a ratio of 0.138% across all sectors).

This indicates that green bonds are used to finance large-scale long-term projects, consistent with the nature of many environmental and energy projects.

----- Insert Table 4 about here -----

Also, note that the coupon is on average lower for green bonds (3.3% compared to 3.5% for ordinary bonds). This difference is harder to interpret due to the many factors that affects the returns of green bonds. In his analysis of green bond yields, Zerbib (2019) compares the yield to maturity (YTM) of green bonds versus ordinary bonds that have similar characteristics (maturity, credit risk, liquidity, etc.). He finds that green bonds have a lower YTM—i.e., investors require a lower return—although the difference is relatively small. Baker, Bergstresser, Serafeim, and Wurgler (2018) obtain similar results in their sample of green muni bonds.

Finally, another interesting feature of green bonds is that they tend to be safer. This can be inferred from the Bloomberg composite credit rating provided at the bottom of the table.[11] As is shown, 30.3% of green bonds have a triple-A rating (compared to 8.5% for ordinary bonds). Moreover, no green bond has ever been issued with a rating in the D range.

2.5 Green municipality bonds

In addition to the "government" and "corporate" asset classes, Bloomberg also compiles fixed income data for a separate asset class: U.S. municipality bonds (often referred to as "munis" or "muni bonds"). To complete the characterization of the green bond market, I provide below a description of the market for green munis.

[11] The Bloomberg composite credit rating is a composite of ratings from four rating agencies (DBRS, Fitch, Moody's, and Standard & Poor's). Note that the large majority of bonds are not rated and hence the rating statistics in Table 4 refer to the subset of bonds with a credit rating. Specifically, 26.9% of the green bonds (499) and 4.2% of the ordinary bonds (61,583) have a rating. Ratings are less common for smaller bonds and non-U.S. bonds.

2.5.1 Green municipality bonds over time

Table 5 reports statistics on the issuance of green muni bonds over time. As can be seen, the "green bond boom" is also observed among muni bonds. The dollar amount of green munis has increased continuously from 2011 to 2017, reaching an all-time high of $11.2B in 2017. In that year, green muni bonds represent 2.6% of the overall muni bond market (in dollar terms).

----- Insert Table 5 about here -----

2.5.2 Green municipality bonds across U.S. states

Table 6 provides a breakdown by U.S. states. As is shown, the main issuers are New York ($8B), California ($7.8B), and Massachusetts ($3.1B). Together, these three states account for about 63% of all green muni bonds (in dollar terms).

----- Insert Table 6 about here -----

Figure 4 provides a visualization of the data from Table 6. (As above, Panel A refers to the dollar amount, while Panel B refers to the number of green munis.) Darker-shaded areas represent higher issuance amounts and a higher number of green munis, respectively. The general pattern is consistent with the above characterization: New York, California, and Massachusetts are the main issuers. While a large set of other states issue green munis as well, they do so to a lesser extent. Note that the pattern in Panel B is very similar to that in Panel A. The main exception is New Jersey, which has issued a relatively large number of green muni bonds (Panel B) for a relatively low dollar amount (Panel A).

----- Insert Figure 4 about here -----

2.5.3 Summary statistics

Finally, Table 7 provides summary statistics on the green versus ordinary muni bonds. The statistics are in line with those provided in Table 4. Compared to ordinary muni bonds, green munis are on average larger ($6.3M compared to $2.4M), have a longer maturity (11.8 years compared to 9.5 years), and have a higher credit rating (40.4% of green muni bonds have a triple-A rating, compared to only 16.6% of the ordinary muni bonds).[12]

----- Insert Table 7 about here -----

3. Corporate green bonds' implications for financial and environmental performance

In this section, I focus on green bonds issued by public companies to study how the issuance of green bonds affect financial and environmental performance. This section is an abbreviated version of Flammer (2018) who studies how corporate green bonds affect firm-level outcomes.

3.1 Stock market reaction

3.1.1 Methodology

I start by studying how the stock market responds to the announcement of green bond issues. To conduct this analysis, I use a sample of 217 corporate green bonds issued by public companies.[13] An appealing feature of Bloomberg's fixed income database is that it records the *announcement date* (in addition to the *issue date*). From the event study perspective, the announcement date is the relevant one, since it is the date on which the information is conveyed to the market.

To perform the event study, I use as event date (i.e., day 0) the announcement date. I then

[12] Note that the Bloomberg composite rating is not available for muni bonds. Instead, Table 7 reports Standard & Poor's credit ratings.
[13] This sample is described in detail in Flammer (2018).

compute abnormal returns several days before and after the event date. Specifically, for each company *i*, I compute abnormal returns (AR) using the market model. (The results are similar if alternative asset pricing models are used such as the three-factor model of Fama and French, 1993, or the four-factor model of Carhart, 1997.) The coefficients a_i and b_i of the market model are estimated by Ordinary Least Square using 200 trading days starting 20 trading days prior to the event date. Formally, I estimate the following regression:

$$r_{it} = a_i + b_i \times r_{mt} + e_{it} ,$$

where r_{it} is the return on the stock of company *i* on day *t*; r_{mt} is the daily market return; and e_{it} is the residual. Daily stock returns r_{it} are obtained from CRSP (for U.S. companies) and the daily stock file of Compustat Global (for non-U.S. companies). Daily market returns r_{mt} are country-specific. For the U.S., I use the S&P 500. For all other countries I use the country's leading stock market index (e.g., the FTSE 100 Index for the U.K.).[14]

The estimated return on the stock of company *i* on day *t* is then given by:

$$\hat{r}_{it} = \hat{a}_i + \hat{b}_i \times r_{mt} .$$

I calculate the abnormal return of company *i* on day *t* as follows:

$$AR_{it} = r_{it} - \hat{r}_{it} .$$

Finally, I compute the cumulative abnormal returns (CAR) by summing up abnormal returns in event time—that is, CAR from t_1 to t_2 is obtained as:

$$CAR_i(t_1, t_2) = \sum_{\tau=t_1}^{t_2} AR_{i\tau} .$$

3.1.2 Results

Figure 6 plots the average cumulative abnormal returns (CARs) ten days before and after the

[14] The results are similar if instead of using country-specific stock market indices, I compute r_{mt} using the MSCI All-Country World Equity Index.

announcement of green bond issues. As can be seen, CARs are essentially zero prior to the announcement, there is a sharp increase around the event date, and the CARs remain high thereafter. The average CAR in the two-day event window (-1, 0) is 0.67%, which is significant at conventional statistical levels (t = 2.42). This indicates that green bonds are perceived as value-enhancing by the stock market.

----- Insert Figure 6 about here -----

Note that the results are unlikely to capture a "bond effect" as opposed to a "green bond effect." Indeed, a common finding in the corporate finance literature is that the stock market does not respond significantly to the announcement of bond issues, while it responds negatively to the announcement of equity issues—see, e.g., Eckbo, Masulis, and Norli (2007) and Masulis and Korwar (1986).

3.1.3 Certification

The previous analysis considered all green bonds of public firms, regardless of whether they are certified or not by independent third parties.

To distinguish between certified and non-certified green bonds, I use the certification information provided in the Climate Bonds Initiative (CBI) database. This database compiles information on the certification of each green bond, along with the identity of the third-party certifier. Common certifiers include Sustainalytics, Vigeo Eiris, Ernst & Young, and CICERO (Center for International Climate Research). Green bonds can be issued under a variety of voluntary standards. Two leading standards that verify the integrity of the green bond label are the Green Bond Principles (GBP) and the Climate Bond Standards (CBS). In a nutshell, the certification process is split into two phases. In the pre-issuance phase, the certifier verifies that a) the projects to be financed by the bond proceeds are eligible under the specific certification

standards, and b) the issuer has established internal processes and controls to keep track of how the bond proceeds are used (which includes the submission of annual reports). In the post-issuance phase, the certifier verifies that the proceeds have been allocated to green projects in accordance with the standards.

Out of the 217 green bonds used in the event study, 147 are certified (68%). In Figure 7, I repeat the event study separately for certified and non-certified green bonds. While the average CAR in the two-day event window (-1, 0) is positive in both groups, it is only significant for certified green bonds. Specifically, the two-day CAR is 0.8% for certified green bonds ($t = 2.27$), while it is 0.4% for non-certified green bonds ($t = 0.94$).[15] Overall, these findings suggest that certification is an important determinant of the effectiveness of green bonds.

----- Insert Figure 7 about here -----

3.2 Analysis of long-term financial and environmental performance

3.2.1 Methodology

The 217 green bonds used in the event study correspond to 106 unique firm-year observations (since companies can issue multiple green bonds in the same year). In the following, I estimate how the issuance of green bonds affects firm-level outcomes using a difference-in-differences specification around these 106 "treatments."

To obtain a control group, I match each treated firm to a control firm in the year prior to the treatment (i.e., the green bond issue). I draw control firms from the pool of public firms that i) are bond issuers (but not green bond issuers), ii) operate in the same 2-digit SIC industry as the treated firms, and iii) are located in the same country as the treated firm. Within this pool of

[15] Note that the difference is not significant (p-value = 0.389). Due to the limited sample size, there is little power to detect cross-sectional differences in statistical terms.

candidates, I select the nearest neighbor based on a large set of observables. The matching characteristics are size, Tobin's Q, ROA, leverage, and the company's environmental, social, and governance ratings. For each characteristic, I consider the variable in the year preceding the green bond issuance (i.e., at $t - 1$), as well as the pre-trend (i.e., the change from $t - 2$ to $t - 1$). Accordingly, fourteen matching variables are used. The nearest neighbor is the firm with the lowest Mahalanobis distance to the treated firm across these fourteen matching characteristics.[16]

Using this matched control sample, I estimate the following difference-in-differences specification:

$$y_{it} = a_i + a_{ct} + a_{st} + \sum_{\tau=-2}^{2+} \beta_\tau \times Green\ bond(\tau)_{it} + e_{it}\ , \qquad (1)$$

where i indexes companies, t indexes years, c indexes countries, and s indexes 2-digit SIC industries; y is the outcome variable of interest (e.g., ROA, CO_2 emissions); α_i are firm fixed effects; α_{ct} are country by year fixed effects; α_{st} are industry by year fixed effects; *Green bond(-2)* is a dummy variable equal to one for green bond issuers two years prior to the green bond issue; *Green bond(-1)* is defined analogously; *Green bond(0)* is a dummy variable equal to one for green bond issuers in the year that ends before the green bond issue; *Green bond(1)* is a dummy variable equal to one for green bond issuers in the year that ends after the green bond issue; *Green bond(2+)* is a dummy variable equal to one for green bond issuers two or more years after the green bond issue.[17] Standard errors are clustered at the 2-digit SIC industry level. For each dependent variable, I plot the full set of coefficients $\{\beta_\tau\}_{\tau=-2}^{2+}$ along with a 90% confidence interval.

[16] See Flammer (2018) for details, along with a characterization of the treated and matched control firms.

[17] The regressions are estimated using all firm-year observations of the treated and matched control firms from 2010-2017. Note that a broader characterization of the dynamics (i.e., splitting the $\tau = 2+$ period into $\tau = 2$, 3, 4, etc.) is not feasible since most green bonds are issued in the later years of the sample, and hence most issuers have no more than two post-issue years available.

3.2.2 Financial performance

To measure financial performance, I use the return on assets (ROA) and the return on equity (ROE). Both measures are obtained from Standard & Poor's Compustat.[18] ROA is defined as operating income before depreciation scaled by the book value of total assets; ROE is defined similarly but using the book value of equity as scaling variable. Both ratios are winsorized at the 1st and 99th percentiles of their empirical distribution.

The ROA coefficients are plotted in Panel A of Figure 8. As can be seen, i) there is no pre-trend; ii) the effect is positive but insignificant in the short run (i.e., one year after the green bond issue), and iii) the effect is positive and significant in the long run (i.e., two and more years after the green bond issue). In terms of magnitudes, ROA increases by 0.006 in the long run. Since the mean of ROA is 0.056, this implies that performance increases by about 11%. This indicates that green bonds yield tangible (long-term) financial benefits to companies. Panel B provides similar results with respect to ROE.

----- Insert Figure 8 about here -----

3.2.3 Environmental performance

In Figure 9, I use two measures of environmental performance. The first measure is the environmental rating from Thomson Reuters' ASSET4. The second measure is the ratio of CO_2 emissions (in tons) from ASSET4 divided by the book value of total assets in U.S. dollars. I winsorize this ratio at the 1st and 99th percentiles of its empirical distribution.

Panel A plots the coefficients pertaining to the ASSET4 environmental rating. The rating increases significantly in the long run, while there is no evidence for pre-trends. Similarly, Panel

[18] Compustat North America is used for U.S. and Canadian companies, while Compustat Global is used for all other companies.

B documents a significant decrease in CO_2 emissions following the issuance of green bonds. In economic terms, the environment rating goes up by 7.3 percentage points in the long run, which corresponds to an increase by 8.8% (given a mean of 83.4). Similarly, emissions are reduced by 21.6 tons of CO_2 per $1M of assets, a reduction by 27.7% (given a mean of 77.9). Overall, these findings indicate that green bonds are effective—they do yield significant improvements in the issuers' environmental performance.

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3.2.4 Certification

In auxiliary regressions, I repeat the previous analysis interacting *Green Bond(τ)* with dummy variables that indicate whether the green bond is certified or not by an independent third party. I find that the long-run effects documented above are large and significant for certified green bonds, while they are small and insignificant for non-certified green bonds. This echoes the event study findings, and further highlights the importance of certification in the green bond market.

4. Discussion and conclusion

Climate change likely represents the greatest challenge faced by our and future generations. The impact of climate change is felt everywhere, and poses an existential threat to ecosystems and communities around the world. The signing of the Paris Agreement in 2015 marked an important milestone in the fight against climate change.[19] Yet, as the recent U.S. example illustrates—

[19] The Paris meeting (often referred to as COP21) was the 21st annual meeting of the Conference of the Parties (COP) pursuant to the United Nations Framework Convention on Climate Change (UNFCCC). The Paris Agreement commits to the following (UNFCCC, 2015): a) holding the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change; b) increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production; and c) making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development.

President Donald J. Trump announced on June 1, 2017 the U.S.' intention to withdraw from the Paris Agreement—international treaties face challenges on their own. Importantly, nations cannot act alone. Addressing climate change requires an enormous amount of funding—the OECD estimates that $93 trillion in infrastructure investment will be needed in the next fifteen years to achieve a low-carbon future (OECD, 2017). In comparison, the world's GDP was about $80 trillion in 2017. This tremendous financing need calls for private solutions in addition to nations' efforts to address climate change.

This paper examines one promising instrument: green bonds—i.e., bonds whose proceeds are committed to the financing of low-carbon, climate-friendly projects. Since their inception in 2007, green bonds have become increasingly popular among private investors, and practitioners often refer to this evolution as a "green bond boom." This paper describes the evolution of the green bond market, highlighting the heterogeneity across countries and industry sectors. Furthermore, it examines the effectiveness of corporate green bonds in terms of both financial and environmental performance. Using a sample of green bonds issued by public companies, I find that the stock market responds positively to the announcement of green bond issues, suggesting that green bonds are value-enhancing. I also find that green bond issuers—compared to a matched sample of (non-green) bond issuers—experience long-term improvements in financial performance (measured by an increase in ROA and ROE) and environmental performance (measured by a decrease in CO_2 emissions and an increase in environmental ratings). Moreover, these findings are only significant for green bonds that are certified by independent third parties, suggesting that certification is a key governance mechanism for green bonds. One caveat of this study is that I do not have an instrument for the issuance of green bonds. That being said, it is difficult to think about unobservables that would i) not be filtered out by the tight matching used

in the analysis *and* ii) explain the full set of results presented in this paper (including the differential outcomes for certified versus non-certified green bonds).

My results highlight the importance of certification in the green bond market. The fact that my findings are only significant for certified green bonds suggests that certification is effective as a private governance regime. Nevertheless, it need not be *the* most effective governance regime. While the green bond market is still in its early years, several challenges have been raised by practitioners. First, the definition of "green" is ambiguous, which complicates the certification. This is exemplified by the recent case of the Spanish energy company Repsol. In 2017, the Climate Bond Initiative (CBI) refused to certify Repsol's green bond. Interestingly, CBI (2017) acknowledged that the bond did aim at reducing emissions ("The goal of the bond is to reduce GHG emissions from refineries and, yes, the bond will avoid emissions: an estimated 1.2M tonnes of CO_2 annually by 2020"), yet CBI's concern was that Repsol's environmental strategy did not go far enough to qualify as green ("[…] any investment in making refineries more efficient, as this bond is aiming to, will likely extend plant operating lifetimes and therefore indirectly increase emissions over time").

Second, there are a number of international and national taxonomies addressing green bond project definitions, including the Green Bond Principles (GBP) and the Climate Bonds Standard (CBS). However, the lack of universal rules and standardization is a common concern among green bond investors. As the OECD notes, "[c]onvergence towards commonly accepted definitions will be essential to maximise the effectiveness, efficiency and integrity of the market" (OECD, 2017, p. 13).

Third, the current certification of green bonds is binary in nature (i.e., certified vs. not certified), whereas green bonds are likely to differ in terms of their environmental impact. A

scheme based on tiered ratings (e.g., a triple A rating for the strongest environmental impact)—similar to the model used by credit rating agencies—could improve the informativeness of the certification and help expand the depth of the green bond market.

Arguably, these challenges are likely to be exacerbated as the market further expands in the years to come. In this context, voices have been raised advocating for a hybrid governance regime that combines the benefits of both public and private governance (Park, 2018). Admittedly, the (current) lack of public governance is likely suboptimal. While private governance is both flexible and pragmatic, it may lack transparency, legitimacy, and accountability. Those could be guaranteed by public governance, which can provide a unified basis that enhances the effectiveness of private governance. More broadly, this discussion illustrates the need for more research that studies the optimal design of the governance of the green bond market.[20]

Several of the challenges that arise in the context of green bonds extend to other instruments that aim at addressing climate change. In particular, carbon offsets are subject to similar concerns. Carbon offsetting is the process of compensating for CO_2 emissions through schemes that are designed to make offsetting reductions in emissions from other parts of the

[20] Relatedly, the lack of public governance pertaining to the disclosure of non-financial information bears the risk that it leads to i) a lack of best practices, ii) a lack of standardization of disclosure, and iii) difficulties for financial analysts and investors to interpret non-financial performance metrics. Also—and perhaps more importantly—the lack of public governance may lead to a lack of disclosure of non-financial information altogether. This issue arises, for example, in the context of companies' exposure to climate change risks. In many countries (including the U.S.), the disclosure of such information is not mandated by law. As a result, many companies do not disclose their exposure to climate change risks, despite the potential (long-term) financial benefits of mitigating climate-related costs and risks (Cheng, Ioannou, and Serafeim, 20014; Dhaliwal, Li, Tsang, and Yang, 2011; Sharfman and Fernando, 2008). To compensate for the absence of government regulation, shareholders increasingly step up and pressure their portfolio companies to disclose and address climate change risks. Indeed, companies are expected to face a record high of climate-related shareholder proposals at the upcoming shareholder meetings (Wall Street Journal, 2019). In line with this trend, a recent survey of institutional investors paints a striking picture: the majority of surveyed investors believe that climate risk reporting is as important as financial reporting, and one-third believe that climate risk reporting is even more important (Krueger, Sautner, and Starks, 2018). In a recent study, Fabrizio, Flammer, Toffel, and Viswanathan (2019) highlight that investors are indeed effective in eliciting greater corporate transparency with respect to firms' climate risk exposure, thereby contributing to their portfolio companies' governance. A direct implication of their findings is that, in absence of mandatory disclosure requirements, this greater ability also implies a greater responsibility of investors to be active owners and engage with the management to elicit the disclosure of climate risks.

economy. For example, several airlines (such as British Airways, Delta, and Emirates) offer carbon offset programs. Essentially, passengers have the option to "offset" the emissions generated by their flight by contributing to a wide variety of offsetting actions—e.g., the replanting of trees in at-risk areas, the development of wind farms, etc. Such carbon offsets have faced skepticism on several grounds (e.g., Anderson, 2012; Forbes 2019). One key issue is the lack of transparency regarding the environmental impact of the offsetting action.[21] Third-party certification is a potential remedy, and certification standards for carbon offsets have started to emerge (such as the Climate Action Reserve and Green-e Climate). Importantly, the insights gained from the green bond market might help shape the governance structure of this (and other) instruments in the fight against climate change.

Relatedly, some of the lessons learned from the carbon offsets might help inform the policy discussion pertaining to green bonds. In particular, a key consideration in the context of carbon offsets is the notion of additionality. For carbon offsets to be effective, the activity that is financed by the carbon offset (e.g., the planting of trees) needs to be "additional"—if it were to happen anyway (regardless of the carbon offset), it is not additional.[22] To help ensure the additionality of carbon offsets, the United Nations' Clean Development Mechanism (CDM) has designed a series of "additionality tests" (see UNFCCC, 2004). For example, one of these tests is the *legal and regulatory additionality test*—if the project is implemented to fulfill formal policies, regulations, or industry standards, it does not qualify as additional. If the project goes beyond compliance

[21] For example, referring to airlines' carbon offset programs, Forbes (2019) notes that "[b]alancing the carbon emitted by your airline seat through the planting of several trees in South America does not involve solely the solitary act of placing the tree in the soil. In order to plant the trees, there are several steps. Firstly, they must be bought from a supplier, transported to a warehouse before being driven out to a site that needs to be cleared prior to them being planted—all these actions produce their own share of carbon emissions, which are not always taken into account. If your offset produces more emissions than if you had done nothing, then it is really not an offset."

[22] For example, if airline passengers buy carbon offsets from entities that would have reduced their emissions anyway (i.e., even absent the carbon offset), such offsets are not additional. In such cases, airline passengers are merely subsidizing an activity that would have happened regardless, as opposed to neutralizing their emissions.

("regulatory surplus"), than it may qualify.[23] Naturally, a similar challenge arises in the context of green bonds. For green bonds to make a difference, the projects that are financed by the bond proceeds need to be additional. If companies were to undertake these projects regardless, little is gained form the "green financing," especially if companies simply refinance their existing (ordinary) bonds into green bonds, with no effective change in companies' actions. Criteria such as the CDM additionality tests might be helpful in shaping this dimension of the green bond market.

[23] Other tests include the *investment test*, *barriers test*, and *common practice test*. See UNFCCC (2004) for details.

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Table 1
Green bonds over time

This table reports the amount (in $B) and number (#) of green bonds issued on an annual basis. The table also reports the corresponding statistics for ordinary bonds (i.e., bonds that are not labelled as "green"). The dataset includes all bonds (excluding muni bonds) in Bloomberg issued between January 1, 2007 and December 31, 2018.

Year	$B Green bonds	# Green bonds	$B Ordinary bonds	# Ordinary bonds	Share of green bonds ($)	Share of green bonds (#)
2018	143.1	519	32,341.7	191,362	0.441%	0.270%
2017	146.6	441	38,893.2	172,645	0.376%	0.255%
2016	95.4	263	37,268.9	146,912	0.255%	0.179%
2015	47.7	328	31,573.7	132,506	0.151%	0.247%
2014	34.5	138	29,300.9	123,106	0.118%	0.112%
2013	13.2	39	27,196.3	114,474	0.049%	0.034%
2012	2.1	21	30,066.0	100,283	0.007%	0.021%
2011	1.2	30	28,125.8	86,096	0.004%	0.035%
2010	4.4	55	28,268.9	83,112	0.015%	0.066%
2009	0.9	13	28,868.6	86,364	0.003%	0.015%
2008	0.4	7	23,686.4	115,269	0.002%	0.006%
2007	0.8	1	20,571.3	118,215	0.004%	0.001%
Total	490.4	1,855	356,161.8	1,470,344	0.138%	0.126%

Table 2
Green bonds across countries

This table reports the amount (in $B) and number (#) of green bonds issued by country. The table also reports the corresponding statistics for ordinary bonds (i.e., bonds that are not labelled as "green"). The dataset includes all bonds (excluding muni bonds) in Bloomberg issued between January 1, 2007 and December 31, 2018.

Country	$B Green bonds	# Green bonds	$B Ordinary bonds	# Ordinary bonds	Share of green bonds ($)	Share of green bonds (#)
China	83.9	199	44,358.9	144,346	0.189%	0.138%
France	58.1	176	12,844.8	20,743	0.450%	0.841%
United States	56.9	464	76,308.6	240,434	0.074%	0.193%
Netherlands	40.5	60	5,540.0	37,723	0.726%	0.159%
Luxembourg	39.8	62	3,446.4	16,775	1.141%	0.368%
Germany	39.6	84	17,564.0	299,037	0.225%	0.028%
Sweden	19.4	194	2,622.6	13,711	0.734%	1.395%
Britain	14.1	87	14,562.2	94,228	0.097%	0.092%
Mexico	13.3	13	2,662.4	3,030	0.499%	0.427%
Canada	10.9	25	9,723.9	34,484	0.112%	0.072%
Spain	9.0	19	5,302.8	4,401	0.170%	0.430%
Norway	8.4	43	1,666.1	18,767	0.504%	0.229%
Japan	7.8	46	78,226.9	26,393	0.010%	0.174%
Belgium	7.6	4	1,842.8	2,014	0.411%	0.198%
Finland	7.5	27	864.2	4,663	0.856%	0.576%
Hong Kong	7.4	31	4,458.5	24,319	0.166%	0.127%
Australia	6.8	17	3,420.2	15,942	0.198%	0.107%
Philippines	6.3	27	567.7	2,341	1.093%	1.140%
Brazil	5.4	8	3,542.7	3,892	0.153%	0.205%
South Korea	5.3	15	6,664.1	64,948	0.079%	0.023%
India	5.2	19	5,158.5	33,595	0.101%	0.057%
Italy	4.6	11	10,060.7	54,532	0.045%	0.020%

Denmark	3.5	6	768.9	4,785	0.455%	0.125%
Ireland	3.5	1	1,732.3	5,368	0.199%	0.019%
Ivory Coast	2.6	22	91.7	558	2.783%	3.793%
Indonesia	2.5	4	1,695.2	3,884	0.149%	0.103%
Switzerland	2.1	9	1,532.9	51,789	0.134%	0.017%
Poland	2.0	2	630.1	2,617	0.317%	0.076%
British Virgin	1.8	5	311.7	1,567	0.572%	0.318%
Austria	1.7	4	1,361.9	14,250	0.124%	0.028%
United Arab Emirates	1.6	3	373.6	14,516	0.423%	0.021%
Taiwan	1.6	21	605.3	3,259	0.257%	0.640%
Cayman Islands	1.2	2	792.1	8,260	0.154%	0.024%
Singapore	1.2	10	3,336.6	7,059	0.036%	0.141%
Chile	1.0	2	827.7	3,745	0.121%	0.053%
Costa Rica	1.0	2	123.5	830	0.803%	0.240%
Malaysia	1.0	98	1,477.5	16,624	0.066%	0.586%
Mauritius	1.0	2	49.3	1,985	1.889%	0.101%
Argentina	0.9	4	1,713.1	2,960	0.053%	0.135%
Lithuania	0.7	3	40.6	508	1.741%	0.587%
New Zealand	0.4	4	353.3	1,866	0.124%	0.214%
Peru	0.4	2	290.1	1,598	0.140%	0.125%
South Africa	0.3	5	937.0	6,124	0.033%	0.082%
Latvia	0.2	3	26.1	368	0.627%	0.809%
Slovenia	0.1	1	94.9	307	0.090%	0.325%
Venezuela	0.1	2	226.7	879	0.036%	0.227%
Honduras	0.1	1	161.1	604	0.048%	0.165%
Greece	0.1	1	1,382.3	718	0.005%	0.139%
Colombia	0.1	1	359.6	1,060	0.018%	0.094%
Estonia	0.1	1	2.9	51	1.868%	1.923%
Fiji	0.0	2	2.2	482	2.126%	0.413%
Nigeria	0.0	1	579.4	1,348	0.005%	0.074%
Other	0.0	0	22,873.2	150,057	0.000%	0.000%
Total	490.4	1,855	356,161.8	1,470,344	0.138%	0.126%

Table 3
Green bonds across industries

This table reports the amount (in $B) and number (#) of green bonds issued by industry. Industries are defined according to BICS (Bloomberg Industry Classification Systems) codes. The table also reports the corresponding statistics for ordinary bonds (i.e., bonds that are not labelled as "green"). The dataset includes all bonds (excluding muni bonds) in Bloomberg issued between January 1, 2007 and December 31, 2018.

Industry	$B Green bonds	# Green bonds	$B Ordinary bonds	# Ordinary bonds	Share of green bonds ($)	Share of green bonds (#)
Government	182.6	638	258,220.6	351,741	0.071%	0.181%
Financials	150.9	570	63,873.7	978,456	0.236%	0.058%
Utilities	86.8	259	4,104.5	17,618	2.071%	1.449%
Industrials	31.4	93	5,641.2	32,247	0.553%	0.288%
Energy	15.4	230	4,738.4	11,894	0.325%	1.897%
Consumer Discretionary	12.3	31	5,116.9	31,533	0.239%	0.098%
Materials	5.2	19	3,575.0	16,011	0.144%	0.119%
Technology	3.2	5	1,885.6	7,454	0.169%	0.067%
Consumer Staples	1.9	6	2,658.3	9,372	0.071%	0.064%
Health Care	0.7	3	2,506.6	6,350	0.028%	0.047%
Communications	0.1	1	3,839.4	7,528	0.002%	0.013%
Other	0.0	0	1.7	140	0.000%	0.000%
Total	490.4	1,855	356,161.8	1,470,344	0.138%	0.126%

Table 4
Summary statistics

This table reports summary statistics for all green bonds and ordinary bonds (i.e., bonds that are not labelled as "green"). *Issuance amount* is the amount issued (in $M). *Maturity* is the maturity of the bond (in years). *Coupon* is the coupon rate (in %). *Coupon type* refers to the type of coupon payment. *Bloomberg rating* refers to the Bloomberg composite credit rating. All figures are sample means (and percentages, respectively). The dataset includes all bonds (excluding muni bonds) in Bloomberg issued between January 1, 2007 and December 31, 2018.

	Green bonds	Ordinary bonds
# bonds	1,855	1,470,344
Issuance amount ($M)	264.38	242.23
Maturity (years)	6.92	3.35
Coupon (%)	3.25	3.52
Coupon type		
Fixed	75.96%	80.77%
Floating	13.05%	8.89%
Other	11.00%	10.34%
Bloomberg rating		
AAA	30.26%	8.52%
AA+	3.41%	21.64%
AA	4.41%	3.26%
AA-	7.21%	7.31%
A+	6.81%	8.01%
A	10.22%	9.06%
A-	7.01%	8.85%
BBB+	9.22%	7.99%
BBB	4.41%	7.04%
BBB-	6.81%	5.79%
BB+	1.00%	2.16%
BB	1.80%	1.56%
BB-	2.00%	2.20%
B+	1.60%	1.67%
B	1.60%	1.93%
B-	1.20%	1.37%
C range	1.00%	1.53%
D range	0.00%	0.11%

Table 5
Green municipal bonds over time

This table reports the amount (in $B) and number (#) of green municipal bonds issued on an annual basis. The table also reports the corresponding statistics for ordinary municipal bonds (i.e., municipal bonds that are not labelled as "green"). The dataset includes all municipal bonds ("munis") in Bloomberg issued between January 1, 2010 and December 31, 2018.

Year	$B Green muni bonds	# Green muni bonds	$B Ordinary muni bonds	# Ordinary muni bonds	Share of green muni bonds ($)	Share of green muni bonds (#)
2018	4.3	925	398.4	107,114	1.063%	0.856%
2017	11.2	1,334	419.2	133,388	2.597%	0.990%
2016	7.4	952	405.6	155,299	1.794%	0.609%
2015	4.1	735	345.1	148,590	1.188%	0.492%
2014	1.9	260	276.6	122,578	0.699%	0.212%
2013	0.3	115	260.2	126,480	0.115%	0.091%
2012	0.2	146	288.3	155,727	0.073%	0.094%
2011	0.1	140	206.8	120,275	0.066%	0.116%
2010	0.6	187	308.3	150,528	0.189%	0.124%
Total	30.2	4,794	2,908.4	1,219,979	1.027%	0.391%

Table 6
Green municipal bonds by state

This table reports the amount (in $B) and number (#) of green municipal bonds issued by U.S. state. The table also reports the corresponding statistics for ordinary municipal bonds (i.e., municipal bonds that are not labelled as "green"). The dataset includes all municipal bonds ("munis") in Bloomberg issued between January 1, 2010 and December 31, 2018.

State	$B Green muni bonds	# Green muni bonds	$B Ordinary muni bonds	# Ordinary muni bonds	Share of green muni bonds ($)	Share of green muni bonds (#)
New York	8.0	959	334.0	85,833	2.353%	1.105%
California	7.8	923	435.5	105,375	1.753%	0.868%
Massachusetts	3.1	412	78.2	32,657	3.871%	1.246%
Washington	2.1	182	79.2	22,961	2.527%	0.786%
Indiana	1.2	236	33.6	32,466	3.314%	0.722%
Connecticut	0.8	95	43.6	19,059	1.809%	0.496%
Iowa	0.7	68	17.8	29,274	4.029%	0.232%
District of Columbia	0.7	27	20.9	1,857	3.149%	1.433%
Colorado	0.7	110	57.2	16,705	1.171%	0.654%
Ohio	0.6	128	83.0	39,542	0.730%	0.323%
Arizona	0.5	112	44.7	11,938	1.166%	0.929%
Illinois	0.5	115	125.0	45,843	0.404%	0.250%
Texas	0.4	33	313.0	166,776	0.114%	0.020%
Maryland	0.3	32	52.2	12,016	0.609%	0.266%
Virginia	0.3	61	58.2	16,489	0.514%	0.369%
New Jersey	0.3	277	92.6	40,825	0.322%	0.674%
Hawaii	0.3	63	20.8	2,566	1.403%	2.396%
Nevada	0.2	5	22.4	4,605	0.969%	0.108%
Minnesota	0.2	158	47.7	49,649	0.442%	0.317%
Florida	0.2	81	119.9	24,746	0.171%	0.326%
Michigan	0.2	68	59.3	32,022	0.295%	0.212%
Rhode Island	0.2	142	7.9	4,445	2.176%	3.096%

Vermont	0.2	83	3.8	2,257	3.910%	3.547%
Tennessee	0.1	24	33.9	16,095	0.292%	0.149%
North Dakota	0.1	19	5.8	8,074	1.642%	0.235%
South Carolina	0.1	27	35.3	10,933	0.267%	0.246%
North Carolina	0.1	29	42.3	12,974	0.164%	0.223%
Pennsylvania	0.1	86	118.4	60,387	0.046%	0.142%
Wisconsin	0.1	30	53.0	48,473	0.098%	0.062%
Kentucky	0.1	21	30.5	23,547	0.166%	0.089%
Maine	0.0	1	7.6	6,175	0.592%	0.016%
Louisiana	0.0	4	31.8	10,926	0.140%	0.037%
Kansas	0.0	38	22.8	24,602	0.137%	0.154%
Alabama	0.0	9	32.4	19,338	0.076%	0.047%
Utah	0.0	20	21.4	7,870	0.093%	0.253%
Oregon	0.0	40	32.1	12,886	0.053%	0.309%
Nebraska	0.0	11	19.3	35,985	0.051%	0.031%
Arkansas	0.0	23	13.0	21,717	0.065%	0.106%
Montana	0.0	2	3.7	4,212	0.224%	0.047%
Missouri	0.0	35	42.5	28,968	0.018%	0.121%
Georgia	0.0	1	55.4	13,256	0.013%	0.008%
South Dakota	0.0	3	5.7	5,815	0.115%	0.052%
Delaware	0.0	1	6.6	1,370	0.041%	0.073%
Alaska	0.0	0	7.2	2,711	0.000%	0.000%
Idaho	0.0	0	6.6	2,944	0.000%	0.000%
Mississippi	0.0	0	12.9	9,141	0.000%	0.000%
New Hampshire	0.0	0	6.3	3,638	0.000%	0.000%
New Mexico	0.0	0	12.0	7,291	0.000%	0.000%
Oklahoma	0.0	0	19.7	14,771	0.000%	0.000%
West Virginia	0.0	0	7.1	2,945	0.000%	0.000%
Wyoming	0.0	0	1.5	1,132	0.000%	0.000%
Territories	0.0	0	71.0	1,897	0.000%	0.000%
Total	30.2	4,794	2,908.4	1,219,979	1.027%	0.391%

Table 7
Green municipal bonds

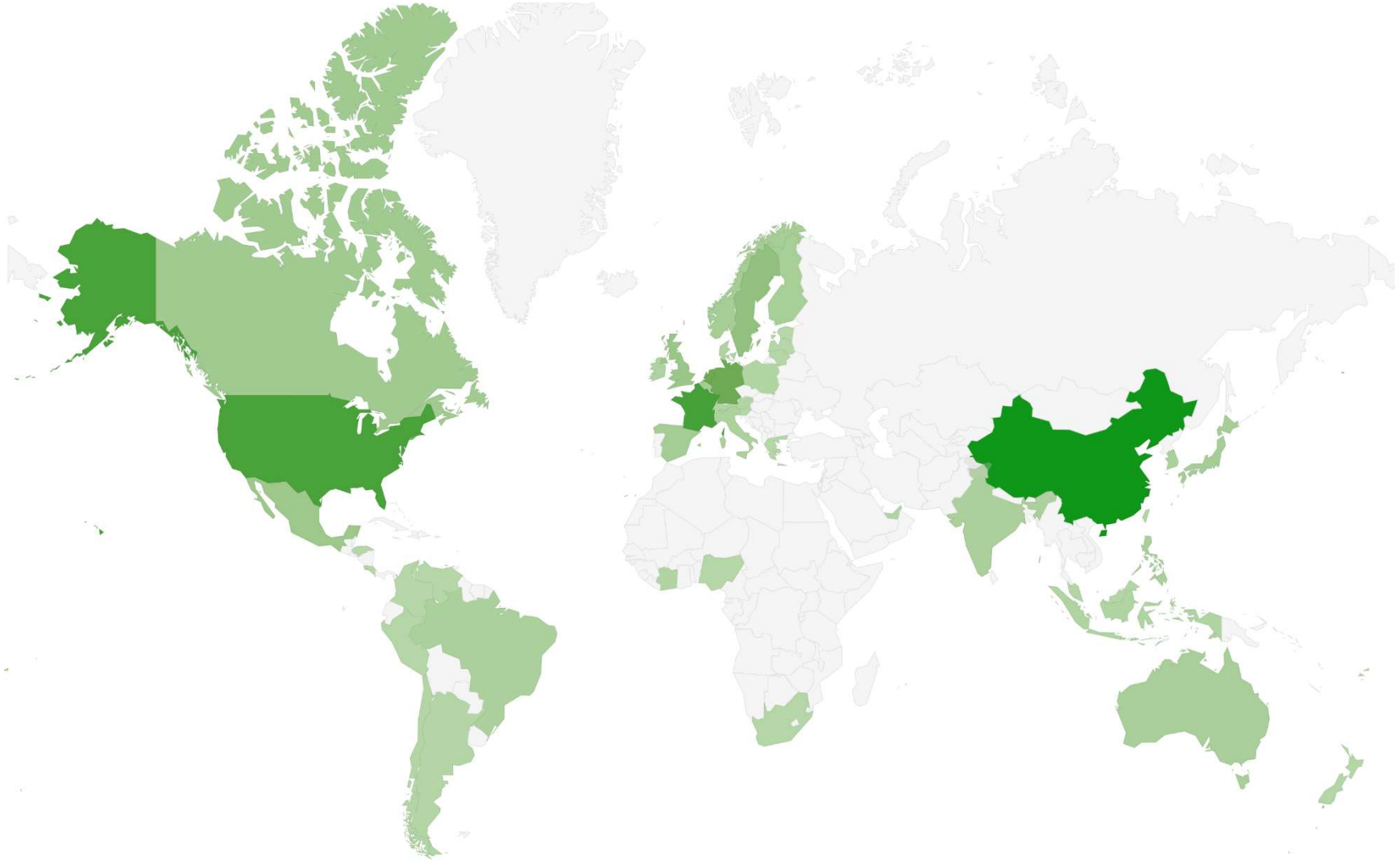
This table reports summary statistics for green municipal bonds and ordinary municipal bonds (i.e., municipal bonds that are not labelled as "green"). *Issuance amount* is the amount issued (in $M). *Maturity* is the maturity of the bond (in years). *Coupon* is the coupon rate (in %). *Coupon type* refers to the type of coupon payment. *S&P rating* refers to the credit rating of Standard & Poor's. All figures are sample means (and percentages, respectively). The dataset includes all municipal bonds ("munis") in Bloomberg issued between January 1, 2010 and December 31, 2018.

	Green muni bonds	Ordinary muni bonds
# bonds	4,794	1,219,979
Issuance amount ($M)	6.30	2.38
Maturity (years)	11.75	9.54
Coupon (%)	4.05	3.34
Coupon type		
Fixed	97.18%	98.35%
Floating	0.10%	0.14%
Other	2.71%	1.51%
S&P rating		
AAA	40.39%	16.59%
AA+	15.37%	15.89%
AA	19.05%	22.38%
AA-	12.39%	16.47%
A+	4.67%	12.65%
A	3.16%	8.21%
A-	2.58%	3.72%
BBB+	1.89%	1.62%
BBB	0.23%	1.44%
BBB-	0.03%	0.87%
BB+	0.25%	0.08%
BB	0.00%	0.05%
BB-	0.00%	0.01%
B+	0.00%	0.01%
B	0.00%	0.01%

Figure 1
Green bonds across countries

This figure reports the prevalence of green bonds (excluding green muni bonds) across countries. Darker-shaded areas represent higher issuance amounts (Panel A) and higher number of green bonds (Panel B), respectively. The underlying statistics are provided in Table 2.

Panel A. Green bond issuance (in $B)



Panel B. Number of green bonds

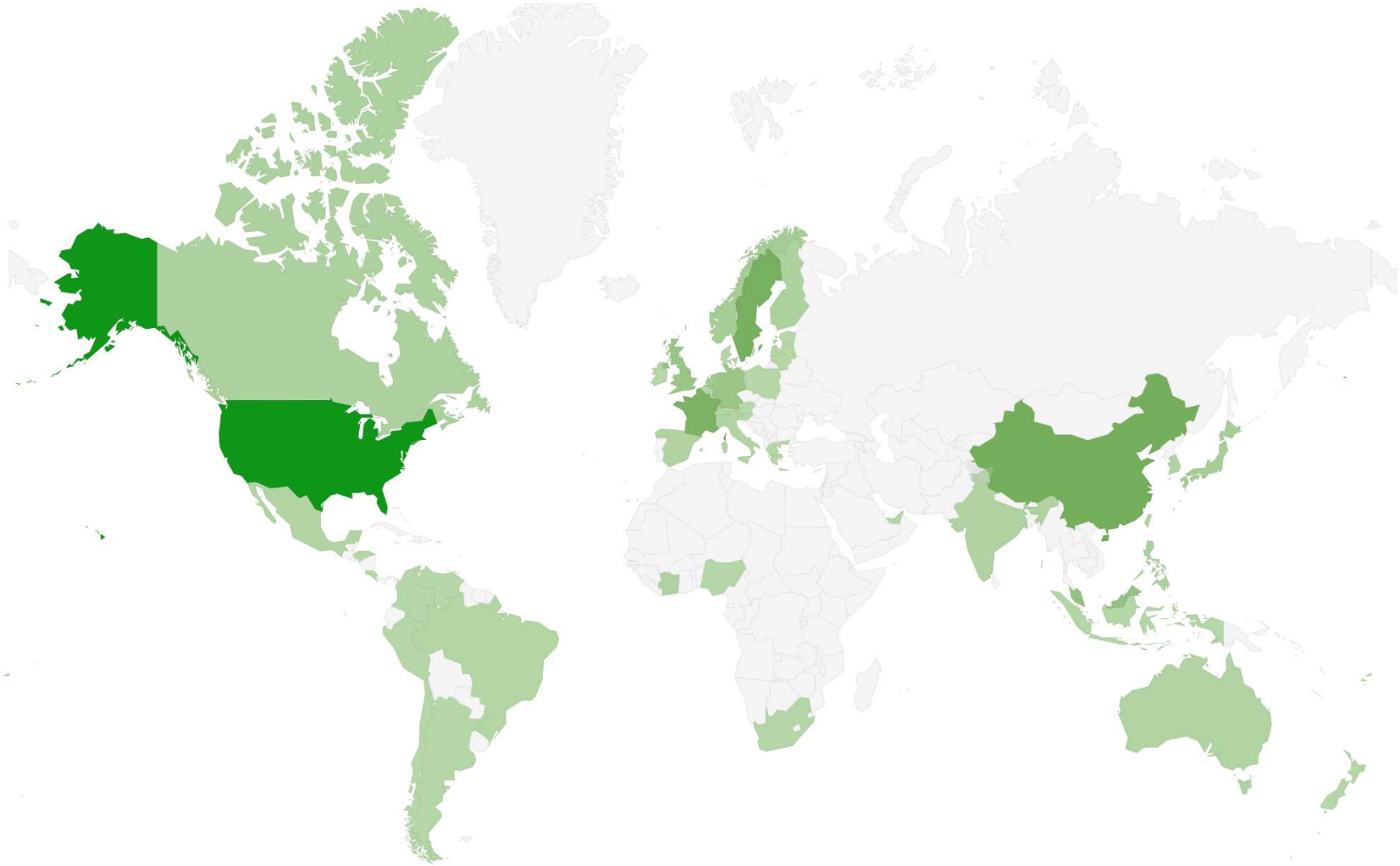
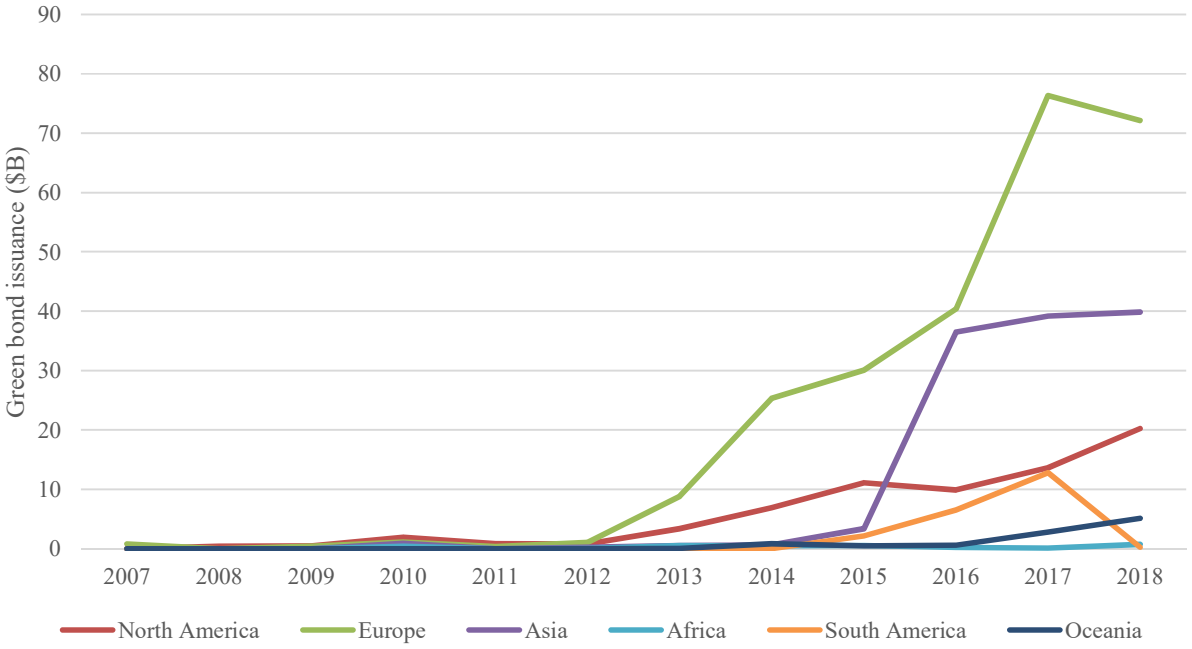


Figure 2
Evolution of green bonds across regions

This figure plots the evolution of green bonds across regions. Panel A reports the amount (in $B) of green bond issuance. Panel B reports the number of green bonds issued. The dataset includes all green bonds (excluding green muni bonds) in Bloomberg issued between January 1, 2007 and December 31, 2018.

Panel A. Green bond issuance (in $B)



Panel B. Number of green bonds

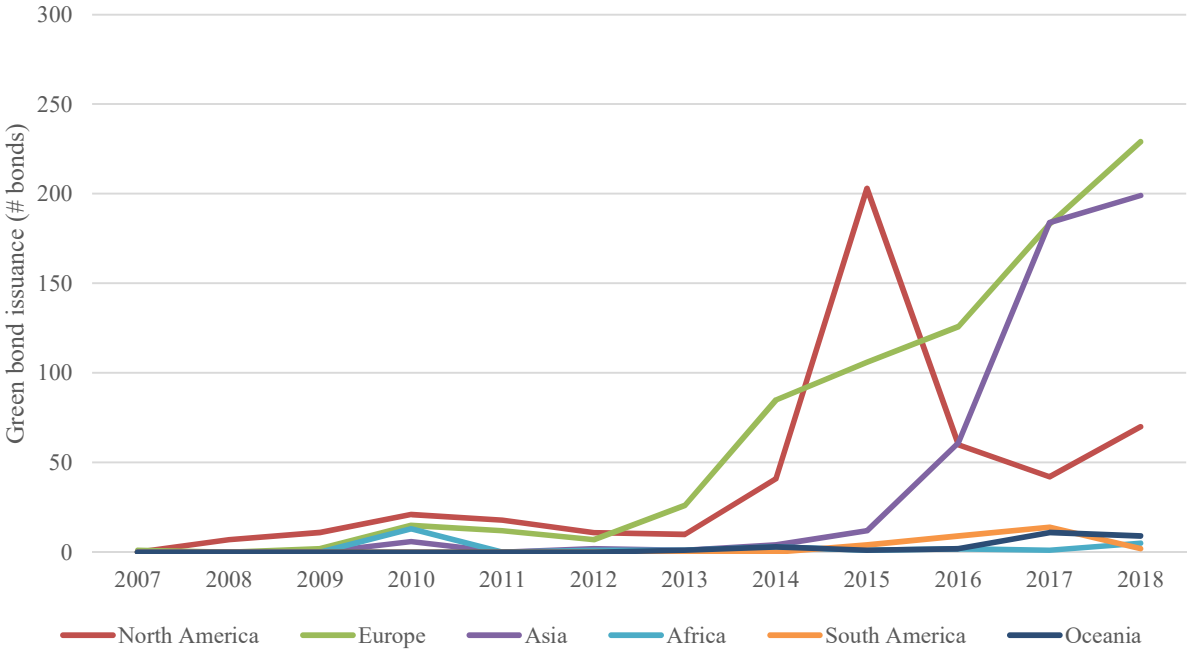
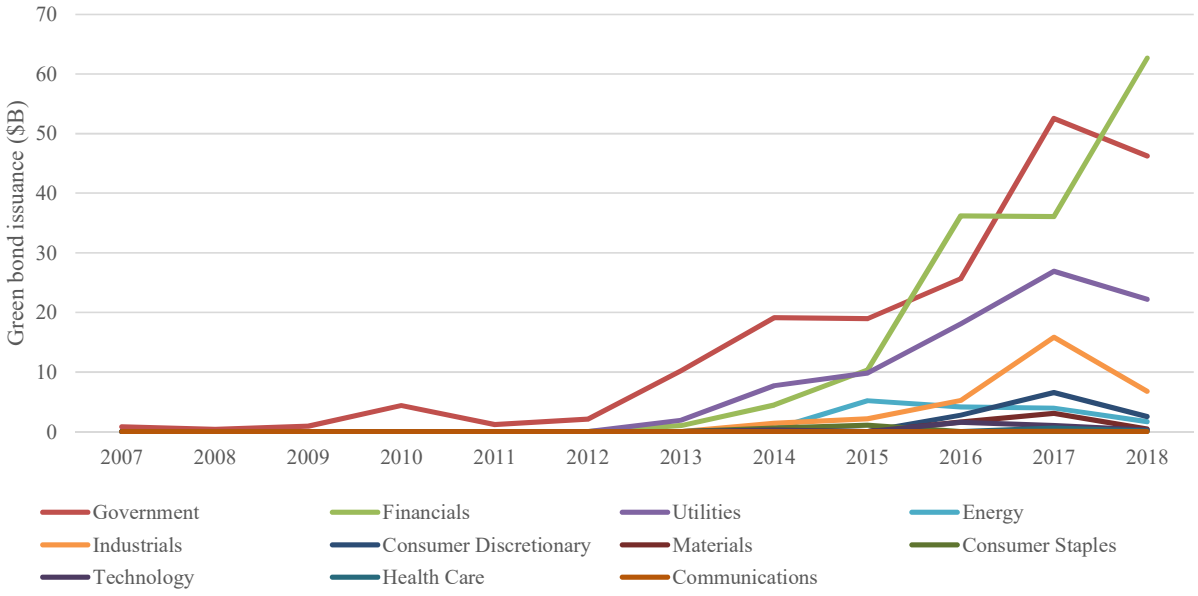


Figure 3
Evolution of green bonds across industries

This figure plots the evolution of green bonds across industries. Industries are defined according to BICS (Bloomberg Industry Classification Systems) codes. Panel A reports the amount (in $B) of green bond issuance. Panel B reports the number of green bonds issued. The dataset includes all green bonds (excluding green muni bonds) in Bloomberg issued between January 1, 2007 and December 31, 2018.

Panel A. Green bond issuance (in $B)



Panel B. Number of green bonds

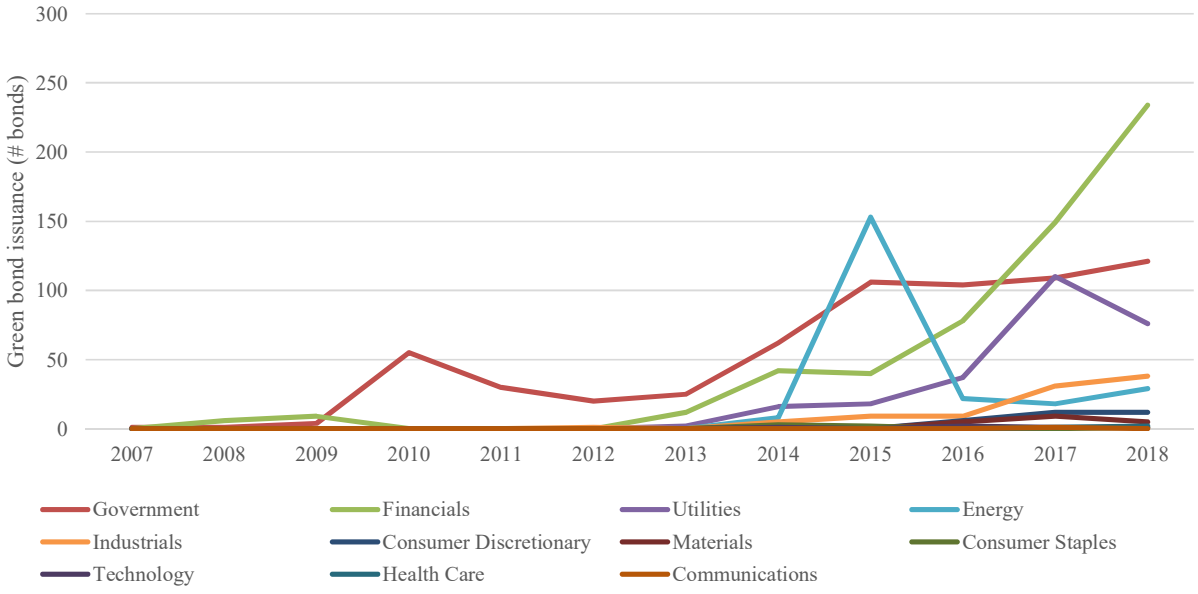
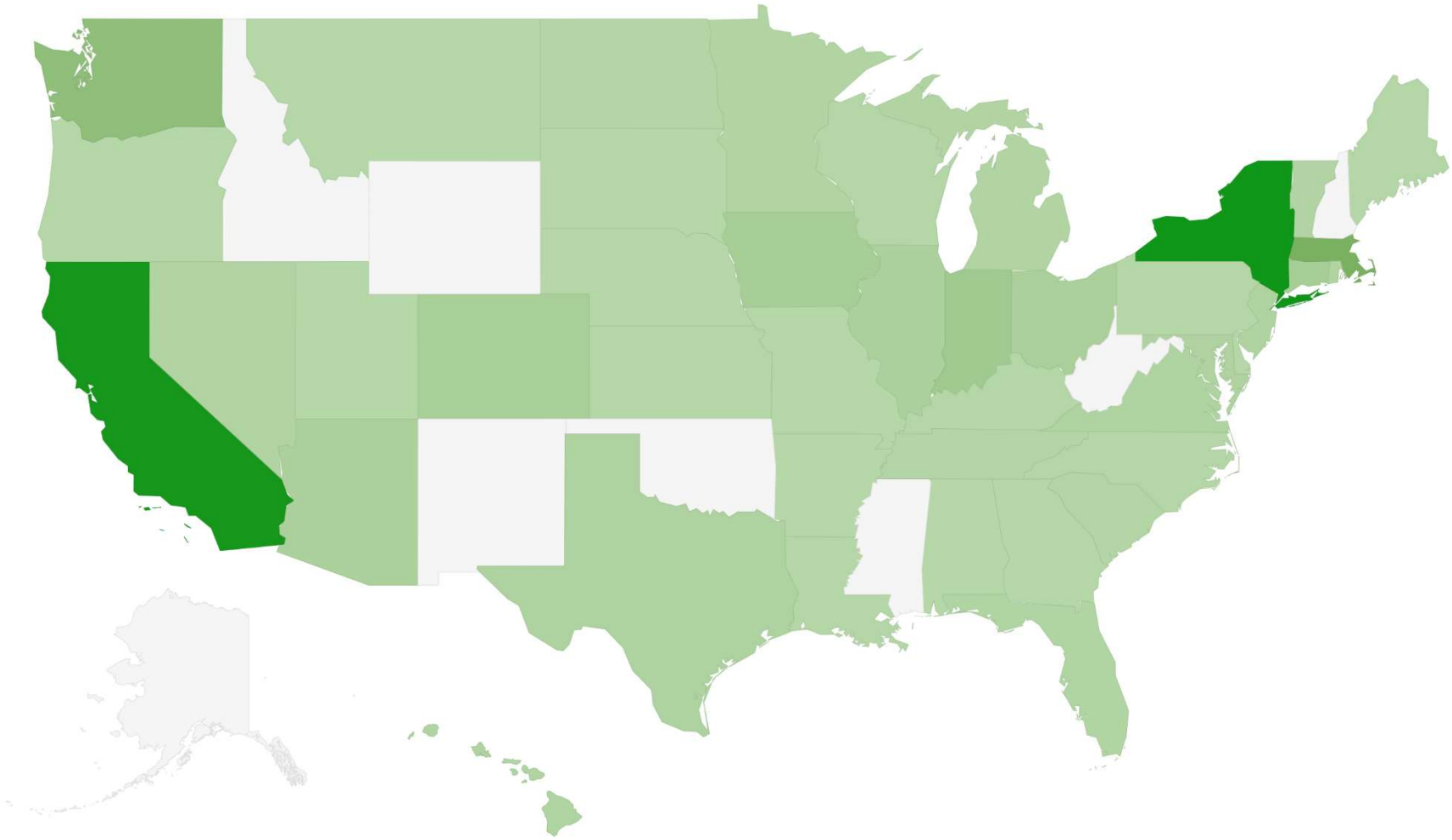


Figure 4
Green municipal bonds across states

This figure reports the prevalence of green municipal bonds across U.S. states. Darker-shaded areas represent higher issuance amounts (Panel A) and higher number of green municipal bonds (Panel B), respectively. The underlying statistics are provided in Table 6.

Panel A. Green muni bond issuance (in $B)



Panel B. Number of green muni bonds

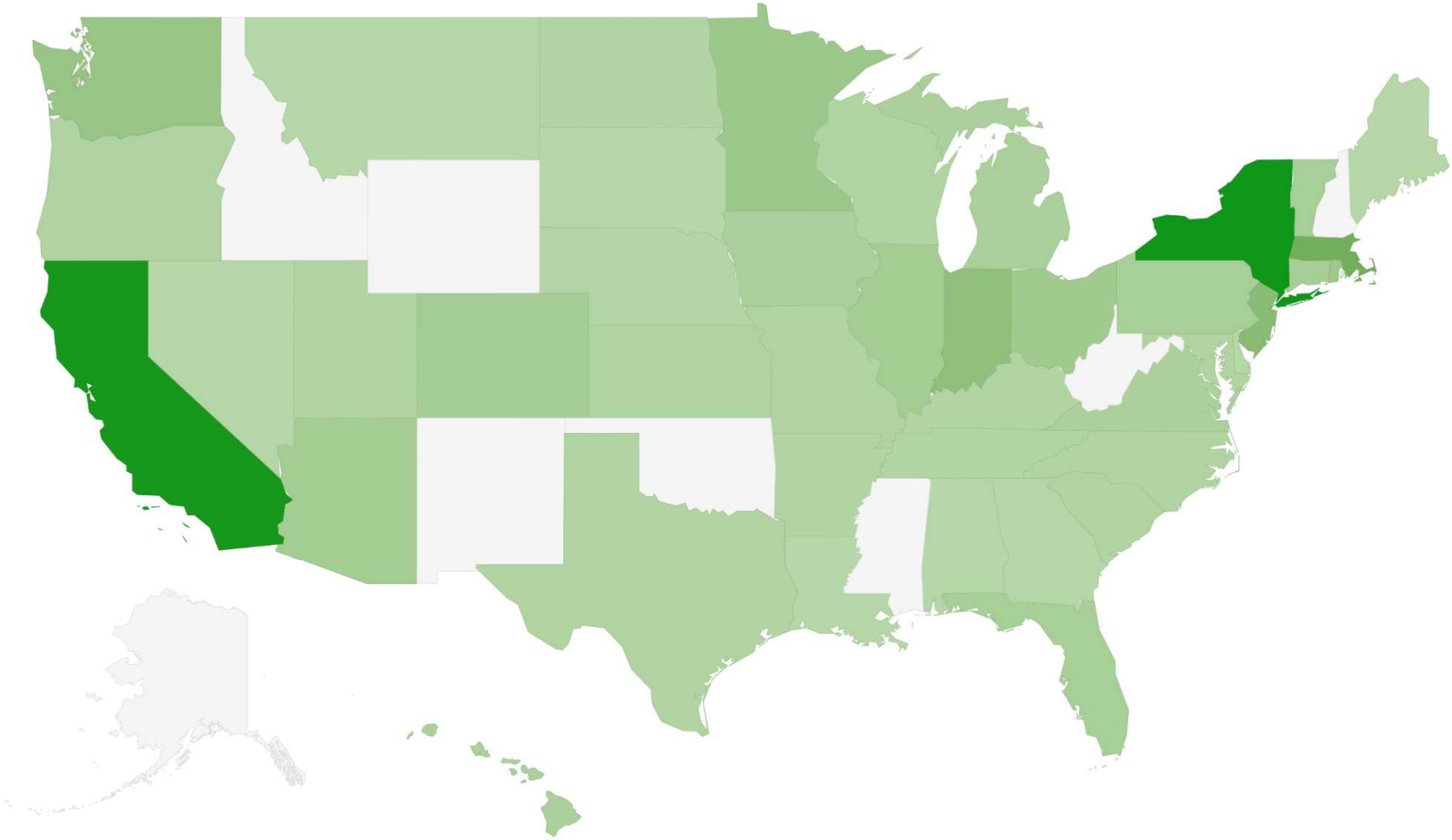
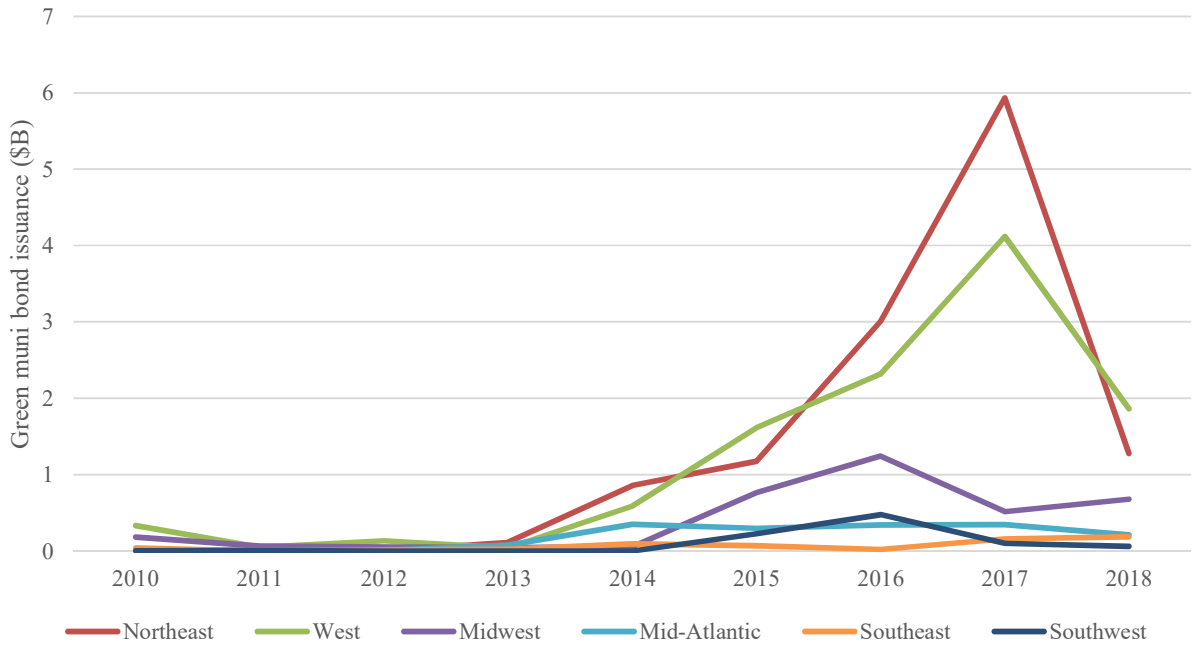


Figure 5
Evolution of green municipal bonds across regions

This figure plots the evolution of green municipal bonds across U.S. regions. Panel A reports the issuance amount (in $B) of green municipal bonds. Panel B reports the number of green municipal bonds issued. The dataset includes all green municipal bonds in Bloomberg issued between January 1, 2010 and December 31, 2018.

Panel A. Green muni bond issuance (in $B)



Panel B. Number of green muni bonds

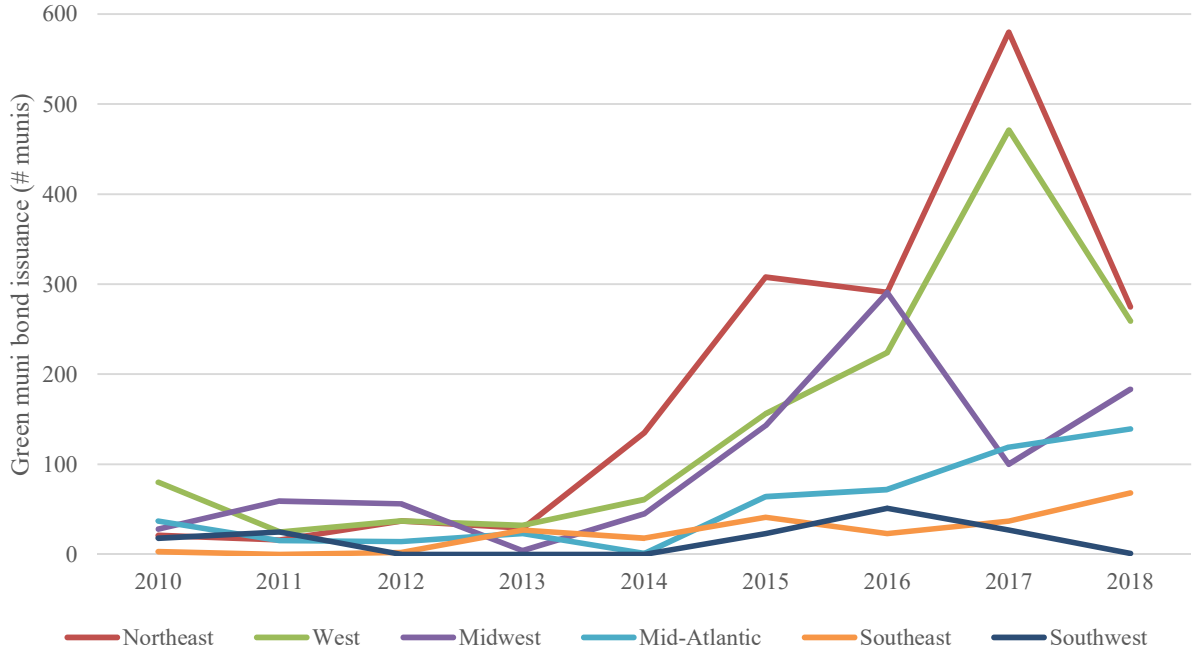


Figure 6
Stock market reaction to the issuance of green bonds

This figure plots the cumulative abnormal returns (CAR) around the announcement of green bond issues. The sample consists of $N = 217$ green bond issues.

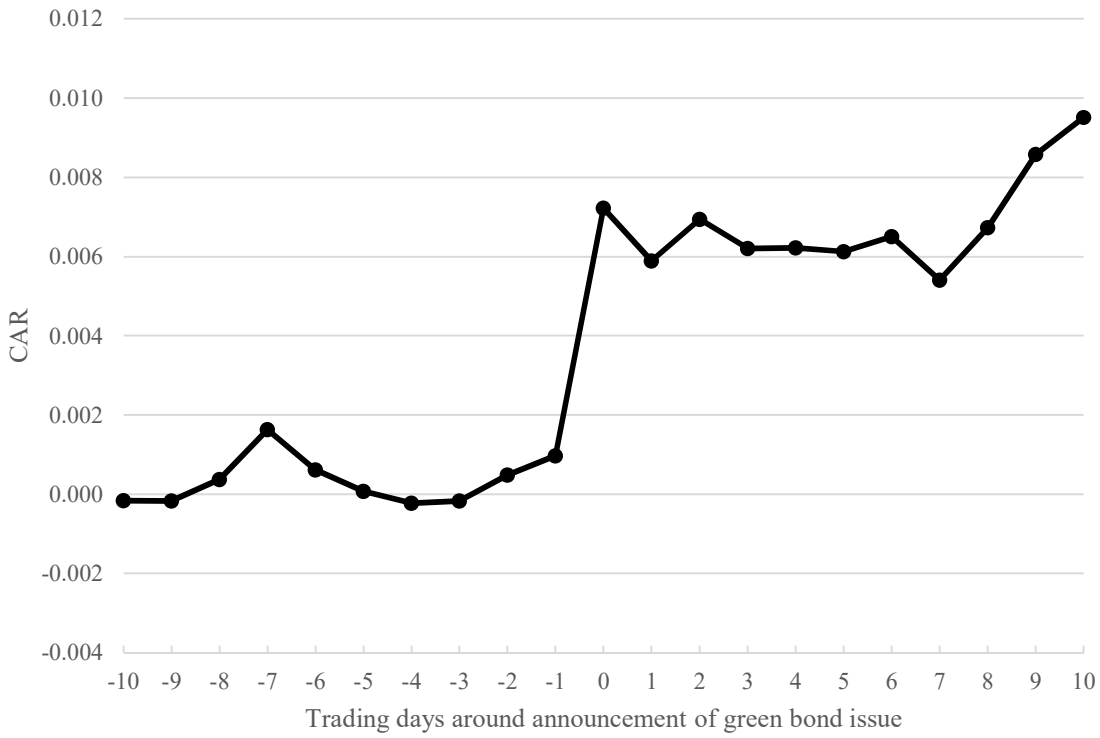


Figure 7
Certification

This figure plots the cumulative abnormal returns (CAR) around the announcement of green bond issues, separately for green bonds that are certified by independent third parties and green bonds that are not. The sample consists of *N* = 217 green bond issues.

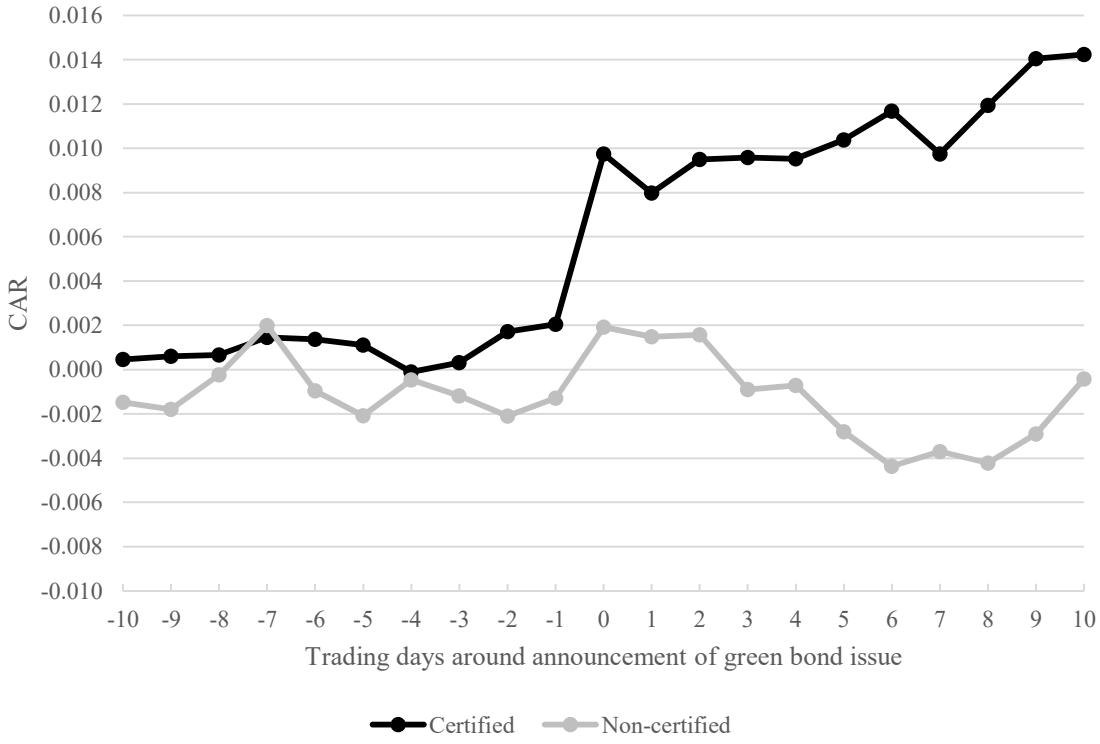
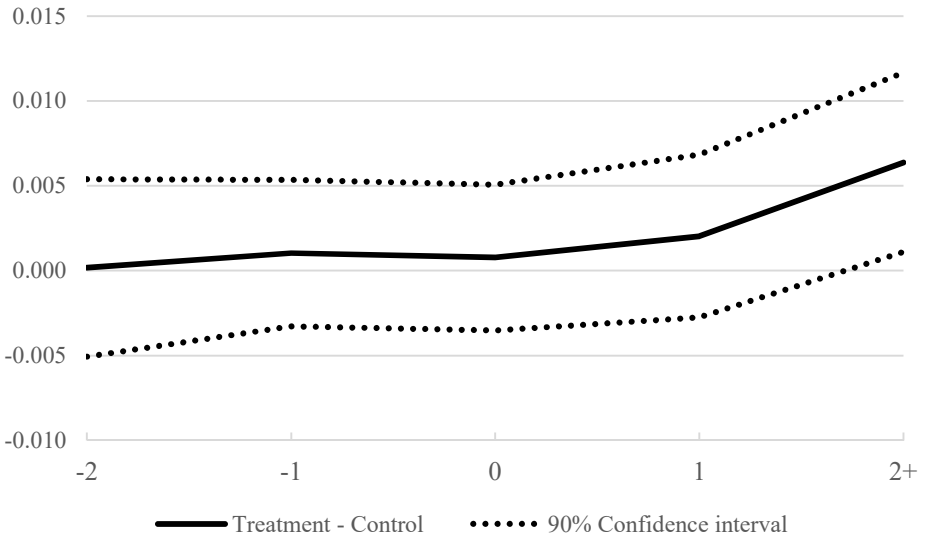


Figure 8
Financial performance

This table reports estimates of the difference-in-differences specification in equation (1) that compares green bond issuers with matched control firms. In Panel A, *return on assets* (ROA) is the ratio of operating income before depreciation to the book value of total assets. In Panel B, *return on equity* (ROE) is the ratio of operating income before depreciation to the book value of equity. The dotted lines represent the 90% confidence interval.

Panel A. Return on assets



Panel B. Return on equity

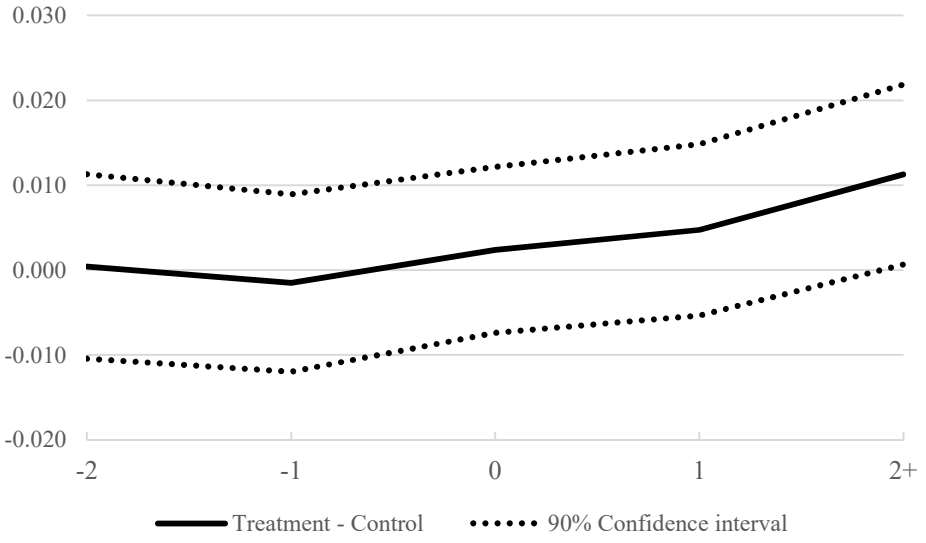
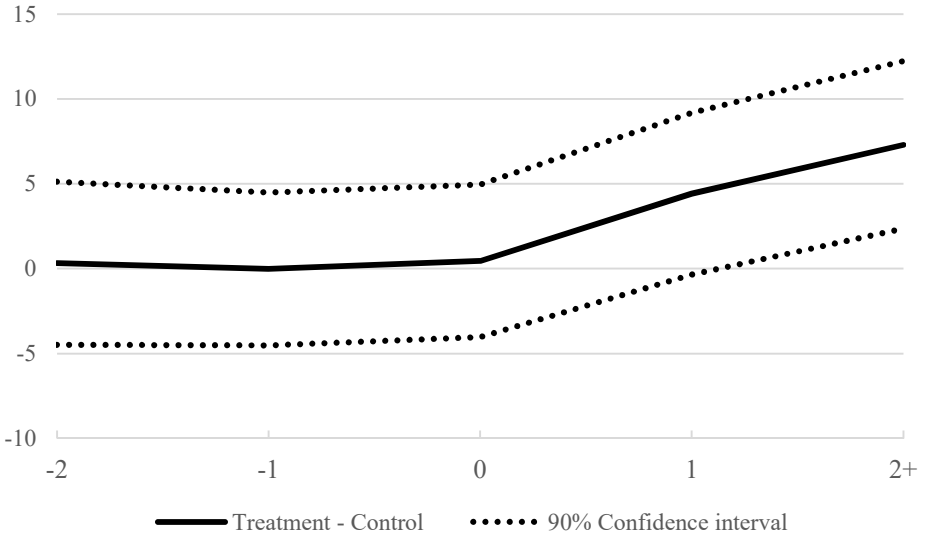


Figure 9
Environmental performance

This table reports estimates of the difference-in-differences specification in equation (1) that compares green bond issuers with matched control firms. In Panel A, *environmental score* is the environmental rating of Thomson Reuters' ASSET4. In Panel B, *CO_2 emissions* is the ratio of CO_2 emissions (in tons) from ASSET4 divided by the book value of total assets in U.S. dollars. The dotted lines represent the 90% confidence interval.

Panel A. Environmental score



Panel B. CO_2 emissions