Green Bonds: Effectiveness and Implications for Public Policy

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Executive Summary

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.

JEL Codes: D2, D22, G1, G2, G3, G14, G23, G32, M1, M14, Q2

Keywords: corporate green bonds, impact investing, sustainable finance, climate change, corporate sustainability, long-term orientation

I. 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. Although 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).

978-0-226-71117-1/2020/2020-0005$10.00

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) although 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; CBI 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 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. Although 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, although 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 United States. 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 United States (i.e., green municipality bonds issued by US states, counties, and cities). The issuance of green muni bonds has grown from $0.6B in 2010 to $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 2-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., 2 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.

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, for example, 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 environmental, social, and governance (ESG) investors. To mitigate this and other potential (endogeneity) concerns, I use a matching approach. Specifically, I match each green bond issuer to another (nongreen) bond issuer that is similar based on observables. Although the matching mitigates the possibility that my results are driven by unobservables, I caution 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 Negri 2016; Markandya, Galarrage, and Ruebbelke 2017; Kotchen and Costello 2018). Second, it contributes to the literature on impact investing that studies how financial instruments (such as Socially Responsible Investment [SRI] funds) can contribute to ESG objectives (e.g., Flammer 2015; Barber, Morse, and Yasuda 2018). 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 with plain-vanilla bonds (e.g., Baker et al. 2018; Zerbib 2019).

The remainder of this paper is structured as follows. Section II describes the green bond market, Section III presents the analysis of green bonds issued by public companies, and Section IV discusses the policy implications and offers conclusions.

II. The Green Bond Market

A. 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 "government."[4] This yields a total of 1,472,199 bonds. To distinguish between green and ordinary bonds, I use Bloomberg's green bond indicator, which reports

whether a bond is labeled 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 US states, counties, 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] Because 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.

B. Green Bonds over Time

Table 1 provides statistics on the issuance of green bonds on a year-by-year basis. The first column reports the issuance of green bonds in billions of US dollars (all foreign currencies are converted in US dollars),

Table 1
Green Bonds over Time

Year	Issuance of Green Bonds ($B)	Number of Green Bonds	Issuance of Ordinary Bonds ($B)	Number of Ordinary Bonds	Share of Green Bonds (Dollar Amount) (%)	Share of Green Bonds (Number of Bonds) (%)
2018	143.1	519	32,341.7	191,362	.441	.270
2017	146.6	441	38,893.2	172,645	.376	.255
2016	95.4	263	37,268.9	146,912	.255	.179
2015	47.7	328	31,573.7	132,506	.151	.247
2014	34.5	138	29,300.9	123,106	.118	.112
2013	13.2	39	27,196.3	114,474	.049	.034
2012	2.1	21	30,066.0	100,283	.007	.021
2011	1.2	30	28,125.8	86,096	.004	.035
2010	4.4	55	28,268.9	83,112	.015	.066
2009	.9	13	28,868.6	86,364	.003	.015
2008	.4	7	23,686.4	115,269	.002	.006
2007	.8	1	20,571.3	118,215	.004	.001
Total	490.4	1,855	356,161.8	1,470,344	.138	.126

Note: 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 labeled as "green"). The data set includes all bonds (excluding muni bonds) in Bloomberg issued between January 1, 2007, and December 31, 2018.

whereas 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.

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 represented less than 0.5% of the overall market (the issuance of ordinary bonds was $32,341.7B, compared with $143.1B for green bonds). Importantly, the share of green bonds has been growing rapidly. Although it was only 0.004% 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]

C. 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 United States ($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).

Figure 1 provides a visualization of the data from table 2 (panel A refers to the dollar amount, whereas 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 is in line with the above characterization: China, France, and the United States are the main issuers, followed by a large set of European countries.

Finally, figure 2 plots the evolution of the green bond market across regions (panel A refers again to the dollar amount, whereas 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 green bond issuance in Asia in recent years: although green bonds were only marginal until 2015, Asia has been a major issuer as of 2016.[9]

D. Green Bonds across Sectors

Table 3 provides a characterization of green bond issuance across sectors. Sectors are defined according to 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]

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.

E. Summary Statistics

Table 4 provides summary statistics for several characteristics of green versus ordinary bonds. As can be seen, green bonds tend to be larger (the average issuance amount is $264M compared with $242M for ordinary bonds) and have longer maturity (6.9 years compared with 3.4 years for ordinary bonds). This indicates that green bonds are used to finance large-scale long-term projects, consistent with the nature of many environmental and energy projects.

Also, note that the coupon is on average lower for green bonds (3.3% compared with 3.5% for ordinary bonds). This difference is harder to interpret due to the many factors that affect 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—that is, investors require a lower return—although the difference is relatively small. Baker et al. (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 with 8.5% for ordinary bonds). Moreover, no green bond has ever been issued with a rating in the D range.

F. Green Municipality Bonds

In addition to the government and corporate asset classes, Bloomberg also compiles fixed-income data for a separate asset class: US 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.

Table 2
Green Bonds across Countries

Country	Issuance of Green Bonds ($B)	Number of Green Bonds	Issuance of Ordinary Bonds ($B)	Number of Ordinary Bonds	Share of Green Bonds (Dollar Amount) (%)	Share of Green Bonds (Number of Bonds) (%)
China	83.9	199	44,358.9	144,346	.189	.138
France	58.1	176	12,844.8	20,743	.450	.841
United States	56.9	464	76,308.6	240,434	.074	.193
Netherlands	40.5	60	5,540.0	37,723	.726	.159
Luxembourg	39.8	62	3,446.4	16,775	1.141	.368
Germany	39.6	84	17,564.0	299,037	.225	.028
Sweden	19.4	194	2,622.6	13,711	.734	1.395
Britain	14.1	87	14,562.2	94,228	.097	.092
Mexico	13.3	13	2,662.4	3,030	.499	.427
Canada	10.9	25	9,723.9	34,484	.112	.072
Spain	9.0	19	5,302.8	4,401	.170	.430
Norway	8.4	43	1,666.1	18,767	.504	.229
Japan	7.8	46	78,226.9	26,393	.010	.174
Belgium	7.6	4	1,842.8	2,014	.411	.198
Finland	7.5	27	864.2	4,663	.856	.576
Hong Kong	7.4	31	4,458.5	24,319	.166	.127
Australia	6.8	17	3,420.2	15,942	.198	.107
Philippines	6.3	27	567.7	2,341	1.093	1.140
Brazil	5.4	8	3,542.7	3,892	.153	.205
South Korea	5.3	15	6,664.1	64,948	.079	.023
India	5.2	19	5,158.5	33,595	.101	.057
Italy	4.6	11	10,060.7	54,532	.045	.020
Denmark	3.5	6	768.9	4,785	.455	.125
Ireland	3.5	1	1,732.3	5,368	.199	.019
Ivory Coast	2.6	22	91.7	558	2.783	3.793
Indonesia	2.5	4	1,695.2	3,884	.149	.103
Switzerland	2.1	9	1,532.9	51,789	.134	.017

Poland	2.0	2	630.1	2,617	.317	.076
British Virgin Islands	1.8	5	311.7	1,567	.572	.318
Austria	1.7	4	1,361.9	14,250	.124	.028
United Arab Emirates	1.6	3	373.6	14,516	.423	.021
Taiwan	1.6	21	605.3	3,259	.257	.640
Cayman Islands	1.2	2	792.1	8,260	.154	.024
Singapore	1.2	10	3,336.6	7,059	.036	.141
Chile	1.0	2	827.7	3,745	.121	.053
Costa Rica	1.0	2	123.5	830	.803	.240
Malaysia	1.0	98	1,477.5	16,624	.066	.586
Mauritius	1.0	2	49.3	1,985	1.889	.101
Argentina	.9	4	1,713.1	2,960	.053	.135
Lithuania	.7	3	40.6	508	1.741	.587
New Zealand	.4	4	353.3	1,866	.124	.214
Peru	.4	2	290.1	1,598	.140	.125
South Africa	.3	5	937.0	6,124	.033	.082
Latvia	.2	3	26.1	368	.627	.809
Slovenia	.1	1	94.9	307	.090	.325
Venezuela	.1	2	226.7	879	.036	.227
Honduras	.1	1	161.1	604	.048	.165
Greece	.1	1	1,382.3	718	.005	.139
Colombia	.1	1	359.6	1,060	.018	.094
Estonia	.1	1	2.9	51	1.868	1.923
Fiji	.0	2	2.2	482	2.126	.413
Nigeria	.0	1	579.4	1,348	.005	.074
Other	.0	0	22,873.2	150,057	.000	.000
Total	490.4	1,855	356,161.8	1,470,344	.138	.126

Note: 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 labeled as “green”). The data set includes all bonds (excluding muni bonds) in Bloomberg issued between January 1, 2007, and December 31, 2018.

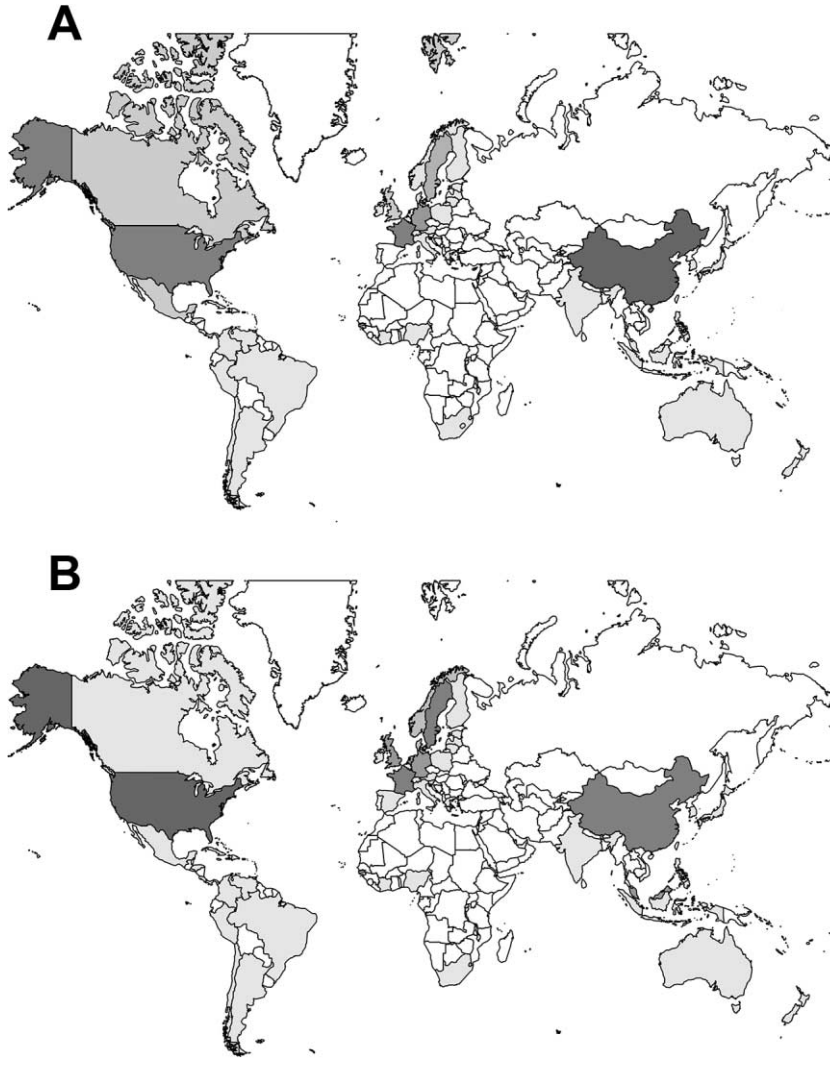

Fig. 1. Green bonds across countries. *A*, Green bond issuance (in $B). *B*, Number of green bonds. Color version available as an online enhancement.

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

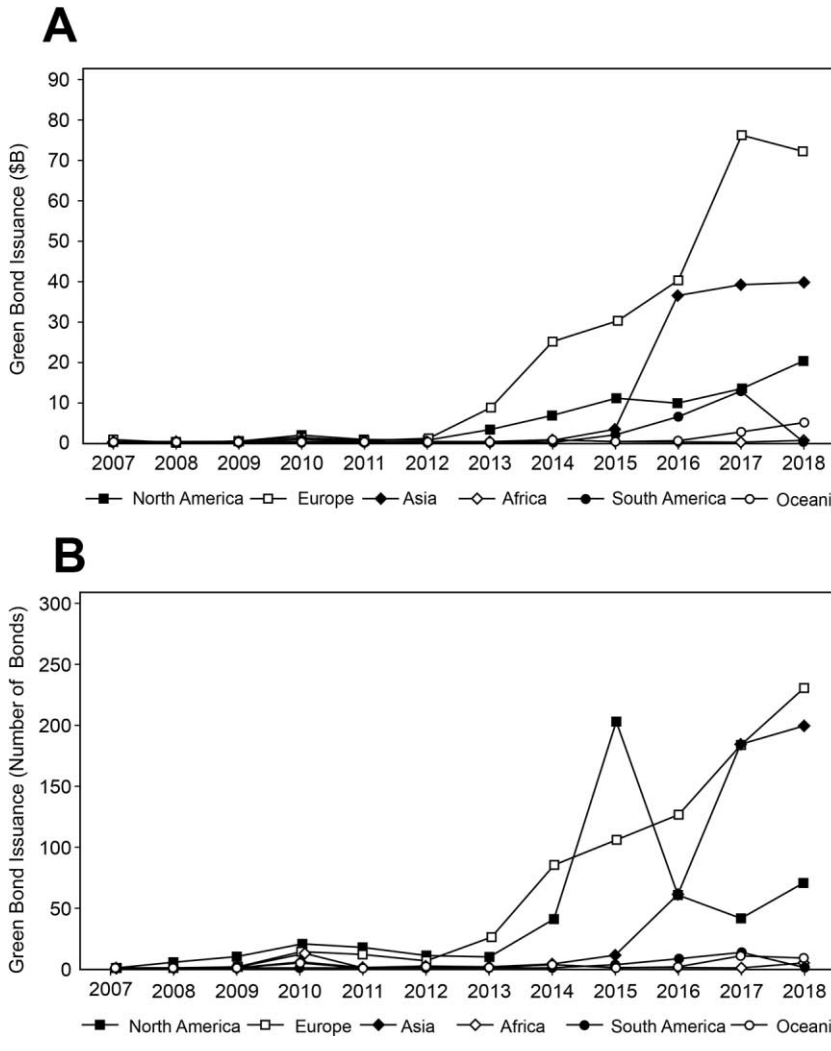

Fig. 2. Evolution of green bonds across regions. *A*, Green bond issuance (in $B). *B*, Number of green bonds. Color version available as an online enhancement.

Notes: 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 data set includes all green bonds (excluding green muni bonds) in Bloomberg issued between January 1, 2007, and December 31, 2018.

Table 3
Green Bonds across Industries

Industry	Issuance of Green Bonds ($B)	Number of Green Bonds	Issuance of Ordinary Bonds ($B)	Number of Ordinary Bonds	Share of Green Bonds (Dollar Amount) (%)	Share of Green Bonds (Number of Bonds) (%)
Government	182.6	638	258,220.6	351,741	.071	.181
Financials	150.9	570	63,873.7	978,456	.236	.058
Utilities	86.8	259	4,104.5	17,618	2.071	1.449
Industrials	31.4	93	5,641.2	32,247	.553	.288
Energy	15.4	230	4,738.4	11,894	.325	1.897
Consumer discretionary	12.3	31	5,116.9	31,533	.239	.098
Materials	5.2	19	3,575.0	16,011	.144	.119
Technology	3.2	5	1,885.6	7,454	.169	.067
Consumer staples	1.9	6	2,658.3	9,372	.071	.064
Health care	.7	3	2,506.6	6,350	.028	.047
Communications	.1	1	3,839.4	7,528	.002	.013
Other	.0	0	1.7	140	.000	.000
Total	490.4	1,855	356,161.8	1,470,344	.138	.126

Note: 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 labeled as "green"). The data set includes all bonds (excluding muni bonds) in Bloomberg issued between January 1, 2007, and December 31, 2018.

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).

Green Municipality Bonds across US States

Table 6 provides a breakdown by US state. 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).

Figure 4 provides a visualization of the data from table 6. (As above, panel A refers to the dollar amount, whereas panel B refers to the number

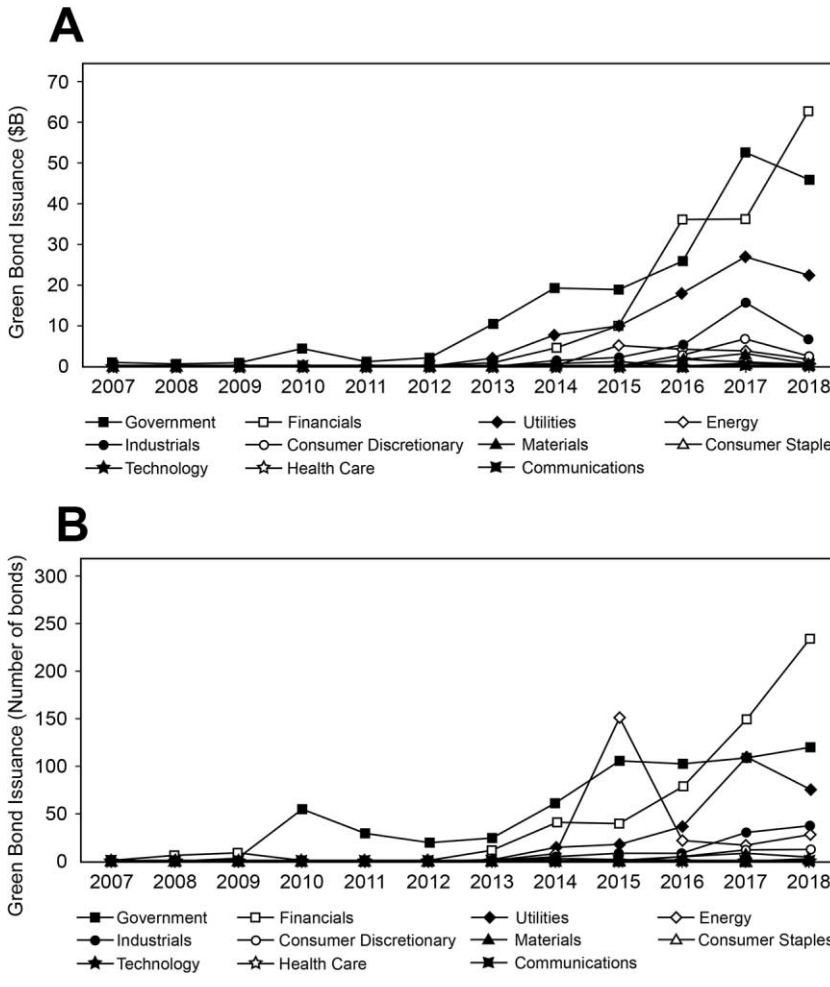

Fig. 3. Evolution of green bonds across industries. *A*, Green bond issuance (in $B). *B*, Number of green bonds. Color version available as an online enhancement.

Notes: 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 data set includes all green bonds (excluding green muni bonds) in Bloomberg issued between January 1, 2007, and December 31, 2018.

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. Although 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

Table 4
Summary Statistics

	Green Bonds	Ordinary Bonds
Number of 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 (%)	.00	.11

Note: This table reports summary statistics for all green bonds and ordinary bonds (i.e., bonds that are not labeled 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 data set includes all bonds (excluding muni bonds) in Bloomberg issued between January 1, 2007, and December 31, 2018.

New Jersey, which has issued a relatively large number of green muni bonds (panel B) for a relatively low dollar amount (panel A). Lastly, figure 5 plots the evolution of green municipal bonds across regions.

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.

Table 5
Green Municipal Bonds over Time

Year	Issuance of Green Muni Bonds ($B)	Number of Green Muni Bonds	Issuance of Ordinary Muni Bonds ($B)	Number of Ordinary Muni Bonds	Share of Green Muni Bonds (Dollar Amount) (%)	Share of Green Muni Bonds (Number of Bonds) (%)
2018	4.3	925	398.4	107,114	1.063	.856
2017	11.2	1,334	419.2	133,388	2.597	.990
2016	7.4	952	405.6	155,299	1.794	.609
2015	4.1	735	345.1	148,590	1.188	.492
2014	1.9	260	276.6	122,578	.699	.212
2013	.3	115	260.2	126,480	.115	.091
2012	.2	146	288.3	155,727	.073	.094
2011	.1	140	206.8	120,275	.066	.116
2010	.6	187	308.3	150,528	.189	.124
Total	30.2	4,794	2,908.4	1,219,979	1.027	.391

Note: 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 labeled as "green"). The data set includes all municipal bonds ("munis") in Bloomberg issued between January 1, 2010, and December 31, 2018.

Compared with ordinary muni bonds, green munis are on average larger ($6.3M compared with $2.4M), have a longer maturity (11.8 years compared with 9.5 years), and have a higher credit rating (40.4% of green muni bonds have a triple-A rating, compared with only 16.6% of the ordinary muni bonds).[12]

III. 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 affects financial and environmental performance. This section is an abbreviated version of Flammer (2018), who studies how corporate green bonds affect firm-level outcomes.

A. Stock Market Reaction

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

Table 6
Green Municipal Bonds by State

State	Issuance of Green Muni Bonds ($B)	Number of Green Muni Bonds	Issuance of Ordinary Muni Bonds ($B)	Number of Ordinary Muni Bonds	Share of Green Muni Bonds (Dollar Amount) (%)	Share of Green Muni Bonds (Number of Bonds) (%)
New York	8.0	959	334.0	85,833	2.353	1.105
California	7.8	923	435.5	105,375	1.753	.868
Massachusetts	3.1	412	78.2	32,657	3.871	1.246
Washington	2.1	182	79.2	22,961	2.527	.786
Indiana	1.2	236	33.6	32,466	3.314	.722
Connecticut	.8	95	43.6	19,059	1.809	.496
Iowa	.7	68	17.8	29,274	4.029	.232
District of Columbia	.7	27	20.9	1,857	3.149	1.433
Colorado	.7	110	57.2	16,705	1.171	.654
Ohio	.6	128	83.0	39,542	.730	.323
Arizona	.5	112	44.7	11,938	1.166	.929
Illinois	.5	115	125.0	45,843	.404	.250
Texas	.4	33	313.0	166,776	.114	.020
Maryland	.3	32	52.2	12,016	.609	.266
Virginia	.3	61	58.2	16,489	.514	.369
New Jersey	.3	277	92.6	40,825	.322	.674
Hawaii	.3	63	20.8	2,566	1.403	2.396
Nevada	.2	5	22.4	4,605	.969	.108
Minnesota	.2	158	47.7	49,649	.442	.317
Florida	.2	81	119.9	24,746	.171	.326
Michigan	.2	68	59.3	32,022	.295	.212
Rhode Island	.2	142	7.9	4,445	2.176	3.096
Vermont	.2	83	3.8	2,257	3.910	3.547
Tennessee	.1	24	33.9	16,095	.292	.149
North Dakota	.1	19	5.8	8,074	1.642	.235
South Carolina	.1	27	35.3	10,933	.267	.246

North Carolina	.1	29	42.3	12,974	.164	.223
Pennsylvania	.1	86	118.4	60,387	.046	.142
Wisconsin	.1	30	53.0	48,473	.098	.062
Kentucky	.1	21	30.5	23,547	.166	.089
Maine	.0	1	7.6	6,175	.592	.016
Louisiana	.0	4	31.8	10,926	.140	.037
Kansas	.0	38	22.8	24,602	.137	.154
Alabama	.0	9	32.4	19,338	.076	.047
Utah	.0	20	21.4	7,870	.093	.253
Oregon	.0	40	32.1	12,886	.053	.309
Nebraska	.0	11	19.3	35,985	.051	.031
Arkansas	.0	23	13.0	21,717	.065	.106
Montana	.0	2	3.7	4,212	.224	.047
Missouri	.0	35	42.5	28,968	.018	.121
Georgia	.0	1	55.4	13,256	.013	.008
South Dakota	.0	3	5.7	5,815	.115	.052
Delaware	.0	1	6.6	1,370	.041	.073
Alaska	.0	0	7.2	2,711	.000	.000
Idaho	.0	0	6.6	2,944	.000	.000
Mississippi	.0	0	12.9	9,141	.000	.000
New Hampshire	.0	0	6.3	3,638	.000	.000
New Mexico	.0	0	12.0	7,291	.000	.000
Oklahoma	.0	0	19.7	14,771	.000	.000
West Virginia	.0	0	7.1	2,945	.000	.000
Wyoming	.0	0	1.5	1,132	.000	.000
Territories	.0	0	71.0	1,897	.000	.000
Total	30.2	4,794	2,908.4	1,219,979	1.027	.391

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

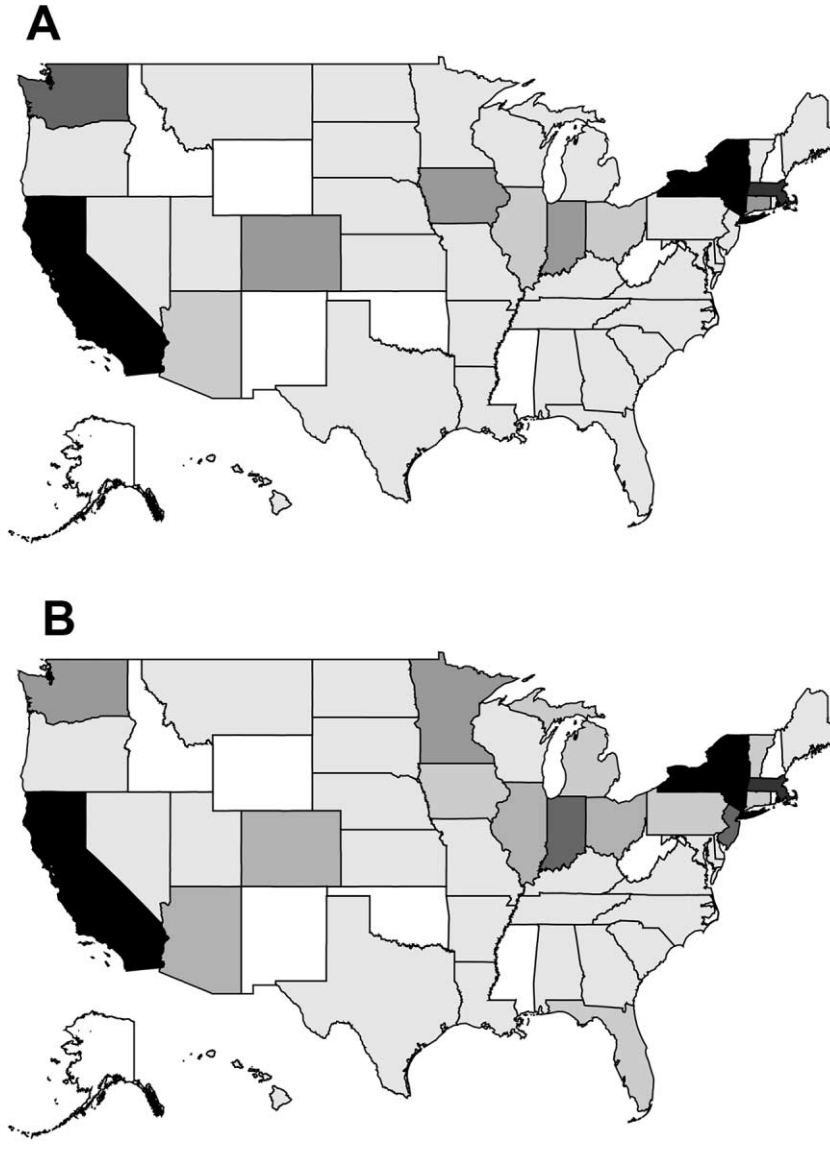

Fig. 4. Green municipal bonds across states. *A*, Green muni bond issuance (in $B). *B*, Number of green muni bonds. Color version available as an online enhancement.

Notes: This figure reports the prevalence of green municipal bonds across US states. Darker-shaded areas represent higher issuance amounts (*A*) and higher number of green municipal bonds (*B*), respectively. The underlying statistics are provided in table 6.

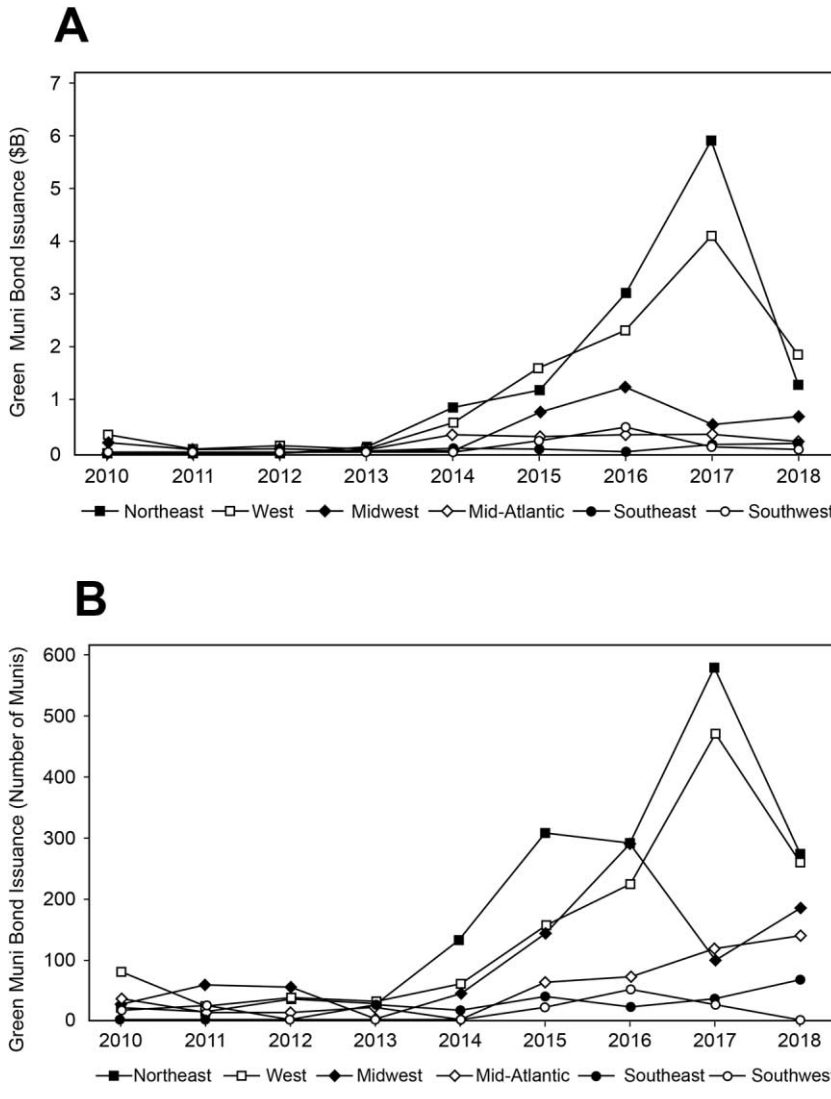

Fig. 5. Evolution of green municipal bonds across regions. *A*, Green muni bond issuance (in $B). *B*, Number of green muni bonds. Color version available as an online enhancement.

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

Table 7
Green Municipal Bonds

	Green Muni Bonds	Ordinary Muni Bonds
Number of 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 (%)	.10	.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 (%)	.23	1.44
BBB– (%)	.03	.87
BB+ (%)	.25	.08
BB (%)	.00	.05
BB– (%)	.00	.01
B+ (%)	.00	.01
B (%)	.00	.01

Note: This table reports summary statistics for green municipal bonds and ordinary municipal bonds (i.e., municipal bonds that are not labeled 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 data set includes all municipal bonds ("munis") in Bloomberg issued between January 1, 2010, and December 31, 2018.

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, because 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 compute abnormal returns (ARs) several days before and after the event date. Specifically, for each company *i*, I compute ARs 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 squares 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 the Center for Research in Security Prices (for US companies) and the daily stock file of Compustat Global (for non-US companies). Daily market returns r_{mt} are country specific. For the United States, I use the S&P 500. For all other countries, I use the country's leading stock market index (e.g., the Financial Times Stock Exchange 100 Index for the United Kingdom).[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 AR of company i on day t as follows:

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

Finally, I compute the CAR by summing up ARs in event time—that is, CAR from t_1 to t_2 is obtained as

$$\mathrm{CAR}_i(t_1, t_2) = \sum_{\tau=t_1}^{t_2} \mathrm{AR}_{i\tau}.$$

Results

Figure 6 plots the average CARs 10 days before and after the 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 2-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.

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, whereas it responds negatively to the announcement of equity issues—see, for example, Eckbo, Masulis, and Norli (2007) and Masulis and Korwar (1986).

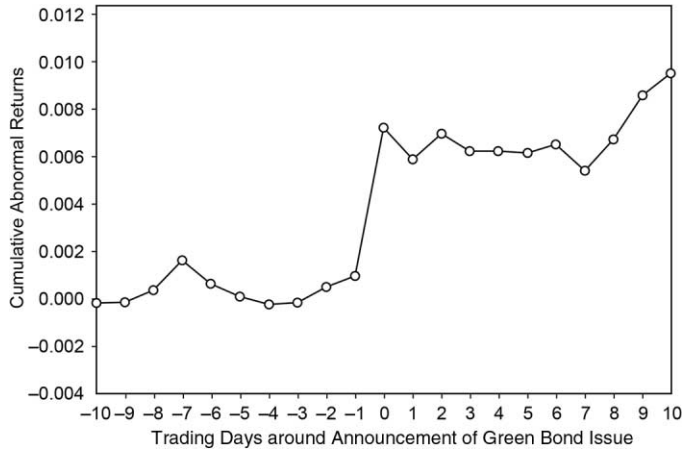

Fig. 6. Stock market reaction to the issuance of green bonds

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

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 noncertified 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 preissuance 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 postissuance 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 noncertified green bonds. Although the average CAR in the 2-day event window (–1, 0) is positive in both groups, it is only significant for certified green bonds. Specifically, the 2-day CAR is 0.8% for certified green bonds ($t = 2.27$), whereas it is 0.4% for noncertified green bonds ($t = 0.94$).[15] Overall, these findings suggest that certification is an important determinant of the effectiveness of green bonds.

B. Analysis of Long-Term Financial and Environmental Performance

Methodology

The 217 green bonds used in the event study correspond to 106 unique firm-year observations (because 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 from the pool of public companies. The matching is done in two steps.

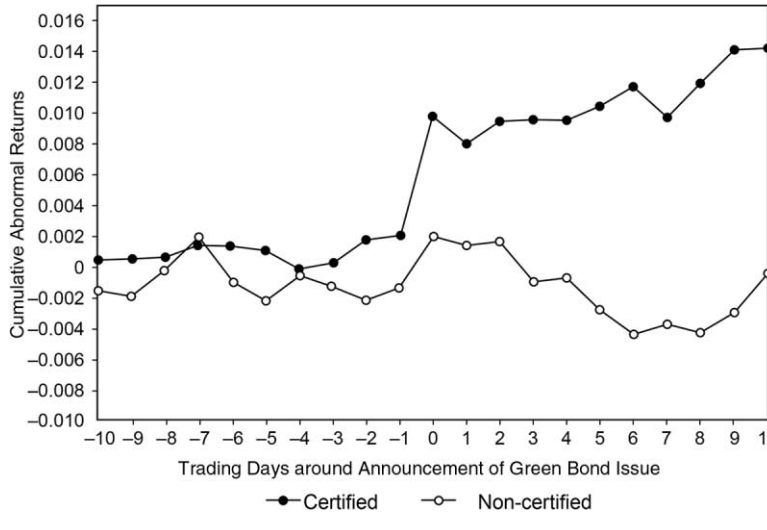

Fig. 7. Certification

Notes: This figure plots the cumulative abnormal returns (CARs) 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.

First, for each treated firm, I restrict the pool of candidates to firms that issue a regular bond in the same calendar year as the green bond issue—this criterion ensures that the results capture a "green bond effect" as opposed to a mere "bond effect". I further restrict the pool of candidates to firms that operate in the same two-digit Standard Industrial Classification (SIC) industry and the same country as the treated firm. Second, among the remaining candidates, I select the nearest neighbor based on a large set of observables prior to the treatment. Specifically, 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 pretrend (i.e., the change from $t-2$ to $t-1$). Accordingly, 14 matching variables are used. The nearest neighbor is the firm with the lowest Mahalanobis distance to the treated firm across these 14 matching characteristics.[16]

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

$$y_{it} = \alpha_i + \theta_{ct} + \mu_{st} + \sum_{\tau=-2}^{2+} \beta_\tau \times \text{Green bond}(\tau)_{it} + e_{it}, \quad (1)$$

where i indexes companies, t indexes years, c indexes countries, and s indexes two-digit SIC industries; y is the outcome variable of interest (e.g., ROA, CO_2 emissions); α_i are firm fixed effects; θ_{ct} are country by year fixed effects; μ_{st} are industry by year fixed effects; Green bond(–2) is a dummy variable equal to one for green bond issuers 2 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; and Green bond(2+) is a dummy variable equal to one for green bond issuers 2 or more years after the green bond issue.[17] Standard errors are clustered at the two-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.

Financial Performance

To measure financial performance, I use ROA and 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 the 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 pretrend, (ii) the effect is positive but insignificant in the short run (i.e., 1 year after the green bond issue), and (iii) the effect is

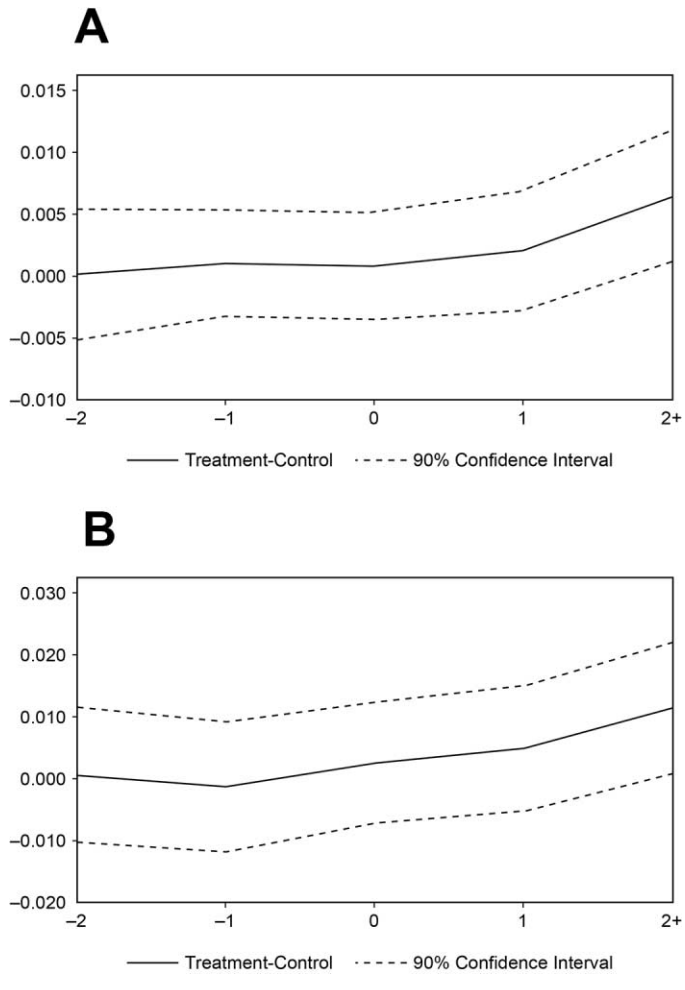

Fig. 8. Financial performance. *A*, Return on assets (ROA). *B*, Return on equity (ROE). Notes: This figure reports estimates of the difference-in-differences specification in equation (1) that compares green bond issuers with matched control firms. In panel *A*, ROA is the ratio of operating income before depreciation to the book value of total assets. In panel *B*, ROE is the ratio of operating income before depreciation to the book value of equity. The dotted lines represent the 90% confidence interval.

positive and significant in the long run (i.e., 2 or 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.

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 US 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, although there is no evidence for pretrends. Similarly, panel B documents a significant decrease in CO_2 emissions following the issuance of green bonds. In economic terms, the environmental 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.

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 earlier are large and significant for certified green bonds, whereas they are small and insignificant for noncertified green bonds. This echoes the event study findings and further highlights the importance of certification in the green bond market.

IV. 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

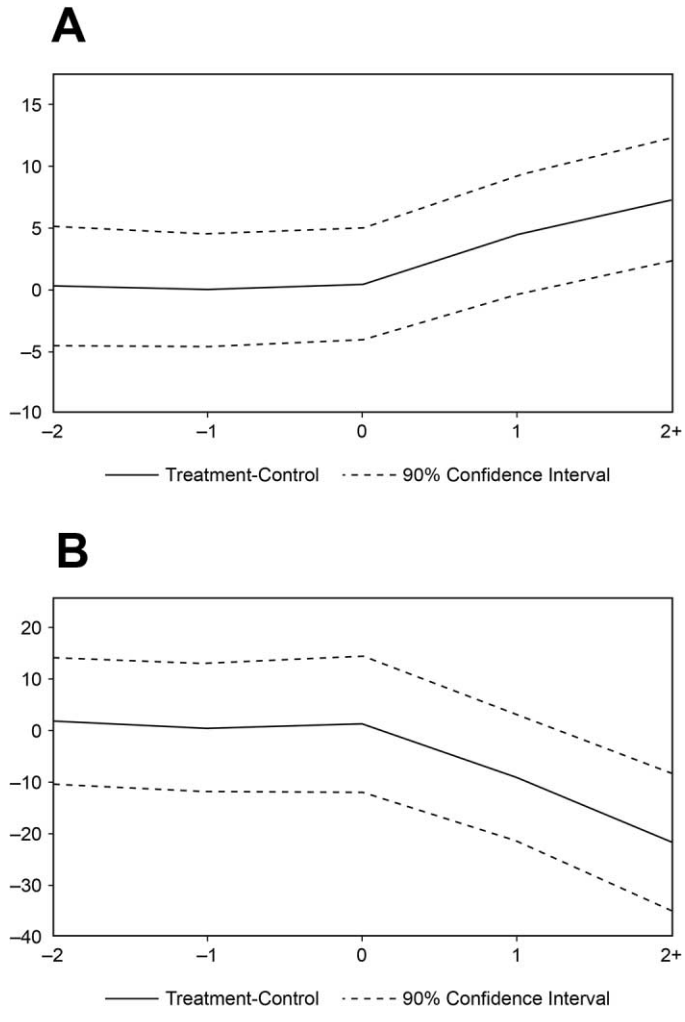

Fig. 9. Environmental performance. *A*, Environmental score. *B*, CO_2 emissions

Notes: This figure 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 US dollars. The dotted lines represent the 90% confidence interval.

world. The signing of the Paris Agreement in 2015 marked an important milestone in the fight against climate change.[19] Yet as the recent US example illustrates—President Donald J. Trump announced on June 1, 2017, the United States' 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 Organization for Economic Cooperation and Development (OECD) estimates that $93 trillion in infrastructure investment will be needed in the next 15 years to achieve a low-carbon future (OECD 2017). In comparison, the world's gross domestic product was about $80 trillion in 2017. This tremendous financing need represents an opportunity for the complementary use of private and public financing structures.

This paper examines one emerging instrument: green bonds—that is, 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 with a matched sample of (nongreen) 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 vs. noncertified 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. Although 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

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 GBP and the CBS. However, the lack of universal rules and standardization is a common concern among green bond investors. As the OECD notes, "Convergence towards commonly accepted definitions will be essential to maximise the effectiveness, efficiency and integrity of the market" (OECD 2017, 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 in terms of both the financial and environmental impact of green bonds. Although 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 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—for example, the replanting of trees in at-risk areas, the development of wind farms, and so forth. 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 ("regulatory surplus"), then 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 from 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.

Endnotes

I am grateful to Matthew Kotchen and Catherine Wolfram, as well as participants at the NBER Conference on Environmental and Energy Policy and the Economy for helpful comments. For acknowledgments, sources of research support, and disclosure of the author's material financial relationships, if any, please see https://www.nber.org/chapters/c14287.ack.

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.

2. More broadly, in a recent article in the *Stanford Law Review*, Park (2018, 1) notes that "in 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."

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.

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

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 labeled as green in Bloomberg.

7. The amount of green bond issuance (in dollars) has increased by about 175 times from 2010 to 2018, whereas the ratio of green bond issuance (compared with 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.

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 with a ratio of 0.138% across all sectors).

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-US bonds.

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).

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

15. Note that the difference is not significant (p-value = .389). Due to the limited sample size, there is little power to detect cross-sectional differences in statistical terms.

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 to 2017. Note that a broader characterization of the dynamics (i.e., splitting the τ = 2+ period into τ = 2, 3, 4, etc.) is not feasible because most green bonds are issued in the later years of the sample, and hence most issuers have no more than 2 postissue years available.

18. Compustat North America is used for US and Canadian companies, and Compustat Global is used for all other companies.

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

preindustrial levels and to pursue efforts to limit the temperature increase to 1.5°C above preindustrial 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 toward low greenhouse gas emissions and climate-resilient development.

20. Relatedly, the lack of public governance pertaining to the disclosure of nonfinancial 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 nonfinancial performance metrics. Also—and perhaps more importantly—the lack of public governance may lead to a lack of disclosure of nonfinancial information altogether. This issue arises, for example, in the context of companies' exposure to climate change risks. In many countries (including the United States), 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 (Sharfman and Fernando 2008; Dhaliwal et al. 2011; Cheng, Ioannou, and Serafeim 2014). 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, 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. They conclude that, in the absence of mandatory disclosure requirements, investors can play an important role in engaging with management to elicit the disclosure of climate risks.

21. For example, referring to airlines' carbon offset programs, Forbes (2019) notes that "balancing 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. 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.

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

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