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Where's the greenium?☆

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ABSTRACT

In this study, we investigate whether investors are willing to trade off wealth for societal benefits. We take advantage of unique institutional features of the municipal securities market to provide insight into this question. Since 2013, states and other governmental entities have issued over $23 billion of green bonds to fund eco-friendly projects. Comparing green securities to nearly identical securities issued for non-green purposes by the same issuers on the same day, we observe economically identical pricing for green and non-green issues. In contrast to a number of recent theoretical and experimental studies, we find that in real market settings investors appear entirely unwilling to forgo wealth to invest in environmentally sustainable projects. When risk and payoffs are held constant and are known to investors ex-ante, investors view green and non-green securities by the same issuer as almost exact substitutes. Thus, the greenium is essentially zero.

1. Introduction

Environmental, Social, and Governance (ESG) measurement, Corporate Social Responsibility (CSR) activities, and Socially Responsible Investing (SRI) are increasingly important research topics in both academic and professional areas. This recent research focus has been primarily due to the increased number of assets invested following ESG principles, now reportedly more than one-quarter of the $88 trillion of assets under management globally (Bernow et al., 2017).[1] As highlighted in Servaes and Tamayo (2013), while there is growing evidence of an association between ESG and CSR activities on security

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[1] Larry Fink, CEO of Blackrock, also highlighted the increased importance of ESG investing in his 2018 annual letter to CEOs that: " … a company's ability to manage environmental, social and, governance matters demonstrate the leadership and good governance that is so essential to sustainable growth, which is why we are increasingly integrating these issues into our investment process" (Fink, 2018). Similarly, the Business Roundtable recently (August 19, 2019) released a new Statement on the Purpose of a Corporation, signed by 181 CEOs who commit to lead their companies for the benefit of all stakeholders – customers, employees, suppliers, communities, and shareholders. See: https://tinyurl.com/y5ygufqs.

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pricing (e.g., Dhaliwal et al., 2011; Christensen, 2016; Christensen et al., 2017), comparatively little is known about the channels through which ESG factors may affect asset prices.

A question of primary importance is this area is whether ESG investments have value to investors beyond the expected risk and return attributes of a security. For instance, if we were to present investors with a high-ESG and low-ESG security whose risk and returns are identical, would investors pay more for the high-ESG security? While standard no-arbitrage arguments suggest these securities should price identically, there is a growing literature that argues otherwise. Several studies present theoretical models where investors are willing to give up financial benefits to invest in environmentally friendly or socially responsible assets (e.g., Friedman and Heinle, 2016; Heinkel and Kraus, 2001; Geczy et al., 2005). Similarly, the broader asset pricing literature that explores how investors' tastes for assets with particular characteristics can affect asset prices makes similar arguments (e.g., Fama and French, 2007; Hong and Kacperczyk, 2009).

Martin and Moser (2016) provide evidence of these effects showing that both investors and managers value green investments for their societal (non-pecuniary) benefits. This study shows that, in experimental markets, investors respond positively to reports of green investments even when it is independent of future cash flows and risk. They conclude that "… investors and managers trade off wealth for societal benefits." The critical question is whether such experimental results generalize to actual market settings.

In our analysis, we focus on United States municipal issuers because these entities have been one of the largest issuers of green bonds. This setting is ideal in exploring our research question in that these securities are explicitly issued to fund environmentally sustainable projects. As importantly, the way municipalities issue bonds provides a novel quasi-natural experiment to assess whether investors value the societal benefits associated with ESG activities. We leverage three unique institutional features of the United States municipal securities market to implement a methodological approach that is less prone to the standard correlated omitted variable critique of prior ESG research.

The first is that municipal issuers commonly price multiple tranches of securities, both green and non-green securities, on the same day with similar maturities. This occurs for several reasons, such as issuer requirements to track their use of funds to comply with IRS requirements (IRS, 2017), and limits to bond issuance by state constitutional mandates.[2]

The second feature of municipal bonds is that the credit for these green bonds is *identical* to the credit for their non-green counterparts (Woeppel, 2016; Fischer et al., 2019). Green bonds are identical to ordinary municipal bonds in all ways except the use of proceeds is allocated to fund "environmentally friendly projects" (e.g., sustainable water management and energy production). As noted in Fischer et al. (2019), "the only effective difference between a green bond and a non-green bond is the use of proceeds." Thus, we can attribute any differences in security pricing to investor preferences for non-monetary security features, rather than differences in expectations about future cash flows or risk.

Finally, although a relatively small and specialized asset class, there are strong reasons to believe that our setting is one where we are *most* likely to find a greenium (if it exists). Specifically, the average issuance size (supply) in our sample is small ($5.36 million on average) compared to corporate green bond issuances, which are often hundreds of millions (or even billions) of dollars. Since the size of green issues are small, there is ample opportunity for green investors to be the marginal trader (which would not be the case for very large green issues in a market setting where green investors do not have the capacity to buy most of the offering). Thus, our focus on small issues of green municipal securities are very likely to provide a powerful test of whether a greenium exists.[3]

The primary result of our paper is that the greenium, or the premium that green assets trade to otherwise identical non-green securities, is precisely equal to zero.[3] Our results are based on a sample of 640 matched pairs of green and non-green issues issued on the same day, with identical maturity and rating, and issued by the same municipality. We observe an economically trivial difference in yield (and spread) between green and non-green bonds of approximately 0.45 basis points (indicating a slight green bond discount).[4] In fact, in approximately 85% of matched cases, the differential yield is *exactly* zero. These results provide strong evidence that investors are unwilling to sacrifice returns to support environmentally friendly projects, and thus the greenium is equal to zero.

We also examine how much investment bankers charge for issuing green securities (or the underwriter's discount) in comparison to non-green securities. This is important for two reasons. First, it indicates whether banks consider green securities as riskier or more challenging to underwrite (e.g., Ederington, 1975; Joehnk and Kidwell, 1979). Second, one of the primary challenges attributed to the growth of green bonds in municipal markets is the perceived cost of issuance (e.g., Chiang, 2017). For our matched sample, we find that the underwriting cost charged for issuing green bonds is higher than non-green bonds. Specifically, borrowing costs are on average approximately 10% higher for green securities than almost

[2] In the context of green bonds, this also occurs so that issuers can ensure the funds generated from the issuance are used exclusively for environmentally friendly purposes.

[3] The inability of investors to take short positions in the municipal market prevents arbitrageurs from collapsing any pricing differential between securities (Duyne and Bullock, 2011).

[4] Specifically, we show that the marginal investor, or the investor that prices the asset, is not willing to pay a premium for the asset. Unsurprisingly, this is the investor of primary interest in the existing asset pricing literature (e.g., Graham et al., 2005; Hanlon et al., 2003; and many others).

identical non-green securities. The combination of equivalent yield and higher transactions costs is not consistent with the existence of greenium.[5]

We rule out several plausible alternative explanations for the lack of an observed premium. Specifically, we explore whether the lack of green demand, differences in liquidity between green and non-green securities, or so-called green-washing[6] behavior (e.g., Chiang, 2017; Grene, 2015) could explain our findings. Our results show that even for securities with the most restricted supply, estimated greeniums are also virtually zero. In general, there appears to be no relationship between issuance size and estimated premiums. We also examine differences in three liquidity proxies across our matched samples using analyses similar to our pricing tests. We find no meaningful association between green and non-green bonds and market liquidity.

Greenwashing concerns have arisen among investors due to the absence of a universal set of standards on whether a security is actually green (e.g., Grene, 2015; Chiang, 2018). In response to these concerns, several agencies have created a new form of economic certification to ensure issuers of green bonds are using the financing proceeds for environmentally friendly purposes. The Climate Bonds Initiative (CBI) is the leading provider of these services and has been used by a number of municipalities to provide third-party certification.[7] We explore the pricing effects of this certification and find no evidence that this leads to incremental yield benefits to municipalities. This finding mitigates concerns that greenwashing is responsible for our documented lack of premium.[8] Additional tests related to the underlying use of proceeds, and bond-specific green ratings also support these inferences.

In our final sets of tests, we explore various non-issuance cost-related benefits associated with green issuances. Specifically, some issuers have suggested that green issuances help to broaden the issuers' investors base (e.g., Chiang, 2017). We find evidence consistent with this as green issues have a lower amount of ownership concentration by approximately 12%–20%.[9] Other market participants have also suggested that while a greenium does not currently exist, as the market matures and gains momentum a greenium may emerge. We hypothesize and find that those states that value environmental sustainability issue more green bonds and pay these slightly higher costs for these perceived future benefits. Despite this effect, even in states with the highest level of green preferences (and therefore issuance), we still find no evidence of a current greenium.

Our study contributes to a burgeoning literature that attempts to isolate the channels through which ESG and CSR activities impact securities prices. Specifically, we present evidence that investor non-pecuniary preferences are unlikely to drive the asset pricing differentials previously found in some of the prior literature. Instead, it is much more likely that asset prices are a function of the impact of ESG and CSR on future firm profitability and risk. These results are consistent with several recent studies that show relations between CSR investment and future performance (e.g., Lys et al., 2015; Chen et al., 2018; Flammer, 2018b).

Our analyses also provide new policy-relevant insights on the pricing of green securities of municipal markets and the benefits of third-party certification. Based on prior research that claims to document a greenium, some policy analysts are calling for *more* green bond issuance to reduce the cost of government borrowing (e.g., Saha, 2018). Our results suggest just the opposite conclusion. Not only is there no pricing differential, but investment banks also appear to charge slightly more to issue green bonds on average. As there are other costs associated with green bond issuance, our results suggest that municipalities increase their borrowing costs by issuing green bonds.[10]

The remainder of the paper consists of six sections. The next section discusses the motivation for our study and a review of the prior literature most pertinent to our research question. Section 3 outlines and justifies our methodological approach. Section 4 describes the sample construction, data sources, and measures used in the empirical analyses. We discuss our main empirical results of the paper in Section 5. Section 6 explores a number of potential alternative explanations for our documented findings. In Section 7, we reconcile why issuers choose to issue these securities despite no apparent cost savings. Finally, Section 8 provides an interpretation of the results and concluding remarks.

2. Motivation and review of prior literature

Understanding the arguments and functional form of investors' utility functions is of first-order importance across accounting, economics, and finance. Given the claimed increased importance of ESG factors for investors (e.g., Białkowski and Starks, 2016; Bernow et al., 2017) and recent regulatory concerns over ESG (e.g., SEC, 2018; Bradford, 2019), it is crucial for practitioners and researchers to know whether investor utility functions only include expected risk and return or exhibit additional (non-pecuniary) arguments related to environmental and social consequences.

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[5] As discussed in Appendix B, this estimated discount is produced by a handful of outliers. In particular, these observations differ in several other ways that are likely to be driving their abnormal behavior. Specifically, these matches tend to vary across security size, as well as the coupon rate. After removing these outliers, the pricing differentials are precisely zero.

[6] However, in approximately 68% of the cases, the differential underwriting cost is equal to zero.

[7] Greenwashing occurs when the use of funding proceeds are for purposes that have little environmental value (Climate Bonds Initiative, 2017).

[8] See: https://www.climatebonds.net/certification.

[9] Among securities that are CBI Climate Certified in our matched sample, the yield differential between green and matched non-green issues is exactly zero in 91% of cases.

[10] We find little evidence of differences related to the makeup of institutional versus retail investors.

The theoretical idea that investors may value securities beyond their expected risk and return attributes is not novel. However, isolating this effect in real market settings has proven challenging. Prior studies attempt to elicit these preferences from experimental or survey data (e.g., Martin and Moser, 2016; Riedl and Smeets, 2017). Other studies use estimates of *ex-ante* expected returns and risk from ex-post returns and security characteristics (e.g., Barber et al., 2018; Białkowski and Starks, 2016; Hong and Kacperczyk, 2009; Geczy et al., 2005). However, whether investors are willing to forgo financial benefits in real market settings, when risk and return are known *ex-ante*, remains an open question.

Green bonds offer a unique setting to explore this issue. Through the end of 2017, bond issuers have raised a cumulative $221 billion through self-labeled green bonds to finance climate change solutions and other green projects (Climate Bonds Initative, 2018). In all other ways, these securities function similar to standard debt securities issued by corporations and municipalities. The interesting research question is whether these securities price with a greenium (Chiang, 2017; Climate Bonds Initiative, 2017); that is, whether investors in bond markets are willing to sacrifice returns to invest in environmentally sustainable assets.

We focus on the municipal green bond market because it offers a nearly ideal setting to explore this research question.[11] From a methodological standpoint, our focus on green municipal bonds allows us to take advantage of several unique institutional attributes of municipal markets. One especially useful feature is that municipal issuers commonly issue otherwise identical green and non-green municipal securities at the same time. These securities are identical to ordinary municipal bonds, with the key exception being that the use of proceeds for one of the bonds funds environmentally friendly projects. Therefore, as noted by Crabbe and Turner (1995), it is possible to use a model-free matching method in our setting to estimate treatment effects.[12] Specifically, we can compare yields, spreads, and other bond attributes for nearly identical securities from the same issuer on the same issue date.

A second useful feature is that the average issuance size of our municipal bonds is only about $5 million. This is much smaller than the average issuance size of approximately $400 million for United States corporate bonds issued during a similar sample period, as reported by Flammer (2018a). Since the size of green issues is small, there is ample opportunity for green investors to be the marginal trader, which would not be the case for very large green issues in a market setting where green investors do not have the capacity to buy most of the offering. This means that investors with utility for green investments and the willingness to trade off bond yield for green use of funds are likely to be the marginal trader setting the price of the bond. Thus, there are strong reasons to believe that our setting is one where we are *most* likely to find a greenium (if it actually exists).

While several contemporaneous studies provide estimates for the green bond premium, the results of these prior studies are quite mixed.[13] The studies most closely related to our paper are Karpf and Mandel (2017) and Baker et al. (2018). Both of these studies use a large sample of issued green bonds in the municipal market (consisting of approximately two-thirds of our sample). Karpf and Mandel (2017) find a green bond discount (positive yield differential) of approximately eight basis points, whereas Baker et al. (2018) find a green bond premium of about six basis points. Although the findings of both studies are provocative, they are inconsistent with discussions by industry practitioners. For instance, participants responding to a survey by the State Treasurers Office of California on green bonds unanimously stated: "their firms would not accept a lower yield for a green bond" (Chiang, 2017).[14]

We believe that the mixed evidence from prior studies is the result of methodological design misspecifications that produce biased estimates. These concerns are not unique to our setting and have been prevalent in the ESG and CSR literature (e.g., Servaes and Tamayo, 2013; McWilliams and Siegel, 2000). As noted in Baker et al. (2018), Karpf and Mandel (2017) compare taxable and non-taxable securities in their tests (i.e., they ignore the critical role of taxation in the municipal securities market). Baker et al. (2018) use a pooled fixed-effects model in their analyses.[15] We show in Section 5.4 that this approach is insufficient to adequately control for nonlinearities and issuer-specific time variation, which ultimately leads to spurious inferences. We avoid these problems by taking advantage of the unique institutional features of the municipal securities market that give us a nearly perfect counterfactual security.

3. Methodology

Our methodological approach is similar to that used in Crabbe and Turner (1995), Bernstein et al. (2019), and Schwert (2020). To illustrate our methodology, consider as an example, the $362 million deal by Arizona State University. As

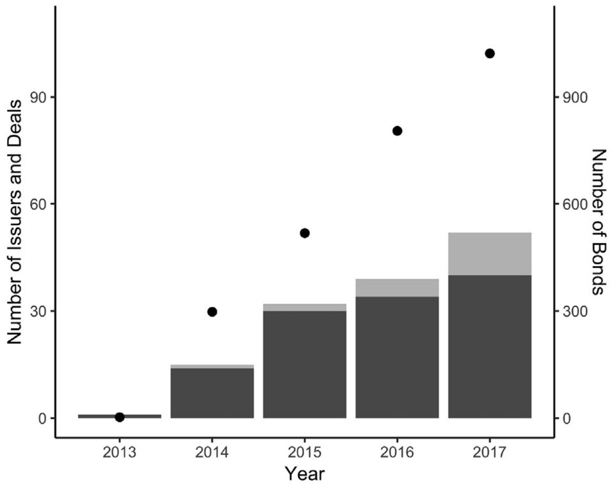
[11] In particular, certification costs are tens of thousands of dollars. One municipal advisor also noted higher administrative costs to track use of proceeds, and ongoing compliance, which can be "a burden" to their clients.

[12] Although still a relatively small portion of the total market in terms of securities outstanding, municipal securities make up a disproportionate amount of the green bond issuance in terms of total securities. For instance, as seen in Fig. 1, from 2013 to 2017, over $23 billion of self-labeled green bonds have been issued in municipal markets, for more than 2500 individual securities. By comparison, over the same sample period, Flammer (2018a) reports approximately $14.3 billion in green corporate securities in the United States, but only 61 individual securities were issued. Thus, focusing on municipal securities provides an extensive sample of securities and issuers for our empirical tests.

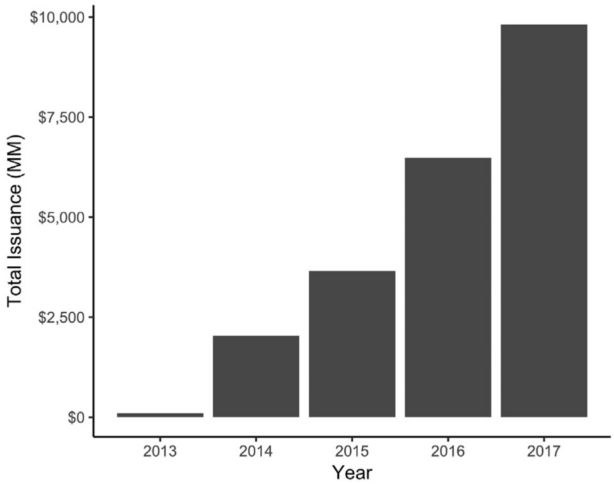
[13] We use the phrase "model-free" to mean that results do not depend on any parametric assumptions about functional form (e.g., Loumioti and Vasvari, 2018).

[14] Moreover, in most cases, the analysis is based on only a small set of securities (e.g. Ehlers and Packer, 2017; Climate Bonds Initiative, 2017).

[15] Our conversations with several traders, portfolio managers, and bankers that are focused on municipal securities mirror these sentiments. This includes a managing director and head of tax-exempt securities at a large fund group; investment bankers at a large bulge bracket bank; and a portfolio manager in charge of tax-exempt securities at a municipal hedge fund.



(a) Growth in Issuers, Deals, and Bonds



(b) Growth in Total Dollar Issuance

Fig. 1. Trends in municipal green bond issuance. Panel (a) presents total annual municipal tax-exempt, fixed-rated green bond issuance statistics on the number of issuers (dark gray bar; left-axis), number of individual deals (dark gray + light gray bars; left-axis), and number of individual bonds (black dots; right-axis). Panel (b) presents total tax-exempt, fixed-rated issuance volume (by par value) of self-labeled green bond issues by year.

shown in Panel A of Fig. 2 (the header of the cover page of the offering statement), the deal was brought to the market on the same day with three series of securities tranches for investors. The funds raised by the three securities were to be used to refinance outstanding debt, refurbish existing buildings, and construct new buildings. The securities also allowed investors to invest directly in the creation of sustainable buildings. The official statement makes the uses of these funds explicit (italics added for emphasis):

The purpose of labeling Series 2015A Bonds as green bonds *is to allow investors to invest directly in projects which the University has identified as promoting environmental sustainability on the University's campuses*. The University intends to pursue LEED (Leadership in Energy & Environmental Design) certification for the green bond Project. LEED is a green building certification program offered by the United States Green Building Council. Projects submitted for LEED certification are reviewed by the Green Building Certification Institute, a third-party organization, and assigned points based on the project's implementation of strategies and solutions aimed at achieving high performance in: sustainable site development, water efficiency, energy efficiency, materials selection, and indoor environmental quality, among other sustainable qualities.

Panel B in Fig. 2 presents the pricing information for these securities. We see that there are many overlapping maturities in both Series 2015B (green bonds) tranche and the non-green 2015B tranche. For each bond in Series 2015B (green bonds) tranche of securities, our matching procedure selects every security in the non-green 2015B tranche with a similar maturity. The securities outlined in red indicate one such match. We repeat this procedure for every identified green bond in our sample described in Section 4.

ARIZONA BOARD OF REGENTS
ARIZONA STATE UNIVERSITY

$182,645,000 SYSTEM REVENUE AND REFUNDING BONDS, SERIES 2015A (GREEN BONDS)	$164,615,000 SYSTEM REVENUE AND REFUNDING BONDS, SERIES 2015B	$15,000,000 SYSTEM REVENUE BONDS, TAXABLE SERIES 2015C

Dated: Date of Delivery **Due: July 1, as shown on the inside front cover page**

(a) Green and non-Green Issuance on the Same Day

$182,645,000
SYSTEM REVENUE AND REFUNDING BONDS,
SERIES 2015A
(GREEN BONDS)

Maturity (July 1)	Principal Amount	Interest Rate	Yield	CUSIP[a] (04048R)	Maturity (July 1)	Principal Amount	Interest Rate	Yield	CUSIP[a] (04048R)
2015	$1,610,000	2.00%	0.10%	KW5	2027	$12,850,000	5.00%	2.70%[b]	LF1
					2028	14,460,000	5.00	2.83[b]	LG9
2019	25,000	2.00	1.32	KX3	2029	3,305,000	5.00	2.91[b]	LH7
2020	7,345,000	5.00	1.58	KY1	2030	3,475,000	5.00	2.97[b]	LJ3
2021	8,100,000	5.00	1.74	KZ8	2031	3,645,000	5.00	3.02[b]	LK0
2022	10,065,000	5.00	2.00	LA2	2032	3,835,000	5.00	3.07[b]	LL8
2023	10,565,000	5.00	2.16	LB0	2033	4,025,000	5.00	3.11[b]	LM6
2024	11,105,000	5.00	2.34	LC8	2034	4,230,000	5.00	3.15[b]	LN4
2025	11,655,000	5.00	2.44	LD6	2035	4,435,000	5.00	3.19[b]	LP9
2026	12,230,000	5.00	2.59[b]	LE4	2036	4,655,000	5.00	3.22[b]	LQ7

$22,670,000 5.00% Term Bond due July 1, 2041 at a yield of 3.31%[b] CUSIP[a]: 04048RLR5

$28,360,000 4.00% Term Bond due July 1, 2046 at a yield of 3.80%[b] CUSIP[a]: 04048RLS3

$164,615,000
SYSTEM REVENUE AND REFUNDING BONDS,
SERIES 2015B

Maturity (July 1)	Principal Amount	Interest Rate	Yield	CUSIP[a] (04048R)	Maturity (July 1)	Principal Amount	Interest Rate	Yield	CUSIP[a] (04048R)
2015	$1,405,000	2.00%	0.10%	LT1	2026	11,640,000	5.00%	2.59%[b]	MB9
2016	185,000	3.00	0.40	MQ6	2027	9,545,000	5.00	2.70[b]	MC7
2017	220,000	3.00	0.75	MR4	2028	4,745,000	5.00	2.83[b]	MD5
2018	250,000	3.00	1.13	MS2	2029	4,930,000	5.00	2.91[b]	ME3
2019	8,475,000	5.00	1.32	LU8	2030	5,195,000	5.00	2.97[b]	MF0
2020	9,790,000	5.00	1.58	LV6	2031	5,505,000	5.00	3.02[b]	MG8
2021	11,515,000	5.00	1.74	LW4	2032	5,815,000	5.00	3.07[b]	MH6
2022	7,080,000	5.00	2.00	LX2	2033	6,140,000	5.00	3.11[b]	MJ2
2023	7,475,000	5.00	2.16	LY0	2034	6,485,000	5.00	3.15[b]	MK9
2024	7,860,000	5.00	2.34	LZ7	2035	6,830,000	5.00	3.19[b]	ML7
2025	8,305,000	5.00	2.44	MA1	2036	2,985,000	5.00	3.22[b]	MM5

$14,320,000 5.00% Term Bond due July 1, 2041 at a yield of 3.31%[b] CUSIP[a]: 04048RMN3

$17,920,000 4.00% Term Bond due July 1, 2046 at a yield of 3.80%[b] CUSIP[a]: 04048RMP8

(b) Example of an "Exact Match"

Fig. 2. Methodological illustration. This figure presents an illustration of the matching procedure used in this study. Panel (a) presents the header of the official statement showing a green and non-green tranche of securities from the same issuer simultaneously being priced on the same day. Panel (b) presents the pricing for the securities in both the green and non-green issues, with the red outlines highlighting one example of a matched set in our sample.

Table 1
Sample construction.

	Bonds	Deals	Issuers	Matches
Panel A: Sample construction				
Full Bloomberg Green bond sample	4321	386	261	
Remove adjustable rate and tender offer bond issues	4200	351	257	
Drop issues dated before June 2013	3694	240	161	
Remove federally taxable securities	3142	175	107	
Mergent match	3097	169	104	
Drop bonds labeled as non-Green by Mergent	2896	154	90	
Total matches	568	48	30	640
Same issuer/structure/issuance day match	555	44	28	627
Same issuer and issuance day match	13	12	10	13

	Mean	SD	$p^{1\%}$	$p^{25\%}$	$p^{50\%}$	$p^{75\%}$	$p^{99\%}$	N
Panel B: Bond Characteristics (Matched Green Sample)								
Issue Amount ($ MM)	5.355	10.054	0.067	0.429	2.127	4.709	50.552	640
Coupon Rate (%)	3.903	1.204	1.400	3.000	4.000	5.000	5.000	640
Yield (bps)	224.196	74.948	62.000	173.750	223.000	278.000	400.000	640
Price (% Par)	111.406	9.857	98.676	100.000	113.402	120.287	128.701	640
Issuance Spread (bps)	25.010	26.063	−33.610	5.500	23.500	43.000	92.000	640
Underwriter Discount (%)	0.418	0.219	0.087	0.234	0.393	0.545	1.203	629
Turnover	0.919	1.241	0.000	0.000	0.427	1.328	6.019	627
Institutional Ownership (%)	74.515	38.955	0.000	59.167	97.955	100.000	100.000	543
Panel C: Bond Characteristics (Matched Non-Green Sample)								
Issue Amount ($ MM)	5.645	10.868	0.062	0.629	2.345	5.836	40.511	640
Coupon Rate (%)	4.063	1.197	1.400	3.000	5.000	5.000	5.000	640
Yield (bps)	223.760	75.261	62.000	172.750	223.500	277.250	400.000	640
Price (% Par)	112.418	9.985	99.479	100.000	115.545	121.216	129.062	640
Issuance Spread (bps)	24.569	26.107	−33.610	6.000	23.000	43.000	92.000	640
Underwriter Discount (%)	0.366	0.199	0.086	0.175	0.373	0.533	0.951	601
Turnover	0.975	1.351	0.000	0.000	0.500	1.395	5.438	627
Institutional Ownership (%)	77.686	38.377	0.000	79.818	100.000	100.000	100.000	508

This table summarizes the construction of the municipal bond transaction sample used throughout this study. Panel A describes the steps in selecting our matched sample. See Section 4 for a description all steps used in the sample construction. Panel B describes the distribution of bond characteristics for all green bonds used in our matched sample. Panel C describes the distribution of bond characteristics for all matched non-green bonds.

Using the pairs created in the above matching procedure, we calculate the average treatment effect of a security being green over various outcome variables as:

$$\widehat{\tau} = \frac{1}{N}\sum_{i=1}^{N}\left(Y_i^G - Y_i^{NG}\right)$$

where N represents the total number of matches in our sample, Y_i^G the outcome variable for the green bond in match i, and similarly Y_i^{NG} the outcome variable for the associated non-green bond. In essence, our design is similar to a behavioral experiment where the experimenter presents a green bond and a similar non-green bond for sale to market participants. The key assumption is that the matching of the two securities issued by the same municipality, at the same date, and having essentially the same terms will effectively control for the primary confounding factors that could lead to spurious inferences. As with any observational study there is always the possibility of unobserved correlated omitted variables. However, we believe our methodological approach mitigates most validity threats.

4. Sample selection

4.1. Data cleaning

We identify our sample of green bonds using Bloomberg's comprehensive sample of self-labeled green bonds in the municipal market. Industry professionals consider this source to be the most comprehensive publicly available list of green municipal securities. We acknowledge that there are some incorrectly marked securities in these data. For example, there are a number of securities identified as green before 2013, even though the first self-labeled green bond was marketed in June 2013 (S&P Global Ratings, 2018). Therefore, we perform several data cleaning steps outlined in Panel A of Table 1 to construct our final sample.

We begin by restricting our sample to fixed-rate coupon bonds to simplify yield calculations. We drop municipal issues before June 2013 because they are unlikely to have been marketed as green bonds. This filter also removes a number of securities subject to special tax credits. Bonds issued under the Clean Renewable Energy Bonds (CREB) and Qualified Energy

Conservation Bonds (QECB) programs, which comprise almost the entirety of the pre-2013 sample, allow tax credits that count against taxable income (IRS, 2018). In this subset of securities, it would be impossible for us to disentangle whether an estimated premium was due to the tax credit or because issuers used the bond proceeds for green projects.

To ensure similar tax treatment across our sample, we remove all federally taxable securities (e.g., Schwert, 2017). The Mergent match step restricts our sample to the period for which we have issuance data (up to July 2018). Our final data cleaning step selects only those securities that are labeled as green by both Bloomberg and Mergent to remove mislabeled securities. This excludes 15 individual deals that we manually confirmed Bloomberg mislabeled as green bonds based on the offering documentation.

4.2. Matched set creation

After the data cleaning stage, 2896 green bonds across 154 separate issues from 90 issuers remain. We attempt to match these green securities to the other 652,391 (non-green) securities issued during this period in the Mergent database. Following Crabbe and Turner (1995), we use a simple matching procedure in which we select issues that are identical in terms of structure and issued by the same issuer on the same day. Specifically, for each green bond, we search our non-green control sample for a security identical in the following ways: issuer, rating, and call dates. We also drop any matched pairs in which the securities are callable, and the coupons are unequal. Differing coupon rates for callable bonds have a substantial effect on the value of the internal interest rate option, which makes comparability impossible across securities.

Our final selection restriction is to limit the differentials in maturity to be within one year. This restriction maximizes the number of securities for which we can obtain matches, while also minimizing the differences in the slope of the credit spread. For securities where we were able to find an exact maturity match, we omit the non-exact maturity matches from our sample. Similar to Crabbe and Turner (1995), we allow any green bond to be matched to multiple control bonds so long as they meet the above restrictions. The final sample of matches contain 640 matched pairs, over 568 individual green bonds across 48 separate offerings for 30 unique issuers.[16] As shown in Panel A of Table 1, 627 matched pairs are considered exact matches (i.e., the pairs have identical maturities).

4.3. Descriptive statistics

In Panels B and C of Table 1, we present descriptive statistics on various characteristics and outcome variables used in this study. Both the green bond sample and non-green control sample are of similar issuance size with a mean (median) of \$5.35 (\$5.65) million, respectively. Average coupons and prices are also quantitatively similar with an average coupon rate of 3.9% and 4.06% and price of 111.41% and 112.42% of par, for the green and control samples, respectively.[17]

Comparing issuance yields, spreads, underwriter's discount, and turnover across samples provide a preview of our main results. Specifically, yield and spread are nearly identical across the green and non-green samples. The sample mean for yield (spread) in basis points is 224.2 and 223.76 (25.01 and 24.57) for the green and matched non-green samples, respectively. Comparative differences for turnover and underwriters discounts also suggest similar inferences. In contrast, there does appear to be a slightly higher underwriter's discount for the green sample with an average underwriter's discount of 0.416% versus 0.366% for the non-green sample.[18]

4.4. Sample comparisons

Since we only select matched pairs of securities, we are dropping a large portion of the outstanding green securities. In Table 2, we consider how our sample differs from both the universe of green securities and the overall sample of municipal securities. We compare the average characteristics of all tax-exempt municipal green bonds in Column 1 (Column All GB), those primarily used in this study in Column 2 (Matched GB), and the full universe of tax-exempt municipal bonds in Column 3 (All Bonds). These comparative results provide insight into whether it is appropriate to generalize our findings to other relevant samples of municipal bonds.[19] It also makes apparent potential issues associated with across-issuer designs to estimate green bond premiums.

In Table 2, we see that our sample of municipal securities exhibits several differences from the general green bond universe. While many of these comparisons are statistically significant, the differences are very modest in substantive economic terms. For instance, our sample of securities is of slightly lower credit quality with differences in the aggregate rating of about -0.13. This maps into approximately one-tenth of a one-notch downgrade (i.e., from A+ to A) by S&P. We also slightly

[16] They also include many securities from the Clean Renewable Energy Bonds (CREB) and Qualified Energy Conservation Bonds (QECB) programs with unique tax benefits that makes cross-asset comparability difficult. We discuss this issue in Section 4.

[17] For comparative purposes, Crabbe and Turner (1995) use a sample of 605 matched pairs over 4 issuers while the primary sample used in Schwert (2020) contains 245 matched pairs over 124 issuers.

[18] Banks structure nearly all tax-exempt municipal bonds at a premium to par because of tax reasons (Landoni, 2018). Observing an issuance price premium in this setting tells us nothing about the existence of a greenium.

[19] The difference in observations for Underwriters Discounts and Turnover is due to missing observations from the Bloomberg database or insufficient secondary market data. We perform all analyses for each matched set where we have information for both the green and non-green securities.

Table 2
Sample characteristic comparisons.

Variable	All GB (1)	Matched GB (2)	All Bonds (3)	(1)-(2)	(1)-(3)
Aggregate Rating	2.492	2.622	3.620	-0.13*	-1.128***
CBI Climate Certification	0.097	0.088	0.000	0.010	0.097***
Large Issuer	0.732	0.966	0.213	-0.234***	0.518***
Offering Year 2013	0.001	0.000	0.104	0.001	-0.103***
Offering Year 2014	0.103	0.084	0.179	0.019	-0.076***
Offering Year 2015	0.179	0.183	0.216	-0.004	-0.037***
Offering Year 2016	0.278	0.195	0.228	0.083***	0.050***
Offering Year 2017	0.353	0.406	0.194	-0.053*	0.159***
Offering Year 2018	0.086	0.131	0.078	-0.045**	0.008
Issuance Yield	2.304	2.242	2.250	0.062	0.054***
Callable	0.547	0.445	0.460	0.101***	0.087***
Fitch LT Rating	2.086	1.797	3.135	0.289***	-1.049***
Moodys LT Rating	2.429	2.827	3.499	-0.399***	-1.07***
S&P LT Rating	2.342	2.387	3.550	-0.045	-1.208***
Refunding	0.313	0.300	0.507	0.013	-0.194***
Issue Amount ($ MM)	8.051	5.355	2.925	2.696***	5.126***
Deal Size ($ MM)	156.128	107.557	43.673	48.571***	112.454***
Years to Maturity	12.011	10.829	9.564	1.182***	2.447***
N	2,896	640	652,391		

This table presents average sample characteristics of all tax-exempt municipal green bonds, the subsample of green bonds used in this study, and all municipal bonds. The column labeled "All GB" presents the average characteristics of all municipal green bonds from Bloomberg's comprehensive sample of self-labeled green bonds. Column "Matched GB" presents the average characteristics of all municipal green bonds for which we are able to identify same issuer, issuance day, and structure matches as described in Section 3. Column "All Bonds" presents the average sample characteristics of the full universe of municipal issues (in the Mergent municipal database) as described in Section 4. All variables are as defined in the Appendix. The differences in sample average between samples is calculated using a standard two-sided *t*-test. Levels of significance are presented as follows: p<0.1*; p<0.05**; p<0.01***.

underweight issuance in the year 2016, while overweighting deals later in the sample in the years 2017 and 2018. Finally, our sample of securities is about 1.2 years shorter in maturity than the general green bond sample.

There are two primary differences between our green bond sample and the general universe of green bonds. First, our sample overweights securities issued by large issuers. We would expect the issuers that are raising funds for multiple projects concurrently to be larger municipalities. Second, the deal and maturity sizes are smaller. These differences are most likely attributable to the fact that issuers have chosen to carve the deal up into multiple series. Importantly, there is no obvious reason to believe that these comparative differences would affect the generalizability of our inferences to the general universe of green municipal bonds.

We see significant differences between the universe of green bonds and the universe of other municipal securities. In particular, we observe numerous differences in green issues from the broader sample of municipal securities related to the size and credit quality of the issuers. For instance, green bonds are, on average, approximately one notch higher in credit quality, which may reflect wealthier municipalities' preferences towards environmental sustainability. Additionally, although green bonds are, on average, 2.4 years longer than the general universe of standard issues, their yields are 5.4 basis points lower. Finally, green bonds are significantly more likely to be issued by large issuers, with a statistically significant difference of approximately 51.8% between the green and non-green samples. These differences are also evident in the considerable differences in the size of the deal, where green bond deals are, on average, more than three times larger than non-green bond deals.

Overall, our matched sample of green bonds exhibits minimal differences across a variety of covariates from the general universe of green municipal bonds. We have little reason to believe this impacts our ability to generalize our results to the broader universe of green municipal bonds. In contrast, the observed differences between green and non-green samples are substantial. These significant differences highlight the difficulty of dealing with selection and omitted variable bias when comparing green to non-green issuers to make inferences about the effects of being green. For these reasons, we rely on a within-issuer, as opposed to across-issuer, design.

4.5. Municipal green rating data

HIP Investor, founded in 2006, is one of the leading providers of ESG data to investors. The company compiles data to provide ratings, across various ESG categories, for approximately 112,500 bond issuances. These ratings, scaled from 0 to 100, are increasing in how ESG compliant the issuer or issue is across various ESG areas, one of which is environmental sustainability.

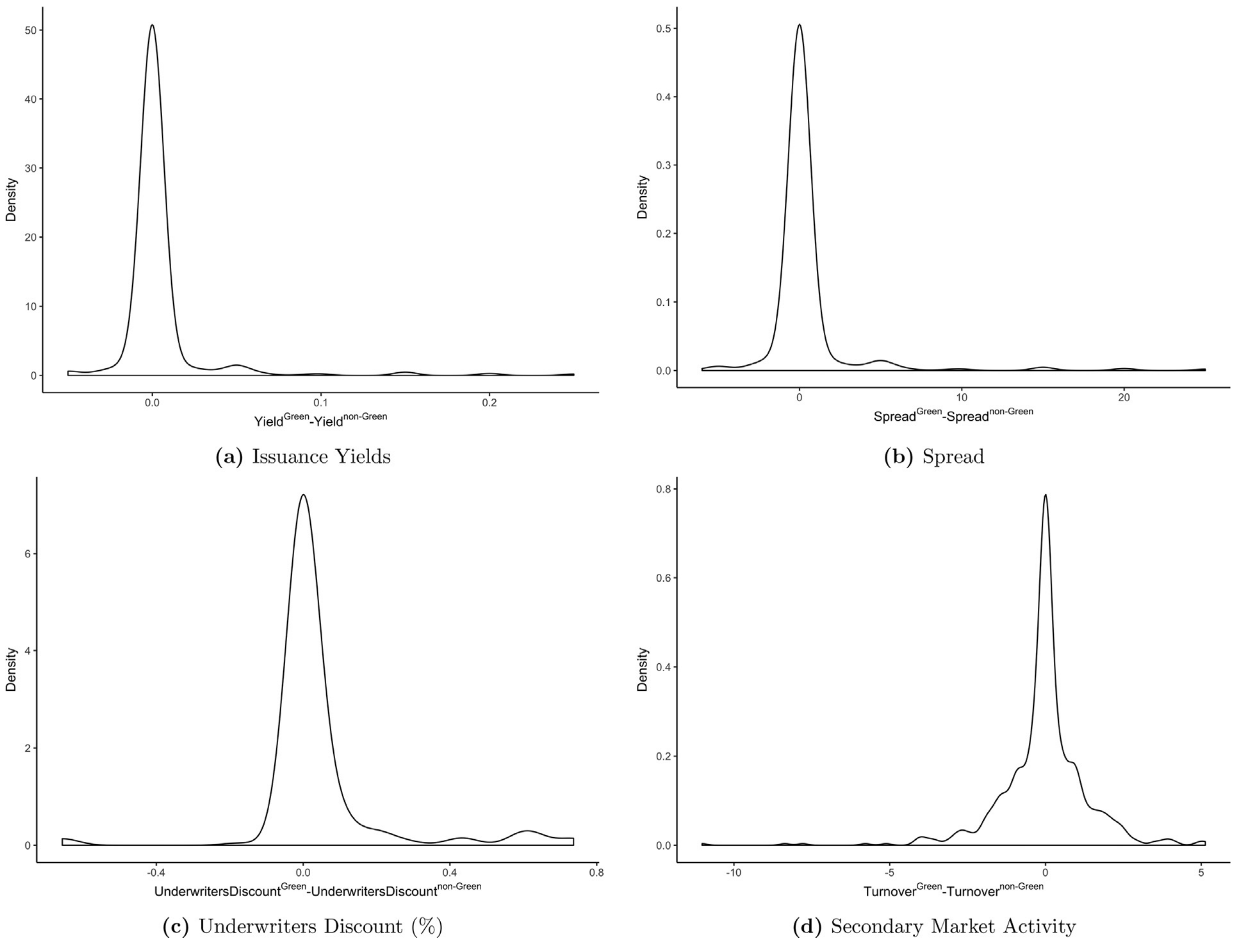
We obtain two data sets from HIP Investor. The first data includes the "Earth" ratings of all census-designated places (CDPs) rated by HIP Investor in all 50 United States, Washington D.C., and Puerto Rico. HIP Investor designed this measure to capture the level of environmental consciousness of local governments based on various inputs such as a city's use of recycled water and many other similar metrics. Second, we obtain bond-level Earth ratings of all green bond issues in our matched sample (where available from HIP Investor). These ratings are project-specific, and higher values indicate that the project makes a more significant impact in terms of improving the environment.

5. Estimating the greenium

5.1. Kernel density estimates of differences

We begin our analyses by considering the univariate distribution of differences between our matched pairs of green and non-green bonds for our variables of interest ($Y_i^G - Y_i^{NG}$). Examining these distributions provides insight into the frequency with which these measures differ, as well as their magnitudes. We present kernel density estimates for each of our four variables of primary interest in Fig. 3.

The top two panels present pricing evidence based on offering yields and spreads. This visual evidence is consistent with there being little pricing differential between green and non-green securities. We see a large mass directly at zero, which is indicative of zero pricing differential (at issuance) between green and non-green securities. The estimated density is extremely right-skewed with thin tails, and this indicates that there are a small number of extreme observations (outliers) in the matched pairs where there exists a positive pricing differential. We discuss this issue in Appendix B and conclude that



(a) Issuance Yields (b) Spread

(c) Underwriters Discount (%) (d) Secondary Market Activity

Fig. 3. Kernel density estimates for green and non-green differentials. These figures provide the estimated kernel densities for the yield, spread, underwriters discounts, and total quarterly turnover differentials for the matched sets described in Section 4. Each plot uses a Gaussian kernel and the Silverman rule for bandwidth selection.

Table 3
Matched sets tests for a relationship between green-label and costs of borrowing.

	Exact Matches		All Matches	
	Mean	Median	Mean	Median
Panel A: Initial offering yields				
Green	222.874	222.000	224.196	223.000
Non-Green	222.415	221.000	223.760	223.500
Difference	0.459	1.000	0.436	−0.500
Statistic	4.217	−3.784	3.797	−3.421
(p-value)	(< .01***)	(< .01***)	(< .01***)	(< .01***)
Total Matches	627		640	
% Matches Zero Difference	84.848		83.438	
% Matches Neg. Difference	5.742		6.406	
% Matches Pos. Difference	9.410		10.156	
Panel B: Initial Offering Spreads				
Green	24.929	23.500	25.010	23.500
Non-Green	24.470	23.000	24.569	23.000
Difference	0.459	0.500	0.441	0.500
Statistic	4.217	−3.827	4.101	−3.499
(p-value)	(< .01***)	(< .01***)	(< .01***)	(< .01***)
Total Matches	627		640	
% Matches Zero Difference	84.848		83.594	
% Matches Neg. Difference	5.742		6.250	
% Matches Pos. Difference	9.410		10.156	
Panel C: Underwriters Discount				
Green	41.087	38.600	40.957	38.600
Non-Green	36.623	37.300	36.591	37.300
Difference	4.465	1.300	4.366	1.300
Statistic	6.060	−6.928	6.025	−6.852
(p-value)	(< .01***)	(< .01***)	(< .01***)	(< .01***)
Total Matches	590		601	
% Matches Zero Difference	67.627		67.72	
% Matches Neg. Difference	9.492		9.651	
% Matches Pos. Difference	22.881		22.629	

This table presents matched sample tests on the borrowing cost differentials between green and non-green securities. All measures are as defined in the Appendix and measured in basis points. Green bonds are assigned to a matched (exact matched) set if they are issued on the same day, have a maturity date within one year (same maturity date) of a non-green bond, have the same rating, and are issued by the same issuer. For each matched set, the differences in mean (median) between green and non-green securities is calculated using a standard paired two-sided *t*-test (Wilcoxon test). Levels of significance are presented as follows: p<0.1*; p<0.05**; p<0.01***.

these observations are quite unusual. For consistency, we retain these securities in our sample since that has virtually no impact on our inferences.

In terms of underwriter's discounts and post-issuance turnover, we again see a distribution essentially centered around zero differential between green and non-green bonds. This finding is interesting, given that markets determine underwriter's discounts and post-issuance turnover in an entirely different manner than yield and spread. Specifically, the issuer and the underwriter typically negotiate the underwriter's discount, while the level of market trading activity determines post-issuance turnover.

Overall, issuance yields, spreads, underwriting discounts, and aftermarket liquidity are virtually identical between green and non-green municipal securities. We also observe a large mass of observations where the differential between these variables is precisely equal to zero.

5.2. Analysis of matched-pairs of green and non-green bonds

In Panels A and B of Table 3, we present the mean and median pricing differentials between the two samples, along with paired t-tests and Wilcoxon tests for the statistical significance in differences between the matched sample.[20] For our sample of exact matches, as defined in Section 4, the difference between mean (median) yield and spread is a statistically significant 0.459 and 0.459 (1.0 and 0.5), respectively. When looking at the difference between mean (median) yield and spread for all matches, we estimate a statistically significant difference of 0.436 and 0.441 (−0.5 and 0.5) respectively. Rather than implying a green bond premium, this slightly positive differential indicates a green bond discount.

[20] By construction, our matched non-green sample (not considered in Table 2) is economically identical across all variables considered here except for Issue Amount. As discussed in the prior section, there are no statistical differences over this variable between our matched green bond sample and non-green bond sample.

As shown in Fig. 3, the economically insignificant 0.4 basis point yield differential appears to be largely the result of a handful of unusual observations or outliers. In fact, for approximately 85% of cases, the differential yield and spread is *exactly* zero. Moreover, among the remaining 15% of securities, approximately 40% imply a negative differential (or a green bond *premium*), while the other 60% imply a positive differential (a green bond *discount*). To our knowledge, there is no theory that suggests a green bond should trade at a discount to their non-green counterparts. Moreover, the fact that this appears to be driven by a handful of issues examined in Appendix B leads us to conclude that the greenium is essentially zero. This result is inconsistent with some concurrent papers (e.g., Baker et al., 2018), but it is completely in line with insights provided to us by industry professionals.

Our next set of tests explores whether there appears to be any differential in the amount investment bankers charge for issuing green securities, or the underwriter's discount. This analysis is interesting for two reasons. First, prior studies assert that one of the significant portions of underwriter discounts represents underwriter's compensation for the risk of an unsuccessful offering (e.g., Ederington, 1975; Joehnk and Kidwell, 1979). To the extent that demand for securities outpaces supply, as some proponents of green bonds have asserted, we might expect this to show up in lower fees charged for underwriting a green issue. Second, to the extent that green bonds are less expensive to issue, it would give some indication as to why municipalities choose to issue green bonds despite the lack of a greenium.

Panel C of Table 3 reports results for the differences in the underwriter's discount for our sample of matched securities. Similar to our results for initial offering yields and spreads, we estimate a statistically significant positive differential between green and non-green securities. In economic terms, differences in underwriter's discount appear significantly larger than our estimates for yields and spreads. The mean (median) positive differentials of 4.47 (1.3) basis points are indicative of investment firms charging approximately 12% (3.5%) more than non-green average (median) bonds in our sample. Given the average deal size of $156.128 MM in our sample, this would equate to an additional $69.7 thousand in borrowing costs, on average. These extra costs are nontrivial given the numerous fiscal challenges facing many municipal issuers.[21]

Although the estimated differentials appear significantly larger than those related to yield or spread (approximately 10 times larger), these results appear to be driven by a sample of outliers. In 70% of cases the differentials are precisely zero, indicating that in most situations underwriters tend to view these securities as identical. However, it does appear that the prevalence of positive differentials is significantly larger for underwriter's discounts than negative differentials (23.8% compared to 6%).

Overall, the results of this section support the notion that there are no substantive price differentials between green and non-green securities. Where differentials are statistically significant, a handful of outliers drive these results, and estimated differences are economically small. Moreover, our findings related to underwriter's discounts indicate a slight premium that investment banks charge for issuing green bonds. This finding confirms industry professionals' suggestions that added costs to issuance are a legitimate threat to the future of green bonds in municipal securities markets (e.g, Chiang, 2017, 2018).

5.3. *Nearest neighbors matching*

There are many ways one might match a treatment sample of municipal bonds to a control sample of municipal bonds. Although the stated expected returns are straightforward for fixed-income securities, it is quite challenging to find appropriate comparison groups for these securities. In addition to matching on credit quality and tax treatment, it is also necessary to account for structural differences between securities such as maturity and whether the securities contain an embedded call option (MSRB, 2018).[22]

These difficulties highlight the advantage of using our within issuer matching approach.[23] Unfortunately, this advantage comes at the cost of severely limiting the sample size for the statistical tests. To expand our sample and assess the sensitivity of our results to alternative matching approaches, we use a nearest neighbor matching algorithm to create three separate matched samples. We then use these new matched samples in the same statistical tests used in the prior subsection.

Our first two matched samples used in the analyses found in Table 4 ("Same Month" and "Same Week") are constructed from the least rigid rules in an attempt to maximize the number of green securities used in our analyses. For each green security, we require an exact match on the state, callability, issuer size, and either issuance month (Same Month) or week (Same Week). Controlling for issuance state is essential given differences in state taxation, which affects asset prices (e.g., Schwert, 2017). As discussed above, controlling for callability is vital, given the significant pricing effects associated with embedded call options (e.g., Kalotay et al. (1993)). Limiting our set of matches to the same issuance month or week holds constant aggregate market conditions such as the general shape of the yield curve and credit curve. Finally, controlling for

[21] We motivate our use of paired test statistics by the fact that our matched sample is constructed from bonds from the same issuer, and similar bond structures. In untabulated analyses, we perform unpaired t-tests and Wilcoxon tests for each analyses using our primary sample of matched pairs. Our inferences remain identical throughout the paper. In untabulated analyses, we also find that our inferences are unaffected by the possible lack of independence resulting from bonds with multiple matches using a sample of uniquely matched green bonds.

[22] Typically, banks set the schedule of underwriters discounts on a per-bond basis (i.e., not as a lump sum per maturity). Therefore, any differentials in the size of the maturity, which we show to be negligible, cannot be responsible for this finding.

[23] Adding to these complications is the fact that the value of these embedded call options, which are prevalent in municipal securities, depends on a myriad of other variables. These variables include: the shape of the entire yield curve, the years to the first call date, and the coupon rate (e.g., Kalotay et al., 1993). As we mention in prior sections, these differences in coupons only affect pricing in the presence of embedded call options.

Table 4
Nearest neighbors matching tests.

	Orig. Sample	Same Month Match	Same Week Match	Same Issuer-Day Match
Panel A: Covariate balance				
Aggregate Rating	−1.120	−0.161	−0.163	0.000
Years to Maturity	2.150	−0.142	−0.143	−0.040
Years to Call	1.076	−0.038	−0.140	−0.039
Coupon	0.638	−0.088	−0.089	−0.113
Large Issuer	0.504	0.000	0.000	0.000
Callable	0.083	0.000	0.000	0.000

	Same Month		Same Week		Same Issuer-Day	
	Mean	Median	Mean	Median	Mean	Median
Panel B: Initial Offering Yields						
Green	221.508	225.000	222.426	225.000	228.424	229.000
Non-Green	225.246	228.000	225.832	226.000	228.409	229.000
Difference	−3.738	−3.000	−3.406	−1.000	0.015	0.000
Statistic	−1.264	−0.624	−0.926	0.044	0.004	2.140
(p-value)	(0.206)	(0.266)	(0.355)	(0.518)	(0.997)	(0.984)
Green Bonds	1685		1035		680	
Green Deals	130		109		57	
Green Issuers	75		66		38	
Panel C: Initial Offering Spreads						
Green	26.405	24.000	26.381	24.000	26.980	26.000
Non-Green	27.598	23.000	28.047	24.000	25.983	23.000
Difference	−1.194	1.000	−1.666	0.000	0.997	3.000
Statistic	−1.231	−0.336	−1.351	−1.029	0.699	−0.110
(p-value)	(0.218)	(0.368)	(0.177)	(0.152)	(0.484)	(0.456)
Green Bonds	1685		1035		680	
Green Deals	130		109		57	
Green Issuers	75		66		38	

This table presents nearest neighbors matched samples tests of the pricing differentials of green and non-green securities. Panel A presents differences in means between green and non-green securities for select matching covariates across the original sample, and our three matched samples. As described in Section 5.3, the "Same Month" ("Same Week") sample is constructed by finding a nearest neighbors (NN) match for each green bond without replacement based on: issue month (issue week); state; issuer size; callability; years to maturity; and call, rating and coupon. The "Same Issuer-Day" matched sample is similarly constructed matching on: issuer (exact); offering date (exact); callability; years to call and maturity, and coupon. In Panel B and C, for each matched set, the differences in mean (median) issuance yields and spreads between green and non-green securities are calculated using a standard two-sided *t*-test (Wilcoxon test). Levels of significance are presented as follows: p<0.1*; p<0.05**; p<0.01***.

issuer size is necessary given that large issuers are typically more sophisticated, well known to investors, and have better access to financing than small issuers.

For each green security, we also match to a non-green security by minimizing the global distance on the following: years to maturity, years to the call, coupon, and aggregate rating.[24] The first three of these variables is essential because of its significant effects on the pricing of the internal call option. Aggregate ratings are of obvious importance to control for differences in issuer credit quality. Our third matched set more closely resembles the main matched set used in this study. Specifically, we match on callability, but we also require the issuer, rating, and issuance date to be the same. We then select the nearest match based on years to call, years to maturity, and coupon. We denote this matched set as a "Same Issuer-Day" match.

We report the results produced for alternative matched samples in Table 4. In Panel A, we see that the new matched samples have considerably more observations, and the matches are more balanced than the original sample of treatment (green bonds) and control securities (all non-green bonds issued during the same period). Specifically, there are improvements in covariate balance across various measures of credit quality (issuer size and aggregate credit rating) and securities structure (coupon, maturity, etc.).[25]

In Panels B and C, we provide univariate pricing tests for our results related to initial offering yields and credit spreads.[26] In every specification we see that the estimated difference across means and medians is economically small and statistically insignificant, mirroring our earlier results of no pricing differential. For instance, in Panel C we see statistically insignificant

[24] This is particularly important in our setting because the size of the spread and yield effects may be relatively small. Thus, modest errors in matching in either direction setting can easily lead to substantial changes in inferences.

[25] All matching variables are standardized and given equal weighting. Our nearest neighbor matching algorithm uses a logistic regression, and a caliper width of 0.1 standard deviations to minimize potential bias (e.g., Rosenbaum and Rubin, 1985; Rajeev and Wahba, 2002). We create each match without replacement, using a greedy algorithm.

[26] In our primary analysis, we obtain a perfect balance over these covariates using a within-issuer design. Our primary matching method is also more flexible in that we allow coupon rates to differ when there is no embedded call option. Differing coupon rates should have a limited effect on pricing in these cases (e.g., Kalotay et al., 1993).

mean (median) differences between the monthly and weekly matched samples of −1.19 (1.00) and −1.67 (0.00) basis points, respectively. The results related to initial offering yields in Panel B are similar.

Overall, our results using nearest-neighbor matching methods and a significantly larger sample of securities support our main results. There is no economically significant relationship between a bond's pricing and whether it funded environmentally friendly projects.

5.4. Reconciling with Baker et al. (2018)

As discussed in Section 2, the study most related to ours is Baker et al. (2018). Except for the inclusion of securities with special tax credits issued in the early 2010's which we have omitted, their sample is largely similar to ours. Using a sample of green bonds from 2010 to 2016 and a pooled regression approach with fixed effects, they report a statistically and economically significant greenium of 8 basis points. Moreover, they show this estimated greenium is significantly stronger for bonds with the CBI Climate Certification. The important point is that rather than using exact matching methods, Baker et al. (2018) use a pooled regression model with various fixed effects.

There are several concerns with the methodological approach used by Baker et al. (2018) models. This approach requires the fixed effects to be effective controls. It is easy to imagine a situation where the fixed effects will be inadequate. For example, green issuers (which tend to be significantly larger) may outperform non-green issuers over the sample period.[27] Even when controlling for rating-maturity-issuance month fixed effects and issuer fixed effects, a greenium would be observed in this setting when it does not actually exist.

The pooled regression approach also essentially compares securities with embedded call options as though they were the same as securities without these options. The complications of this issue are well documented and discussed in the prior section. This problem is an obvious concern in this setting as we see in Table 2 that green bonds have a higher tendency to have an embedded call option. Following market convention, data providers quote municipal securities in terms of "yield-to-worst," which is typically the yield to call for callable municipal securities given that municipal bonds are nearly always issued at a premium (e.g., Landoni, 2018). Due to this quoting convention, comparing callable green and non-green securities without call options may mechanically lead to an estimated greenium. These differences would be estimated even though the green security may have the same or potentially higher option-adjusted yield.[28]

Since it is possible to implement an exact match between green and non-green bonds, there is no reason to use a pooled fixed-effect regression model when assessing the existence of greenium. This matched-pairs approach directly controls for virtually all of the factors that affect bond yield, and it is not necessary to rely on questionable indirect controls using fixed effects. Nevertheless, it is important to reconcile our results with those of Baker et al. (2018).

We first replicate the main Baker et al. (2018) findings for all tax-exempt green bonds in our sample, and also our matched sample of green bonds in Panels A and B of Table 5. The first three columns use the exact sample years of the Baker et al. (2018). We extend their results to the end of our sample in June 2018 in the last three columns.

Using all green securities in Panel A, we closely match the results in Baker et al. (2018). For instance, in Column 2, we calculate a green bond premium of 6.98 basis points with CBI Climate Certified bonds exhibiting a premium of an additional 14.78 basis points. The same specification in Baker et al. (2018) yields inferences remarkably similar − a green bond premium of 7 basis points and CBI Climate Certified bonds exhibiting an additional premium of 16.9 basis points.

Extending their methodology to the more recent years leaves their main inference unchanged, but it shows that those related to the CBI Climate Certification become sensitive to specification. Specifically, their methodology continues to yield an estimated green bond premium ranging from 11.85 basis points to 5.46 basis points depending on specification. The estimates related to the CBI Climate Certification are significantly smaller and statistically insignificant in some cases. This difference may be attributable to the fact that there were only four CBI Certified deals during this earlier sample period, whereas there are 11 CBI Certified deals in the later time period.

Our next set of results, presented in Panel B of Table 5, uses the same methodology on our sample of matched securities. For our sample of matched green securities, we estimate a green bond premium using their methodology. In fact, in most specifications we find significantly larger premiums than those in Baker et al. (2018). One plausible explanation for this is that larger issuers tended to outperform over this period. As shown in Table 2, our sample of green securities are more likely to be issued by larger issuers, and therefore yield larger estimated premiums. However, we know from our exact matching tests, that there is no difference in premiums for green and non-green securities.

Finally, we examine the pricing results for a placebo sample of the non-green securities or non-green bonds from our matched sets. These securities are placebo in the sense that they have no green attributes. In Panel B of Table 5, we show that the coefficients on the placebo bond variable are virtually identical to the corresponding coefficients on the green bond variable. This finding strongly suggests that using a simple fixed-effects methodology to estimate premiums leads to biased inference due to issuer-related omitted variables.

[27] Because we are now comparing securities over different issuance days, we focus our discussion on credit spreads. This allows us to isolate effects on issuer-specific components of municipal borrowing costs.

[28] In an untabulated analysis, we find evidence of a large issuer time trend of approximately two basis points per year.

Table 5
Estimating green bond premiums with fixed-effect regressions.

	Dependent variable:					
	Offering Yield					
	2010–2016			Full Sample		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Relationship between premiums and green issuance size						
Green Bond	−11.035	−6.975	−5.587	−11.846	−8.780	−5.464
	(−4.151)***	(−4.447)***	(−1.669)*	(−5.079)***	(−5.140)***	(−2.567)**
CBI Climate Certified	−15.517	−14.778	−12.384	−6.399	−8.115	−2.243
	(−3.506)***	(−5.270)***	(−2.918)***	(−1.785)*	(−2.245)**	(−0.706)
Rating FEs	Yes	No	No	Yes	No	No
Maturity FEs	Yes	No	No	Yes	No	No
Month FEs	Yes	No	No	Yes	No	No
Month × Maturity × Rating FEs	No	Yes	Yes	No	Yes	Yes
Issuer FEs	No	No	Yes	No	No	Yes
Observations	784,225	784,225	784,225	939,850	939,850	939,850
Adjusted R^2	0.894	0.932	0.928	0.880	0.931	0.960
Panel B: Matched Green Bonds						
Green Bond	−15.346	−11.807	−9.442	−17.326	−15.509	−4.845
	(−2.828)***	(−2.764)***	(−2.095)**	(−3.200)***	(−4.024)***	(−2.247)**
Placebo Bond	−15.089	−12.095	−9.141	−17.566	−16.029	−5.288
	(−2.683)***	(−2.779)***	(−1.979)**	(−3.199)***	(−4.151)***	(−2.453)**
Rating FEs	Yes	No	No	Yes	No	No
Maturity FEs	Yes	No	No	Yes	No	No
Month FEs	Yes	No	No	Yes	No	No
Month × Maturity × Rating FEs	No	Yes	Yes	No	Yes	Yes
Issuer FEs	No	No	Yes	No	No	Yes
Observations	782,863	782,863	782,863	937,536	937,536	937,536
Adjusted R^2	0.894	0.932	0.928	0.881	0.931	0.960

This table presents regressions of bond yields at issue on green bond indicators and other bond characteristic fixed effects. Panel A presents estimates using the full sample of green bonds, and Panel B presents estimates using just the sample with matching non-green bonds as described in Section 4. *Green Bond* is an indicator if the bond is a marketed green bond, *CBI Climate Certified* an indicator if the green bond obtained the CBI climate certification, and *Placebo Bond* an indicator if it is a non-green bond from a green issuer in our matched sample. All specifications include fixed effects for use of proceeds, insurance, AMT, bank qualified, new money, and issuer size. Two-way cluster robust t-statistics, by issuer and offering month, are included in parentheses. Levels of significance are presented as follows: *p<0.1; **p<0.05; ***p<0.01.

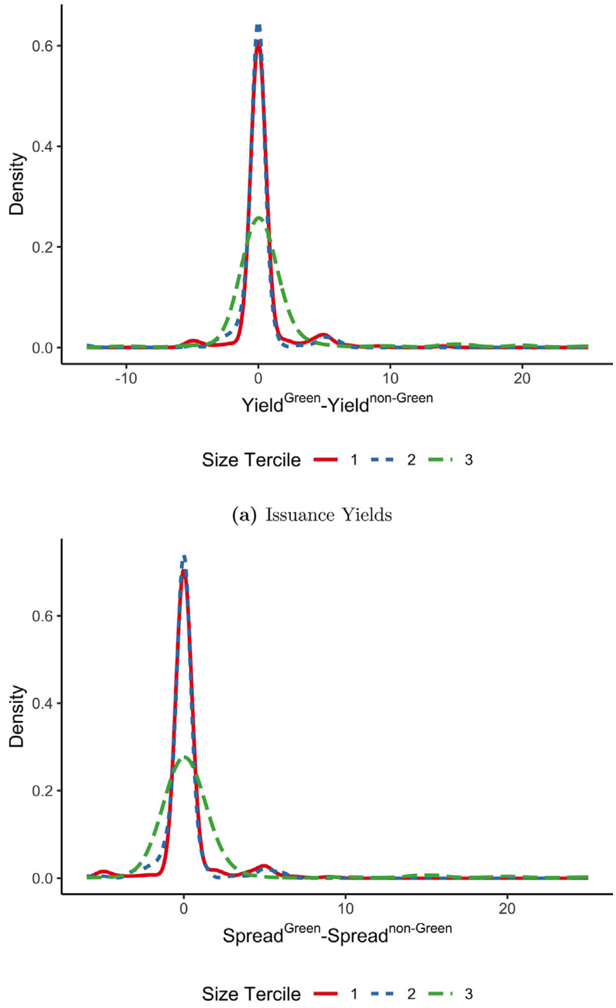
In summary, this section replicates the results from Baker et al. (2018) that suggest the existence of a green bond premium. However, we find a similar result when we estimate the premium on a group of placebo bonds (non-green securities from green issuers). Moreover, if the pooled fixed-effects regression model is well specified, the results should closely mimic the results of the exact matching approach. Interestingly, we find little correspondence between results produced by the regression and matching approaches. Therefore, we conclude that the fixed-effects approach is inadequate for examining the greenium research question.

6. Alternative explanations for No greenium

6.1. Supply-demand explanations

In Section 5, we provide compelling evidence that the municipal market greenium is zero. This finding suggests that the marginal investor in the municipal market is not willing to forgo returns to invest in environmentally friendly assets. However, to the extent that the amount of green supply (here the issuance size of the green bond) exceeds the demand, this may confound our inferences. For a greenium to emerge, the amount of green demand must be sufficient to clear the entire supply of the issue at a higher price (lower yield and spread). That is, a green investor must be the marginal trading for this asset in order to observe greenium (if it exists).

To provide insight into the supply-demand considerations, we conduct several analyses on the relationship between the amount of green supply for a particular security and its measured premiums. We first plot kernel density estimates of green spread and yield premiums by issuance size terciles in Fig. 4. We see that even for the smallest supply tercile (issuance sizes of $400 thousand on average) there is a large mass around zero differential. Consistent with our findings in Table 3, in approximately 87% of instances, estimated premiums are precisely zero, and the average estimated yield (spread) premium is 0.29 (0.24) basis points. Overall, there appears to be no apparent relationship between issuance size and premiums.



(a) Issuance Yields

(b) Spread

Fig. 4. Kernel density estimates for green and non-green differentials by issuance size tercile. These figures provide the estimated kernel densities for the yield and spread differentials for the matched sets described in Section 4 by issuance size (of the green bond). Each plot uses a Gaussian kernel and the Silverman rule for bandwidth selection.

In Table 6, we present associations between two issuance size variables and the issuance cost differential between green and non-green bonds. In Panel A, we regress the matched green and non-green bond differentials described in Section 4 on the issuance size of the green bond, $\textit{Issue Amount}^{Green}$. We conduct a similar analysis in Panel B, substituting an indicator of whether the green bond in the match is in the lowest issuance size tercile. As in Fig. 4, there appears to be no relationship evident between issuance cost premiums and issuance size ($\textit{Issue Amount Tercile}^{Green}_{Bottom}$).

Overall, there appears to be no meaningful relationship between green bond security size and the measured issuance cost premiums. Even for the smallest securities in our sample, there is no greenium present. Therefore, we conclude that the lack of green investor demand is an unlikely explanation for our findings.

6.2. Differences in after-issuance liquidity

One of the cited explanations for the lack of a pricing difference is that the green bond market has poor liquidity (e.g, Chiang, 2017). Prior findings of a negative relationship between bond yields and liquidity (e.g., Schwert, 2017; Chen et al.,

Table 6
Green bond premiums and issuance size.

	Dependent variable:					
	All Matches			Exact Matches		
	Yield	*Spread*	*Takedown*	*Yield*	*Spread*	*Takedown*
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Relationship between premiums and green issuance size						
Issue Amount^{Green}	0.044	0.046	−0.001	0.047	0.047	−0.001
	(0.888)	(0.913)	(−1.078)	(0.897)	(0.897)	(−1.092)
Observations	640	640	601	627	627	590
Adjusted R^2	0.022	0.027	0.005	0.028	0.028	0.005
Panel B: Lowest Green Issuance Tercile						
Issue Amount Tercile$^{Green}_{Bottom}$	−0.206	−0.300	0.082	−0.340	−0.340	0.082
	(−0.340)	(−0.536)	(0.967)	(−0.593)	(−0.593)	(0.957)
Observations	640	640	601	627	627	590
Adjusted R^2	0.000	0.001	0.044	0.002	0.002	0.043

This table reports the relationship between the differences in borrowing costs of green and non-green matched bond pairs discussed in Section 4, and the green bonds issuance size (i.e., the total supply). Each dependent variable, described in the Appendix, is regressed on various characteristics related to the issuance size of the green bond. Regressions are run using the full sample of matches (All Matches), as well as exact matches with the same maturity (Exact Matches) described in Section 4. Two-way cluster robust t-statistics, by issuer and offering month, are included in parentheses. Levels of significance are presented as follows: *p<0.1; **p<0.05; ***p<0.01.

2007) support this argument.[29] In this section, we examine whether there are liquidity differentials between bonds in our issuer matched pairs.

We construct liquidity and trading activity metrics derived from the comprehensive historical data set of municipal bond transaction prices from the Municipal Securities Rulemaking Board (MSRB) accessed through WRDS. After data cleaning procedures outlined in Green et al. (2007b), we construct three separate trading activity and liquidity metrics commonly used for OTC bonds. As noted in previous studies (e.g., Schwert, 2017), the municipal securities market is by nature extremely illiquid with limited trading. Because of this, many commonly used liquidity metrics, such as bid-ask spread, which requires both buy and sell prices, are not always available. The selected metrics enable us to retain the most significant proportion of our sample. All variables are as described in Appendix A.

Our first measure, quarterly bond turnover, is a commonly-used liquidity metric from prior studies on bonds (e.g., Bessembinder et al., 2018; Oehmke and Zawadowski, 2017). This variable gives an issuance size-weighted (by the number of securities outstanding) assessment of the total volume transacted on in the post-issuance period. A higher value of quarterly turnover is indicative of greater market liquidity.

Panel A of Table 7 presents our univariate results comparing quarterly turnover between our matched green and non-green securities. The estimates confirm a limited difference in turnover between green and non-green securities. The mean (median) difference is −1.3% (−5.6%) in the exactly matched sample, and these differences are not statistically significant at conventional levels. Moreover, in approximately 17% of cases, this difference is exactly zero, while the ratio of positive to negative differentials is almost one. These findings do not indicate any differences in liquidity between green and non-green securities.

We next explore a similar metric based on the total number of trades in the quarter following bond issuance. Prior studies have used this as a measure of both market liquidity and trading activity (e.g., Schwert, 2017; Mahanti et al., 2008). We again find no statistically significant difference in the number of trades between green and non-green securities. The estimated mean (median) differences are also quite small at −1.6 (0.0) trades per quarter. Again, the distribution of these is roughly split between positive and negative differentials, with a large mass of observations at exactly zero differential.

Finally, we consider the price dispersion metric proposed by Jankowitsch et al. (2011) and used in prior literature on the municipal securities market (e.g., Schwert, 2017). This measure offers advantages over traditional measures of bid-ask spreads in that we can calculate it for a significantly larger portion of our matched sample. It only requires two trades a day rather than a customer buy (ask-price) and customer sell (bid-price). Similar to the results related to trading turnover and number of trades, we see no statistical or economically significant difference in price dispersion between green and non-green securities. The distributions are nearly equal between positive and negative differentials with a large mass directly at zero.

The results of this section strongly suggest that there is no liquidity differential between green and non-green securities. These results confirm that liquidity differences do not appear to be an explanation for our documented lack of a green bond premium.

[29] In untabulated analyses, we find evidence consistent with this logic. Specifically, we run the same specifications in Panel A of Table 5 on just the sample of non-callable bonds. The economic magnitude of the coefficient estimates on the *Green Bond* indicator shrinks *at least* 47% in all specifications. The coefficient becomes statistically insignificant once we control for Issuer FEs and Month × Maturity × Rating FEs.

Table 7
Matched sets tests for a relationship between green-label and after-issuance liquidity.

	Exact Matches		All Matches	
	Mean	Median	Mean	Median
Panel A: Turnover.				
Green	0.920	0.418	0.919	0.427
Non-Green	0.980	0.500	0.975	0.500
Difference	−0.059	−0.083	−0.056	−0.073
Statistic	−1.042	0.268	−0.995	0.632
(p-value)	(0.298)	(0.606)	(0.320)	(0.736)
Total Matches	614		627	
% Matches Zero Difference	15.798		15.470	
% Matches Neg. Difference	42.020		41.946	
% Matches Pos. Difference	42.182		42.584	
Panel B: Number of Trades				
Green	10.700	3.000	10.879	3.000
Non-Green	11.292	3.000	11.453	3.000
Difference	−0.591	0.000	−0.574	0.000
Statistic	−0.552	−0.534	−0.543	−0.406
(p-value)	(0.581)	(0.297)	(0.588)	(0.343)
Total Matches	614		627	
% Matches Zero Difference	19.544		19.139	
% Matches Neg. Difference	37.459		37.959	
% Matches Pos. Difference	42.997		42.903	
Panel C: Price Dispersion				
Green	0.209	0.124	0.211	0.125
Non-Green	0.216	0.100	0.219	0.109
Difference	−0.007	0.024	−0.008	0.016
Statistic	−0.478	1.634	−0.516	1.951
(p-value)	(0.633)	(0.949)	(0.606)	(0.974)
Total Matches	274		280	
% Matches Zero Difference	12.044		11.786	
% Matches Neg. Difference	41.241		41.429	
% Matches Pos. Difference	46.715		46.786	

This table presents matched sample tests on the issuance cost differentials between green and non-green securities. All measures are as defined in the Appendix. Green bonds are assigned to a matched (exact matched) set if they are issued on the same day, have a maturity date within one-year (same maturity date) of a non-green bond, and are issued by the same issuer. For each matched set, the differences in mean (median) between green and non-green securities is calculated using a standard paired two-sided *t*-test (Wilcoxon test). Levels of significance are presented as follows: p<0.1*; p<0.05**; p<0.01***.

6.3. Heterogeneity in environmental impact

Greenwashing − the issuance of securities labeled as green that lack genuine environmental benefits − is a concern for investors in the green bond market (e.g., Grene, 2015). This concern is mainly attributable to the fact that there are no universally agreed-on criteria for what makes a bond green. In theory, any municipality can issue a bond under a green label, so long as it can convince investors it uses the funds for eco-friendly purposes. This type of measurement error is a threat to our inferences. Specifically, the lack of a greenium we document could be due to investors' uncertainty about whether issuers use the funds generated by the bond issuance to benefit the environment. To investigate this issue, we perform two sets of analyses to determine whether the measured differentials over our matched pairs vary by the environmental impact perceived by investors.

In the first set of analyses, we explore whether the cost differentials from our matched pairs sample is associated with two variables that practitioners suggest are related to greenwashing. A possible indicator for greenwashing is whether issuers use a green bond for an economic refunding. Many market participants are divided over whether it is acceptable to issue green bonds to refinance existing projects (e.g., Chiang, 2017; Grene, 2015). As such, we may expect there to be a positive relationship between our various cost of borrowing differentials and an indicator for whether municipalities issued the green security for refunding purposes.[30]

As a result of the lack of standardization in this market, several third-party certification providers have emerged to certify green bond issuers use the funds for eco-friendly purposes. At a cost (ranging up to $50,000), these services verify that bond issues comply with their standards to ensure that the assets and projects of the issue will contribute to a low carbon economy

[30] Following this line of reasoning, a greenium may exist in our setting, but the associated illiquidity discount of green bonds (relative to normal bonds) would offset these pricing benefits. Our tests would still document zero pricing differential, despite investors valuing green bonds (for their non-pecuniary benefits) more.

Table 8
Green bond premiums and issuance environmental impact.

	Dependent variable:					
	All Matches			Exact Matches		
	Yield	*Spread*	*Takedown*	*Yield*	*Spread*	*Takedown*
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Certification and use of proceeds						
CBI Climate Certified	1.196	1.194	−0.058	1.164	1.164	−0.060
	(4.803)	(4.783)	(−1.134)	(4.378)	(4.378)	(−1.135)
Refunding	−0.265	−0.257	−0.037	−0.291	−0.291	−0.039
	(−1.207)	(−1.150)	(−0.679)	(−1.237)	(−1.237)	(−0.688)
Observations	640	640	601	627	627	590
Adjusted R^2	0.014	0.016	0.009	0.017	0.017	0.010
Panel B: Third-party Green Rating						
HIP Green Rating	0.978	0.666	−0.612	0.676	0.676	−0.624
	(0.481)	(0.330)	(−1.478)	(0.331)	(0.331)	(−1.482)
Observations	479	479	449	473	473	443
Adjusted R^2	0.000	0.000	0.197	0.000	0.000	0.202

This table reports the relationship between the differences in borrowing costs of green and non-green matched bond pairs discussed in Section 4, and the green bonds environmental impact. Each dependent variable, described in the appendix, is regressed on various characteristics related to the environmental impact of the green bond issuance. Regressions are run using the full sample of matches (All Matches), as well as exact matches with the same maturity (Exact Matches) described in Section 4. Two-way cluster robust t-statistics, by issuer and offering month, are included in parentheses. Levels of significance are presented as follows: *p<0.1; **p<0.05; ***p<0.01.

(Saha, 2018).[31] Among green municipal bonds, the CBI Climate Certification is the primary certification that municipalities have purchased for these purposes (Chiang, 2017). We identify 15 such deals issued with this certification in our sample of green securities. These certified securities are precisely the cases where we would expect to see a negative impact (if it exists) on the cost of borrowing differentials. Because of the rigorous standards these securities must meet to qualify for the certification, there should be little doubt among investors about whether issuers use these funds for green purposes.

We present the results of these analyses in Panel A of Table 8. We find no statistically or economically significant relationship between green issuance cost premiums and whether the security was used for a refunding. Second, in our subsample of matched securities, the CBI Climate Certification has a statistically positive association with yield differentials. Nevertheless, these estimates (approximately 1.2 bps) are very small relative to the average yields (spreads) of approximately 224 (25) basis points in our matched sample. Moreover, of the 56 CBI Climate Certification securities in our matched sample, 91% of the observations have identical yields to their non-green counterparts. Therefore, we conclude that CBI Climate Certification appears to make little substantive difference in green bond pricing. It also appears to make no statistical difference in what investment banks charge for underwriting the securities (Takedown).

In our second set of analyses, presented in Panel B of Table 8, we regress the cost differentials from our matched pairs sample on proprietary ratings of issuance-specific environmental impact by HIP Investor, denoted *HIP Green Rating*.[32] Assuming greenwashing is a real concern to our inferences, we should expect a negative association between issuance cost premiums and *HIP Green Rating*. In all specifications, however, we find no statistically or economically significant relationship.

Overall, these results suggest there is no heterogeneous relationship between green bond premiums and the environmental impact of a green bonds project. There appears to be little economic relationship between the cost of borrowing differentials and two variables that market participants have traditionally associated with greenwashing. Greener projects, as measured by issuance-specific environmental impact rating by HIP Investor, also do not appear to trade with a premium. In general, these analyses suggest that the greenium is zero for all projects, even those clearly identified as green investments.

7. Benefits of green bond issuance

7.1. Ownership concentration

Our results essentially show that there is little yield or spread differences between green and non-green bonds, but green bonds are more costly to issue than non-green bonds. This raises the important question about why green bonds are used by

[31] This could indicate that green bonds used for refundings exhibit no greenium while new project green bonds exhibit a greenium.
[32] These organizations verify that the firm (1) uses the proceeds to fund eligible project types, and (2) has internal processes and controls in place to ensure the generated proceeds are used to fund the stated projects. For instance, see https://www.climatebonds.net/certification.

Table 9
Matched sets tests for a relationship between green-label and ownership structures.

	Exact Matches		All Matches	
	Mean	Median	Mean	Median
Panel A: Institutional ownership.				
Green	76.310	97.974	76.846	98.253
Non-Green	76.566	100.000	77.179	100.000
Difference	−0.256	−2.026	−0.333	−1.747
Statistic	−0.148	−1.155	−0.198	−1.297
(p-value)	(0.882)	(0.124)	(0.843)	(0.097)*
Total Matches	458		471	
% Matches Zero Difference	39.738		39.915	
% Matches Neg. Difference	35.590		35.456	
% Matches Pos. Difference	24.672		24.628	
Panel B: Herfindahl-Hirschman Index				
Green	0.573	0.500	0.571	0.500
Non-Green	0.646	0.608	0.641	0.594
Difference	−0.073	−0.108	−0.070	−0.094
Statistic	−4.002	−3.718	−3.895	−3.582
(p-value)	(< .01***)	(< .01***)	(< .01***)	(< .01***)
Total Matches	458		471	
% Matches Zero Difference	15.284		14.862	
% Matches Neg. Difference	50.000		49.682	
% Matches Pos. Difference	34.716		35.456	

This table presents matched sample tests on the ownership differentials between green and non-green securities. All measures are as defined in the Appendix. Green bonds are assigned to a matched (exact matched) set if they are issued on the same day, have a maturity date within one-year (same maturity date) of a non-green bond, and are issued by the same issuer. For each matched set, the differences in mean (median) between green and non-green securities is calculated using a standard paired two-sided *t*-test (Wilcoxon test). Levels of significance are presented as follows: p<0.1*; p<0.05**; p<0.01***.

municipalities when they are more costly than non-green bonds. For this set of observations to be an equilibrium, there must be benefits associated with issuing green bonds.

One potential benefit of green bonds that market participants have suggested is that it helps to broaden the issuer's investor base (Braun, 2019). To examine this issue, we construct holdings proxies using the comprehensive MSRB transactions database. For each security, we identify the initial placement of securities by looking at all customer purchases labeled as a primary market transaction.[33] Prior studies (e.g., Chernenko et al., 2016; Manconi et al., 2012) have leveraged the Thomson Reuters eMAXX to identify bond ownership, primarily for taxable securities. Our choice to construct ownership proxies from the MSRB transactions data is twofold. First, the eMAXX Thomson Reuters database is expensive, whereas the MSRB transaction data are free. Second, since reported holdings of individual bonds are not mandatory and only include institutional holdings, the eMAXX database is far from complete. This is also particularly problematic for measures of ownership concentration in municipal markets given its large retail investor base (which these other measures would not reflect).

We construct two ownership measures. Following prior studies, we base our first measure on the idea that institutional (retail) purchases are assigned to be purchases with par volume greater than or equal (less than) to $100,000 (e.g., Green et al., 2007a; Dick-Nielsen et al., 2012). We define institutional ownership as the total sum of institutional purchases divided by total securities outstanding. Our second measure, following Baker et al. (2018), uses the Herfindahl-Hirschman index (HHI) of ownership concentration, which we calculate as:

$$HHI_i = \sum_{k=1}^{N} \frac{P_k}{O_i}$$

where P_k is the total par value of primary market customer purchase k, and O_i is the total par value of bonds outstanding. A larger value of HHI indicates more concentrated ownership levels.

We present the ownership analyses for our matched-pairs in Table 9. In general, we find little difference in institutional ownership. As we see in Panel A, mean (median) institutional ownership differences are 0.25% (2.03%) and statistically insignificant for our sample of exact matches. Similar inferences follow from looking at the difference in means for our full matched sample.

The only test indicating a statistically significant difference between green and non-green securities is the Wilcoxon test of differences in medians for the full matched sample. However, differences are only marginally significant at the 10% level, and the estimated differences are also quite small. Overall, we conclude little difference in institutional ownership between green and non-green securities from the same issuer.

[33] We describe this data in Section 4.5.

Our analyses in Panel B related to ownership concentration suggest that green bonds do lead to a slightly more diverse ownership base. We find significantly higher concentration in ownership for non-green securities. The mean (median) level of HHI is 0.573 (0.500) for our sample of green securities, the mean (median) HHI is 0.646 (0.608) for non-green securities. These differences are statistically significant across all specifications and imply that non-green securities are approximately 12%–20% more concentrated than green securities.

Overall, these results suggest that there are indeed benefits associated with issuing green bonds. As suggested by industry professionals, green bonds appear to have less concentrated ownership levels measured by the Herfindahl-Hirschman index. However, there seems to be no meaningful differences in institutional ownership between green and non-green bonds.

7.2. State-level ESG preferences

Some green bond advocates have suggested that as the market matures greeniums may emerge (e.g., Chiang, 2017). In this sense, issuers may be looking at these issuances as a longer-term investment that may pay off in future time periods. Presumably, those states that value environmental friendliness would be more willing to pay slightly higher costs for perceived future benefits. Moreover, decision-makers at the issuers in these states would have the most to gain politically by issuing green bonds.[34] Finally, it is in these environmentally friendly states where we may expect greeniums to be most prevalent. Municipal bonds are typically priced locally due to tax-benefits and information-related reasons (e.g., Butler, 2008; Gao et al., 2020). As a result, green bonds issued in states where investors value environmental sustainability more may be where we are most likely to observe issuance premiums[35].

We explore these possibilities using state-level green preference indices based on CDP-level green rating data of local governments by HIP Investor, described in Section 4.5. For each state, *s*, we construct state-level green preference measures as:

$$State\ Green\ Preferences_s = \frac{1}{N_s}\sum_{i=1}^{N_s} Earth_i$$

where $Earth_i$ is assigned HIP score for the eco-friendliness of each CDP i, and N_s are all CDPs in the HIP database for state s. As local governments likely reflect the beliefs of its constituents, this serves as a proxy for state-level green preferences.

We begin by exploring the relationship between green bond issuance and state-level ESG preferences visually in Fig. 5. In Panel (a) we present a heat map of all green bonds issued as a percentage of total bonds issued during our sample period within each state. Similarly, in Panel (b), we present a "heat map" of average state-level ESG preferences for each state. While there are some exceptions, we see that environmentally friendly states have been the primary issuers of green bonds to-date. Similarly, states with large quantities of issuance tend to be among the states that are the most environmentally friendly.

In Panel A of Table 10, we regress four proxies of total state-level issuance on our constructed state green preferences proxy. We see a positive and statistically significant coefficient in each of our three specifications at the 5% level of significance or lower. Our estimates indicate that a one standard deviation increase in green preferences (0.08) is associated with an increase of 0.51% in the number of green bonds issued in a state (as a percentage of total bonds), 0.71% in the absolute number of green bonds issued, 0.54% in the total dollar amount of green bonds issued, and 0.84% in the dollar amount of green bonds issued. These results are consistent with the idea that states that value the environment also issue more green bonds.

Finally, we explore whether there is an association between the green preferences and green bond cost of issuance premiums in Panel B of Table 10. In general, there does not appear to be a significant relationship between green bond premiums and local green preferences. Even in states with preferences for environmental sustainability, the greenium is zero.

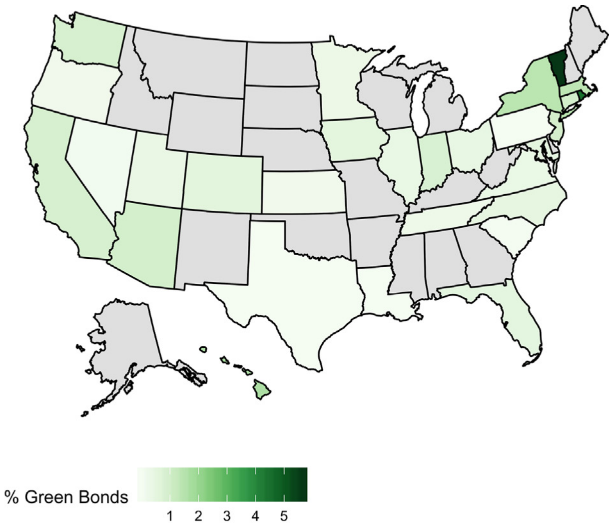
8. Summary and concluding remarks

In this paper, we examine whether investors are willing to forgo pecuniary benefits to invest in environmentally friendly projects. Using a matched sample of nearly identical green and non-green municipal securities, we find little evidence of a pricing differential between green and non-green bonds. This pattern is robust to perceived differences in liquidity or institutional ownership. We also show that greenwashing by issuers is unlikely to be responsible for our findings. Overall, our results strongly suggest that United States municipal investors are entirely unwilling to sacrifice returns to invest in green securities.

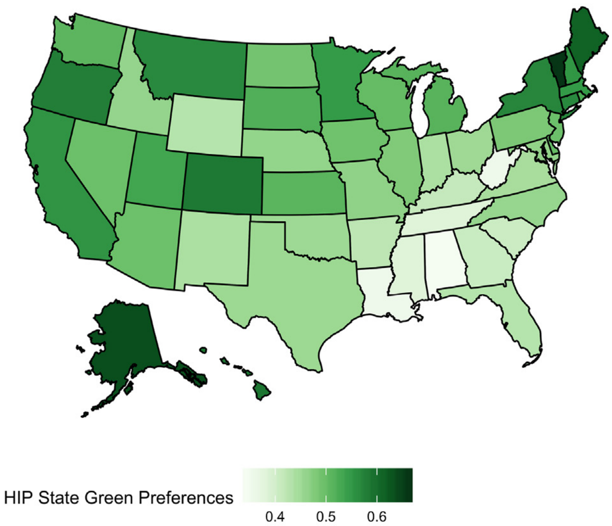
While there has been substantial growth in green bond markets, they make up only a small fraction of debt markets. The primary reason cited for the low market penetration to date is higher issuance costs (Chiang, 2017), a sentiment echoed by

[34] We do this by considering all trades labeled with the "price takedown indicator." As described on the MSRB Transaction Data document on WRDS, this variable is: "an indicator showing that the transaction price was reported as a primary market sale transaction executed on the first day of trading of a new issue … "

[35] Several practitioners we spoke with posited that much of this issuance is likely, mainly for marketing purposes. Specifically, they indicated that by appearing to follow policies inline with the beliefs of their constituents, decision-makers might be hoping to further their professional agendas.



(a) State-level Green Bond Issuance



(b) State Preferences for ESG

Fig. 5. Green bond issuance and state-level ESG preferences. This figure presents a state-level heat map of green bond issuance frequency and ESG preferences. Panel (a) presents a heat map of the number of green bond issues (as a percentage of total issues) from June (2013) through July 2017. States in gray indicate zero green bond issuances during this time period. Panel (b) presents heat map scores of local preferences for ESG as measured by average local government ESG scores by state.

several practitioners and a result that we find in our sample. At least currently, the cost of capital benefits of these securities appears largely hypothetical, although it may arise as the market matures. The only apparent benefit we find for green bonds is that they seem to diversify the issuer's investor base, which is also consistent with views of practitioners (e.g., Braun, 2019).

In considering whether our results might generalize to other markets, it is important to understand that the municipal securities market is institutionally quite different than other asset classes. While we find no greenium in this market, a greenium may exist in other markets such as the corporate green bond market. We view this conjecture as unlikely. Specifically, if a greenium exists we believe that the municipal securities market is a setting where it is *most* likely to be observed. The primary reason is that the average issuance size (supply) in our sample is tiny, and thus it is very possible that green investors are the marginal trader for pricing this asset. Therefore, municipal green bond pricing should reveal whether this green marginal trader is willing to pay a premium for a security used to fund environmentally friendly projects.

Table 10
Relationship Between State Green Preferences, Green bond Premiums, and Issuance.

	Dependent variable:			
	Count		Total $ Issued	
	% Green Issue	*ln*(1 +*Green Issue*)	*% Green Issue*	*ln*(1 +*Green Issue*)
	(1)	(2)	(3)	(4)
Panel A: State-level Issuance Tests				
State Green Preferences	6.321	8.911	6.841	10.683
	(3.786)	(2.526)	(2.730)	(2.182)
Observations	52	52	52	52
Adjusted R^2	0.207	0.095	0.112	0.069

	Dependent variable:					
	All Matches			Exact Matches		
	Yield	*Spread*	*Takedown*	*Yield*	*Spread*	*Takedown*
	(1)	(2)	(3)	(4)	(5)	(6)
Panel B: Matched Pair Pricing Tests						
State Green Preferences	−0.316	0.380	−0.348	0.677	0.677	−0.344
	(−0.097)	(0.118)	(−0.612)	(0.205)	(0.205)	(−0.600)
Observations	640	640	601	627	627	590
Adjusted R^2	0.000	0.000	0.008	0.000	0.000	0.008

This table reports the relationship between state-level green preferences, the propensity for a state to have issued a green bond, and differences in borrowing costs of green and non-green matched bond pairs discussed in Section 4. Each dependent variable, described in the Appendix, is regressed on a state-level green rating of preferences derived from the equal-weighted average HIP Investor green rating of local governments in each state. As described in Section 7.2, regressions in Panel A are run on the sample based on all tax-exempt municipal issuances over the period of June 2013 through July 2017. In Panel B, regressions are run using the full sample of matches (All Matches), as well as exact matches with the same maturity (Exact Matches) described in Section 4. Two-way cluster robust t-statistics, by issuer and offering month, are included in parentheses. Levels of significance are presented as follows: p<0.1*; p<0.05**; p<0.01***.

Appendix A. Variable Definitions

Variable	Description	Data Source
Aggregate Rating	The median long-term rating assigned by Fitch, Moodys, and S&P at issuance. Converted to a numerical scale from 1 (highest rated) to 22 (lowest rated or unrated).	Mergent
Callable	An indicator that takes the value of one if the bond contains an embedded call option.	Mergent
CBI Climate Bond Certified	An indicator variable that takes a value of one if the bond was issued with the Climate Bond Initiative's climate bond certification.	Mergent
Coupon	The coupon rate of the bond (measured in %).	Mergent
Deal Size ($ MM)	The total dollar amount outstanding of all securities issued as part of the same deal of the bond.	Mergent
Fitch LT Rating	The long-term rating of the security assigned by Fitch at the date of issuance. Converted to a numerical scale from 1 (highest rated) to 22 (lowest rated or unrated).	Mergent
Green Bond	An indicator variable that takes a value of one if the bond was issued as a self-labeled green bond.	Bloomberg, Mergent
Herfindahl-Hirschman Index (*HHI*)	Calculated as: $HHI_i = \sum_{k=1}^{N} \frac{P_k}{O_i}$ where P_k is the total par value of primary market customer purchase k, and O_i is the total number of bonds outstanding.	MSRB
HIP Green Rating	The assigned environmental impact rating of the bond assigned by HIP Investor.	HIP Investor
Initial Offering Spread (*Spread*)	This is calculated as the initial offering yield less the matched benchmark maturity yield derived from the Municipal Market Advisors (MMA) 5% AAA G.O. benchmark yield. Measured in basis points.	Mergent, Bloomberg
Initial Offering Yield (*Yield*)	Yield to maturity at the time of issuance, based on the coupon and any discount or premium to par value. Measured in basis points.	Mergent
Institutional Ownership	Defined as total sum of institutional primary market purchases (those greater than or equal to $100,000) divided by total securities outstanding.	MSRB
Issue Amount ($ MM)	The total dollar amount outstanding of the bond at issuance.	Mergent
Large Issuer	An indicator variable that takes the value of one if the issuer is in the upper quartile of total issuance in the Mergent database.	Mergent
Moodys LT Rating	The long-term rating of the security assigned by Moodys at the date of issuance. Converted to a numerical scale from 1 (highest rated) to 22 (lowest rated or unrated).	Mergent
Number of Trades	Calculated as the total number of trades over the quarter (90-days) after issuance.	MSRB

(*continued on next page*)

(*continued*)

Variable	Description	Data Source
Offering Year X	An indicator which takes the value of one if the bonds issuance date is in the year X.	Mergent
Placebo Bond	An indicator variable that takes a value of one if the bond is a non-green security from our matched sample.	Bloomberg, Mergent
Price Dispersion	Jankowitsch et al. (2011) propose a measure of transaction costs based on the dispersion of traded prices around the market consensus valuation. For each day, we calculate daily price dispersion following Schwert (2017). Quarterly estimates of the price dispersion measure are obtained by taking the mean of the daily estimates over the quarter (90-days) after the initial bond issuance.	MSRB
Refunding	An indicator variable that takes a value of one if the bond was issued for the purposes of refinancing outstanding debt.	Mergent
S&P LT Rating	The long-term rating of the security assigned by Standard and Poors at the date of issuance. Converted to a numerical scale from 1 (highest rated) to 22 (lowest rated or unrated).	Mergent
State Green Preferences (*SGP*)	For each state, *s*, we construct state-level Green preference measures as: $SGP_s = \frac{1}{N_s}\sum_{i=1}^{N_s} Earth_i$ where $Earth_i$ is assigned HIP score for the eco-friendliness of each census designated place (CDP) *i*, and N_s are all CDPs in the HIP database for state *s*.	HIP Investor
Turnover	Calculated as the total sum of par value trades over the quarter (90-days) after issuance divided by the total issuance amount.	MSRB
Underwriters Discount (*Takedown*)	The fee paid to the investment bank for selling the bonds. Calculated as a % of par.	Bloomberg
Years to Call	Years to the first call date at issuance.	Mergent
Years to Maturity	Years to the maturity date at issuance.	Mergent

Appendix B. Discussion of Outliers

As shown in Fig. 3, the small positive yield differential (implying a green bond discount) that we estimate in Section 5 appears to be driven by a small number of unusual observations or outliers. In Table B-1, we report the matched pairs associated with the largest *absolute* deviations in spread and yield in our sample. Specifically, we show all matched pairs in which the spread differential is in the upper 5% of all absolute spread differences. These matches make up the very right and left tails of Panels (a) and (b) of Fig. 3.

The matching procedure used to construct our primary sample matches green and non-green issues on issuer, issuance day, maturity, and whether the bond contained an embedded option. Coupons are allowed to differ so long as this does not affect the option-adjusted yield of the security. While the structural differences that we allow across matched bonds generally do not affect pricing, there is anecdotal evidence and prior research that shows that these structural attributes *can* affect pricing. For instance, there may be outsized demand for specific coupons by particular investors (e.g., Albano, 2016). Extreme differences in issuance size can change the index eligibility of a bond issue (Bloomberg, 2017), and this can have significant effects on pricing (e.g., Chen et al., 2014). In addition, underwriters may structure some portion of a deal for retail investors who are generally less price-sensitive than institutional investors (e.g., Green et al., 2010).

Consistent with these observations, we see in Table B-1 that there are *significant* structural differences across issuance size or coupon structure for the matched pairs that exhibit the largest pricing differentials. We forgo an in-depth discussion of each outlier, but as a salient example, consider the first outlier reported. The green bond is a New York State Housing Authority $25.15 million bond issued at par with a 1.65% coupon. The matched non-green bond is a $60,000 bond issued at par with a 1.4% coupon. We asked several industry professionals about this specific case, and they indicated that the more likely explanation for this aberrant behavior is that the underwriter was able to allocate a significantly smaller tranche of securities to price-insensitive retail investors.

Once we remove unusual observations or outliers, the average mean (median) yield differential is 0.01 (0.00) basis points, while the mean (median) spread differential is 0.00 (0.00) basis points. The yield (spread) differentials are precisely zero in 88% (88%) of cases with occurrences of positive and negative equally split at 6% of the cases.

Table B-1
Outliers

$Cusip_g$	$Cusip_c$	$Issue\ Amt_g$	$Issue\ Amt_c$	Cpn_g	Cpn_c	*CBI Cert.*	*Sprd. Diff.(bps)*
64987B3G1	64987B3N6	25.150	0.060	1.650	1.400	0.000	25.000
64987B3H9	64987B3N6	16.630	0.060	1.650	1.400	0.000	25.000
64987DNA8	64987DNK6	7.200	0.140	2.200	2.000	1.000	20.000
64987DNB6	64987DNK6	15.330	0.140	2.200	2.000	1.000	20.000
64987DNC4	64987DNK6	22.050	0.140	2.200	2.000	1.000	20.000
64987DJF2	64987DKJ2	17.650	0.080	2.450	2.300	0.000	15.000
64987DFV1	64987DHC1	12.480	0.100	2.050	1.900	1.000	15.000
64987DGA6	64987DHF4	27.000	0.100	2.350	2.200	1.000	15.000
64987DJD7	64987DKH6	51.510	0.070	2.350	2.200	0.000	15.000
64987BM54	64987BN46	24.750	0.840	1.750	1.600	0.000	15.000

Table B-1 (*continued*)

$Cusip_g$	$Cusip_c$	$Issue\ Amt_g$	$Issue\ Amt_c$	Cpn_g	Cpn_c	*CBI Cert*.	*Sprd. Diff*.(*bps*)
64987BL71	64987BN20	4.600	0.820	1.500	1.400	0.000	10.000
79768HCQ9	79768HDL9	7.780	2.190	5.000	5.000	0.000	10.000
93974DQH4	93974DSC3	1.120	3.900	3.000	5.000	0.000	9.000
93974DQH4	93974DQW1	1.120	4.970	3.000	5.000	0.000	7.000
93974DQK7	93974DSE9	0.860	15.300	2.500	5.000	0.000	6.000
645791V92	6457912D5	1.170	6.380	4.000	5.000	0.000	6.000
645791V92	645791Z49	1.170	5.300	4.000	5.000	0.000	6.000
93974DQJ0	93974DSD1	2.940	12.460	4.000	5.000	0.000	6.000
645791V76	6457912B9	1.080	5.900	5.000	5.000	0.000	5.000
645791V84	6457912C7	1.140	6.130	4.000	5.000	0.000	5.000
645791W26	6457912E3	1.220	6.380	4.000	5.000	0.000	5.000
645791V50	645791Y81	0.980	5.960	5.000	5.000	0.000	5.000
645791V76	645791Z23	1.080	6.280	5.000	5.000	0.000	5.000
645791V84	645791Z31	1.140	5.380	4.000	5.000	0.000	5.000
645791W26	645791Z56	1.220	5.190	4.000	4.500	0.000	5.000
645791V50	645791Z98	0.980	5.360	5.000	5.000	0.000	5.000
93974DQG6	93974DQV3	6.060	4.730	2.000	5.000	0.000	5.000
93974DQJ0	93974DQX9	2.940	5.220	4.000	5.000	0.000	5.000
93974DQK7	93974DQY7	0.860	5.500	2.500	5.000	0.000	5.000
645791H31	645791K60	0.450	9.120	5.000	5.000	0.000	−5.000
64987BL89	64987BN46	1.570	0.840	1.550	1.600	0.000	−5.000
64987BL71	64987BQ50	4.600	33.700	1.500	1.550	0.000	−5.000
357172YZ2	357172XZ3	1.990	7.070	4.000	4.000	0.000	−6.000

This table presents all matches with absolute spread differentials in the top 5% of our matched sample described in Section 4. We report the associated green and non-green CUSIPS ($Cusip_g$ and $Cusip_c$), issuance sizes (Issue Amt_g and Issue Amt_c), coupons (Cpn_g and Cpn_c), and whether the security attained the CBI Climate Certification (CBI Cert.) and the spread differential (Sprd. Diff.).

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