Financing the Response to Climate Change: The Pricing and Ownership of U.S. Green Bonds*

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Abstract

Estimates suggest that mitigating and adapting to climate change will cost trillions of dollars. We study the developing market for green bonds, which are bonds whose proceeds are used for environmentally sensitive purposes. After an overview of the U.S. corporate and municipal green bonds market, we study pricing and ownership patterns of municipal green bonds using a framework that incorporates assets with nonpecuniary sources of utility. The results support the prediction that green bonds are issued at a premium to otherwise similar ordinary bonds—that is, with lower yields—on an after-tax basis. They also support the prediction that green bonds are more closely held than ordinary bonds, particularly small or essentially riskless green bonds. Both pricing and ownership effects are stronger for bonds that are externally certified as green.

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1. Introduction

Climate change is accelerating. Of the seventeen warmest measured years since recordkeeping began in 1880, sixteen have occurred since 2001.[1] The rising temperature and increasing acidity of ocean water, climbing sea levels and the retreat of ice sheets and glaciers, and the increasing frequency of droughts and floods all reflect a changing climate and increasing atmospheric carbon levels.[2] One estimate suggests that keeping the world below the 2 degree Celsius scenario, a threshold viewed as limiting the probability of devastating consequences, will require $12 trillion over the next 25 years (Bloomberg New Energy Finance, 2015).

In the absence of a massive carbon tax scheme, bond markets will be central to financing these interventions. In this paper, we study the U.S. market for "green bonds," which we and others define as bonds whose proceeds are used for an environmentally friendly purpose. Examples include renewable energy, clean transportation, sustainable agriculture and forestry, energy efficiency, or biodiversity conservation. After reviewing the market and green bond characteristics, we set out and test predictions for pricing and ownership patterns. The stark facts of climate change alone are enough to motivate study of green bonds, but our framework and results also tie to broader themes in the socially responsible investing literature.

Since the first green bond was issued in 2007 by the European Investment Bank, the market has expanded to include a variety of issuers, including supranationals, sovereigns, corporations, and U.S. and international municipalities. It is a small but increasingly well-defined area of the fixed income markets. Yet in spite of the general acceptance of the notion of a "green" bond, there is not yet a single universally-recognized system for determining the green status of a bond. Green bonds may be labeled and promoted as such by the issuer, officially

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[1] https://www.giss.nasa.gov/research/news/20170118.

[2] https://climate.nasa.gov/evidence/.

certified by a third party according to some guidelines, or labeled green by a data provider, for example Bloomberg. We review the origins of the market and standards for identifying green bonds in the next section.

Our U.S. sample includes 2,083 green municipal bonds issued between 2010 and 2016 and 19 green corporate bonds issued between 2014 and 2016. Municipal bonds, at the cusip level, are typically far smaller than corporates; the total par outstanding for municipal green bonds and corporate green bonds is roughly the same as of the end of 2016, around $12 billion. In 2016, about 2% of new municipal issues were green, while only about 0.3% of corporate issues were green. On average, green municipal bonds have higher credit ratings and longer maturities than ordinary municipal bonds. They are more likely to be taxable and are somewhat larger. In contrast, green corporate bonds resemble ordinary corporates.

Our core analysis of pricing and ownership patterns is organized by a simple framework featuring a subset of investors whose objective function includes nonpecuniary sources of utility, such as a sense of social responsibility from holding green bonds, in addition to standard portfolio mean and variance. In this framework, expected returns include the usual CAPM beta term plus a second term, reflecting demand for a security's environmental attributes, which illustrates that securities with higher scores—such as green bonds—are priced at a premium and earn lower returns.

We confirm that green municipal bonds are indeed priced at a premium. After-tax yields at issue for green bonds versus ordinary bonds are, on average, about 6 basis points below yields paid by otherwise equivalent bonds. The estimates control for numerous factors related to ratings maturity, tax status, the yield curve, and other time-varying and bond-specific characteristics, even issuer fixed effects. On a bond with a 10-year duration, a yield difference of 6 basis points corresponds to approximately a 0.60 percentage-point difference in value, which seems plausible and economically meaningful. We find that this premium doubles or triples for bonds that are not only self-labeled as green (and confirmed by Bloomberg) but also externally certified as green, according to industry guidelines, and publicly registered with the Climate Bonds Initiative (CBI).

Our framework also makes predictions for ownership concentration of green bonds. Specifically, green bonds should be held disproportionately by concerned investors, who must be willing to accept their equilibrium lower returns. This concentration will be particularly strong for small bonds, where tilting away from market weights is less consequential, and when the bond is almost riskless, since risk aversion limits the extent to which concerned investors are willing to pursue a nonpecuniary benefit. Using institutional bond ownership data, we find supportive evidence for these predictions. The Herfindahl-Hirschman index is indeed higher for green bonds, especially relatively small bonds and those rated AAA. Also, echoing the pricing effect, concentration is particularly elevated for CBI certified green bonds.

There is a small amount of other recent work on green bonds. There are many categories of green bonds one might study—supranationals, sovereigns, municipals, agencies, corporates, and others—and each differs in its target investor base and currency risks, among other characteristics. So far, pricing results have been mixed. Using secondary market prices, a green vs. ordinary bond matching procedure, and a sample that includes 135 large, investment grade green bonds of many categories and currencies, Zerbib (2017) finds a moderate green bond premium in some subcategories. Karpf and Mandel (2017) use secondary market yields in a larger sample of municipals. Quite in contrast to our own results, they find a green bond discount. Our sample is broader and our methodology is different, but our results suggest this conclusion is incorrect. Pricing in the U.S. municipals market is highly sensitive to tax features, as shown by Atwood (2003). Many green municipal bonds in the first half of the sample are taxable, so they were issued and naturally traded at higher yields. In after-tax terms, however, they actually sold for a premium.[3]

Although green bonds are a new setting, the analysis fits into an existing literature on socially responsible investing. Renneboog, Ter Horst, and Zhang (2008) survey the literature and conclude that that a subset of investors is willing to accept lower financial performance in exchange for investing in funds that meet social objectives. This is consistent with Riedl and Smeets (2015), who combine administrative data and survey data from a sample of Dutch investors in mutual funds that have Socially Responsible Investment (SRI) mandates. Białkowski and Starks (2016) examine U.S. equity mutual funds with SRI mandates and conclude that inflows to those funds have been higher than inflows to comparable funds without similar mandates. Barber, Morse, and Yasuda (2017) analyze the flows of limited partner investments across venture capital funds and reach a similar conclusion.

Conversely, a large body of work has examined the stock returns of companies that have potentially negative social effects, for example those that produce alcohol, tobacco, or firearms, or that manage prisons or casinos. Hong and Kacperzyk (2009) suggests that "sin" stocks trade at a discount relative to other stocks and display higher average returns. Statman and Glushkov (2009) use a somewhat broader category of "sin stocks" and a different time period and come to the opposite conclusion. Recent work by Bansal, Wu, and Yaron (2016) suggests that a time-

[3] The available practitioner research is also somewhat mixed. Shurey (2017) finds a green bond premium in a sample of 12 supranational, euro-denominated green bonds, but reports that "similar yield curves for other portfolios, including U.S. dollar denominated and corporate-issued green bonds do not consistently demonstrate a premium for green securities" (p. 2). Ehlers and Packer (2017) provide an excellent review of green bond certification schemes and find a green bond premium at issuance in a sample of 21 green bonds collected across issuer and currency categories.

varying investor taste for socially responsible stocks may partially reconcile the contradictory conclusions of the earlier literature.

Our contributions relative to this prior work are to provide: an overview of the U.S. market for green bonds; a consistent framework to study both pricing and ownership patterns; a consistent set of empirical results on both dimensions in a comprehensive sample; and, suggestive evidence that formal green bond certification may be important in this emerging market. Nonetheless, the problems that the green bond market are attempting to address are enormous. There is a commensurate need for additional research on green bonds and other areas of climate finance.

The rest of the paper proceeds as follows. Section 2 presents an overview of the green bond market and the characteristics of green bonds versus ordinary bonds. Section 3 uses a simple model to develop the prediction that green bonds should price at a premium, then tests and confirms that prediction. Section 4 extends the framework to predict that green bonds should be held in greater concentration, then confirms that prediction and finer theoretical predictions. Section 5 concludes.

2. An Overview of U.S. Green Bonds

2.1. Historical Origins

The green bond market has international origins and embraces many bond issuer types. The first bond labeled as a "green bond" was issued in 2007 by the European Investment Bank (EIB). Other supranational issuers include the International Finance Corporation arm of the World Bank, which in 2013 issued the first $1 billion green bond. A benchmark example of a modern sovereign green bond is France's $10 billion bond, issued in 2017.

Corporate and sub-sovereign issuance of green bonds has also grown rapidly. The first corporate green bonds were issued by the French utility EDF, the Swedish property development company Vasakronan, and Bank of America. The first U.S. municipal bond to use the green bond label in its offering documents (that is, to self-label), as opposed to having acquired the label by market convention, was issued by Massachusetts in 2013. However, municipal bonds issued as early as 2010 under the federal Clean Renewable Energy Bonds (CREB) and Qualified Energy Conservation Bond (QECB) programs are considered labeled green bonds by market convention. These represent most of the early green bonds in our sample.[4]

The first sub-sovereign issuer outside of the U.S. was Gothenburg, Sweden, which issued SEK 500 million par value in 2013.[5] Other recent international issuers include the Province of Ontario and Johannesburg, South Africa. Fannie Mae has pioneered green mortgage-backed securities, which pool mortgages made to finance environment-related investments.

The emergence of the green bond market occurred alongside the development of other services for issuers, regulators, and investors. In 2014, a consortium of investment banks established voluntary guidelines for the green bonds market. These "Green Bond Principles" are organized around four elements: the use of proceeds of the bond issue; the process for evaluating projects; the management of the proceeds; and, reporting and disclosure regarding the proceeds and the project financed.[6] Third-party agents such as the Climate Bonds Initiative now offer certification services for potentially green bonds, and the Moody's and Standard & Poor's ratings agencies have also developed criteria and indexes for this market. The introduction of green bond ETFs is another indicator of the maturation of the market.

[4] Both programs were eliminated effective January 1, 2018 by the Tax Cuts and Jobs Act, which repeals tax credit bonds.
[5] http://unfccc.int/secretariat/momentum_for_change/items/9935.php.
[6] https://www.icmagroup.org/green-social-and-sustainability-bonds/green-bond-principles-gbp. .

2.2. *Identifying Green Bonds*

What is a "green bond"? The category is not as strictly defined as "S&P 500 stocks" but not as fuzzy as "junk bonds" or "growth stocks." We use the Bloomberg green bond tag for our sample of U.S. corporate and municipal bonds as an objective, replicable identification that meets institutional standards. To maintain focus, we do not consider green bonds issued by supranationals or foreign issuers.

Bloomberg describes the task as follows: "There are many shades of green … In addition, terminology often varies, with issuers using different titles to promote the environmental benefits of their bonds. While the use of proceeds often varies by bond as well, all issuers must commit to deploying 100% of bond proceeds for environmental sustainability-oriented activities in order for their bond to be identified as a labeled green bond" (Shurey 2016, p. 3). Bloomberg's process is based loosely on the Green Bond Principles described above.

Specifically, Bloomberg takes into account issuer self-labeling as "green" and/or additional statements in the issuance documentation about the issuer's intention to deploy funds toward environmentally friendly projects. Acceptable uses of funds include renewable energy, energy smart technologies, green infrastructure, clean transportation, sustainable water management, sustainable agriculture and forestry, pollution control, biodiversity conservation, climate change adaptation, and eco-efficient products. CREB and QECB bonds are considered green bonds by Bloomberg and market convention and represent most of the early green bonds in the sample.

There are currently only a few U.S. corporate green bonds, which is unsurprising given the requirement to isolate and designate proceeds exclusively for projects with the uses listed above. Several corporates do satisfy Bloomberg's requirements, however, and, occasionally, Bloomberg will tag a corporate bond as green, even if it is described as for general purposes, if the issuer is a pure play such that "all the company's business activities fit solely within the list of accepted green activities" (p. 8).

A subset of labeled green bonds are further certified by third parties as conforming to standards established by the Climate Bonds Initiative (CBI). An interesting question is whether this additional distinction, which is intended to further highlight the bond to investors as a green bond but is not costless, is associated with issue pricing or ownership patterns above and beyond those associated with the general Bloomberg green bond flag.[7]

Such effects are conceivable because the issuer engages the verifier in the pre-issuance phase (there would be little benefit to the issuer to pay to certify the bond as green after it is floated); certification at this phase thereby enables the issuer and underwriters to market the bond as certified by CBI in their roadshow. To provide ex post reconciliation, after the bond issuance and the allocation of proceeds, the verifier must confirm that the bond aligns with the post-issuance requirements of the Climate Bond Standard.[8] We elaborate on the costs of certification later, but we note that costs could relate to internal organizational processes (e.g. tracking allocation and management) and costs related to the certifier's fees and the CBI's own modest fee.

2.3. Sample, Market Size, and Growth

Using the Bloomberg identifications of green bonds, we gather initial yields and other characteristics data for corporates from Bloomberg and for municipals from Mergent (which is more comprehensive for municipal bonds). The Mergent data are from the Official Statements filed with the Municipal Securities Rulemaking Board in the context of bond issuances. MSRB regulations require that filing with each municipal bond issue. We exclude floating rate bonds.

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[7] https://www.brookings.edu/blog/the-avenue/2016/10/25/green-bonds-take-root-in-the-u-s-municipal-bond-market/
[8] For more details on the process, see: https://www.climatebonds.net/standards/certification/get-certified.

The unit of observation is the individual bond, as identified by a separate CUSIP number. Municipal bonds are typically sold in issues that consist of multiple bonds; an issue is a set of bonds that are sold at the same time and are generally subject to the same bond indenture but may include both green and ordinary bonds across a range of maturities.

As the top panel of Table 1 indicates, our total municipal bond sample, which runs from 2010 through 2016, contains 2,083 green bonds, versus 643,299 ordinary bonds. There are 204 unique issuer-year observations. The green bond sample begins in 2010 with the introduction of the CREB and QECB programs. As a percentage of ordinary bond issuance dollar volume, green bonds increased by a factor of ten over the sample period, from 0.18% of ordinary issuance in 2010 to 1.9% of ordinary issuance in 2016. Hence, green bonds are a still-modest but rapidly expanding segment of the municipal market. It is worth noting that the green municipal bond market has been growing even though the CREB and QECB programs, which presented special incentives for issuers, have now phased out.

The corporate bond sample begins in 2014 and contains only 19 bonds, with 13 unique issuer-year observations. As of 2016, they totaled 0.31% of ordinary corporate dollar volume. Green corporate bonds therefore remain a very small component of the U.S. corporate bond market. As mentioned above, this is not surprising in light of the difficulty of ring-fencing corporate proceeds and reporting in the presence of unclear benefits.

2.4. Uses of Green Bonds

Green bonds are defined by their environmentally-friendly uses. Table 2 shows the breakdown of uses by Mergent for green municipals. It also shows our own characterization of uses for green corporates based on offering documents and other sources.

The most popular uses for municipal green bonds proceeds include public power, mass transit, education (e.g., energy-efficient school buildings and dormitories), and water and sewer projects. In no category do green bonds make up a large fraction of total municipal issuance between 2010 and 2016, however. The table suggests that numerous municipal bonds which are not labeled green by Bloomberg, because they were not self-labeled as green bonds by the issuer, could be labeled green bonds.

For example, intrinsically environmentally-sensitive uses such as pollution control and mass transit are overwhelmingly financed by ordinary bonds. This in turn suggests that the U.S. green bond "market" could enlarge dramatically just by broader use of the label, but in terms of financing climate change solutions this is significant only to the extent that there are unique patterns in ownership or pricing associated with the label (which we document later) or has real effects in terms of financing projects that could or would have been financed by ordinary bonds anyway. In fact, the Climate Bond Initiative (CBI) was set up with a focus on this broader "climate aligned" bond market which dwarfs the labeled green bond market. The majority of the non-labelled but climate aligned green bonds were financing low carbon transportation solutions such as railways. The pricing of climate aligned bonds, as opposed to explicitly labeled green bonds, is a natural topic for future research.

2.5. Bond Characteristics

Table 3 presents bond-level summary statistics. Panel A begins with the municipal sample. We use the first rating available in Mergent, regardless of whether it is from Standard and Poor's, Moodys, or Fitch. When required, we translate the other agencies' ratings to the S&P scale and then to an ordinal numerical scale, with "1" assigned to the top rating of AAA, "2" to the next highest rating of "AA+", and so forth. BBB-, the lowest S&P rating considered investment grade, is a “10” on this scale. Green municipal bonds carry higher credit ratings than the ordinary bonds, with a median rating of AA+. The median rating of the ordinary bonds is AA. The modal green bond carries an essentially riskless AAA rating.

Green municipal bonds also have longer maturities. The difference between the mean maturities is 1.25 years. Green bonds are less likely to be identified by Mergent as being sold with third-party insurance or other credit guarantees. Driven by the CREB and QECB green bonds from the first few years in the sample, green bonds are much more likely to be Federally taxable, which is crucial to incorporate into their pricing at issue. Green bonds are slightly less likely to be subject to state tax and their coupons are never subject to the Alternative Minimum Tax, unlike some private-activity bonds issued to fund stadiums, hospitals, or similar projects.

Green bonds are both larger and, on average, part of larger bond issues than ordinary bonds, a fact that may owe something to the fixed costs of green status. They are significantly less likely to be identified as “bank-eligible”, a category of bonds where commercial banks under the Tax Reform Act of 1986 are allowed to deduct 80 percent of the interest cost incurred in order to own the bond. These bonds are required by law to be small in size and have other restrictions that may be difficult to square with green status.

Green bonds are much more likely to be “new money” bonds as opposed to being used to refund existing bonds. They are much less likely—14.7 percent versus 46.8 percent for ordinary bonds—to be “General Obligation” bonds, meaning that their security consists of a claim on the issuer’s tax revenue and not merely to the revenue generated by a specific project. To repeat, whether a bond is labeled green is based entirely on its use of proceeds, not its backing.

Finally, 6.6% of the green municipal bonds in our sample are certified by the Climate Bonds Initiative as conforming to the Green Bond Principles. All of these bonds were issued in 2016, the last year of our sample, so this is a recent practice.

Corporate bond-level statistics are presented in Panel B. Credit ratings of green corporate bonds do not differ significantly from those of ordinary bonds. Green corporates exhibit slightly lower maturity and larger size but are, in the main, similar to ordinary corporate bonds.

3. Pricing Green Bonds

3.1. Asset Prices with a Nonpecuniary Clientele

We start with a relatively standard asset pricing framework to understand how a clientele with a preference for green bonds, or more generically for any non-financial objective, affects prices and portfolio choice. It will also be useful later to study ownership concentration.[9]

There are two groups of investors, each facing a one-period portfolio choice problem. Both groups have a common risk aversion parameter γ and common expectations for security returns $\mathbf{r}$ and risk $\boldsymbol{\Sigma}$. They choose a vector of portfolio weights $\mathbf{w}$ in each security. Group 1 investors are mean-variance maximizers while Group 2 investors also care about environmental ratings (or another nonpecuniary attribute). That is, some securities have positive environmental scores $e > 0$, and Group 2 investors obtain extra utility from holding them. Without loss of generality we assume the overall average e is zero. Specifically, the two groups solve:

$$\text{Group 1: } \max \mathbf{w}_1'\mathbf{r} - \frac{\gamma}{2}\mathbf{w}_1'\boldsymbol{\Sigma}\mathbf{w}_1$$

$$\text{Group 2: } \max \mathbf{w}_2'\mathbf{r} + \mathbf{w}_2'\mathbf{e} - \frac{\gamma}{2}\mathbf{w}_2'\boldsymbol{\Sigma}\mathbf{w}_2$$

[9] See also the theoretical paper of Angel and Rivoli (1997), who present a refinement of Merton's (1987) model that they use to investigate the asset pricing implications of an economy where a subset of investors reject certain stocks on ethical grounds.

Note that Group 2's objective function resembles how ESG mandates are implemented in practice. In particular, if Group 2 investors require that their portfolios maintain a minimal average environmental score, this is equivalent to imposing a linear constraint of the form $\mathbf{w}_2'\mathbf{e} \geq k$ and leads to the same maximization problem as above. Also, this formulation accommodates not only so-called positive screening, where extra utility is gained for holding a subset of securities, but also negative screening, where extra utility is lost by holding fossil fuel or sin stocks, by appropriately flipping signs and redefining e.[10]

The two groups have capital of a_1 and a_2, respectively, and the market clears. Because we are also interested in ownership concentration in a following section, we stipulate that Group 1's capital comes from a_1 individuals each with \$1, and likewise Group 2's capital comes from a_2 individuals each with \$1. We express this as:

$$\frac{a_1}{a_1 + a_2}\mathbf{w}_1 + \frac{a_2}{a_1 + a_2}\mathbf{w}_2 = \mathbf{w}_m$$

where $\mathbf{w}_m$ is the market portfolio, a vector of weights in each security equal to its market values as a fraction of the total market value of all securities.

We start with the uninteresting case where a_2 is equal to zero, so that there are only Group 1 investors, which have no environmental preference. They choose weights, given common return and risk expectations, and these representative investor weights must equal market weights for the market to clear:

$$\mathbf{w}_1 = \frac{1}{\gamma}\mathbf{\Sigma}^{-1}\mathbf{r} = \mathbf{w}_m$$

[10] In the case of e measured by a green bond indicator, the $e > 0$ designation is at the extreme because the score is binary and green bonds are comparatively rare. This means that a z-scored green flag will contain many small negative scores and relatively few very positive ones in order to preserve zero mean and unit standard deviation.

We can use this equation to compute the expected return of the market as a whole, which allows us to substitute the market Sharpe ratio for the inverse of risk aversion γ, leading to the familiar Capital Asset Pricing Model (CAPM) formula:

$$\mathbf{r} = \frac{r_m}{\sigma_m^2}\boldsymbol{\Sigma}\mathbf{w}_m = \boldsymbol{\beta} r_m$$

Now, we add Group 2 investors, who have an environmental preference, to the mix. Their portfolio weights are simply

$$\mathbf{w}_2 = \frac{1}{\gamma}\boldsymbol{\Sigma}^{-1}(\mathbf{r} + \mathbf{e})$$

Since the average environmental score is mean zero, we can make the same substitution for γ using market clearing. The CAPM then holds up to a small twist:

$$\mathbf{r} = \frac{r_m}{\sigma_m^2}\boldsymbol{\Sigma}\mathbf{w}_m = \boldsymbol{\beta} r_m - \frac{a_2}{a_1 + a_2}\mathbf{e}$$

Prediction 1: *Securities with positive environmental scores (such as green bonds) have lower expected returns.*

Put simply, when some investors have an additional, nonpecuniary preference for a security, they bid up its price, and more so when their preference is widespread. We test this prediction next.

3.2. Yield Data

The green bond market is young and there have been few, if any, defaults. To detect differences in expected returns, we focus on annual yields at issue. Due to the very small number of U.S. corporate green bonds we concentrate on municipal bonds for the rest of our analysis.

Like ordinary municipal bonds, green bonds are generally tax exempt. As mentioned earlier, green bonds issued under the CREB and QECB programs were taxable, however. We therefore concentrate on the after-tax yield at issue to allow yields on green and ordinary bonds to be judged on the yardstick most relevant to the tax-sensitive investors who influence the municipal bond market.

We combine data from multiple sources to compute after-tax yields. Data on the tax status of the bonds come from Mergent and are based on the issues' official statements. These data identify both the federal and the state tax status of each bond. Bonds are identified as being taxable, tax-exempt, or subject to Alternative Minimum Tax at the federal level. Bonds are also identified as being taxable or not taxable at the state level.

Federal tax rates come from the Tax Policy Center.[11] The marginal tax rate used is the tax rate prevailing at the highest income levels in that year. Post-2013 tax rates include the 3.8% ACA surcharge in addition to the 39.6% top marginal income tax rate. State tax rates come from the Taxsim model of the National Bureau of Economic Research.[12] For each state the rate used is also the rate applicable to top income levels.

We then calculate a pre-tax and after-tax yield as the internal rate of return on each bond's cash flows before and after taxation, respectively. We assume that the bond's relevant tax rate is the rate at the time of issuance and that the bond is held by a top-income resident of the state from which the bond is issued. In cases where our calculated pre-tax yield differs from the yield reported by Mergent, we reset the after-tax yield to the Mergent yield from the official statements minus the difference between our calculated pre-tax and after-tax yields.

Table 4 shows average yields by year for green and ordinary bonds. The need to carefully account for tax features is apparent for the 2010-2013 green bonds sample, which is dominated

[11] http://www.taxpolicycenter.org/statistics/historical-individual-income-tax-parameters.
[12] http://users.nber.org/~taxsim/state-rates/.

by taxable CREB and QECB bonds.[13] Overall average after-tax yields are somewhat lower for green bonds than ordinary bonds, at 2.28% versus 2.50%. We have seen that green bonds and ordinary municipal bonds have moderate but statistically significant differences in some characteristics, however, that are likely to correlate with their yields, and coincidental movements in the credit curve can upset the impression from simple averages.

3.3. Yield Regressions

To more properly test the prediction that green bonds sell for a premium, we regress after-tax yields on green bond indicators and controls in Table 5. In all specifications, we control for maturity, rating, and month fixed effects. We also include size category, the presence of insurance, tax features (as a precaution, in that we are already directly measuring after-tax issue yield in the dependent variable), bank qualification status, new money, general obligation collateralization, and use of proceeds. In some specifications we flexibly control for maturityXratingXmonth interaction fixed effects, thus taking account of twists in the credit curve, and even issuer fixed effects. These controls account for most of the variation in yields in the sample.

All specifications support the prediction that green bonds sell for a moderate premium. Holding characteristics and the state of the yield and credit curves equal, green bonds are issued at after-tax yields around five to seven basis points lower than those of ordinary bonds. To put this in extremely crude perspective, consider that the average after-tax yield for AAA ordinary bonds is 2.31% (unreported). The average after-tax yield for an ordinary bond rated BBB-, which is the lowest investment grade rating and nine notches lower than AAA, is 3.27% (unreported). This works out to about a 12 basis point increase for every ratings notch. A green bond

[13] Karpf and Mandel (2017) found that green bonds had higher yields at issue but, crucially, did not adjust for the fact that early green bonds were disproportionately taxable.

coefficient on the order of six basis points thus implies that green bonds are priced as if they were "half a notch" more highly rated.

Of course, greenness is not assigned at random, so the extent of causality cannot be determined with certainty. However, in regressions that control for use of proceeds, maturityXratingXmonth interaction fixed effects, collateral type, and (in some specifications) even issuer fixed effects, it is harder to attribute the coefficient to, for example, an unobserved difference in the risk of green versus ordinary bonds.

Interestingly, bonds that are certified green are priced at a greater premium. These are a subset of the standard Bloomberg green bonds, so the total premium for certified over ordinary bonds is the sum of the two coefficients in Table 5. In the first specification, CBI-certified green bonds have yields 26 basis points lower than ordinary bonds with similar characteristics and timing. In the context of low-risk municipal bonds issued in a historically low interest-rate environment, this is a sizeable difference. The calculation above suggests that 26 basis points is equivalent to the reduction in yield that comes from climbing more than two ratings notches. Even with issuer fixed effects and many other controls and interactions, the average difference between the aftertax issue yield on certified green bonds and ordinary bonds amounts to 15 basis points per year.

3.4. Is Certification Worth It?

Green bond certification by third parties is not randomly assigned—municipalities must pay for it—so it is unclear how much of the incremental reduction in yield in Table 5 associated with certification is causal. If bonds that are certified were already recognized by investors and priced as "especially green," the coefficient will overstate the effect of certification. On the other hand, green bond issuers pay for third-party certification because they fear that the bond would not otherwise attract the full attention of concerned investors. From that perspective, the coefficient on certification might understate the price that investors are willing to pay to get an indisputably green bond.

In any event, a back of the envelope calculation helps to think about the decision to pay for certification. There are five CBI-certified municipal issues in our sample. These comprise 137 individual bonds. The median total issue size, corresponding to the 22-bond issue by San Francisco Public Utilities in December 2016, is $259 million. If the figures in Table 5 are taken as causal, a reduction of ten basis points per year would imply a savings of $259,000 per year. Even a miniscule amount of causality, consisting of a single basis point savings, would still save $25,900 per year, which has a nontrivial present value.

Against this pricing benefit falls two categories of costs. Internal processes to allocate and confirm the management of proceeds might involve some costs, but we have no evidence on their magnitude. We have more evidence on external costs related to parties contracted for the certification. The main certification fee is to be paid once and immediately after the issuance of the bond. The cost of the verifier (in our sample, the certifier is typically Sustainalytics, but in practice it might be a Big 4 firm, environmental consultancy, or environmental NGO) is negotiable; anecdotal evidence suggest that this fluctuates between $10,000 and $50,000 depending on issuance size.[14] If the issuer chooses, it can engage a certifier for ongoing evaluations. Registration of the bond with the Climate Bonds Standard Board requires a certification fee equal to one-tenth of a basis point of the bond principal. All together, the present value of the external costs of certifying an issue appear to be well under $100,000 and possibly a

[14] For example: https://www.cdfa.net/cdfa/cdfaweb.nsf/pages/31935/$file/How%20Green%20Bond%20Issuers%20Weigh%20Certification%20_%20The%20Bond%20Buyer.pdf .

fraction of that. Comparing these costs to the potential pricing benefits suggests that certification could be a good deal for larger and/or longer-maturity bonds.

4. Ownership Concentration of Green Bonds

4.1. Ownership with a Nonpecuniary Clientele

Coming back to the framework used to study pricing, we can examine ownership patterns by substituting expected returns into each group's first-order condition. These are neatly summarized as deviations from market weights:

$$\text{Group 1: } \mathbf{w}_1 = \mathbf{w}_m - \frac{1}{\gamma}\frac{a_2}{a_1 + a_2}\mathbf{\Sigma}^{-1}\mathbf{e}$$

$$\text{Group 2: } \mathbf{w}_2 = \mathbf{w}_m + \frac{1}{\gamma}\frac{a_1}{a_1 + a_2}\mathbf{\Sigma}^{-1}\mathbf{e}$$

As is intuitive, Group 2 investors, with their environmental objective, overweight securities with positive environmental scores and vice-versa. The magnitude of the overweights are a function of the environmental score and the relative size of Group 2. When Group 2 is small and the environmental score is extreme, the overweights are material. Market clearing requires Group 1 investors to do the opposite. They underweight securities with a positive environmental score because their equilibrium expected returns are lower, for reasons that are not related to risk.

We can also compute the concentration of holdings. To simplify notation, define the vector $\tilde{\mathbf{e}} = \mathbf{\Sigma}^{-1}\mathbf{e}$. In the case of uncorrelated returns, the elements of $\tilde{\mathbf{e}}$ are simply equal to a security's environmental score divided by its return variance, or $\tilde{e_i} = \frac{e_i}{\sigma_i^2}$. This is the risk-adjusted environmental score. Because investors are risk averse, risk reduces the extent to which the score influences portfolio choice.

We measure ownership concentration using the familiar Herfindahl-Hirschman Index (HHI), the sum of the squared percentage holdings. For security i,

$$HHI_i = \frac{1}{c_i^2}\sum_{s=1}^{a_1}\left(w_{mi} - \frac{1}{\gamma}\frac{a_2}{a_1 + a_2}\tilde{e}_i\right)^2 + \frac{1}{c_i^2}\sum_{s=1}^{a_2}\left(w_{mi} + \frac{1}{\gamma}\frac{a_1}{a_1 + a_2}\tilde{e}_i\right)^2$$

where c_i is a constant equal to the total market value of security i. Holding constant total capital at $a_1 + a_2$, this sum is minimized when the risk-adjusted environmental score is zero or when there are no investors with an environmental preference so that a_2 is equal to zero. In both cases, the holdings are constant across all investors, and hence concentration is minimized. As the number of investors becomes large, this total approaches zero. By contrast, holding constant the proportions of investor types, the sum is maximized at extreme levels of the risk-adjusted environmental score. The derivative of HHI with respect to $\tilde{e}_i$ is:

$$\frac{2}{\gamma^2 c_i^2}\frac{a_1\, a_2}{a_1+a_2}\tilde{e}_i$$

HHI is therefore a parabola with a minimum at zero—concentration is minimized at a security with a neutral environmental score. Securities with extreme scores, whether favorable or unfavorable, have higher ownership concentration.

Although green bonds are difficult to short in practice, we have not precluded short positions here for simplicity, so the HHI is not bounded in the usual way. But, one can see that with two investor types, it is possible to get to maximum concentration even without short positions. For example, suppose that there is a single individual in Group 2 with environmental preferences, so that a_2 is equal to 1, and that the risk-adjusted environmental score is large enough to make the optimal weight in Group 1 exactly equal to zero. This is an example of maximal concentration: a single investor holds the entire capitalization of the security.

Finally, to build further intuition, consider the case where $a_1 = a_2 = a$. Since we have assumed that each investor has one dollar in order to discuss ownership concentration, in equilibrium the total number of investors N equals the total capitalization of all securities C, i.e.,

$N = a_1 + a_2 = 2a = C$. After some algebra, this allows us to write equilibrium concentration in a more intuitive form:

$$HHI_i = \frac{1}{N} + \left(\frac{1}{2\gamma\left(\frac{c_i}{C}\right)}\right)^2 \tilde{e}_i{}^2$$

The parabola HHI rests at its theoretical minimum value of $1/N$, the uniform ownership that would obtain if investors were homogenous or, if they are not, if the risk-adjusted environmental score is zero. Concentration then rises as the risk-adjusted score moves away from zero in either direction. Here, we can also see that the effect of environmental scores is stronger when the security has a smaller weight in the market portfolio and when risk aversion is low, so that Group 1 investors are willing to tilt their portfolios more aggressively in response to differences in price and Group 2 in response to differences in environmental benefits.

Prediction 2: *Securities with positive environmental scores (such as green bonds) have more concentrated ownership, particularly for those with low market values and low risk.*

Again, this is based on a symmetric effect. If there were a set of particularly un-green securities that could be measured sensibly on the same spectrum, they will also be held in greater concentration. This observation may be useful in the sin stocks context. In our empirical setting of municipal bonds, however, the situation is simpler. There is a small set of green bonds versus a large set of ordinary bonds.

4.2. Ownership Data

Bond ownership data are from the Thomson Reuters eMAXX database, used by Manconi, Massa, and Yasuda (2012) and others, which includes fixed income positions of thousands of U.S. and international insurance companies, pension funds, and mutual funds. Insurance company holdings are based on NAIC disclosures; mutual fund holdings are based on SEC disclosures; and pension fund holdings are disclosed voluntarily.

Our ownership sample is based on twelve quarters of reported holdings of municipal bonds from the first quarter of 2014 through the last quarter of 2016. To be included, a bond must have data on all control variables used earlier and, to balance coverage against measurement error in the calculation of HHI, at least 25% of a bond's par outstanding must be reported within eMAXX. We use ownership data from the first quarter for which this level of bond ownership is available. Since eMAXX-reporting institutions often buy municipal bonds at the issue date and hold for long periods, often to maturity, most of our ownership data reflect the cross-section of holdings that prevails within one quarter of the issue date. In all, we have 70,690 green bonds and 436 ordinary bonds for the ownership analysis.

Ownership summary statistics are in Table 6. Most smaller bonds do not appear in eMAXX because they are owned entirely by retail investors or small institutions. For bonds that do appear, a majority of par amount outstanding is owned within eMAXX. In particular, among all bonds with at least 25% eMAXX ownership and other control variables, green bonds have a mean of 76.1% of par amount outstanding held within eMAXX and ordinary bonds have a median of 71.1% ownership within the database.

Next, we use the fund name to estimate the percentage of par outstanding held by concerned investors. Specifically, we proxy for whether a fund has "green" concerns based on whether it has a substring in its eMAXX fund name that indicates an association with socially responsible investing.[15] This will undercount the number of investors that actually consider

[15] The substrings are: CALVERT, CATHOLIC, CHURCH, CLEAN, DOMINI, ENVIRON, ESG, FAITH, GREEN, IMPACT, KLD, PARNASSUS, SOCIAL, SRI, WALDEN.

social objectives, since many such funds do not include one of these substrings in their names. Nonetheless, even this methodology indicates that green bonds are disproportionately held by socially-oriented investors. For the average green bond in this subsample, 13.5% of par outstanding can be associated with a socially-responsible fund through the fund's name. In contrast, for the average ordinary bond in this subsample, only 0.6% can be associated with a socially responsible fund. Therefore, green bonds are recognized by the types of concerned investors one would expect.

We use HHI as a formal estimate of ownership concentration that maps into the analytical framwork. We estimate HHI under the assumption that the distribution of holdings is the same across investors outside the eMAXX database as we observe within the database. For example, for a bond with 50% of par outstanding accounted for in eMAXX, we estimate the overall HHI by doubling the sum of squared ownership shares (of par outstanding) among eMAXX-reporting institutions. There is no univariate difference in HHI between green and ordinary bonds, but we need to use regressions to control for various differences in bond characteristics that will also affect bond ownership patterns. For example, green bonds are larger than average, so they are likely to have a broader investor base, other characteristics being equal.

4.3. Ownership Regressions

Our regression tests involving green bond ownership concentration are in Table 7. For simplicity, we include the same series of controls and fixed effects to be consistent with the yield regressions—although maturityXratingXissue-month effects are less needed than in the case of yield regressions—and find qualitatively similar results.

In all specifications, green bonds are held in greater concentration. The relationship is statistically significant and economically plausible. Controlling for numerous bond, month, and issuer characteristics, HHI is approximately 0.05 higher for green bonds, which can be viewed in the context of the sample's unconditional municipal bond HHI of 0.79.

As in the case of yields, CBI-certified green bonds provide especially strong support for model predictions. The total predicted difference in concentration between a certified green bond and an ordinary bond, all else equal, is the sum of the two coefficients reported in Table 7. For example, the first specification suggests that relative to ordinary bonds with similar characteristics, HHI is 0.04 higher for green bonds but 0.24 higher for certified green bonds. The extent to which this effect is causal is unclear, but as with the pricing results it seems likely that there is a degree of causality, given that certification is costly and its explicit purpose is to improve the marketing of the bond to concerned investors.

As mentioned above, we predict that concentration of green bonds should be particularly high when the bond is relatively small and low risk, therefore presenting relatively small consequences for investor-level portfolio weights or disutility due to risk aversion. We turn to these finer predictions in Table 8.

We define a green bond as "small" if it is below the top quintile of the full sample bond size distribution. Since green bonds are larger than ordinary bonds, as confirmed in Table 3, this roughly divides the green bond sample into equal halves, small and large (not small). As noted earlier, almost all green bonds are investment grade, so risk, like size, is a highly relative concept in this market. We define a green bond as "low risk" if its rating is AAA, which is the modal municipal green bond rating and which is also chosen to divide the sample of green bonds with ownership data roughly into halves.

The results in Table 8 support these two finer predictions. AAA-rated, effectively riskless green bonds have an HHI between 0.08 and 0.20 higher than other bonds, controlling for various combinations of fixed effects. Green bonds that are not in the top size quintile have an HHI between 0.07 and 0.16 higher than other bonds, controlling for various combinations of fixed effects. As in the previous table, there remains an incremental association between CBI certification and ownership concentration.

Overall, the ownership results tie together the yield findings and a simple analytical framework. A subset of investors appears willing to sacrifice some return to hold green bonds, particularly "certified" green bonds. Green bonds are held disproportionately by these investors. Further, and as predicted, ownership is particularly concentrated for smaller and especially low-risk bonds.

5. Conclusion

The need for climate change solutions is imminent, and green bonds are currently the front-line response offered by the financial markets. In this paper, we study the U.S. corporate and municipal green bond markets. Our work complements other research in climate finance which focus on how investors might measure and manage climate risks.

We start with a history and overview of the U.S. green bond markets and basic bond characteristics. In terms of their current total dollar value and growth rates, the markets bear a resemblance to the high-yield corporate debt market as of the mid-1980s. We then narrow the focus to the municipal bond sample, since there are currently far more green municipal bonds than green corporate bonds available for study and much of the response to climate change necessarily involves public infrastructure of some form.

A simple asset pricing framework that incorporates an investor preference for nonpecuniary attributes—in our application, a preference for green versus ordinary bonds—

makes two predictions. The first is that green bonds will sell for a premium. After controlling for numerous fixed and time-varying factors, we find that green bonds indeed are issued at a premium, with yields lower by several basis points. This is a natural flip side to the Hong and Kacperczyk (2009) result that sin stocks are associated with higher returns. The second prediction is that green bond ownership is more concentrated, with a subset of investors holding them in greater than market weights, particularly when the par value is small or the bond is especially low risk. The data also support those predictions. Overall, a natural explanation is that a subset of investors is willing to sacrifice some return to hold green bonds.

An additional finding with practical implications is that both the pricing and ownership effects, while apparent across green bonds, are stronger among bonds that are certified by external verifiers. This has immediate practical implications for green bond issuers and supports efforts to create standards upon which certifications could be granted.

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Table 1. Volume of issuance of U.S. green and ordinary bonds by year. Data on municipal bonds come from Mergent and data on corporate bonds come from Bloomberg. Within each category of bonds, data from Bloomberg are used to identify green bonds. Floating-rate bonds are excluded. Dollar values are nominal par issuance amounts, and are not adjusted for inflation.

	Green			*Ordinary*
Year	**Unique Bonds**	**Unique Issuers**	**$ (M)**	**$ (M)**
Panel A. Municipal				
2010	116	32	466	255,000
2011	97	34	137	180,000
2012	106	24	180	261,000
2013	78	15	261	224,000
2014	309	22	2,130	244,000
2015	593	38	2,940	309,000
2016	784	39	6,530	353,000
Total	2,083	204	12,644	1,826,000
Panel B. Corporate				
2014	2	2	700	1,270,000
2015	11	6	6,720	1,390,000
2016	6	5	4,080	1,330,000
Total	19	13	11,500	3,990,000

Table 2. Volume of issuance of green and ordinary bonds by use of proceeds. Based on data from Mergent, with green bonds identified using data from Bloomberg. Dollar figures are par value issued, and are not adjusted for inflation. Municipal bond data cover 2010-2016 issuance, and corporate bond data cover 2014-2016 issuance.

	Green			*Ordinary*
Use	**Unique Bonds**	**Unique Issuers**	**$ (M)**	**$ (M)**
Panel A. Municipal				
Agriculture	0	0	0	93
Airlines	0	0	0	2,300
Airports	0	0	0	54,600
Bridges	0	0	0	6,830
Courts	0	0	0	2,170
Civic/Convention Centers	0	0	0	8,100
Correctional Facilities	10	2	6	7,080
Multiple Public Utilities	0	0	0	14,900
Economic Development	31	2	267	12,200
Public Power	246	40	1,080	64,600
Fire Station/Equipment	0	0	0	1,530
Flood Ctl/Storm Drain	0	0	0	2,430
Gas	0	0	0	5,600
General Purpose	515	41	2,380	591,000
Government/Public Buildings	2	2	9	8,650
Higher Education	194	20	1,010	161,000
Hospitals	3	3	101	86,900
Industrial Development	0	0	0	3,360
Irrigation	0	0	0	831
Library or Museums	0	0	0	3,560
Malls/Shopping Centers	0	0	0	22
Mass/Rapid Transit	83	4	1,480	27,100
Multi-Family Housing	0	0	0	14,900
New Public Housing	0	0	0	16
Nursing Homes	0	0	0	3,740
Office Bldg	0	0	0	864
Other Healthcare	5	1	53	29,400
Other Public Service	0	0	0	233
Other Recreation	0	0	0	1,840
Other Education	0	0	0	7,050
Other Housing	20	1	40	5,480
Other Transportation	43	2	492	45,900
Other Utilities	0	0	0	2,070

Table 2 continued on next page

Table 2 continued from previous page				
	Green			*Ordinary*
	Unique Bonds	**Unique Issuers**	**$ (M)**	**$ (M)**
Panel A (Municipal bonds) continued				
Parks/Zoos/Beaches	0	0	0	4,360
Pension Funding/Retirement	0	0	0	4,750
Parking Facilities	0	0	0	2,250
Police Station/Equip	1	1	7	648
Pollution Control	21	1	19	10,200
Land Preservation	0	0	0	505
Primary/Secondary Education	114	33	262	335,000
Redevelopment/Land Clearance	5	1	2	11,400
Retirement Centers	0	0	0	3,500
Sanitation	24	1	167	1,340
Seaports/Marine Terminals	0	0	0	10,800
Single Family Housing	0	0	0	23,400
Single/Multi-Family Housing	0	0	0	2,690
Stadiums/Sports Complex	0	0	0	5,460
Student Loans	0	0	0	4,170
Theaters	0	0	0	228
Toll Road and Highway	0	0	0	51,500
Tunnels	0	0	0	40
Veterans	0	0	0	1,510
Solid Waste	42	3	51	6,060
Water and Sewer	724	32	5,210	170,000
Total	2,083	190	12,637	1,826,160
Panel B. Corporate				
(Not Green)				3,990,000
Green Buildings	3	3	1,200	
Renewable Energy	12	6	6,700	
Mixed Green Use	4	4	3,600	
Total	19	13	11,500	3,990,000

Table 3. Characteristics of green and ordinary bonds. Data on municipal bond characteristics come from Mergent. Corporate bond characteristics are from Bloomberg. P-values for test of differences in means are calculated using a one-variable regression model, with standard errors adjusted for issuer-level clustering. The municipal sample runs from 2010 to 2016 issuance and includes 2,083 green bonds and 643,299 ordinary bonds. The corporate sample runs from 2014 to 2016 issuance and includes 19 green bonds and 8,315 ordinary bonds. Standard errors for differences are clustered by issuer.

	Green				*Ordinary*				*Diff*	
Variable	**Mean**	**Median**	**Min**	**Max**	**Mean**	**Median**	**Min**	**Max**	**Mean**	**P-Value**
Panel A. Municipal										
Rating (AAA=1)	2.78	2.00	1	14	3.40	3.00	1	21	-0.63	(0.005)
Maturity (Years)	11.94	11.22	1	30	10.70	9.82	1	30	1.25	(<0.001)
Insured (Yes=1)	0.060	0.00	0	1	0.170	0.00	0	1	-0.11	(<0.001)
Taxable (Yes=1)	0.280	0.00	0	1	0.069	0.00	0	1	0.21	(<0.001)
Taxable AMT (Yes=1)	0.000	0.00	0	0	0.011	0.00	0	1	-0.01	(<0.001)
Taxable State (Yes=1)	0.056	0.00	0	1	0.091	0.00	0	1	-0.03	(0.101)
Total Issue Size ($M)	6.3	2.3	0.1	250	3.0	0.7	0.1	3500	3.27	(<0.001)
Bank Qualified (Yes=1)	0.016	0.00	0	1	0.383	0.00	0	1	-0.37	(<0.001)
New Money (Yes=1)	0.711	1.00	0	1	0.434	0.00	0	1	0.28	(<0.001)
General Obligation (Yes=1)	0.147	0.00	0	1	0.468	0.00	0	1	-0.32	(<0.001)
CBI Certified Green (Yes = 1)	0.066	0.00	0	1	0.000	0.00	0	0	0.07	(0.029)
Panel B. Corporate										
Rating (AAA=1)	9.26	8.00	2	14	9.10	9.00	1	21	0.17	(0.879)
Maturity (Years)	6.84	7.03	2	10	8.37	7.52	1	30	-1.52	(0.085)
Total Issue Size ($M)	605	500	250	1,500	487	350	0.1	11,000	118.0	(0.129)

Table 4. Offering yields of green and ordinary municipal bonds. Data on municipal bond characteristics come from Mergent. Corporate bond characteristics are from Bloomberg. Pre-tax yields come directly from Mergent and Bloomberg data. After-tax yields are calculated for a hypothetical investor paying the marginal tax rates prevailing at the highest levels of income; calculations use Mergent data on bonds' tax status and data from the Tax Policy Center on federal tax rates. State-level year-specific tax rates come from the Taxsim model of the National Bureau of Economic Research. Calculations for each bond use the tax rates prevailing in the year of issuance.

	Green			*Ordinary*		
Year	**N**	**Pre-Tax Yield (%)**	**After-Tax Yield (%)**	**N**	**Pre-Tax Yield (%)**	**After-Tax Yield (%)**
2010	116	5.21	3.38	71,643	3.76	3.40
2011	97	4.69	3.00	64,485	3.38	3.30
2012	106	3.12	2.01	92,259	2.39	2.32
2013	78	3.51	2.04	80,666	2.67	2.57
2014	309	2.54	2.39	89,720	2.48	2.41
2015	593	2.52	2.31	116,377	2.37	2.29
2016	784	2.12	2.03	128,149	1.98	1.92
Total	2,083	2.69	2.28	643,299	2.61	2.50

Table 5. Regressions to explain offering yields of municipal bonds. Table presents the results of ordinary least-squares regressions of after-tax bond yields at issue on green bond indicators and other bond characteristics and fixed effects. After-tax yields are calculated using Mergent, Tax Policy Center, and NBER data as described in notes to Table 4, and assume that the marginal tax rate paid by the investor is the marginal tax rate prevailing at the highest level of income in a given state in each bond's year of issuance. T-statistics are reported in brackets. "Green" is a dummy variable for bonds that Bloomberg tags as green. "CBI" Certified is a dummy variable for green bonds that also carry Climate Bonds Initiative green certification.

	Dependent variable: After-Tax Yield			
Variable	**Model 1**	**Model 2**	**Model 3**	**Model 4**
Green	-7.4	-7.0	-5.4	-7.2
	[-8.91]	[-9.60]	[-6.73]	[-10.93]
CBI Certified Green	-18.8	-16.9	-13.9	-8.2
	[-5.87]	[-6.08]	[-5.19]	[-3.77]
R-Squared	0.88	0.91	0.93	0.96
Adjusted R-Squared	0.88	0.91	0.93	0.95
N	614,440	610,485	613,912	609,907
Fixed Effects				
Maturity	Yes		Yes	
Rating	Yes		Yes	
Month	Yes		Yes	
Maturity x Rating x Month		Yes		Yes
Issuer Fixed Effects	No	No	Yes	Yes
Additional Fixed Effects (all specifications)	Size Category, Insured, Taxable, Taxable AMT, Taxable State, Bank Qualified, New Money, Code = GO, Use of Proceeds			

Table 6. Ownership of green and ordinary municipal bonds. Data are based on combining Mergent data on bond characteristics with Bloomberg data identifying green bonds and eMAXX data on institutional ownership of individual bonds. eMAXX Ownership is the percentage of bond par value accounted for by eMAXX-reporting institutions. We require at least 25% ownership to be included in the sample. Green Fund Ownership is the percentage of bonds owned by a fund that has some green or social investing orientation, based on whether it has any of the following strings in its name: CALVERT, CATHOLIC, CHURCH, CLEAN, DOMINI, ENVIRON, ESG, FAITH, GREEN, IMPACT, KLD, PARNASSUS, SOCIAL, SRI, WALDEN. HHI is the Hirschman-Herfindahl Index, calculated as the sum of the squared values of ownership shares. Higher values reflect more ownership concentration, with a value of 1 reflecting a single owner owning all of the bond and 0 reflecting infinite dispersion of ownership. When eMAXX-reporting owners hold less than the total par outstanding, HHI is calculated assuming that the distribution of ownership shares in that universe match what is observed within the eMAXX universe. The sample runs from 2014 to 2016 and includes 70,690 ordinary bonds and 436 green bonds with sufficient ownership data and control variables. Standard errors for differenes are clustered by issuer.

	Green				*Ordinary*				*Diff*	
Variable	**Mean**	**Median**	**Min**	**Max**	**Mean**	**Median**	**Min**	**Max**	**Mean**	**P-Value**
eMAXX Ownership	76.1%	84.1%	25%	100%	71.1%	73.9%	25%	100%	5.0%	(0.010)
Green Fund Ownership	13.5%	0%	0%	100%	0.6%	0%	0%	100%	12.8%	(0.098)
HHI	0.78	1.00	0.07	1	0.79	1.00	0.03	1	-0.01	(0.541)

Table 7. Regressions to explain ownership concentration of municipal bonds. Table presents results of ordinary least-squares regressions of HHI on green bond indicators and bond characteristics and fixed effects. T-statistics are in brackets below the reported coefficients.

	Dependent variable: HHI			
Variable	**Model 1**	**Model 2**	**Model 3**	**Model 4**
Green	0.04	0.03	0.05	0.06
	[2.81]	[2.10]	[2.78]	[2.88]
CBI Certified Green	0.20	0.23	0.09	0.06
	[4.09]	[4.27]	[1.70]	[1.05]
R-Squared	0.24	0.34	0.42	0.51
Adjusted R-Squared	0.23	0.23	0.37	0.38
N	71,126	67,200	69,625	65,546
Fixed Effects				
Maturity	Yes		Yes	
Rating	Yes		Yes	
Month	Yes		Yes	
Maturity x Rating x Month		Yes		Yes
Issuer Fixed Effects	No	No	Yes	Yes
Additional Fixed Effects (all specifications)	Size Category, Insured, Taxable, Taxable AMT, Taxable State, Bank Qualified, New Money, Code = GO, Use of Proceeds			

Table 8. Regressions to explain ownership concentration of municipal bonds: Interactions. Table presents results of ordinary least-squares regressions of ownership HHI measures on green bond indicators, interacted with characteristics, and bond characteristics and fixed effects. T-statistics are in brackets below the reported coefficients.

	Dependent variable: HHI			
Variable	**Model 1**	**Model 2**	**Model 3**	**Model 4**
Green	-0.01	-0.02	-0.05	-0.05
	[-0.60]	[-0.87]	[-2.10]	[-1.60]
Green x (Rating = AAA)	0.08	0.09	0.20	0.19
	[2.86]	[2.83]	[5.50]	[4.58]
Green x (Not Top Size Quintile)	0.09	0.07	0.14	0.16
	[2.53]	[1.59]	[3.37]	[3.42]
CBI Certified Green	0.25	0.28	0.19	0.17
	[4.91]	[4.98]	[3.50]	[2.60]
R-Squared	0.24	0.34	0.42	0.52
Adjusted R-Squared	0.23	0.23	0.37	0.38
N	71,126	67,200	69,625	65,546
Fixed Effects				
Maturity	Yes		Yes	
Rating	Yes		Yes	
Month	Yes		Yes	
Maturity x Rating x Month		Yes		Yes
Issuer Fixed Effects	No	No	Yes	Yes
Additional Fixed Effects (all specifications)	Size Category, Insured, Taxable, Taxable AMT, Taxable State, Bank Qualified, New Money, Code = GO, Use of Proceeds			