The Public Cost of Net Zero

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Abstract

We examine the economic effects of mandates to consume renewable and clean energy. U.S. state governments that adopt Renewable Portfolio Standards (RPS) see an increase in bond yields and a decrease in credit ratings. The higher cost of funding is predicted by the rise in electricity prices driven by RPS. However, we observe muted and often opposite results when states introduce Clean Energy Standards (CES) that permit the inclusion of energy generated by a more diverse set of technologies. These results are robust in primary and secondary market transactions and extend to local municipalities and school district funding. Overall, our results highlight the costs to taxpayers of renewable and clean energy commitments.

JEL classification codes: G1, G2, H2, H7, Q4, Q5

Keywords: Renewable energy, Municipal finance, Energy transition, State funding

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U.S. state governments have taken an active role in addressing climate change by adopting and enforcing Renewable Portfolio Standards (RPS) (Engel, 2006; Thombs and Jorgenson, 2020). RPS, also referred to as renewable electricity standards, are mandates that require utility providers to include a minimum percentage of electricity from eligible renewable sources. These sources include wind, solar, geothermal, biomass, and some types of hydroelectricity, and can also include landfill gas, municipal solid waste, or ocean energy. Notably, no national RPS or other clean energy policies are currently in place in the USA.[1] As a result, state RPS are the primary vehicle for mandating renewable targets and these policies have set in motion a variety of economic changes through the integration of renewable energy into the electrical grid. The implementation of these policies shows that RPS are an effective policy tool, and existing evidence shows they are responsible for significant growth in renewable energy generation in the U.S. (Deschenes, Malloy, and McDonald, 2023).

This paper examines the financial impact of renewable energy mandates. In particular, we ask whether RPS affect the financial health of states that adopt them. We study the cost of capital at both the state and local levels. The answer to this question is unclear. On the one hand, existing evidence shows that RPS raise the cost of electric systems and raise retail electricity prices (Barbose et al., 2015). These increases are non-trivial: Greenstone and Nath (2020) estimate that electricity prices increase by 11% seven years after the passage of RPS mandates and 17% twelve years later. Furthermore, RPS achieve carbon reductions, but these reductions come at a much higher cost than the conventional estimates of the social cost of carbon. These higher costs may disrupt states' economies if they cause firms and residents to reduce investment and consumption

[1] On April 22, 2021, President Biden announced a goal of "a 50-52 percent reduction from 2005 levels in economy-wide net greenhouse gas pollution in 2030" and "100 percent carbon pollution-free electricity by 2035".

in non-energy sectors or the economy. On the other hand, RPS could stimulate states' economies because they create demand for technology and infrastructure that supports new sources of energy. A study conducted by the Lawrence Berkeley National Laboratory and the National Renewable Energy Laboratory (NREL) estimates that RPS will generate 4.7 million jobs from 2015 to 2050. This study also estimates significant benefits associated with improved air quality, reduced greenhouse gas emissions, and reduced water use (Mai et al. 2016). State RPS standards also put adopting states at the forefront of the energy transition and can potentially reduce uncertainty in the future if national standards are set. Finally, it is also possible that the adoption of RPS standards will not affect state financing. If energy markets are resilient and can switch at a low cost to alternative sources of energy, then RPS standards will not affect the local economy and state financing costs.

Yields and credit ratings on bonds issued by U.S. states provide useful metrics for assessing the economic impact of RPS. Bond yields reflect the return investors expect to receive from state governments and credit ratings reflect the likelihood that states will default on their bonds over the long term. Both metrics convey comprehensive perceptions of states' economic conditions and are more indicative of the net effect of renewable standards on the local economy than other measures used in the literature to capture the economic consequences of RPS, such as job creation or electricity prices. We also extend our analysis to local issuers, like school districts. These issuers' cost of capital is also likely to be affected by the state-wide financial conditions but will incorporate any costs of the RPS plans at the county level.

We rely on the state-level RPS targets as our main treatment variable.[2] RPS standards mandate a steady increase in the percentage of renewable energy generation. However, some states are aggressive in their targets (e.g., California has a target of 60% by 2030), while other states have modest targets (e.g., Pennsylvania has a target of 18% by 2030). Further, some states let their RPS targets expire in response to changing energy priorities. We use the RPS target for a particular year as a treatment variable. This measure adjusts both for whether a state has an RPS mandate and also for the intensity of the treatment. Our main variables measure yields and credit ratings of state bonds, we later also study bonds from local issuers like counties, cities, and schools. As a first pass, we include state and year fixed effects to control for the influence of time-invariant state characteristics and macroeconomic fluctuations, and we use county fixed effects when studying local issuers. Our results gain statistical and economic significance when we use a stacked approach with year-cohort fixed effects and either state- or county-cohort fixed effects. We also control for a variety of bond characteristics and time-varying state characteristics.

Our main finding is that states' cost of capital increases and credit ratings deteriorate after mandates to increase renewable energy production and consumption. A typical change in targeted renewable energy (going from a state with no RPS target to a state with an average RPS target) results in an increase in the yield of the state's traded bonds of about 11 basis points. This effect is relative to any changes in adjusted yields of similar bonds issued by similar states. For credit ratings, the effect is a reduction of about 0.56 rating notches. These magnitudes are large relative to other factors shown to impact local bond yields. For example, Goldsmith-Pinkham, Gustafson, and Lewis (2023) find a two-basis point effect of sea level rise on the yields of public debt in

[2] We complement the main analysis with two related approaches. We use event time estimations relative to the first adoption of a state's RPS mandate to provide a dynamic measure of the effect. We also use an alternative measure of RPS "demand" that adjusts for any transitional rules towards the target that affect the RPS electricity requirements.

exposed areas. These results are robust in a variety of settings. For example, we verify the parallel pre-trends assumption in a dynamic, event time setting. We estimate effects relative to the first adoption of a state's RPS mandate and find the effect emerges steadily over the years after adoption. We also find that our results are robust to alternative ways of measuring bond yields, as well as an alternative measure of RPS targets that accounts for any transitional rules towards the target that affect electricity requirements.

We next extend our analysis to the local level. On the one hand, local governments might be shielded by some of the costs that come with RPS mandates as they will not bear the costs of any state-level subsidies and tax shortfalls. On the other hand, clean energy mandates can be particularly salient to local governments that are proximate to changes in energy infrastructure. We find similar results among bonds issued by lower levels of government, including counties, cities, and school districts. These results indicate that local issuers absorb the consequences of state-level energy policies. We study one channel behind these results by using RPS targets as instruments for electricity prices. We find that increasing yields and decreasing credit ratings are associated with instrumented electricity prices, indicating that RPS-driven electricity price increases are an important determinant of local government financial health. We also study yields on new bonds issued in the primary market and again find that yields increase and credit ratings decrease after states adopt RPS.

In recent years, some states have augmented their RPS with Clean Energy Standards (CES). CES are similar to RPS, in that they require utilities to provide electricity from clean sources. However, the definition of "clean" is more inclusive than "renewable" in that CES are technology-neutral. That is, CES permit the use of nuclear energy, coal, or natural gas fitted with carbon capture and other technologies that are not on the list of renewable sources of energy. CES are

usually more ambitious than RPS in terms of targeted levels of clean energy but they often also represent a substantial relaxation in terms of allowable sources of energy. The majority of CES mandates are aspirational, with goals of up to 100% clean energy, and are targeted at long-term time horizons, with many of them becoming fully effective in 2050. Although they have far-reaching goals, they have limited bite for the period we study. For these reasons, we expect CES mandates to have no effect or even opposite effects of RPS because CES introduce goals that are easier and cheaper to achieve. Moreover, CES commitments might work as a signal about the future directions of energy mandates and therefore might have an important immediate effect to reduce regulatory uncertainty.

We replicate our analysis after including a separate variable for whether states adopt CES mandates. The increase in yields and decrease in credit ratings due to RPS remains robust, both in the state and local issuer samples. However, we observe generally opposite results for CES mandates. These results are particularly pronounced when we used a stacked difference-in-differences approach. Bond yields are generally insensitive to CES mandates but credit ratings for local issuers improve after states adopt CES. These results indicate states face contrasting economic consequences depending on the technologies they employ as they seek to reduce carbon emissions. The disparate effects among state and local issuers also suggest an asymmetry in terms of how mandates made at the state level affect different types of issuers within states.

Our results are robust to a variety of concerns. For example, state characteristics that are difficult to measure could explain both economic conditions and the decision to adopt clean energy mandates. Examples include political ideology, a state's stock of fossil fuels or other energy sources, or the condition of the power grid. State-fixed effects control for these characteristics to the extent they are time-invariant. However, we use the sample of bonds issued by local

governments along with a border discontinuity design to narrow the possible influence of unobserved characteristics. This approach compares changes in yields and credit ratings among bonds issued in states that adopt RPS or CES to changes among similar bonds issued in adjacent counties that share a border but are in states that do not adopt RPS or CES. To the extent that unobserved characteristics such as politics, natural resources, and energy infrastructure vary smoothly across state borders, this approach rules out the influence of such characteristics on yields and credit ratings. We find robust results. Secondary market yields increase after states adopt RPS and we find some evidence that yields decrease after states adopt CES. We even find that yields decrease after the few instances where states freeze or repeal RPS standards.

Finally, we also study the effect of RPS and CES on yields in primary markets. Initial bond issuances are important because they determine the cost of funding for state and local issuers. However, these issuances can be timed to mitigate the effects of climate commitments. An increase in the primary yields indicates that the higher yields in the secondary markets translate into higher issuance costs. Indeed, we find that the increase in trading yields translates into increased funding costs, both for state and local issuances. The increases can be measured better in the more liquid local bonds market, where we find a very similar magnitude to the increases in the trading yields. This suggests that local issuers, like schools, cannot use market timing to overcome the increased costs of funding.

Our paper is part of the growing literature on the costs and benefits of clean energy. Existing studies have primarily concentrated on the expenses linked to high emissions, such as Matsumura, Prakash, and Vera-Muñoz (2014), who illustrate a decline in firm value associated with carbon emissions, and Bolton and Kacperczyk (2021), who highlight investor demand for compensation due to exposure to carbon emission risk, and Ilhan, Sautner, and Velikov (2021), who provide

evidence of the pricing of carbon risk in the options market. Hong, Kubik, and Shore (2023) model and demonstrate that RPS increase the yield spreads and renewables capacity of private firms in the utilities sector. We, instead, provide broader evidence that clean energy targets have consequences for the public. We also study CES. Both states and local public issuers face a higher cost of funding when they opt for an aggressive push toward clean energy generation, and these effects are partially offset when states permit a more diverse range of energy technologies.

We contribute to the literature on the economic effects of renewable energy on the local economy. Deschenes et al. (2023) show that RPS are effective at incentivizing the installation of wind turbines. Cornaggia and Iliev (2023) show that the presence of natural resources in the form of wind and solar energy reduces yields and increases credit ratings. We contribute to this literature by showing the costs and benefits to taxpayers of regulatory efforts to incentivize and harness renewable energy. We find mixed results depending on which technology(s) regulators are willing to include in the pursuit of net zero. We also provide the first analysis of the impact of RPS and CES on the credit ratings and cost of capital for state and local governments.

We also add to the literature on the determinants of the cost of municipal debt. Noteworthy determinants explored in previous research include state corruption (Butler, Fauver, and Mortal, 2009), population aging (Butler and Yi, 2022), corporate subsidies (Chava, Malakar, and Singh, 2023), medical marijuana (Cheng, Franco, and Lin, 2022), the opioid crisis (Cornaggia, Hund, Nguyen, and Ye, 2022), newspaper closures (Gao, Lee, and Murphy, 2020), sea level rise (Painter, 2020; Goldsmith-Pinkham, Gustafson, Lewis, and Schwert, 2023), credit ratings (Cornaggia, Cornaggia, and Israelsen, 2018 and 2023), and natural disasters (Jerch, Kahn, and Lin, 2023). Our contribution to this body of literature lies in an examination of the impact of state-level targets of

renewable energy production, specifically RPS and CES mandates.

2. State Governments and the Pursuit of Net-Zero

U.S. state governments have long been more proactive than the federal government in implementing policies to curb greenhouse gas emissions. The U.S. federal government only recently announced plans for the nation to have a fully clean electrical grid by 2035 and net-zero carbon emissions by 2050.[3] These goals, however, are not supported by explicit and immediately escalating targets for renewable electricity production and consumption and are not enshrined in federal laws.[4] At least 76 proposals for a national portfolio standard have been introduced, but none has become law.[5] Observers view these goals as vague, with support from Congress as the most salient remaining obstacle (Waldman 2021).

In the meantime, the goal of clean energy transition has been mostly left to states to regulate and enforce.[6] For example, Engel (2006) notes, "Here it is the state governments that are actively pursuing programs to reduce emissions of greenhouse gases and sequester carbon while the federal government has adopted a nonregulatory approach, and, many would argue, a mostly do very little approach" (pp. 1015). Renewable Portfolio Standards (RPS) are states' most common policy tool for reducing greenhouse gas emissions (Thombs and Jorgenson, 2020). RPS are mandates that

[3] U.S. Department of Energy, U.S. Department of Transportation, U.S. Environmental Protection Agency, and U.S. Department of Housing (2023), "The U.S. National Blueprint for Transportation Decarbonization", URL: https://www.energy.gov/sites/default/files/2023-01/the-us-national-blueprint-for-transportation-decarbonization.pdf

[4] The idea of national clean energy standards received bipartisan support in 2009 in the House but failed in the Senate. Subsequent attempts in 2010 and 2012 to pass a Clean Energy Standard Act also failed.

[5] Congressional Research Service (2021), "A Brief History of U.S. Electricity Portfolio Standard Proposals", URL: A Brief History of U.S. Electricity Portfolio Standard Proposals (congress.gov)

[6] Hundreds of cities and municipalities in the U.S. have pledged reduce their carbon footprints by adopting climate action plans. However, the majority of those cities' specific plans are viewed as aspirational rather than realistic (Pulver, Bowman, Harvilla, and Wilson 2021).

require electricity suppliers to provide their customers with a stated minimum share of electricity from renewable sources. RPS are exclusively a policy tool of state governments. RPS have been effective in that they are responsible for approximately half of the growth of renewable energy generation in the U.S.[7] Deschenes et al. (2023) find that RPS policies increase wind generation capacity by 44 percent, or an additional 600 to 1,200 megawatts.

A relatively new development, Clean Energy Standards (CES) are similar to RPS in that they require a certain percentage of electricity to come from renewable sources. However, CES differ from RPS in that they allow a more inclusive set of energy-generation technologies to be used to meet the standard. These additional technologies typically include nuclear power or fossil fuels fitted with carbon capture technologies.[8] CES are new policy tools and represent an evolution of RPS, as Massachusetts passed the first CES in 2017. CES and RPS operate similarly in that they both allow energy producers to earn clean energy credits. These credits are tradable and retail suppliers of electricity must hold a particular amount of them at the end of each compliance period to meet RPS or CES.[9] For example, a retail electricity supplier must hold 1,000 megawatt-hours of clean energy credits if it delivers a total of 5,000 megawatt-hours of electricity over a year in a state with a CES of 20%. Therefore, because CES are market-based and technology-neutral, they are potentially a cost-effective approach to pricing and restricting carbon emissions in the electricity sector (Cleary, Palmer, and Rennert, 2019). Because CES are similar to RPS in requiring

[7] Lawrence Berkeley National Laboratory, U.S. Department of Energy (2021), "U.S. Renewables Portfolio Standards 2021 Status Update Early Release", URL: https://eta-publications.lbl.gov/sites/default/files/rps_status_update-2021_early_release.pdf

[8] CES plans, however, have been criticized for including different energy sources. For example, Friends of the Earth President Erich Pica commented that, "There is no role for nuclear in a least-cost, low carbon world. Including these dinosaurs in a clean energy standard is going to incentivize industry efforts to keep aging, dangerous facilities online." (Muyskens and Eilperin, 2020).

[9] Bipartisan Policy Center (2020), "Pathways to Decarbonization: A National Clean Energy Standard", URL: bipartisanpolicy.org/download/?file=/wp-content/uploads/2020/03/BPC_Energy_Clean-Energy-StandardV2.pdf

investment in new electricity infrastructure, the passage of a CES can pre-empt RPS standards and therefore reduce the burden of regulation and compliance that ultimately falls on taxpayers.

3. Data

3.1. Data Sources

We study the relationship between RPS and CES and outcomes for state and local bonds. We collect secondary market yields from the Municipal Securities Rulemaking Board (MSRB). The data are available from 2005 to 2022. We include general obligation tax-exempt bonds that have credit ratings. We obtain a list of state bonds from the Electronic Municipal Market Access website. We use this list to create separate samples of bonds issued by state governments and local entities. We also perform analysis for the subsample of local entities that are school issuers. We obtain a list of school districts through the National Center for Education Statistics.

We compute credit spreads for each transaction by subtracting the maturity-matched Municipal Market Advisors (MMA) AAA-rated curve from the raw yield. We weight observations by the transaction amount and compute *Adjusted Yield*, the average credit spread for all trades for a bond over a month. *Adjusted Yield* and bonds' credit ratings at the time of the transaction are our main dependent variables. We use Mergent FISD to obtain up to three credit ratings for each bond from Moody's, Standard & Poor's, and Fitch at the time of each transaction. We assign numerical values to ratings, where AAA or Aaa is equivalent to 21, AA+ or Aa1 is equivalent to 20, and so on. *Credit Rating* represents the lowest rating assigned to a bond.

We obtain a variety of bond characteristics that also come from Mergent FISD. These include the bond's coupon rate, offer amount, remaining years to maturity, age, call features, and

whether the bond is wrapped with third-party insurance. We measure time-varying characteristics, such as credit ratings and years to maturity, at the time of the trade. We combine our data with state-year information from the U.S. Census and Bureau of Economic Analysis, such as population, income per capita, real GDP, and real GDP growth. We employ the geolocation procedure outlined in Cornaggia, Hund, Nguyen, and Ye (2022) to allocate bonds to their respective counties. We use data from the U.S. Census to create a mapping of counties that are on state borders and are adjacent to counties in bordering states. We augment our sample with data on electricity prices (measured in cents per kilowatt-hour) that vary by state and year. These data are from the U.S. Energy Information Administration.

We additionally examine the issuance of state and local debt in the primary market. We collect offer yields in the primary market from Mergent FISD. To account for market conditions, we normalize offer yields by subtracting the MMA curve yield at the issuance date. Our analysis focuses on bonds issued between 2001 and 2021. The remaining variables remain consistent with those in the secondary market sample, with measurements taken at the point of initial bond issuance.

3.2. Sample Descriptive Statistics

Panels A and B of Table I display summary statistics for the secondary market and primary market samples, respectively. Panel A includes nearly one million observations for state issuers and nearly 6.4 million observations for local issuers from 2005 to 2022. Each observation in this panel is a cusip-month containing at least one transaction. Panel B includes over 34,000 observations for state issuers and over 900,000 observations for local issuers from 2001 to 2021.

Each observation in this panel is an issuance cusip. *Adjusted Yield* is a key dependent variable. In the secondary market sample, *Adjusted Yield* has a mean of 16.69 basis points for state issuers and 28.37 for local issuers. These amounts are smaller in the primary market sample, at 14.38 basis points and 20.03 basis points, respectively. Lower yields in the primary market could be due to market timing on the part of issuers. That is, state and local government entities are less likely to issue debt when debt is expensive.

Credit Rating is another key dependent variable. In the secondary market sample, *Credit Rating* has a mean of 18.85 rating notches (≈AA/Aa2) for state issuers and 18.20 rating notches (≈AA-/Aa3) for local issuers. These amounts are similar in the primary market sample, at 19.01 (≈AA/Aa2) and 17.83 (≈AA-/Aa3), respectively. Summary statistics for other bond characteristics, such as coupon rates, offering amount, maturity, callability, and insurance status are similar to samples appearing in other papers.

[Insert Table I here.]

Our key independent variables capture the extent to which states adopt Renewable Portfolio Standards (RPS) and Clean Electricity Standards (CES). *RPS Target* is the percentage of electricity that utilities must supply from renewable sources in a given state-year.[10] We collect this information from the supplementary data included with the June 2023 U.S. State Renewables Portfolio & Clean Electricity Standards report provided by the Lawrence Berkeley National Laboratory and U.S. Department of Energy.

Figure I plots examples of *RPS Target* for several states. Conditional on adoption, most

[10] These values are referred to as "nominal" targets. Certain load-serving entities (LSE) in each state may be subject to lower targets or be even exempt from the RPS target (Barbose, 2023). We also provide analysis based on RPS targets that adjusts for these exemptions. These adjusted targets are referred to as "RPS demand".

states gradually increase renewable energy targets over time. For example, California mandates that 60 percent of its electricity should derive from renewable sources by 2030 with an initial jump to a 10% target and then a gradual increase in the targets over time. Two states (Kansas and Ohio) eventually repealed their RPS targets. Many of the states with RPS targets are similar to Minnesota, Colorado, Pennsylvania, and Washington with increasing targets towards 15%-25%. Figure AI in the Internet Appendix displays *RPS Target* for all state-years, conditional on adopting an RPS at any point over the sample period. Our analysis includes the 30 states that adopt RPS targets and 21 states without an RPS target in 2022, the last year of our sample.

[Insert Figure I here.]

States adopt RPS and CES at different times. Figure II shows the number of states that adopt RPS and CES each year of our sample. Eleven states adopted RPS before 2000, including Iowa, which adopted the first RPS in 1983. Since then, 21 more states adopted RPS for a total of 32 states. (Kansas and Ohio repealed their RPS, hence there are 30 states with active RPS as of 2022.) CES are relatively new, with the first state, Massachusetts, adopting them in 2017. Since then, 13 more states have adopted CES for a total of 14 states. Figure AII in the Internet Appendix displays states' CES targets, conditional on a state having adopted a CES by the end of the sample. Only two states have a CES target as of 2022, with most targets starting after 2030 and four of them becoming effective only in 2050. Our main variable measuring CES pledges is *CES Standard.* It is an indicator variable that takes a value of one in years after a state adopts a CES and zero otherwise. We collect this information from Barbose (2023). Table I Panels A and B show *CES Standard* has a mean of less than ten percent for both state and local issuers, in both secondary and primary market samples. These relatively low values obtain for two reasons. First, less than a third of states adopt CES, and second, conditional on adoption, states adopt CES toward

the end of the sample, meaning fewer observations are treated with CES. We use *CES Standard* as a key independent variable. We also build tests around the introduction of RPS.

[Insert Figure II here.]

4. Results from Bond Trades

Our main approach features observations associated with secondary market transactions. This approach provides at least two advantages. First, it allows bonds to enter the sample every time the bond trades, potentially providing time-series variation in yields and credit ratings. Second, observations are not dependent on state and local governments' decisions to issue bonds, which are likely a function of market conditions. Trading changes the prices of bonds to reflect changes in bonds' risk profiles and therefore provides an opportunity to observe the effects of time-varying RPS targets. We complement our analysis of secondary market observations with observations based on primary market transactions in the next section.

4.1. States' Secondary Market Yields

We estimate the following OLS regression equation using the sample of secondary market observations for state issuers described in Table I Panel A:

$$\text{Adjusted Yield}_{i(j),t(y)} = \alpha + \beta\ \text{RPS Target}_j + \text{Bond characteristics}_{i,t} + \text{State characteristics}_{j,y} + \text{State fixed effects} + \text{Year fixed effects} + \varepsilon_{i,t} \quad (1)$$

where *i* indexes bond (*j* indexes state) and *t* indexes month (*y* indexes year). We take logs of skewed variables, including bond characteristics such as offering amount and state characteristics

such as population and real GDP. We include state and year fixed effects and cluster standard errors two ways, by bond and month. Table II presents the results.

[Insert Table II here.]

The results reveal a positive and statistically significant relation between RPS targets and state bond yields. The difference in *RPS Target* between a state without a target and a state with an average target is 0.19 in our sample. Column (1) shows that this change is associated with an increase in adjusted yield of about 11 basis points ($55.76 \times 0.19 = 10.59$).[11] These effects are large relative to findings in related literature. For example, Goldsmith-Pinkham et al. (2023) find a two-basis point increase in yields among municipal bond issuers in coastal areas at risk for sea level rise. They also argue that a moderate increase in bond yields corresponds to a large decrease in the present value of the underlying issuer cash flows.

Some states announced ambitious CES standards during our sample period. Column (2) repeats the analysis while including *RPS Target* and *CES Standard* together. While CES prescribes clean energy targets for the future, such mandates might signal an increase or decrease in the effect of RPS targets because they benchmark a more general set of technologies but at the same time set more ambitious goals. Therefore, the independent effects of RPS and CES on yields are ex-ante ambiguous. However, the coefficient on *RPS Target* is nearly unchanged. The coefficient on *CES Standard* is positive and smaller than the coefficient on *RPS Target*. It is marginally significant, indicating states' secondary market yields are weakly influenced by the adoption of CES.

The dependent variable in Table II, *Adjusted Yield*, is a transaction amount-weighted

[11] A one-standard deviation increase in a state's targeted renewable energy consumption (0.13, per Table I Panel A) results in an increase in adjusted yield of about 7.3 basis points ($55.76 \times 0.13 = 7.25$) relative to any changes in adjusted yields of similar bonds issued by similar states.

measure of the spread between raw yields and the MMA AAA-rated curve. We examine the robustness of our results to how we measure yields in Table AI in the Internet Appendix. Column (1) in Panel A of Table AI replicates column (1) from Table II for ease of comparison. We compute three alternative yield measures. First, we compute yields based on equal-weighting rather than transaction-amount weighting. Second, we compute a raw yield that does not subtract the MMA AAA-rated curve. Third, we compute a measure that is both equal-weighted and raw. Columns (2) through (4) in Panel A of Table AI report results with each of these dependent variables. Across specifications, the coefficients on *RPS Target* are similar in sign, statistical significance, and magnitude (if not larger for measures based on raw yields), indicating our results are not sensitive to how we measure yields.

Next, we examine the robustness of our results to how we measure RPS targets. Some states provide exemptions from RPS mandates for certain load-serving entities (LSE). These exemptions affect the actual amounts of renewable energy that must be supplied. Figure AIII in the Internet Appendix provides examples of this effect for several states. *RPS Target* is the same as before. *RPS Demand* is *RPS Target* net of exemptions and other state-specific adjustments. We obtain this measure from the Lawrence Berkeley National Laboratory and the U.S. Department of Energy. As expected, *RPS Demand* is generally lower than *RPS Target*. For example, *RPS Target* is 20% for California in 2010, but *RPS Demand* is only 16.8%. We replicate Table II after substituting *RPS Demand* for *RPS Target*. The results are in Table AII in the Internet Appendix. Panel A of Table AII shows a robust, positive relation between *RPS Demand* and adjusted yield, indicating our results are not driven by how we measure RPS. The coefficient on *CES Standard*, however, is insignificant, indicating there is no relation between the presence of CES standards and secondary market yields on state issuer bonds after accounting for the actual amount of

renewable energy that must be supplied in a state-year.

The results in Table II show that yields increase as states increase RPS targets. Next, we provide year-by-year estimates of the relation in event time to gain a clearer understanding of the dynamic relation between RPS standards and yields. Specifically, we estimate the following OLS regression equation using the sample of secondary market observations for state issuers described in Table I Panel A:

$$\text{Adjusted Yield}_{i(j),t(y)} = \alpha + \beta_e \text{ RPS} \times \text{Event Year}_e + \text{Bond characteristics}_{i,t} + \text{State characteristics}_{j,y} + \text{State fixed effects} + \text{Year fixed effects} + \varepsilon_{i,t} \quad (2)$$

where *i* indexes bond (*j* indexes state) and *t* indexes month (*y* indexes year). *RPS* is an indicator if the state ever adopted an RPS and *Event Year* is a set of indicators that indicate event time (indexed by *e*) relative to the actual adoption year. We include state and year fixed effects and cluster standard errors two ways, by bond and month. Figure III presents the results.

[Insert Figure III here.]

The results indicate a gradual increase in yields following the introduction of RPS standards. This result echoes findings by Deschenes et al. (2023) who find that RPS have slow dynamic effects. These authors show that most renewable energy capacity additions occur five years after RPS implementation. Importantly, we observe no clear trend in states' yields leading up to RPS adoptions. This pattern indicates that states' cost of capital does not dictate the timing of state adoptions of RPS and that our regression specification does an adequate job of controlling

for any residual economic factors that drive states' decisions to adopt RPS targets.

4.2. States' Credit Ratings

Ratings produced by the big three credit rating agencies (Moody's, Standard & Poor's, and Fitch) measure the long-term credit risk of bond issuers.[12] These metrics update slowly and avoid incorporating short-term fluctuations in credit risk (Cornaggia and Cornaggia, 2013; Bruno, Cornaggia, and Cornaggia, 2016). Therefore, credit ratings provide an alternative and less volatile measure of states' financial health. We test the relation between credit ratings and states' adoption of clean energy targets. We use the specification from Equation (1) and Table II with *Credit Rating* substituted as the dependent variable. Table III presents the results.

[Insert Table III here.]

The results for credit ratings are consistent with those for yield spreads in Table II. Column (1) shows that a shift in *RPS Target* from a state without a target to a state with an average target (0.19 in our sample) will result in a decrease in credit ratings of about 0.56 notches (-2.94 × 0.19 = 0.56) relative to any changes in ratings of similar bonds issued by similar states. The magnitude of this effect is in line with or larger than other determinants of credit ratings. For example, Becker and Milbourn (2011) find that increased competition among credit rating agencies leads to an increase in ratings of about 0.19 notches. Cornaggia, Cornaggia, and Xia (2016) find a "revolving door" effect of credit analysts who take jobs at investment banks of 0.18 to 0.23 notches.

[12] We do not control for credit ratings when we study the effect of renewable or clean energy targets on yields. Credit ratings capture credit spreads relative to a risk-free asset. They are a predictor of yields that takes into account all covariates. Iliev and Vitanova (2023) demonstrate the challenges associated with using endogenous variables as controls.

Cornaggia, Cornaggia, and Israelsen (2020) find that ratings increase by 0.09 to 0.13 notches due to a home bias on the part of analysts.

Column (2) of Table III shows that states' credit ratings decrease by about a similar amount once we control for *CES Standard* and that the adoption of *CES Standard* have a limited impact on states' credit ratings. This result highlights an important difference between RPS and CES. Whereas the adoption of RPS increases a state's risk, the adoption of CES does not. This result reveals that credit rating agencies take different views about how the use of "renewable energy" versus "clean energy" will impact states' economies.

4.3. Local Issuers' Secondary Market Yields

We estimate the following OLS regression equation using the sample of secondary market observations for local issuers described in Table I Panel A:

$$\text{Adjusted Yield}_{i(j),t(y)} = \alpha + \beta\ \text{RPS Target}_j + \text{Bond characteristics}_{i,t} + \text{State characteristics}_{j,y} + \text{County fixed effects} + \text{Year fixed effects} + \varepsilon_{i,t} \quad (3)$$

where *i* indexes bond (*j* indexes state) and *t* indexes month (*y* indexes year). A benefit of this setting is that it allows us to control for any unobserved, time-invariant confounds at a more granular level of geography. We use county and year fixed effects instead of the state and year fixed effects we used when studying state issuer bonds. We cluster standard errors two ways, by bond and month. Table IV presents the results.

A benefit of this setting is that it allows us to control for any unobserved, time-invariant confounds at a more granular level of geography. We use county and year fixed effects instead of

the state and year fixed effects we used when studying state issuer bonds. The results are broadly similar to what we observe for state bonds. We observe a positive and statistically significant relation between RPS targets and local bond yields. Column (1) shows that the average increase in RPS target between an untreated and treated state (0.13 in our sample of local bonds) will increase the adjusted yield of about six basis points (42.36 × 0.13 = 5.51) relative to any changes in adjusted yields of similar bonds issued in similar states.[13] Column (2) repeats the analysis while including *RPS Standard* and *CES Standard* together. The coefficient on *RPS Standard* is nearly unchanged. The coefficient on the *CES Standard* is insignificant, indicating local secondary market yields are not influenced by the adoption of CES.

[Insert Table IV here.]

Columns (3) and (4) restrict the sample to school bonds. Unlike counties and cities, schools cannot levy taxes that support the repayment of general obligation bonds. We therefore look at this sample as a unique case of how renewable energy targets can affect the financial health of public issuers absent the degree of freedom that comes from taxation. The results are similar, if not stronger, to what we observe in the sample of all local issuers. Columns (3) and (4) of Table IV indicate that schools' financial conditions are susceptible to state policies that mandate renewable energy. Specifically, among our sample of school bonds, the change in *RPS Target* for a state without an RPS target to a state with an average RPS target is 0.14. Therefore, the average increase in *RPS Target* between a treated and untreated state implies an increase in yield of about eight basis points (55.09 × 0.14 = 7.71).

The dependent variable in Table IV, *Adjusted Yield*, is a transaction amount-weighted

[13] A one-standard-deviation increase in a local issuer's targeted renewable energy consumption (0.11, per Table I Panel A) will increase adjusted yield of about five basis points (42.36 × 0.11 = 4.66).

measure of the spread between raw yields and the MMA AAA-rated curve. We examine the robustness of our results to how we measure yields in Table AI in the Internet Appendix. Column (1) in Panel B of Table AI replicates column (1) from Table IV for ease of comparison. We compute three alternative yield measures. First, we compute yields based on equal-weighting rather than transaction-amount weighting. Second, we compute a raw yield that does not subtract the MMA AAA-rated curve. Third, we compute a measure that is both equal-weighted and raw. Columns (2) through (4) in Panel B of Table AI report results with each of these dependent variables. Across specifications, the coefficients on *RPS Target* are similar in sign, statistical significance, and magnitude (although smaller for measures based on raw yields), indicating our results are not sensitive to how we measure yields.

Next, we examine the robustness of our results to how we measure RPS targets. Some states provide exemptions from RPS mandates for certain load-serving entities (LSE). These exemptions affect the actual amounts of renewable energy that must be supplied. *RPS Demand* is *RPS Target* net of exemptions and other state-specific adjustments. We obtain this measure from the Lawrence Berkeley National Laboratory and the U.S. Department of Energy. We replicate Table IV after substituting *RPS Demand* for *RPS Target*. The results are in Table AII in the Internet Appendix. Panel B of Table AII shows a robust, positive relation between *RPS Demand* and adjusted yield, indicating our results are not driven by how we measure RPS. The coefficient on *CES Standard*, however, is insignificant, indicating there is no relation between the presence of CES standards and secondary market yields on local bonds after accounting for the actual amount of renewable energy that must be supplied in a state-year.

The results in Table IV show that yields on local bonds increase, on average, after their host states increase RPS targets. Next, we examine in detail the dynamic relation between RPS

targets and local issuers' yields. Specifically, we estimate the equation below using the sample of secondary market observations for local issuers described in Table I Panel A:

$$\text{Adjusted Yield}_{i(j),t(y)} = \alpha + \beta_e \text{ RPS} \times \text{Event Year}_e + \text{Bond characteristics}_{i,t} + \text{State characteristics}_{j,y} + \text{County fixed effects} + \text{Year fixed effects} + \varepsilon_{i,t} \quad (4)$$

where *i* indexes bond (*j* indexes state) and *t* indexes month (*y* indexes year). *RPS* is an indicator if the state ever adopted an RPS and *Event Year* is a set of indicators that indicate event time (indexed by *e*) relative to the actual adoption year. We include county and year fixed effects and cluster standard errors two ways, by bond and month. Figure IV presents the results.

[Insert Figure IV here.]

The results are consistent with what we observe for observations associated with state issuers. We observe minimal increases in yields for the first three years after states change RPS targets. Most of the increase in yields occurs starting after five years. Importantly, we observe no trends in local issuers' yields leading up to changes in RPS targets. This pattern verifies the parallel pre-trends assumption for this sample of issuers.

4.4. Secondary Market Yields for Local Issuers in Border Counties

We replicate Table IV after restricting the sample to observations associated with bonds in counties that border adjacent states. This approach narrows the opportunity for unobserved factors that are correlated with the adoption of RPS or CES to influence the results. For example, a state's political ideology could influence the decision to adopt RPS or CES. Political ideology could also influence the yields on state bonds as well as the bonds of local issuers within the state. Although

political ideology varies significantly from state to state, it varies less dramatically across adjacent counties. The state of Washington, for example, voted 58.0% for Joe Biden in the 2020 presidential election, whereas Idaho, an adjacent state, voted just 33.1% for Biden. However, Asotin County in Washington voted 35.6% for Biden while Nez Perce County in Idaho voted 31.8%.[14] These counties share a border and similar political preferences despite belonging to states with markedly different political preferences in aggregate. The underlying assumption of the analysis in this section is that unobserved factors that are correlated with the adoption of RPS or CES vary smoothly across state borders. Table V presents the results.

[Insert Table V here.]

The results are similar to those in Table IV but with some differences. The coefficients on the *RPS Target* are similar in magnitude and statistical significance. This pattern confirms that once local bonds in hinterland counties that are subject to a variety of unobserved influences are excluded, a cleaner comparison emerges showing a similar relation between the presence of RPS standards and bond yields. The coefficient on the *CES Standard* in column (2) reinforces this point. Whereas in Table IV the relation between the adoption of CES standards and yields is insignificant, here we observe a robust, negative relation. Yields on local bonds decline after their states adopt CES, relative to similar bonds across state borders that do not adopt CES. Columns (3) and (4) repeat the analysis for bonds issued by schools. The results are similar in sign, magnitude, and statistical significance, both with respect to columns (1) and (2), and with respect to earlier results for school bonds in Table IV. We continue to observe a robust, positive relation between RPS targets and yields for school issuers. This result confirms that schools face higher costs of capital

[14] Source: https://www.cnn.com/election/2020/results/president

after states increase RPS targets, relative to schools in otherwise similar states.

Finally, we also study the yields of border counties that reside in Kansas and Ohio. Those are the only two states that effectively repealed their RPS mandates. In 2014, Ohio froze its RPS target at 2.5% for two years and also significantly lowered its 2026 targets to just 12.5%. In May 2015, Kansas repealed its RPS standard that called for 20% renewable energy by 2020 by and instead made this standard voluntary (Bryson and Glendening, 2015) We therefore create a *Repeal* indicator that takes the value of one for those two states after they freeze or repeal their RPS. We then study the impact of unwinding the RPS standard in these two states by comparing the yields of border counties in Ohio and Kansas before and after their repeal and relative to counties in the neighboring states. The results, reported in Table AIII, show that repeal has the opposite effect of adopting an RPS standard. For example, column (3) shows a decrease in yields of 11.8 basis points after a repeal of the RPS standards. This effect is robust even when we control for the actual realized RPS targets of each state.

4.5. Local Issuers' Credit Ratings

We use the specification from Equation (3) and Table IV with *Credit Rating* substituted as the dependent variable. Table VI presents the results. Column (1) shows that the average increase in a local issuer's targeted renewable energy consumption (0.13 in our sample) will result in a decrease in credit ratings of about 0.08 notches ($-0.64 \times 0.13 = 0.08$) relative to any changes in ratings of similar bonds issued in similar states. Column (3) shows that schools' credit ratings experience larger effects, as they decrease by about 0.22 notches after their host states increase

RPS targets (-1.54 × 0.14 = -0.22).

[Insert Table VI here.]

The results are consistent with those in Table IV. However, as we saw when comparing results for secondary market yields and ratings for state issuers, we again observe an important difference with respect to the results for *CES Standard* in column (2). Column (2) repeats the analysis while including *RPS Target* and *CES Standard* together. The coefficient on *RPS Target* is similar in magnitude, implying a change in ratings of -0.07 notches for a typical difference in *RPS Target* between a treated and untreated state (-0.56 × 0.13 = -0.07). However, the coefficient on *CES Standard* is positive and significant. Local issuers' credit ratings increase by 0.15 notches after adopting CES, relative to any changes in credit ratings for similar bonds issued by similar states. Columns (3) and (4) repeat the analysis for school issuers. We find school credit ratings also decrease, with a typical treatment effect of -0.20 notches (-1.54 × 0.14 = -0.20) We also observe an increase in school credit ratings after their host states adopt CES standards. The magnitude is 0.19 notches. This result reinforces the idea that credit rating agencies have contrasting views about how mandates made at the state level to use "renewable energy" versus "clean energy" will affect local economic outcomes.

4.6. RPS, Electricity Prices, and Yields and Credit Rating for Local Bonds

We conclude the main analysis by examining whether electricity prices are a channel through which RPS affect secondary market yields and credit ratings for local bonds. While the literature has confirmed that RPS targets lead to more expensive electricity (e.g., Barbose et al., 2015; Greenstone and Nath, 2020), we take the analysis a step further and link the RPS-predicted

electricity cost increases to a county's cost of funding. We begin by modelling electricity prices with RPS targets. Specifically, we estimate the following first-stage regression:

$$\text{Electricity Price}_{i(j),t(y)} = \alpha + \beta\ \text{RPS Target}_j + \text{Bond characteristics}_{i,t} + \text{State characteristics}_{j,y} + \text{County fixed effects} + \text{Year fixed effects} + \varepsilon_{i,t} \quad (5)$$

where *i* indexes bond (*j* indexes state) and *t* indexes month (*y* indexes year). We use county and year fixed effects and cluster standard errors two ways, by bond and month. Column (1) of Table VII presents the results. We observe a first-stage F-statistic of nearly 10.

[Insert Table VII here.]

Columns (2) and (3) provide second-stage regression results. In these estimations, we use the instrumented electricity prices from the first stage to predict its effects on local electricity yields and credit ratings. These regressions include the same control variables and fixed effects as the first stage. The results in columns (2) and (3) show that electricity prices, as instrumented by RPS targets, are associated with higher yields and lower credit ratings. These patterns in the data are intuitive because they confirm that RPS leads to higher electricity prices and that this increase in costs is associated with deteriorating credit quality among local issuers in states that adopt RPS targets.

5. Results from New Bond Issues

Our main approach features observations associated with secondary market transactions. Here we test the robustness of our results using observations associated with primary market transactions. Studying primary market transactions is useful because these transactions capture the

realized costs issuers face as they raise capital.

5.1. States' Primary Market Yields

We estimate equation (1) using the sample of primary market observations for state issuers described in Table I Panel B. As before, we include controls for bond characteristics and state-level economic activity. We also include state and year fixed effects and cluster standard errors two ways, by bond and month. Table VIII presents the results.

[Insert Table VIII here.]

The results reveal a positive and statistically significant relation between RPS targets and bond yields. Column (1) shows that RPS targets result in an increase in adjusted yield of about five basis points (25.85 × 0.19 = 4.91) relative to any changes in adjusted yields of similar bonds issued by similar states.[15] We next control for the adoption of CES standards. Column (2) shows evidence that bonds' offer yields decline by about 23 basis points after states adopt CES, relative to similar bonds in similar states that do not adopt CES. This result stands in contrast to earlier evidence based on secondary market transactions. Whereas we observe a small, positive relation between states' secondary market yields and the adoption of CES standards, here we find that yields decline by an economically significant amount. This result obtains despite the sample size for primary market tests being smaller than the sample for secondary market tests. (Comparing Panels A and B of Table I, we have nearly one million observations for the secondary market sample and just over 34 thousand observations in the primary market sample.) Next, we turn to the

[15] A one-standard deviation increase in a state's targeted renewable energy consumption (0.11, per Table I Panel B) will result in an increase in adjusted yield of about three basis points (25.88 × 0.11 = 2.85).

primary market of local bond issuers.

5.2. Local Issuers' Primary Market Yields

Table IX presents the results for local issuers' yields. We estimate equation (3) using the sample of primary market observations for local issuers described in Table I Panel B. The results are similar to what we observe among secondary market yields for these issuers but with a few differences. We observe a positive and significant relation between *RPS Target* and yields. This relationship is similar in magnitude to the result among secondary market observations. It is also nearly double the magnitude we observe for state issuers. As before, the magnitude is even larger when we focus on the subset of school district issuers. Primary market yields on bonds issued by school entities decline by about 3.8 basis points after states adopt CES, relative to primary market yields on similar bonds issued by local entities in similar states that do not adopt CES. This relationship, however, is not statistically significant.

[Insert Table IX here.]

5.3. Primary Market Yields for Local Issuers in Border Counties

We conclude the analysis by replicating Table X after restricting the sample to observations associated with bonds in counties that border adjacent states. Table X presents the results. The results are similar to what we observe among secondary market observations with the same border county filter. They are also similar in sign, economic magnitude, and statistical significance to the

results in the previous table.

[Insert Table X here.]

Overall, we conclude that our results are robust whether we use observations in secondary markets or primary markets. We find comprehensive evidence that states experience a deterioration in credit risk after adopting RPS targets. This effect extends to local entities within the states, including schools that lack the ability to levy taxes. However, credit ratings among state- and local-level issuers improve after states adopt CES. We also observe some evidence that yields decline in response to CES adoption.

6. Conclusion

This paper examines the economic consequences of decisions made by state governments to adopt Renewable Portfolio Standards (RPS) or Clean Electricity Standards (CES). We find that states' bond yields increase and their credit ratings decrease after the adoption of RPS targets. The magnitudes of these changes are larger than those documented in the literature on climate change. These effects filter down to the local level, as we observe similar and robust evidence among issuers inside adopting states, such as counties, cities, and school districts. We find that these changes are further explained by rising electricity prices. However, we observe opposite results when states adopt Clean Energy Standards, as yields decrease and credit ratings increase, particularly among local bonds. This comparison reveals that market participants take contrasting views as to the economic consequences of RPS versus CES. These observers interpret the use of "renewable" energy as a signal of declining financial health. However, the use of "clean" energy, which subsumes "renewable" energy and includes additional sources (such as nuclear energy or

fossil fuels fitted with carbon capture technologies), has a muted if not positive effect on the financial health of states and local issuers. This study is the first to present evidence of the effect of both Renewable Portfolio Standards and Clean Energy Standards on the cost of funding of state and local entities.

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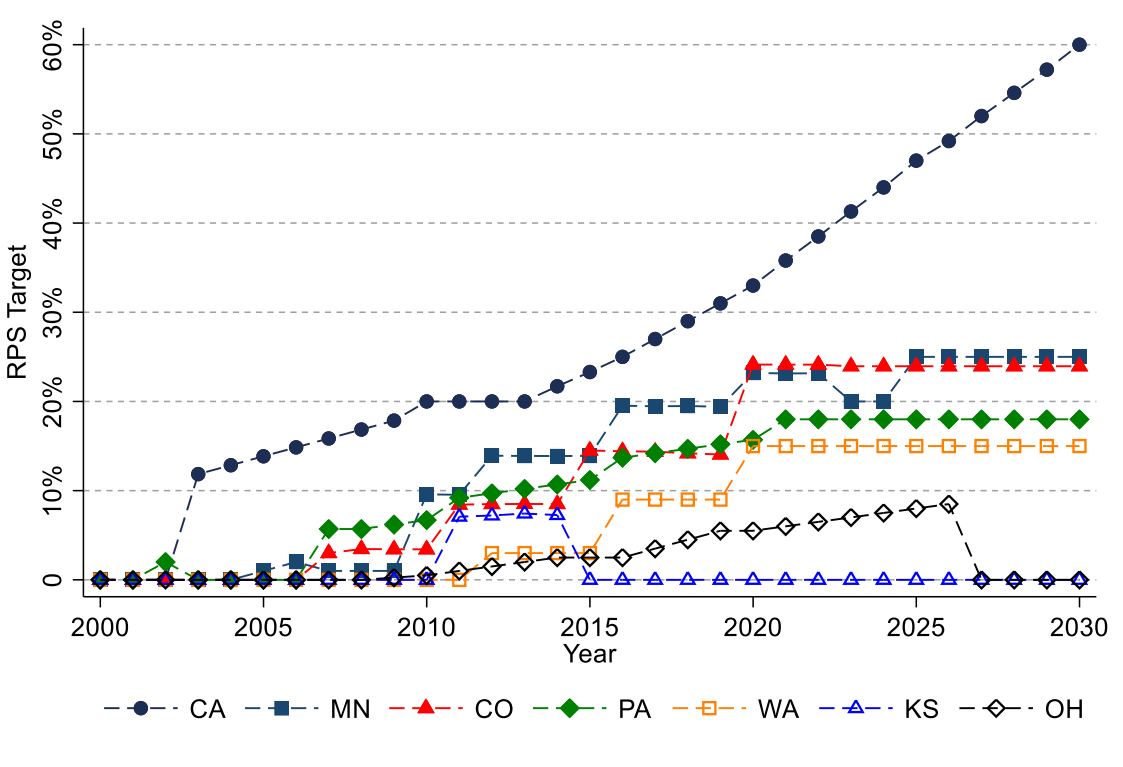

Figure I – Renewable Portfolio Standard Examples

This figure plots examples of states' RPS targets. *RPS Target* is the state-year target for the percentage of electricity to be sourced from renewable sources as reported by the Lawrence Berkeley National Laboratory and U.S. Department of Energy.

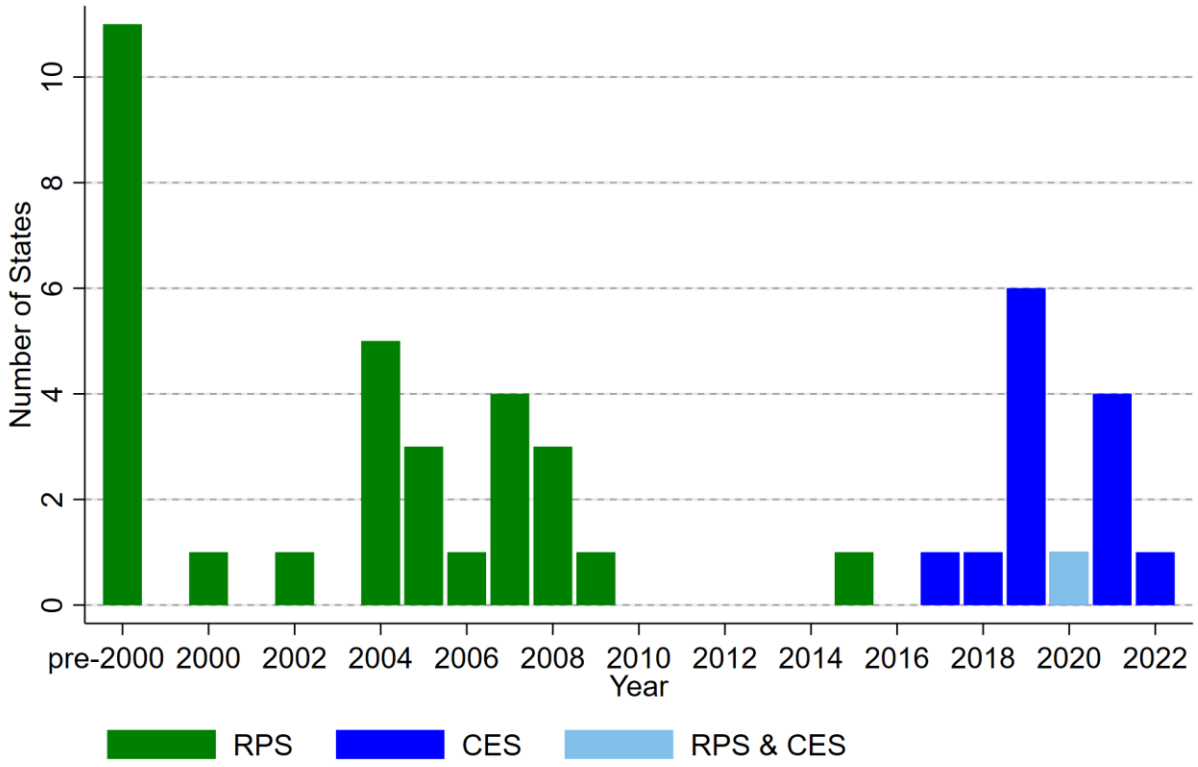

Figure II – Renewable Portfolio Standards and Clean Electricity Standards Adoptions over Time

This figure plots the number of states that have adopted Renewable Portfolio Standards (RPS) and Clean Electricity Standards (CES) over time. Data are from the Lawrence Berkeley National Laboratory and the U.S. Department of Energy.

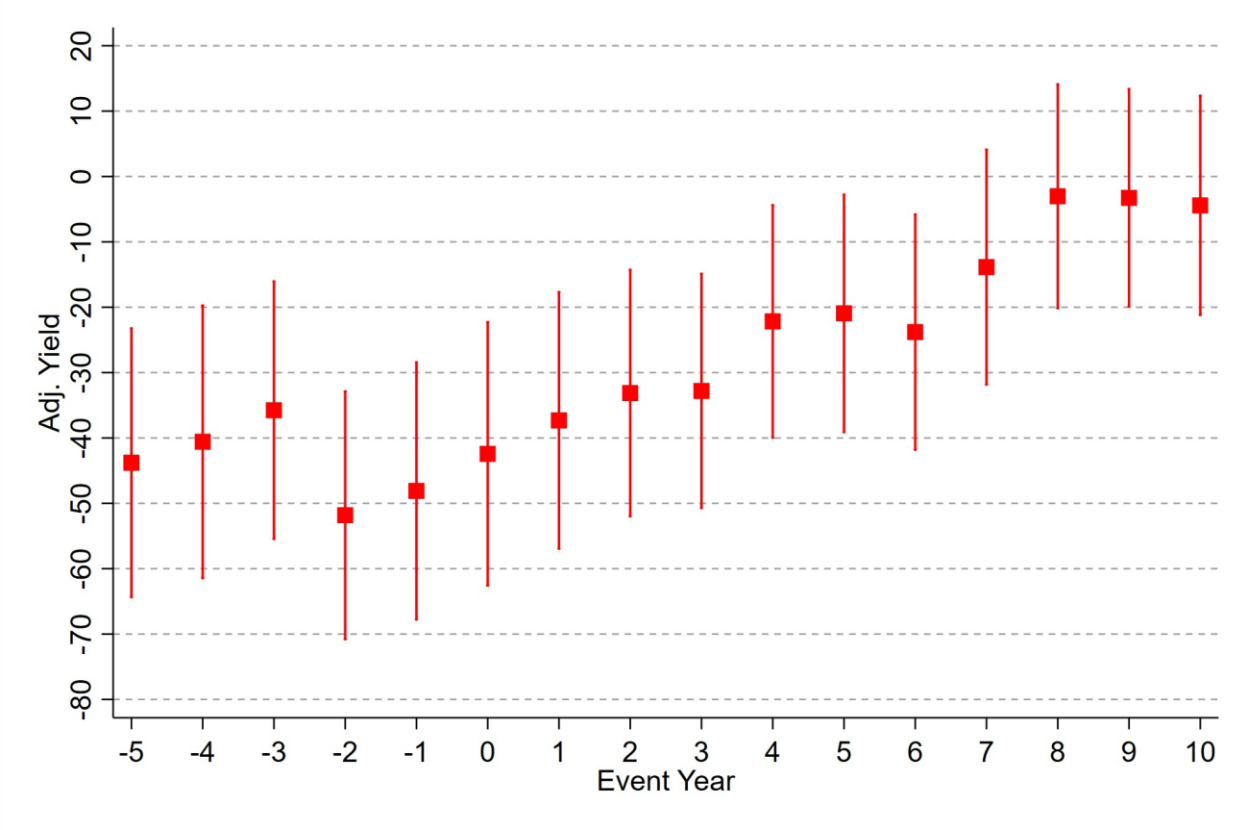

Figure III – States' Secondary Market Yields around Changes in RPS Targets

This figure plots estimates of β_{-5} through β_{+10} from the following OLS regression equation based on the sample of observations associated with state issuers in Table I Panel A:

$$\text{Adjusted Yield}_{i(j),t(y)} = \alpha + \beta_e \text{ RPS}_j \times \text{Event Year}_e + \text{Bond characteristics}_{i,t} + \text{State characteristics}_{j,y} + \text{State fixed effects} + \text{Year fixed effects} + \varepsilon_{i,t}$$

where *i* indexes bond (*j* indexes state) and *t* indexes day (*y* indexes year). *Event Year*$_e$ represents a vector of indicator variables, one for each year *e* relative to the year a state adopts RPS for the first time. Other variable definitions are in the legend of Table I. Whiskers represent 95% confidence intervals.

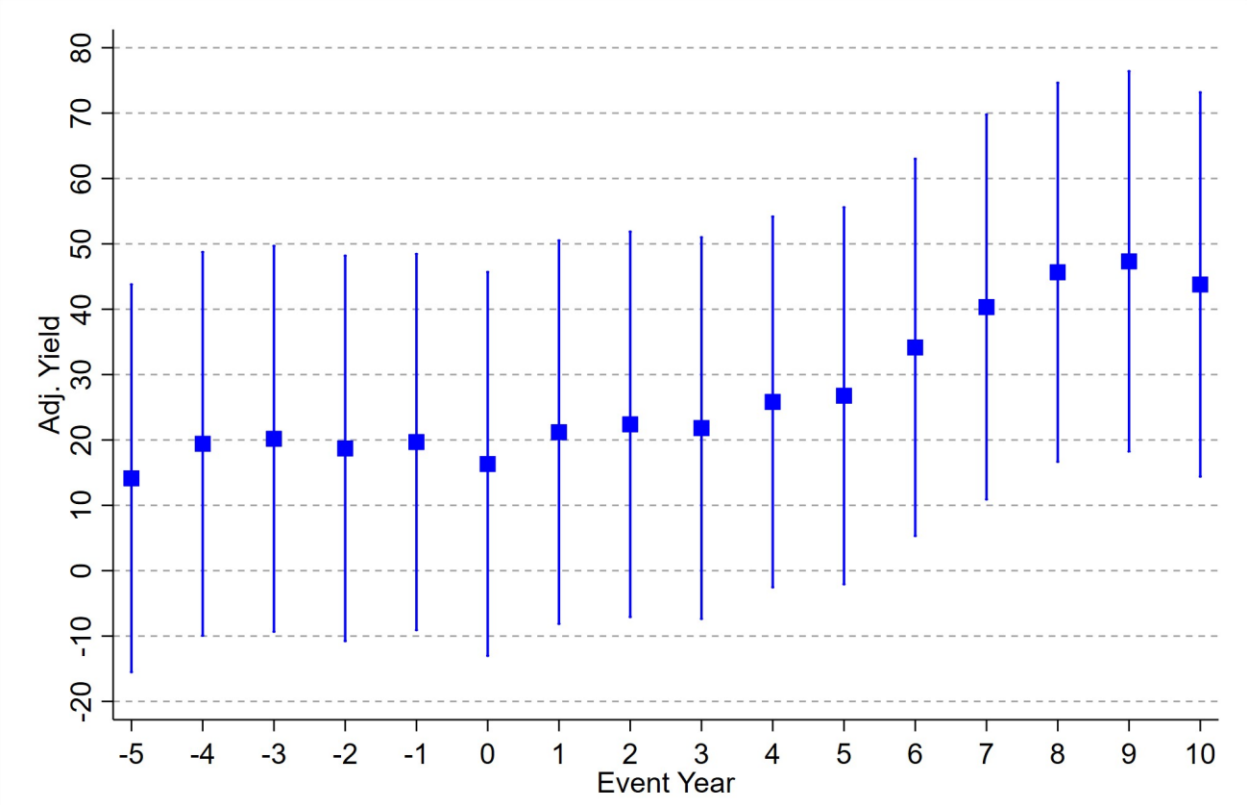

Figure IV – Local Issuers' Secondary Market Yields around Changes in RPS Targets

This figure plots estimates of β_{-5} through β_{+10} from the following OLS regression equation based on the sample of observations associated with local issuers in Table I Panel A:

$$\text{Adjusted Yield}_{i(j),t(y)} = \alpha + \beta_e \text{ RPS}_j \times \text{Event Year}_e + \text{Bond characteristics}_{i,t} + \text{State characteristics}_{j,y} + \text{County fixed effects} + \text{Year fixed effects} + \varepsilon_{i,t}$$

where *i* indexes bond (*j* indexes state) and *t* indexes day (*y* indexes year). *Event Year*$_e$ represents a vector of indicator variables, one for each year *e* relative to the year a state adopts with RPS for the first time. Other variable definitions are in the legend of Table I. Whiskers represent 95% confidence intervals.

Table I – Summary Statistics

This table provides definitions and summary statistics for dependent and independent variables. Data sources are in parentheses. Panel A provides definitions and summarizes the secondary market variables measured at the time of the transaction, and Panel B summarizes the primary market observations at the time of issuance. *RPS Target* is the state-year target for the percentage of electricity to be sourced from renewable sources as reported by the Lawrence Berkeley National Laboratory and U.S. Department of Energy. *CES Standard* is an indicator equal to one if the state has adopted a Clean Energy Standard (from U.S. State Renewables Portfolio & Clean Electricity Standards: 2023 Status Update). *Adjusted Yield* is the difference in basis points between the bond yield to maturity reported by the Municipal Securities Rulemaking Board (MSRB) and the maturity-matched Municipal Market Advisors (MMA) AAA-rated yield curve (Bloomberg). *Electricity Price* is the average price of electricity in the state for the month in cents (U.S. Energy Information Administration). *Credit Rating* is the lowest numerical rating issued by Moody's, Standard & Poor's, and Fitch (Mergent FISD). Ratings are scaled so that "AAA" is 21 and "D" is 1. *The coupon Rate* is the coupon rate of the bond in percentage (Mergent FISD). *Log Offering Amount* is the natural logarithm of the bond offering amounts in $ millions (Mergent FISD). *Years to Maturity* is years left until the bond matures (Mergent FISD). *Call Option* is an indicator equal to one if the bond has a call option (Mergent FISD). *Insured* is an indicator equal to one if the bond is insured (Mergent FISD). *State Population* is the state population in millions (U.S. Census Bureau). *State Income per Capita* is county per capita personal income in a given year (U.S. Bureau of Economic Analysis). *State Real GDP* is the state GDP in 2012 trillion dollars, and Real GDP Growth is the state real GDP growth in percentages (both from the U.S. Bureau of Economic Analysis).

Panel A: Trade Level Sample

	State Issuers (978,412 Obs.)			Local (6,392,991 Obs.)		
	Mean	St. Dev.	Median	Mean	St. Dev.	Median
RPS Target	0.15	0.13	0.13	0.11	0.11	0.06
CES Standard	0.06	0.24	0.00	0.06	0.24	0.00
Adj. Yield	16.95	85.78	13.73	28.78	91.19	23.00
Credit Rating	18.85	1.60	19.00	18.20	2.04	18.00
Coupon Rate	4.62	0.93	5.00	3.90	1.37	4.10
Log Offering Amount	16.42	1.25	16.55	14.28	1.38	14.29
Years to Maturity	7.93	5.77	7.00	8.41	6.17	7.00
Bond Age	5.17	3.84	4.75	4.29	3.58	3.84
Callable	0.56	0.50	1.00	0.54	0.50	1.00
Insured	0.15	0.36	0.00	0.46	0.50	0.00
State Population	14.86	12.30	11.54	15.96	11.83	11.64
State Income per Capita	50.84	11.58	48.50	48.48	10.34	47.26
State Real GDP	0.89	0.77	0.56	0.92	0.74	0.58
Real GDP Growth	1.57	2.61	1.80	1.76	2.55	1.90
Electricity Price	12.70	4.58	12.14	11.27	3.43	10.05

Panel B: Issuance Level Sample

	State Issuers (34,337 Obs.)			Local Issuers (917,258 Obs.)		
	Mean	St. Dev.	Median	Mean	St. Dev.	Median
RPS Target	0.08	0.11	0.02	0.07	0.10	0.03
CES Standard	0.01	0.09	0.00	0.01	0.10	0.00
Adj. Yield	14.37	34.21	10.00	20.04	38.04	15.00
Credit Rating	19.01	1.58	19.00	17.83	2.13	18.00
Coupon Rate	4.45	0.86	5.00	3.53	1.23	3.95
Log Offering Amount	15.45	1.69	15.76	13.08	1.34	13.05
Years to Maturity	11.04	6.12	10.00	9.70	6.04	9.00
Callable	0.50	0.50	1.00	0.46	0.50	0.00
Insured	0.15	0.36	0.00	0.46	0.50	0.00
State Population	11.39	10.63	6.74	13.77	10.18	11.45
State Income per Capita	42.71	10.23	40.88	42.89	9.14	41.75
State Real GDP	0.64	0.63	0.37	0.76	0.60	0.54
Real GDP Growth	1.68	2.46	1.90	1.83	2.31	1.90

Table II – Renewable Commitments and Yields in Secondary Market Trading of State Bonds

This table reports results from OLS regressions with *Adjusted Yield* as the dependent variable. The sample consists of monthly trading yields of state bonds between 2005 and 2022. *RPS Target* is the state target for renewable energy production for that year. *CES Standard* is an indicator equal to one if the state has a Clean Energy Standard in place. Bond Controls include Coupon Rate, Log Offering Amount, Years to Maturity, Call Option, and Insured indicator. State controls include State Population, State Income per Capita, State Real GDP, and Real GDP Growth. Variable definitions are in Table I. We cluster standard errors two-way at the bond and month level and report them below coefficient estimates. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)
	State Adj. Yield	State Adj. Yield
RPS Target	55.76***	59.27***
	(8.15)	(8.61)
CES Standard		4.49*
		(2.39)
Bond Controls	Yes	Yes
State Controls	Yes	Yes
State Fixed Effects	Yes	Yes
Year Fixed Effects	Yes	Yes
Adj. R-squared	0.17	0.17
Observations	978,412	978,412

Table III – Renewable Commitments and Credit Ratings of State Bonds

This table reports results from OLS regressions with *Credit Rating* as the dependent variable. The sample consists of monthly ratings on traded state bonds between 2005 and 2022. *RPS Target* is the state target for renewable energy production for that year. *CES Standard* is an indicator equal to one if the state has a Clean Energy Standard in place. Bond Controls include Coupon Rate, Log Offering Amount, Years to Maturity, Call Option, and Insured indicator. State controls include State Population, State Income per Capita, State Real GDP, and Real GDP Growth. Variable definitions are in Table I. We cluster standard errors two-way at the bond and month level and report them below coefficient estimates. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	(1)	(3)
	State Credit Ratings	State Credit Ratings
RPS Target	-2.94***	-2.90***
	(0.22)	(0.24)
CES Standard		0.05
		(0.08)
Bond Controls	Yes	Yes
State Controls	Yes	Yes
State Fixed Effects	Yes	Yes
Year Fixed Effects	Yes	Yes
Adj. R-squared	0.60	0.60
Observations	978,412	978,412

Table IV – Renewable Commitments and Yields in Secondary Market Trading of Local Bonds

This table reports results from OLS regressions with *Adjusted Yield* as the dependent variable. The sample consists of monthly trading yields of local municipal bonds between 2005 and 2022. *RPS Target* is the state target for renewable energy production for that year. *CES Standard* is an indicator equal to one if the state has a Clean Energy Standard in place. Bond Controls include Coupon Rate, Log Offering Amount, Years to Maturity, Call Option, and Insured indicator. State controls include State Population, State Income per Capita, State Real GDP, and Real GDP Growth. Variable definitions are in Table I. We cluster standard errors two-way at the bond and month level and report them below coefficient estimates. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)	(3)	(4)
	Local Adj. Yield	Local Adj. Yield	School Adj. Yield	School Adj. Yield
RPS Target	42.36***	42.85***	55.09***	55.51***
	(5.06)	(5.27)	(5.98)	(6.24)
CES Standard		0.86		0.90
		(1.26)		(1.77)
Bond Controls	Yes	Yes	Yes	Yes
State Controls	Yes	Yes	Yes	Yes
County Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Adj. R-squared	0.13	0.13	0.16	0.16
Observations	6,392,991	6,392,991	3,001,754	3,001,754

Table V – Renewable Commitments and Yields in Secondary Market Trading of Local Bonds in Border Counties

This table reports results from OLS regressions with *Adjusted Yield* as the dependent variable. The sample consists of monthly trading yields of local municipal bonds that are in counties that border adjacent states between 2005 and 2022. *RPS Target* is the state target for renewable energy production for that year. *CES Standard* is an indicator equal to one if the state has a Clean Energy Standard in place. Bond Controls include Coupon Rate, Log Offering Amount, Years to Maturity, Call Option, and Insured indicator. State controls include State Population, State Income per Capita, State Real GDP, and Real GDP Growth. Variable definitions are in Table I. We cluster standard errors two-way at the bond and month level and report them below coefficient estimates. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)	(3)	(4)
	Local Adj. Yield	Local Adj. Yield	School Adj. Yield	School Adj. Yield
RPS Target	35.28***	33.54***	32.33***	31.65***
	(5.20)	(5.41)	(5.61)	(5.59)
CES Standard		-2.10**		-0.98
		(0.90)		(1.10)
Bond Controls	Yes	Yes	Yes	Yes
State Controls	Yes	Yes	Yes	Yes
County Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Adj. R-squared	0.12	0.12	0.12	0.12
Observations	1,937,160	1,937,160	785,374	785,374

Table VI – Renewable Commitments and Credit Ratings of Local Bonds

This table reports results from OLS regressions with *Credit Rating* as the dependent variable. The sample consists of monthly ratings on traded local bonds between 2005 and 2022. *RPS Target* is the state target for renewable energy production for that year. *CES Standard* is an indicator equal to one if the state has a Clean Energy Standard in place. Bond Controls include Coupon Rate, Log Offering Amount, Years to Maturity, Call Option, and Insured indicator. State controls include State Population, State Income per Capita, State Real GDP, and Real GDP Growth. Variable definitions are in Table I. We cluster standard errors two-way at the bond and month level and report them below coefficient estimates. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)	(3)	(4)
	Local Credit Ratings	Local Credit Ratings	School Credit Ratings	School Credit Ratings
RPS Target	-0.64***	-0.56***	-1.54***	-1.46***
	(0.12)	(0.12)	(0.31)	(0.31)
CES Standard		0.15***		0.19***
		(0.02)		(0.04)
Bond Controls	Yes	Yes	Yes	Yes
State Controls	Yes	Yes	Yes	Yes
County Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Adj. R-squared	0.40	0.40	0.41	0.41
Observations	6,392,991	6,392,991	3,001,754	3,001,754

Table VII – Renewable Commitments, Yields, and Electricity Prices in Secondary Market Trading of Local Bonds

This table reports results from instrumental variable regressions with *Adjusted Yield* and *Credit Rating* as the dependent variable. The models in column (2) and (3) implement a two-stage least squares procedure using *RPS Target* as an instrument for *Electricity Price*. The model in column (1) reports the first stage regression. The sample consists of monthly adjusted yields and ratings on traded local bonds between 2005 and 2022. *RPS Target* is the state target for renewable energy production for that year. *Electricity Price* is the average price of electricity in the state for the month. Bond Controls include Coupon Rate, Log Offering Amount, Years to Maturity, Call Option, and Insured indicator. State controls include State Population, State Income per Capita, State Real GDP, and Real GDP Growth. Variable definitions are in Table I. We cluster standard errors two-way at the bond and month level and report them below coefficient estimates. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	(1) Electricity Price	(2) Local Adj. Yield	(3) Credit Rating
RPS Target	2.71***		
	(0.87)		
Instrumented Electricity Price		15.66**	-0.24***
		(6.08)	(0.06)
Bond Controls	Yes	Yes	Yes
State Controls	Yes	Yes	Yes
County Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
First Stage F-test	9.73		
Adj. R-squared	0.91	0.04	0.14
Observations	6,392,991	6,392,991	6,392,991

Table VIII – Renewable Commitments and Offering Yields of State Bonds

This table reports results from OLS regressions with *Adjusted Yield* as the dependent variable. The sample consists of offering yields of state bonds between 2001 and 2021. *RPS Target* is the state target for renewable energy production for that year. *CES Standard* is an indicator equal to one if the state has a Clean Energy Standard in place. Bond Controls include Coupon Rate, Log Offering Amount, Years to Maturity, Call Option, and Insured indicator. State controls include State Population, State Income per Capita, State Real GDP, and Real GDP Growth. Variable definitions are in Table I. We cluster standard errors two-way at the bond and month level and report them below coefficient estimates. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)
	State Adj. Yield	State Adj. Yield
RPS Target	25.85*	19.21
	(13.38)	(13.27)
CES Standard		-22.56*
		(12.34)
Bond Controls	Yes	Yes
State Controls	Yes	Yes
State Fixed Effects	Yes	Yes
Year Fixed Effects	Yes	Yes
Adj. R-squared	0.33	0.33
Observations	34,337	34,337

Table IX – Renewable Commitments and Offering Yields of Local Bonds

This table reports results from OLS regressions with *Adjusted Yield* as the dependent variable. The sample consists of offering yields of local bonds between 2001 and 2021. *RPS Target* is the state target for renewable energy production for that year. *CES Standard* is an indicator equal to one if the state has a Clean Energy Standard in place. Bond Controls include Coupon Rate, Log Offering Amount, Years to Maturity, Call Option, and Insured indicator. State controls include State Population, State Income per Capita, State Real GDP, and Real GDP Growth. Variable definitions are in Table I. We cluster standard errors two-way at the bond and month level and report them below coefficient estimates. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)	(3)	(4)
	Local Adj. Yield	Local Adj. Yield	School Adj. Yield	School Adj. Yield
RPS Target	46.27***	45.90***	60.55***	58.46***
	(5.54)	(5.67)	(8.66)	(8.93)
CES Standard		-0.74		-3.83
		(2.20)		(2.82)
Bond Controls	Yes	Yes	Yes	Yes
State Controls	Yes	Yes	Yes	Yes
County Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Adj. R-squared	0.29	0.29	0.31	0.31
Observations	917,258	917,258	403,667	403,667

Table X – Renewable Commitments and Offering Yields of Local Bonds in Border Counties

This table reports results from OLS regressions with *Adjusted Yield* as the dependent variable. The sample consists of offering yields of local bonds between 2001 and 2021 for border counties. *RPS Target* is the state target for renewable energy production for that year. *CES Standard* is an indicator equal to one if the state has a Clean Energy Standard in place. Bond Controls include Coupon Rate, Log Offering Amount, Years to Maturity, Call Option, and Insured indicator. State controls include State Population, State Income per Capita, State Real GDP, and Real GDP Growth. Variable definitions are in Table I. We cluster standard errors two-way at the bond and month level and report them below coefficient estimates. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)	(3)	(4)
	Local Adj. Yield	Local Adj. Yield	School Adj. Yield	School Adj. Yield
RPS Target	23.26***	23.59***	31.68***	30.89***
	(4.80)	(4.82)	(8.24)	(8.26)
CES Standard		0.82		-1.98
		(2.04)		(2.40)
Bond Controls	Yes	Yes	Yes	Yes
State Controls	Yes	Yes	Yes	Yes
County Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Adj. R-squared	0.29	0.29	0.31	0.31
Observations	297,765	297,765	122,359	122,359

Internet Appendix

for

The Public Cost of Net Zero

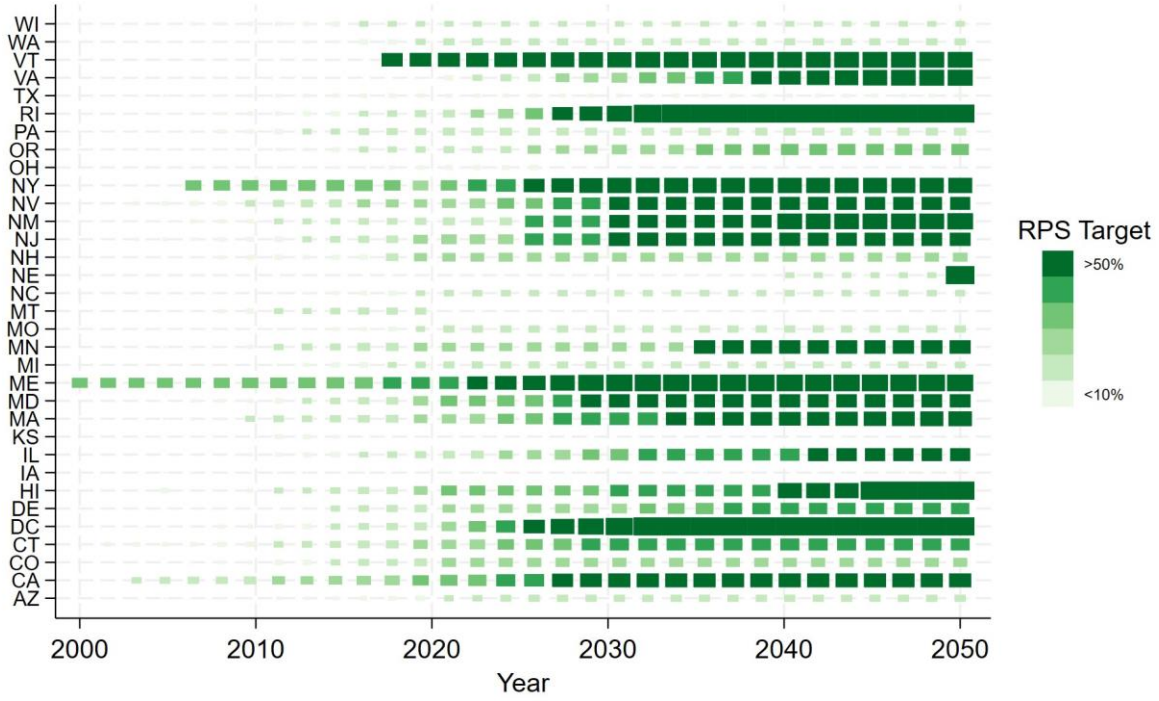

Figure AI – Renewable Portfolio Standards for Adopting States

This figure plots RPS targets for the 32 states that implemented an RPS target at any point over the sample period. *RPS Target* is the state-year target for the percentage of electricity to be sourced from renewable sources as reported by the Lawrence Berkeley National Laboratory and U.S. Department of Energy.

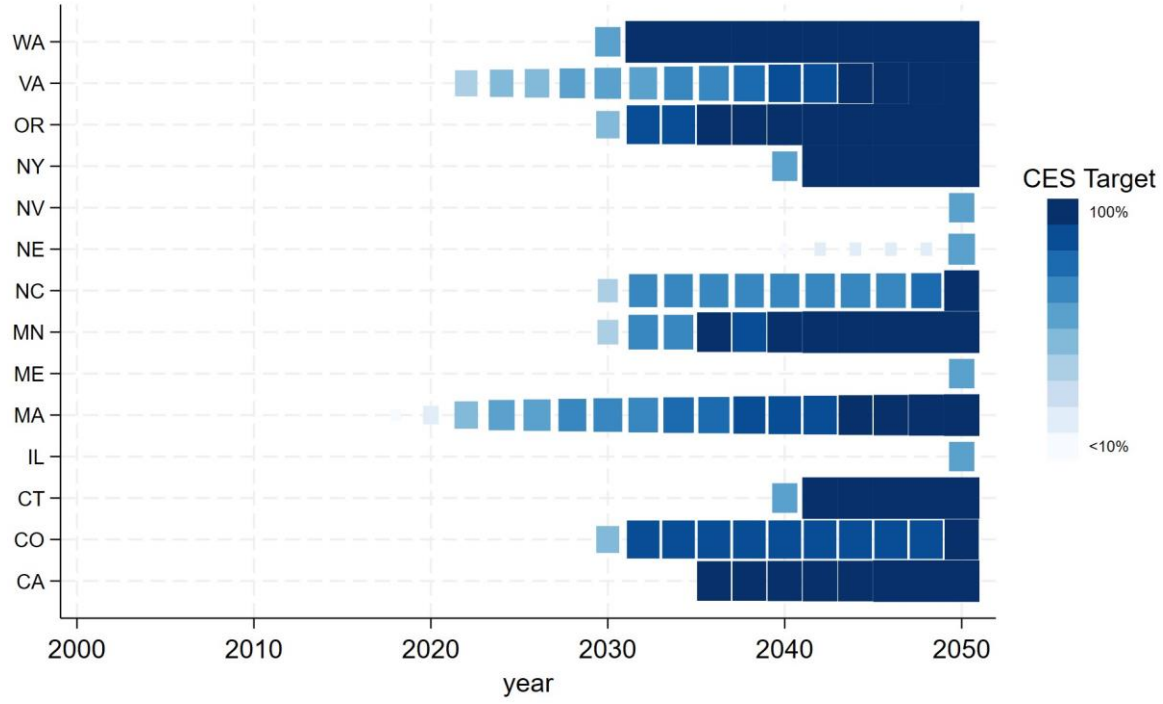

Figure AII – Clean Energy Standards for Adopting States

This figure plots CES targets for the 14 states that implemented a CES at any point over the sample period. *CES Target* is the state-year target for the percentage of electricity to be sourced from technology-neutral renewable sources including nuclear power or fossil fuels fitted with carbon capture technologies. We collect this information from the Lawrence Berkeley National Laboratory and U.S. Department of Energy.

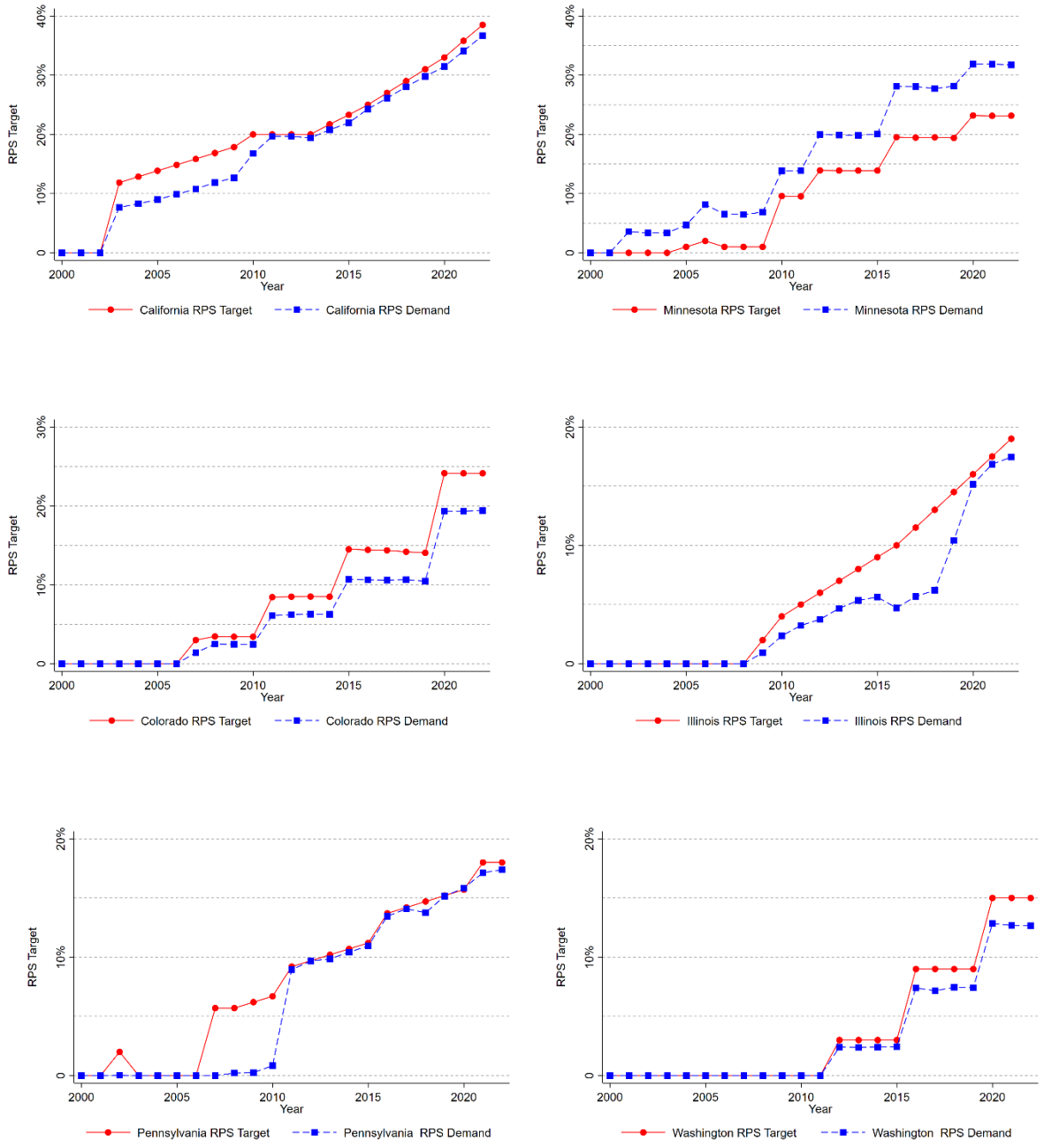

Figure AIII – RPS Target vs. RPS Demand

This figure plots examples of states' RPS targets over time. It shows the percentage of electricity that RPS mandate to be derived from renewable sources (solid line) and the projected RPS demand as a percentage of electricity sales that adjusts for state exemptions and other provisions (dashed line). Data are from the Lawrence Berkeley National Laboratory and U.S. Department of Energy.

Table AI – Renewable Commitments and Yields in Secondary Market Trading with Alternative Yield Definitions

This table reports results from OLS regressions with three alternative yield definitions for state yields as the dependent variable. Panel A reports results from the state issuer sample while Panel B reports results for the local issuer sample. In Panel A (Panel B), column 1 reports results with *Adjusted Yield* from Table II (Table IV) that uses transaction-amount weighted yield spreads relative to maturity-matched MMA yields. Column 2 in both panels reports results with *Equal-Weighted Adjusted Yield* as the dependent variable. This dependent variable uses average equally weighted yield spreads instead of weighting by transaction amount. Column 3 reports results with *Trade-Weighted Raw Yield* as the dependent variable. This variable uses transaction-amount weighted yields and does not subtract maturity-matched MMA yields. Column 4 reports results with *Equal-Weighted Raw Yield* as the dependent variable. This variable uses average equally-weighted yields and does not subtract maturity-matched MMA yields. . State controls include State Population, State Income per Capita, State Real GDP, and Real GDP Growth. Variable definitions are in Table I. We cluster standard errors two-way at the bond and month level and report them below coefficient estimates. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Panel A: State Issuers

	(1)	(2)	(3)	(4)
	Trade-Weighted State Adj. Yield	Equal-Weighted State Adj. Yield	Trade-Weighted State Yield	Equal-Weighted State Yield
RPS Target	55.76***	55.30***	79.11***	78.65***
	(8.15)	(8.10)	(7.63)	(7.54)
Bond Controls	Yes	Yes	Yes	Yes
State Controls	Yes	Yes	Yes	Yes
State Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Adj. R-squared	0.17	0.17	0.62	0.61
Observations	978,412	978,412	978,412	978,412

Panel B: Local Issuers

	(1)	(2)	(3)	(4)
	Trade-Weighted Local Adj. Yield	Equal-Weighted Local Adj. Yield	Trade-Weighted Local Yield	Equal-Weighted Local Yield
RPS Target	42.36***	42.27***	28.91***	28.86***
	(5.06)	(5.04)	(6.95)	(6.92)
Bond Controls	Yes	Yes	Yes	Yes
State Controls	Yes	Yes	Yes	Yes
County Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Adj. R-squared	0.13	0.13	0.58	0.58
Observations	6,392,991	6,392,991	6,392,991	6,392,991

Table AII – Renewable Demand and Yields in Secondary Market Trading

This table reports results from OLS regressions with *Adjusted Yield* as the dependent variable. The sample consists of monthly trading yields of state bonds between 2005 and 2022. *RPS Demand* is the demand for RPS electricity (adjusted for exempt load and other state-specific provisions) divided by the total electricity sales in the state. *CES Standard* is an indicator equal to one if the state has a Clean Energy Standard in place. Bond controls include Coupon Rate, Log Offering Amount, Years to Maturity, Call Option, and Insured indicator. State controls include State Population, State Income per Capita, State Real GDP, and Real GDP Growth. Variable definitions are in Table I. We cluster standard errors two-way at the bond and month level and report them below coefficient estimates. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Panel A: State Issuers

	(1)	(2)
	State Adj. Yield	State Adj. Yield
RPS Demand	73.36***	74.51***
	(10.30)	(10.46)
CES Standard		2.57
		(2.28)
Bond Controls	Yes	Yes
State Controls	Yes	Yes
State Fixed Effects	Yes	Yes
Year Fixed Effects	Yes	Yes
Adj. R-squared	0.17	0.17
Observations	978,412	978,412

Panel B: Local Issuers

	(1)	(2)	(3)	(4)
	Local Adj. Yield	Local Adj. Yield	School Adj. Yield	School Adj. Yield
RPS Demand	68.39***	68.60***	138.38***	138.67***
	(7.86)	(8.05)	(10.62)	(10.79)
CES Standard		0.59		1.03
		(1.24)		(1.80)
Bond Controls	Yes	Yes	Yes	Yes
State Controls	Yes	Yes	Yes	Yes
County Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Adj. R-squared	0.13	0.13	0.16	0.16
Observations	6,392,991	6,392,991	3,001,754	3,001,754

Table AIII – Renewable Commitments and Yields in Secondary Market Trading of Local Bonds in Border Counties for Kansas and Ohio

This table reports results from OLS regressions with *Adjusted Yield* as the dependent variable. The sample consists of monthly trading yields of local municipal bonds from Kansas and Ohio that are in counties that border adjacent states between 2005 and 2022. *Repeal* is an indicator equal to one in Ohio after 2014 and Kansas after 2015, the years when those states repealed or froze their RPS standards. *RPS Target* is the state target for renewable energy production for that year. Bond Controls include Coupon Rate, Log Offering Amount, Years to Maturity, Call Option, and Insured indicator. State controls include State Population, State Income per Capita, State Real GDP, and Real GDP Growth. Variable definitions are in Table I. We cluster standard errors two-way at the bond and month level and report them below coefficient estimates. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)	(3)	(4)
	Local Adj. Yield	Local Adj. Yield	School Adj. Yield	School Adj. Yield
Repeal	-5.28**	-1.34	-11.85***	-7.89**
	(2.47)	(2.59)	(3.32)	(3.50)
RPS Target		91.81***		85.53***
		(19.11)		(26.42)
Bond Controls	Yes	Yes	Yes	Yes
State Controls	Yes	Yes	Yes	Yes
County Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Adj. R-squared	0.10	0.10	0.12	0.12
Observations	380,961	380,961	209,937	209,937