Title: The Fiscal Impact of Biodiversity Loss and a Pathway for Conservation Finance

Anya Nakhmurina[1], Dale T. Manning[2], Eli P. Fenichel[3]*†

Affiliations:

[1] Yale School of Management, Yale University, New Haven, CT, USA.

[2]Baker School of Public Policy and Agricultural and Resource Economics, University of Tennessee, Knoxville, TN, USA.

[3] Yale School of the Environment, Yale University, New Haven, CT, USA.

*Corresponding author. Email: eli.fenichel@yale.edu

†These authors contributed equally to this work.

Abstract: The Global Biodiversity Framework seeks to leverage private finance to achieve conservation goals. Therefore, identifying instances where conservation investment can generate positive returns for private investors is an imperative. Here, we investigate how natural asset changes impact municipal bond yields by examining the effects of sudden bat population losses on the bonds of rural counties. Bats provide pest control services for farmers. Bat population losses reduce agricultural land tax revenues, driving up bond spreads in affected counties by 11.5 basis points, a 27% increase. This result implies that conservation investors purchasing bonds with a principal value of $1 million and restoring bats could expect bond prices to increase by $14,124. This payoff can potentially cover conservation costs without new government actions.

The Kunming-Montreal Global Biodiversity Framework (GBF)[i] identifies an annual biodiversity funding gap of $700 billion. Given insufficient public funds (*1*), GBF Target 19 seeks to leverage private finance to fill this funding gap. To qualify as financing, rather than private philanthropy, there must be opportunities that enable investors to capture financial returns from enhancing ecosystems, while simultaneously providing ecological benefits to current and future generations (*2*). Yet, viable and scalable private conservation strategies remain uncommon (*3, 4*).[ii] Most emerging solutions, e.g., green bonds (*6*) or biodiversity credits (*7*), require creating new legal frameworks, building compliance market infrastructure, or relying on voluntary conservation goals coupled with offset markets.

Here, we provide evidence that changes in local biodiversity affect municipal borrowing costs[iii] using a case study of how a sudden decrease in bat populations impacts U.S. rural county governments. By studying bats, which provide natural pest control services to farms, we reveal a direct link between a component of biodiversity, and natural asset, and municipal financial outcomes. The connection between biodiversity and municipal borrowing costs creates a novel pathway for private conservation investment (Figure 1). Profit-seeking investors may strategically invest in municipal bonds whose valuation is likely to change due to changes in the condition of local biodiversity. This investment strategy may allow investors to monetize conservation efforts by aligning their bond investment strategy with conservation actions.

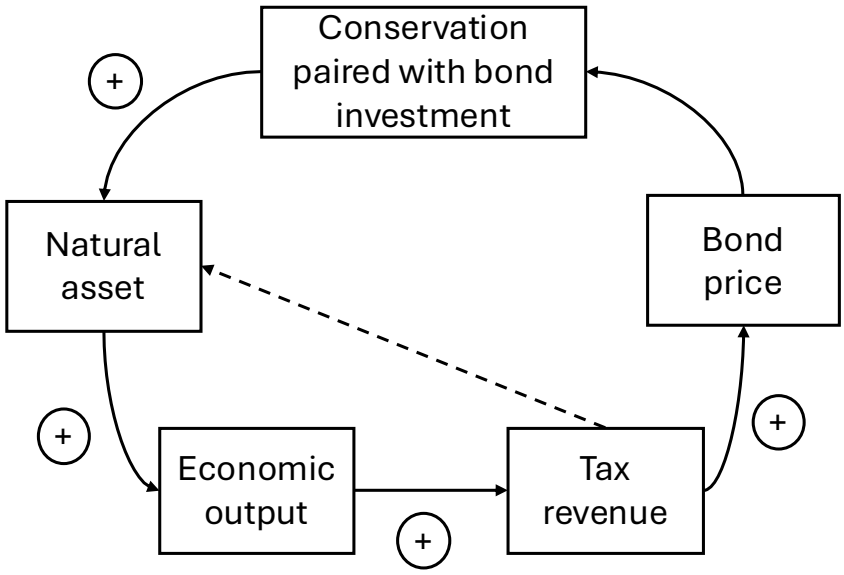


Figure 1: Generating Returns to Conservation
External investors invest in restoration of a natural asset while also purchasing municipal bonds. Improved natural assets increase economic output. This increases tax revenue and the outlook for future revenues. Improved government revenue lowers borrowing costs and raises municipal bond prices. Higher government revenues can also create a positive return to local government investment in natural assets (dotted arrow).

Nature, biodiversity, and their constituent parts are the natural assets that often provide important inputs to production processes (*8*). For example, all else equal, greater fish stocks increase fisheries' productivity, groundwater availability increases agricultural profitability (*9*-*11*) and natural amenities enhance home values (*12*). The role of nature as a productive input means that it can lead to higher economic output and greater government revenues. However, the rapid pace of global biodiversity loss threatens productivity, fiscal sustainability, and, ultimately, human well-being (*13*). We show that a municipality's financial health is inherently linked to its natural assets.

Identifying mechanisms that match conservation project costs with financial returns is necessary for creating conservation finance opportunities. When conservation projects operate at a much larger scale than their financing sources, private investors interested in financial returns are unlikely to see benefits that justify their costs, and conservation investment is sub-optimal due to free riding (*14*). On the other hand, if the conservation scale is substantially finer than the investment scale, then the returns might not be detectable because of other sources of variation, statistical noise, and risk diversification. For example, food processing firms faced with possible local supply shocks can diversify the risk away by sourcing produce from many regions. Municipal finance may provide the appropriate scale for many conservation investment opportunities. If declines in natural assets reduce municipal revenue, increase revenue variability, or both, then municipal borrowing costs are expected to increase. This can affect municipal bonds' valuation and creates private investment opportunities. Accurately measuring the size of a natural asset's contributions to public finances can create an incentive, and defensible pathways, for private investors and local governments to invest in the maintenance of natural assets.

There is evidence that news about biodiversity loss can affect investors' perception of default risk at the country level (*15*). At the local level, investing in conservation, for example in ecosystems that lower coastal flooding risk, can keep municipal borrowing costs lower (*16*). Prior analyses of environmental connections to public debt show that bond prices respond to sea

level rise (*17, 18*), protected areas (*19*), heat (*20*), and hurricanes (*21*). Here, we expand this line of research, which has primarily focused on climate- and weather-related events, to biodiversity. We demonstrate that natural assets are priced in municipal bonds and illustrate a potential pathway for conservation interventions financed by municipal bond trades.

Municipal Bonds and Biodiversity

If natural resources capitalize like other assets, we expect local conservation actions to increase the value of bonds issued by subnational governments (e.g., municipalities). This creates an opportunity for conservation investors to purchase municipal bonds, implement conservation actions, and subsequently sell the bonds at increased value, potentially recovering some or all the conservation costs. This financing mechanism could generate returns in many settings where nature influences local government revenues, including flood-risk-reducing dunes, wetlands, and mangroves (*19*); greenway development (*22*); water quality (*23*); and brownfield remediation (*24*). Here, we test the viability of this conservation finance opportunity through the case of bats that control insect pests. We document that White Nose Syndrome (WNS), a disease that causes unprecedented bat mortality, is priced in municipal bonds issued by U.S. rural counties.

In the U.S., local governments issue municipal bonds to fund ongoing operations and finance capital projects, such as paving roads or enhancing sewer systems. This debt, with a current value of $4.2 trillion (*25*), is often secured by municipalities' future tax revenues. Municipal bonds are debt securities that investors can buy and sell in the publicly traded market. Bondholders receive, and municipalities pay, regular interest (or 'coupon') payments. Coupons are typically paid semiannually, with the principal repaid at the maturity date. The municipality-specific interest rate is equal to the sum of the risk-free interest rate and an adjustment for local conditions, called a spread. The spread predominantly depends on local default risk, as assessed by the municipal bond market (*26*). Consequently, events that change the likelihood of future default impact the spread. Larger spreads reflect greater risk, and bonds with higher spreads trade at lower prices (see SI for bond price details).[iv]

The case of bats illustrates how biodiversity can support productivity and influence municipal bond spreads by affecting tax revenues and altering default risk. By providing pest control services, bats enable greater crop yields with reduced chemical pesticide use, which in turn increases farm profits through higher production and lower costs (*28-31*).

The link between bats and county finances may be especially pronounced in rural, agricultural counties, where farm property taxes are a major revenue source (*32*), and tax assessments are directly tied to agricultural profitability. Under the Current Agricultural Use-Value Assessment (CAUVA) system used by counties across U.S. states, farmland is taxed based on its current value in agriculture (revenues minus costs) rather than its potential market value (i.e., sale price) (*33*). These assessments are updated frequently, often annually, using multi-year rolling averages of net agricultural income and other factors.

To document an empirical causal connection between bat-provided ecosystem services and county financing, we rely on the natural experiment provided by the quasi-random spread of WNS (Figure 2). WNS unexpectedly and suddenly arrived in the Northeastern U.S. in 2006 and spread across the country, infecting bats and greatly reducing their population sizes (*34*). See the SI for details of the data used for the analysis.

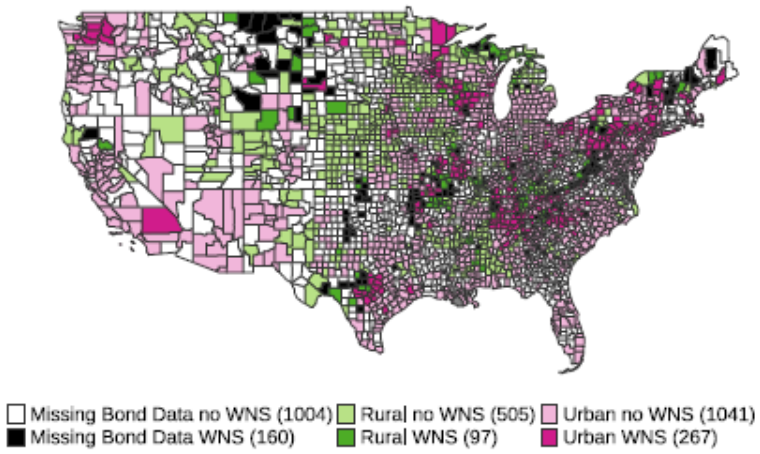


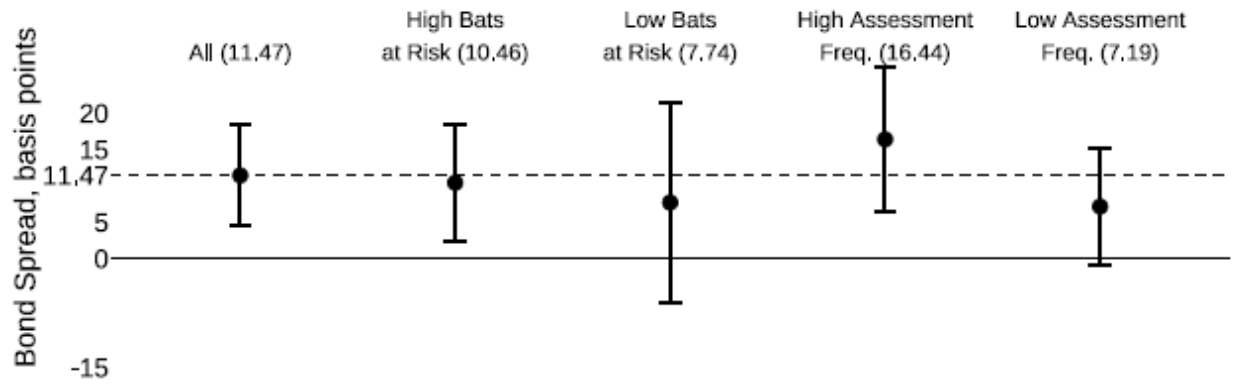
Figure 2: Map of spatial and temporal extent of WNS across US counties.
Figure shows rural counties in shades of green, and urban counties in shades of pink. Darker shades indicate the presence of WNS in a county as of 2022. Counties with missing data in our bond analyses are shown in black (white) if they were (were not) affected by WNS. Data Sources: whitenosesyndrome.org; USDA; *Mergent.*

We hypothesize that by decreasing farm profits (*29*), WNS puts downward pressure on CAUVA-based land use taxes, consequently decreasing county tax revenues. The municipal bond market recognizes an increased default risk from declining tax collections and demands higher interest rates on the bonds issued by the WNS-affected counties. This market response does not require

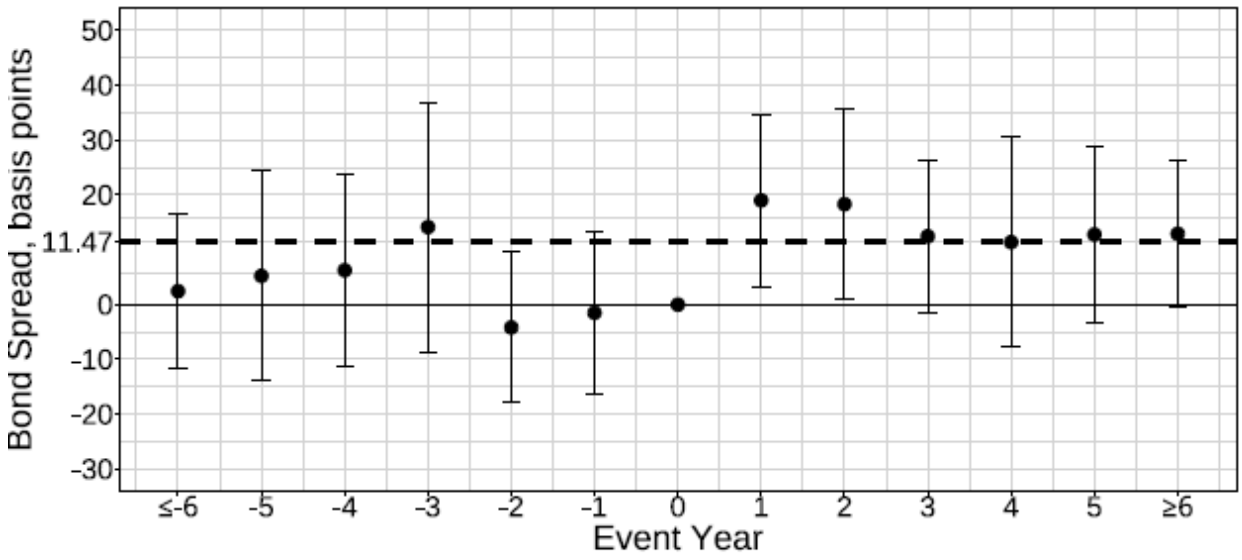
investors to recognize WNS as the underlying cause of declining tax revenues - they need only perceive the increased default risk. Because bond prices are forward-looking, we expect to observe nearly immediate changes in bond spreads, even if tax revenue declines take several years to materialize. In this setting, conservation investors could purchase municipal bonds from WNS-affected counties, implement bat restoration projects, and then benefit from the subsequent increase in bond values.

The impact of bat loss on municipal borrowing costs

The loss of bats to WNS increases municipal bond spreads in rural counties by 11.47 basis points (0.1147 percentage points (pp)), or 27% of the average spread (Figure 3), equivalent to 4% of the average bond yield. Consistent with the proposed mechanism that WNS causes the loss of pest control from bats, we find that rural counties with an above-median number of bat species that are susceptible to WNS experience more precise impacts compared to rural counties with fewer bat species at risk (Figure 3 Panel a). This suggests that, considering only bats, more species richness implies more value at risk from a shock. This contrasts with other contexts in which greater species diversity is expected to provide greater resilience, for example if potential shocks only affect a small share of species (*15, 35-37*). Further, the impacts of bat loss are strongest in counties that update assessed values more frequently. This supports the hypothesis that changes in tax assessments drive changes in county revenue and default risk.



(a) Increase in bond spreads after WNS arrival in all counties, and splitting by whether the county has a high number of bats at risk, and by county-specific assessment frequency.



(b) Increase in bond spreads after WNS arrival in event-time.

Figure 3: Impact of WNS on bond spreads in rural counties.

Panel (a) displays coefficient estimates and 95% confidence intervals from our main specification for bond spreads in all rural counties (Table SI-3, Panel (a), column 6) (first bar and dashed line), and rural counties with high (second bar), and rural counties with low numbers of bat species at risk from WNS (Table SI-4, Panel (a)) (third bar). The fourth and fifth bars present coefficients and confidence intervals for rural counties with high and low tax assessment frequency (Table SI-5, Panel (a)). Panel (b) of the figure shows bond spreads over event time. It includes all standard bond controls described in the text. All results are in basis points, or one hundredth of a percentage point.

The increase in bond spreads remains significant 6 years after WNS detection (Figure 3 Panel b). Prior to WNS detection, we find no significant difference in bond spread changes between affected and unaffected counties. These results are robust to alternative sets of controls and specifications (see the SI).

Conservation finance opportunities

To fix ideas, consider a conservation finance opportunity. An investor can purchase municipal bonds issued by a county that has lost bat populations, while simultaneously investing in bat restoration. The price of a bond is the present value of expected cash flows (coupons and principal payment), discounted at a bond-specific interest rate r (e.g., *38*). Bond prices reflect bond-specific default risk, with riskier borrowers facing higher interest rates.

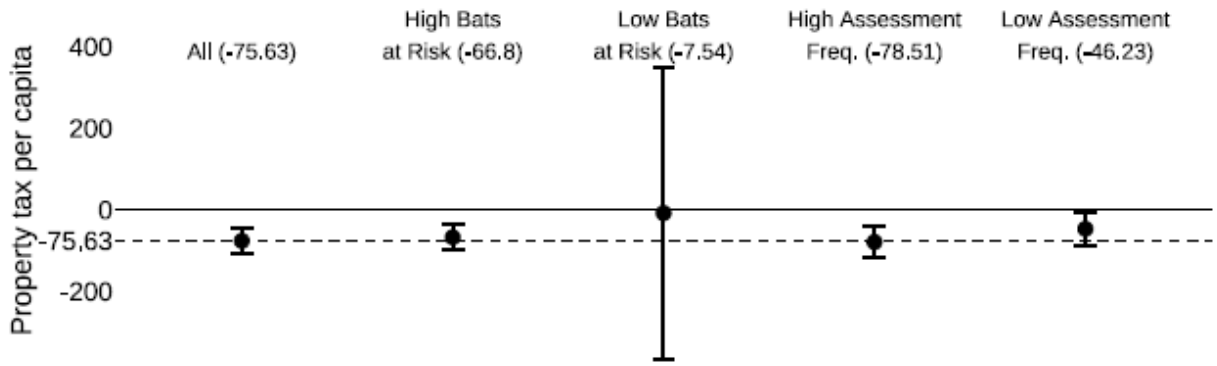
Based on sample averages, a WNS-affected county issues bonds with annual interest rate $r_{WNS} = 3.03\%$, coupon rate 3.31%, and maturity of 15 years. With this parameterization, the price of the bond that repays \$1 million at maturity is $P_{WNS} = \$1{,}032{,}936$ (see the SI section 2.1 for details on bond pricing and the calculation).

After buying this bond, the investor announces plans to invest B in bat restoration. If the investor is credible, an efficient market immediately prices in this information, decreasing the interest rate to $r_0 \equiv r_{WNS} - 0.1147\ pp = 2.92\%$, where 0.1147 pp is the estimated impact of WNS on bond spreads. Following the announcement, the bond price is expected to increase to $P_0 = \$1{,}047{,}060$. Investor's tax-adjusted financial gain is $\$14{,}124 - B$. The US Fish and Wildlife Service estimates that bat conservation efforts could cost between \$9,450 and \$18,000 per county (*29*).

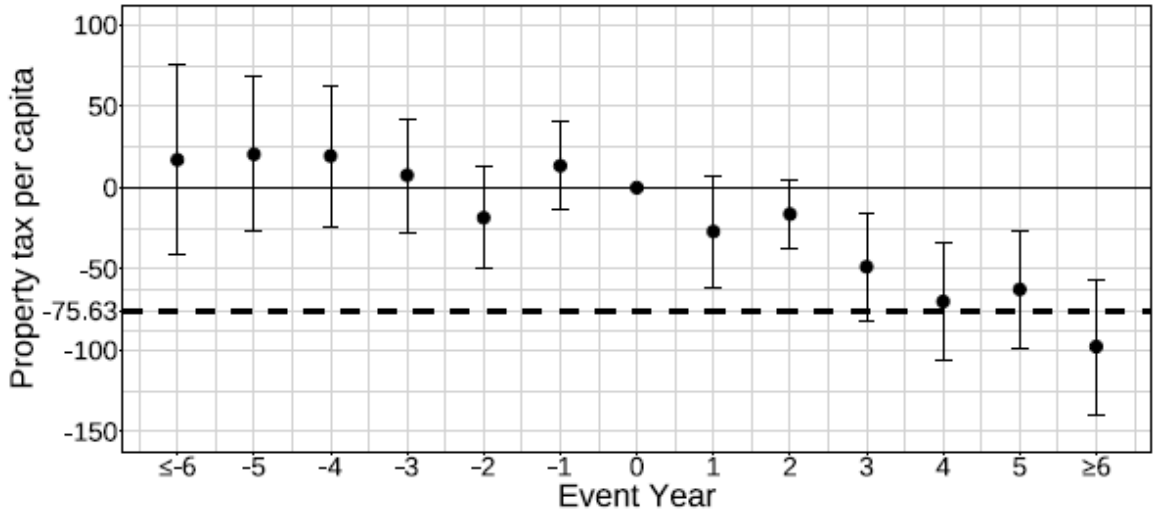
The impact of bat loss on tax revenue

We estimate WNS impact on tax revenues for two reasons. First, the hypothesized causal link between bat populations and bond spreads implies tax revenue effects. Second, the revenue gain from conservation investments is an incentive for even solely fiscal-health-focused counties to invest in conservation.

Property tax revenue per capita decreases by \$75.63 following WNS detection, a 16% decline from rural county average. When considering all local tax revenue, the decrease is \$149 per capita, or 14% of average local revenue per capita (see SI).



(a) Decrease in property tax per capita after WNS arrival in all counties, and splitting by whether the county has a high number of bats at risk, and by county-specific assessment frequency.



(b) Decrease in property tax per capita after WNS arrival in event-time.

Figure 4: Impact of WNS on property tax revenues in rural counties.

Panel (a) displays coefficient estimates and 95% confidence intervals from our main specification for tax revenue in all rural counties (Table SI-3, Panel (b), column 2) (first bar and dashed line), rural counties with high (second bar), and rural counties with low (second bar) numbers of bats at risk from WNS (Table SI-4, Panel (b), columns 1 and 2). The fourth and fifth bars present coefficients and confidence intervals for rural counties with high- and low- tax assessment frequency (Table SI-5, Panel (b), columns 1 and 2). Panel (b) of the figure shows property tax revenue impacts over event time. All results are in property tax per capita.

Heterogeneous impacts to property tax mirror impacts to bond spreads, with larger impacts in counties with above-median levels of WNS- susceptible bat species and counties that reassess agricultural land values more frequently (Figure 4 Panel a). In the SI, we present robustness tests

using alternative samples, different revenue measurements, and agricultural land assessment data, all of which consistently support these findings.

Impacts to government revenues become significant 3 years after WNS arrival (Figure 4, Panel b). Falls in agricultural profitability may lag the first detection of WNS, particularly because the agricultural land assessments depend on backward-looking agricultural outcomes. While revenues drop three years after WNS detection, forward-looking bond markets incorporate the increased risk into bond yields immediately (Figure 3, Panel b).

Discussion

We show that loss of a critical biodiversity component has measurable fiscal impacts for local governments. Such fiscal impacts can create investment opportunities in the municipal bond market. Our findings also provide new insights into the scale at which biodiversity and conservation investments influence the economy and fiscal risk and demonstrate that local governments and private investors can achieve positive returns from such investments.

Our numerical example illustrates an investment strategy that can generate positive returns from conservation actions. In the bat example, the strategy is qualitatively viable across our robustness checks (SI material), especially since there are likely counties with larger than average bond impacts and smaller than average treatment costs that could be targeted.

In practice, many challenges remain. For example, if municipal bond offerings are small relative to investment amounts needed to fund conservation, bond prices could respond to conservation focused buyers. Next, our strategy requires an efficient secondary bond market. In our example we assume an immediate impact on forward-looking bond prices based on announced conservation plans. This relies on the credibility of the conservation investor. When the conservation investor lacks credibility, results may need to materialize before bond prices change, leading to time lags that would affect the returns calculation. Moreover, if the market learns about the conservation plan before the conservation investor purchases the bonds, prices would be expected to adjust accordingly, reducing the expected returns of our proposed strategy. Higher bond prices also benefit all municipal bond investors, not just the entity funding the conservation actions, so this strategy does not eliminate the free-rider incentive.

Our proposed strategy involves a capital allocation tradeoff. We propose investing larger amounts in municipal bonds, while allocating smaller sums to conservation activities directly. In our example, we show that a $1+ million municipal bond investment yields a positive return of

$14,124 to fund conservation costs. This return enables conservation funding without requiring additional capital. However, this may mean that conservation investors are allocating fewer resources to current conservation actions, and greater allocations might be preferred in some contexts. The risk-reward tradeoff will depend on the expectations for conservation success and on how much the conservation investor is willing to forego returns in favor of conservation. The higher yields in the conservation strategy exist assuming the conservation strategy itself is risk free. To earn an additional $17,655[v] in the investment market, investors would typically have to make high-risk investments. An important question for investors is what is the failure probability of the conservation action?

We assume that bat population losses and restoration have symmetric impacts, though we cannot verify this assumption due to the absence of detailed panel data on bat populations. Future efforts to improve the measurement of species, biodiversity, and ecosystems could help verify this assumption and identify other contexts in which conservation investments can yield positive returns.

Despite these challenges, our analysis illustrates a pathway for private finance to play a role in biodiversity conservation and for biodiversity conservation to play an important role in finance. Actors in conservation finance often talk about "concessionary finance," which is finance at below market rates to support public goods. Perhaps what we are talking about here is "concessionary conservation" – the idea that conservation is a risk management strategy to boost risk-adjusted investment returns. Locally-dependent municipal finance and bonds provide opportunities to create a conservation finance strategy. While not a panacea, this approach represents a promising avenue for attracting private resources to biodiversity conservation efforts.

Materials and methods summary

We employ a staggered difference-in-difference analysis that regresses fiscal outcome variables on the emergence of WNS. Specifically, we compare county outcomes before and after WNS detection (treatment counties) against counties that have not yet detected the disease (control counties). See the SI for additional details of our analysis. Bond-specific data come from the Mergent Municipal database and Municipal Market Advisors. County-level government revenue and socio-demographic data come from The Government Finance Database (*39*). Both data span

2001-2022. To compare counties with different sizes, we normalize revenue by county population (e.g., *40*). We estimate equation (1):

$$y_{ct} = \beta_0 Post_{ct} + \beta_1 X_{ct} + \delta_t + \alpha_c + \varepsilon_{ct}. \quad (1)$$

where y_{ct} is the county outcome of interest (bond spread, property tax per capita) for county c in year t. $Post_{ct}$ is an indicator equal to 1 in all years after a county is treated by WNS. X_{ct} includes controls for quarterly precipitation and temperature because they could potentially correlate with WNS arrival in a county and affect government finances. δ_t and α_c are year and county fixed effects respectively. Standard errors are clustered at the county level. Interpreting β_0 as a causal effect of bat loss requires that counties would have followed a parallel trend in the absence of WNS. While this is not directly testable, we show that counties follow a parallel trend in fiscal outcomes prior to WNS treatment (see panel B of Figures 3 and 4). To ensure that spillovers from treated to non-treated counties do not affect our causal estimate, we exclude neighboring counties never impacted by WNS. Finally, $Post_{ct}$ must be quasi-random conditional on controls. The spread of WNS over space provides a natural experiment that generates this plausibly random variation in WNS treatment.

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Visualization: DTM, EPF, AN

Project administration: DTM, EPF, AN

Writing – original draft: DTM, EPF, AN

Writing – review & editing: DTM, EPF, AN

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Data and materials availability: All freely available data, code, and materials used in the analysis will be made available. All data in the analysis are publicly available, though some require licensing agreements. Clear instruction for accessing the data are provided in the SI.

Supplementary Materials

Materials and Methods

Supplementary Text

Figs. SI-1 to SI-2

Tables SI-1 to SI-14

References (*30*) (*41*) (*26*) (*39*) (*40*) (*17*) (*42-44*) (*44, 45*)

Supplemental Information for

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This PDF includes a presentation of
Materials and Methods
Supplementary Text
Figs SI-1 to SI-2
Tables SI-1 to SI-14
References

1. Materials and Methods

Our analyses require data on White Nose Syndrome (WNS), county bond spreads, and local taxes collected. Below, we describe the sources of these data.

1.1. Data on White-nose Syndrome

We obtain data on the location and timing of WNS detection from the White Nose Syndrome Response Team[1], a centralized repository of WNS-related information sourcing its data from state and federal authorities.

We categorize a county as rural if, as of 2003, the U.S. Department of Agriculture classified it as (1) a non-metro county completely rural or less than 2,500 urban population, both adjacent and not adjacent to a metro area, (2) a nonmetro county with urban population of 2,500-19,999, both adjacent and not adjacent to a metro area, or (3) a nonmetro county with urban population of 20,000 or more, both adjacent and not adjacent to a metro area. We choose the 2003 classification because it is closest to the beginning of our sample.

We define treatment as counties with bats that become WNS Positive or WNS Suspect.[2]

[1] whitenosesyndrome.org

[2] White Nose Syndrome Response team defines *WNS Positive* when characteristic histologic lesions of WNS1 are present on an individual bat and the bat is positive for *Pseudogymnoascus destructans* (Pd) either by qPCR2 or by fungal culture. *WNS Suspect* is defined when one of the following criteria are met (a) Characteristic histologic lesions of WNS1 are present on an individual bat but Pd is not detected, the test result for Pd is inconclusive (either by qPCR2 or by fungal culture), or testing for Pd is not performed; (b) One or more field signs are observed in a bat colony and Pd is detected (either by qPCR2, fungal culture, or a tapelift performed directly on visible fungal growth on bat skin) on at least one individual of the same species and histopathology is negative or is not performed; (c) Multiple field signs are observed among species known to be susceptible to WNS and are within the currently recognized range of WNS but no samples are collected for diagnostic evaluation; or (d) Individual bats that are part of a confirmed WNS morbidity/mortality event are submitted to, but not tested by, a diagnostician. This criterion is for instances in which multiple samples from the same site are submitted, but only a subset of those samples is tested. The untested samples may be classified as suspect for WNS if the subset of tested samples is positive for WNS and consists of the same species as the untested samples. Representatives of all species involved in the disease event should be tested.

Prior research documented a two-year lag between when WNS first appears in a county and when it is officially detected. Following Frank (2024), our main specifications classify counties as WNS-affected two years before their formal designation. We define treated counties as those that whitenosesyndrome.org has classified as either WNS "Positive" or WNS "Suspect." Counties where only the underlying fungus *Pseudogymnoascus destructans* has been detected, together with unaffected counties serve as control groups in our analysis. Also following Frank (2024), we exclude counties that neighbor WNS-positive counties, but never experience WNS. This mitigates concerns related to spillover effects.

1.2. County bond and revenue data

Data on municipal bond primary offerings come from the Mergent Municipal database (Mergent).[3] This database contains bond characteristics, including bond yields at the time of offering, bond size, time to maturity, credit rating, bond type (e.g., general obligation or revenue bond), and information about whether the bond is callable, insured, and bank qualified (see below for definitions). We subset these data into county-issued bonds by manually identifying the issuer-specific identifiers (six-digit CUSIPs) that belong to county issuers.[4] We exclude variable-rate and taxable bonds to ensure consistent comparison across our sample (Green, Li, and Schürhoff, 2010).

We define municipal bond spread as the difference between the offering yield and the maturity-matched AAA-rated Municipal Market Advisors rate (MMA, downloaded

[3]For a description of these data, see `https://bv.mergent.com/view/scripts/common/index.php`.

[4]CUSIP (Committee on Uniform Security Identification Procedures) is an alpha-numeric code system that is used to uniquely identify financial securities. Nine-digit CUSIPs identify securities, while the first six digits of CUSIPs identify issuers.

from Bloomberg). For example, we match a 10-year maturity bond with the 10-year rate provided by MMA. For maturities where the MMA data are unavailable, we perform a linear interpolation. To account for different state-level tax regimes, spreads are tax-adjusted following Schwert (2017). The resulting offering yield spreads can be interpreted as interest rates on municipal debt that account for the risk-free rate and state-specific capital tax differences, making them comparable across different times and states. Because the MMA curve starts in 2001, and our Mergent data end in 2022, our final bond sample spans 2001-2022.

Table SI-1 reports summary statistics, showing that the average spread for rural counties issuing bonds is 42.03 basis points.[5] This means, for example, that a rural county paying the average spread would have a yield of 2.92% when the corresponding AAA MMA yield is 2.50%. 74% of our sample bonds are bank qualified, 73% are general obligation, 46% are callable, and 36% are insured. The average time to maturity is 8.85 years, and ranges from 2 to 17 years for the 10th and 90th percentiles, respectively. For a single bond, the average value is $550,000.

County-level government revenue and socio-demographic data come from The Government Finance Database, United States, 2001-2022. We consider this time period to maintain consistency with our bond offering data (as described above).[6] Figure SI-1 illustrates counties in our county revenue data sample that experienced WNS between 2006 and 2022. To connect the change in the ecological system (bats) to agricultural land markets, we focus on property taxes and revenues raised from local sources, excluding state and

[5]A basis point is one hundredth of a percentage point.
[6]Pierson, Hand, and Thompson (2015) describe the construction of this dataset from the US Census.

federal transfers, commonly referred to as own revenue. To compare across counties with different sizes, we normalize revenue variables by county population and focus on per capita impacts (e.g., Dagostino and Nakhmurina (2023)).

1.3. Bond model controls definitions

In this section, we define the variables used in models describing bond spreads. These variables are used as statistical controls to remove potentially confounding factors and identify the marginal effects of interest. Our bond-specific controls include the natural logarithm of bond size, the natural logarithm of maturity time, and indicators for bank qualification, general obligation status, an indicator of the callability status, and indicator of insurance status—all standard controls in municipal bond literature(e.g., Schwert (2017), Painter (2020)).

Bond size is the principal amount borrowed. Time to maturity is the time after which the bond repays the principal. General obligation bonds are backed by the full taxing power of the county, while revenue bonds are backed by a pre-specified revenue stream. Callable bonds are bonds that can be paid off or redeemed by the issuer (i.e., county) prior to the bonds' maturity date. Insured bonds are backed by an insurance company that guarantees all scheduled interest and principal payments will be made to bondholders, even if the original issuer defaults. Bank-qualified municipal bonds receive preferential tax treatment when commercial banks purchase them.

A credit rating is the underlying rating assigned by one of the credit rating agencies (Moody's, S&P, or Fitch) at the time of issuance. To ensure comparability across agencies,

we harmonize their letter ratings into 22 categories. For bonds rated by multiple agencies, we calculate the rounded average of these numeric ratings to measure the underlying credit quality. We include fixed effects of these aggregate credit rating measures in our regressions.

1.4. Weather and sociodemographic controls

To limit the influence of potential confounders, we control for the natural logarithm of the human population, as humans can inadvertently transmit WNS between bat populations through contaminated boots and equipment.

We also control for minimum quarterly precipitation levels and temperatures. Temperature and precipitation impact agricultural output, while cold temperatures, particularly in winter, can affect WNS transmission. Minimum quarterly precipitation levels and temperatures come from the Parameter-elevation Regressions on Independent Slopes Model (PRISM) data.[7]

In some specifications, we also control for the number of neighboring counties with WNS in any year. This controls for any spillover effect that changes outcomes in neighboring counties at the same time that treatment occurs.

1.5. Summary statistics for rural and urban counties

Bond spreads and tax revenues differ systematically between rural and urban counties (see Tables SI-1, SI-2, and SI-3). On average, property taxes represent approximately 42% of rural county revenue from local sources, compared to 39% in non-rural counties. Similarly,

[7]These data can be accessed at `http://www.prism.oregonstate.edu/`.

property taxes account for nearly 81% of rural county tax revenue compared to 70% in non-rural counties.

Given rural counties' disproportionate reliance on property taxes and agriculture's larger role in rural economies, our main analysis focuses on rural counties. As shown in Table SI-1, 11% of the rural county-year observations in our analysis have documented WNS presence.

1.6. Empirical approach

Our linear regression model estimates the impact of WNS by comparing county fiscal outcomes before and after WNS detection (treatment counties) relative to counties that have not yet detected the disease (control counties). This staggered difference-in-differences approach allows us to isolate the effect of WNS by tracking how county finances change when the disease arrives. Our primary specification is a two-way fixed effect model, where we control for time-invariant characteristics of counties and common shocks that vary over time. We estimate equation SI-1:

$$y_{ct} = \beta_0 Post_{ct} + \beta_1 X_{ct} + \delta_t + \alpha_c + \varepsilon_{ct}, \quad \text{(SI-1)}$$

where y_{ct} is the county outcome of interest (bond spread, property tax per capita, or own revenue per capita) for county c in year t. $Post_{ct}$ is an indicator equal to 1 if a county has WNS in or before year t. X_{ct} includes controls for factors that could potentially correlate with WNS arrival in a county and affect government finances. δ_t and α_c are year and county fixed effects respectively. To limit the influence of outliers, we winsorize all continuous

variables at the 1% level. Standard errors are clustered at the county level for bond and revenue analyses.

We begin by estimating the average impact of WNS on government financial outcomes. We test the robustness of our coefficient estimates to alternative datasets and model specifi- cations (details below).

We then examine variation in treatment effects based on two county characteristics: (1) whether a county has an above-median number of bat species susceptible to WNS as defined in Frank (2024), and (2) whether a county performs frequent updates of assessed property values.

We expect stronger impacts in counties with a greater stock of natural assets at risk, which we measure as an indicator of having an above-median number of WNS-susceptible bat species. Counties with more vulnerable species likely experience more severe damage to their overall bat populations. Such counties may experience greater reductions to farm profitability, subsequently leading to more pronounced declines in property tax revenue and larger bond spread reactions.

We also expect stronger impacts in counties that update their land assessments more frequently because these counties incorporate changes in agricultural property values into their tax base quicker. When bat populations decline, the resulting reduction in ecosystem services quickly translates to lower property tax revenues in counties with frequent reassessments, while counties with infrequent cycles may experience larger delays.

While we cannot directly test the identifying assumption that counterfactual outcomes would have followed parallel trends in the absence of WNS, we can examine whether treatment and control counties exhibited similar trends before WNS arrival. To do this, we

modify equation SI-1 to include both leads and lags of WNS exposure:

$$y_{ct} = \sum_{k} \gamma_k \mu_{ct} + \beta_1 X_{ct} + \delta_t + \alpha_c + \varepsilon_{ct}, \quad \text{(SI-2)}$$

where μ_{ct} are binary indicators equal to one when the time since initial WNS detection equals k and zero otherwise. Here, we consider $k = [-6, 6]$. We omit the indicator for the first year with WNS. We also present alternative estimates of treatment effects for the treated subpopulation to address econometric challenges in the presence of staggered treatment effects (Cunninham, 2021).

2. Supplementary Text

2.1. Bond Pricing

Here we describe the standard bond pricing procedure. A price of a bond is the expected present value of interest payments made to the bondholder over the life of the bond plus the expected present value of the principal, or maturity, amount paid when the bond matures. To fix ideas, let the time to maturity be T periods and the maturity amount be M. The bond also has a coupon rate, equal to c, that determines the coupon amount paid every time period, equal to $C = c \times M$. Bonds typically pay semi-annually meaning that T equals twice the number of years until maturity.

The bond price, P, depends on the bond-specific interest rate, r, which reflects bond-specific default risk and is used as a discounting factor in present value calculations. Since coupons are paid semi-annually, r is half the annual interest rate. The value r is

conventionally referred to as "yield." The price of a bond is:

$$P = C \times \frac{1 - (1 + r)^{-T}}{r} + \frac{M}{(1 + r)^{T}}. \quad \text{(SI-3)}$$

The first term in equation SI-3 describes the present value of all coupon payments ($C \times \sum_{t=1}^{T} \frac{1}{(1+r)^t}$) and the second term is the present value of receiving the principal at maturity, M, after T periods. The price, P is decreasing in yield, r. We use our bond data and estimated impacts to parameterize this bond pricing formula to compare bond valuations for average rural counties with and without WNS.

2.2. Main results

Our main results for the bond and revenue analyses are presented in Figures 3 and 4 of the manuscript, respectively. We tabulate the underlying regressions in Tables SI-4, SI-5, and SI-6.

In Table SI-4 Panel A, we present the average effect of WNS on municipal bond spreads. Column 1 reports the results of our simplest specification, including only county and year-fixed effects. County fixed effects isolate the impact of WNS on bond spreads after substracting any time-invariant county characteristic that may affect its borrowing costs. Year fixed effects remove any time-specific factors that could have influenced bond spreads in a given year. Using this specification, we find that WNS-affected counties face 10.32 basis points higher primary offering spreads than counties without WNS.

As we move from Column 1 to Column 6, we introduce additional control variables that account for bond characteristics, including the number of neighboring counties affected

by WNS, the natural logarithm of bond size, the natural logarithm of time to maturity, as well as indicators for whether the bond is bank-qualified, general obligation, callable, and insured. We also include weather controls (quartiles of minimum temperature and precipitation, not tabulated to keep the tables concise), bond rating fixed effects, and the natural logarithm of human population. The gap in offering spreads between WNS-affected and unaffected counties persists after introducing this detailed set of controls. Column 6 reports an estimated impact of WNS of 11.47 basis points and is used to create Figure 3 in the main text.

In Table SI-4 Panel B we tabulate the effect of WNS on property tax revenue per capita (columns 1 and 2) and total revenue from own sources per capita (columns 3 and 4). In these regressions, columns 1 and 3 only include the weather controls, while columns 2 and 4 also account for the number of neighboring counties with WNS and the natural logarithm of population. The estimate in column 2 is used to create Figure 4 in the main text.

2.3. Measuring species richness

In Table SI-5, we present our results separately for counties with a high number of bat species at risk of being infected by WNS and those with a low number of bat species at risk. We expect counties that are habitats for a greater number of susceptible bat species to experience larger impacts when WNS arrives. To identify counties with a high number of species at risk, we rely on bat species richness data provided by Frank (2024) to create an indicator variable that equals one if a county has an above-median number of bat species susceptible to WNS.[8] The estimates from Table SI-5 indicate that WNS impacts in counties

[8]We thank Eyal Frank for sharing these data, calculated from the USGS Gap Analysis Project.

with more species at risk are larger and more precise. The estimates presented in Table SI-5 Panel A and Table SI-5 Panel B are used to make Figures 3 and 4 in the main text, respectively.

2.3.1. Measuring assessment frequency

In Table SI-6, we explore whether the impact of WNS varies depending on the frequency of agricultural land value tax assessments updates. Since agricultural land is usually taxed at its agricultural use value (farm revenues minus farm costs), we expect that counties that update their assessments more frequently experience greater revenue changes with the loss of bats to WNS. While we do not observe counties' statutory assessment schedules directly, we infer county-level assessment frequency using CoreLogic *Tax* data. First, for each county-year, we calculate the proportion of parcels that show changes in their tax payments compared to the previous year. When this proportion exceeds 50%, we designate that year as a likely assessment year for the county. Second, we calculate the ratio of assessment years to total observed years for each county. Counties with above-average ratios are classified as *High-frequency Assessment*. Results from Table SI-6 are used to create Figures 3 and 4 in the main text. The estimates from Table SI-6 indicate that counties with more frequent assessments experience larger WNS impacts. The estimates presented in Table SI-6 Panel A and Table SI-6 Panel B are used to make Figures 3 and 4 in the main text, respectively.

2.3.2. Bats, local government revenue, and borrowing costs

Results also suggest that local governments have strong fiscal incentives to invest in biodiversity conservation. Through bat conservation, local governments can increase their property tax revenue by nearly $2.7 million per year on average before considering savings on interest to bondholders.[9] Making conservation investments that maintain higher revenues while lowering borrowing costs means that county governments can continue to provide services, keep taxes low, or both. Conversely, failing to address biodiversity losses will force governments to do some combination of cutting services, raising taxes, or increasing public sector borrowing.

Finally, a municipality may also be concerned with its borrowing costs. Higher bond spreads mean that the cost of borrowing money is greater. Higher borrowing costs ultimately need to be covered by increased tax revenue or cuts in public services. In our data, rural counties issue bonds worth an average of $8.34 million (see offering size in Table SI-1 Panel C). If the coupon rate in our example increases proportionately to the rate of increase in bond yield, resulting in a higher coupon payment, a county that issues the average bond amount and has experienced bat losses can expect to pay $280,474 more on those bonds over 15 years.

2.4. Additional evidence of impacts to county revenue

The proposed mechanism behind our main results is that municipal bond investors recognize the financial strain imposed on county finances by the arrival of WNS by demanding

[9]To arrive at $2.7 million, we multiply our estimate of WNS impact on property tax revenue per capita, 149.074 (Table SI-4, Panel B, column 4), by average rural county population 18,013.22 (Table SI-1, Panel A.)

higher yield spreads. Because the Current Agricultural Use Value Assessment (CAUVA) system directly reflects changes in farm profitability, we expect these financial impacts to emerge soon after WNS arrival. Table SI-4, panel B establishes a general connection between WNS and property tax collections using Census data. Here, we provide additional evidence supporting this mechanism, we analyze land assessment data from CoreLogic *Tax* to measure impacts to agricultural taxes payments.

CoreLogic is a database that tracks property tax assessments throughout the US by compiling county records. This dataset is a property-level panel that contains a unified parcel identifier, land use code, assessment date, assessment amount, and the amount of taxes paid in each tax year. We restrict our data to the land use codes ranging between 400 and 600. These are the codes that are associated with agricultural activity.

In Table SI-7, we show that agricultural property taxes paid systematically decrease following WNS arrival in a county. We aggregate observations at the county-year-land use level, and estimate our main regression specification using assessed taxes per capita as our main dependent variable. In column 1 of Table SI-7, Panel A, we show that assessed agricultural property taxes per capita go down by 15.3 dollars, a 25% decrease compared to the sample mean. In column 2, we then include our usual controls of the natural logarithm of population and the number of neighboring counties that have WNS. The results are qualitatively unchanged.

While CoreLogic data begin in 2001, the data are filled more consistently starting in 2016. To assess whether this impacts our results, in column 3 of Table SI-7 Panel A, we repeat our main analyses after limiting the data to begin in 2016. In column 4 of Table SI-7 Panel A, we re-estimate our main specification on the subsample of land uses that is

more likely to engage in commercial agriculture (landuse codes above 500). As reported in columns 3 and 4, the results remain similar, but larger in magnitude. This suggests that changes in taxes from commercial agricultural land are a driver of our results.

In Panel B of Table SI-7, we perform robustness analyses of the results documented in Panel A using alternative dependent variables. In column 1, our dependent variable is the natural logarithm of the absolute assessed taxes on agricultural land in a county. In column 2, our dependent variable is the natural logarithm of the assessed agricultural taxes per acre. In column 3, our dependent variable is the natural logarithm of the number of assessed agricultural acres. Supporting the inferences shown in Panel A of Table SI-7, we observe consistent negative effects of WNS on each of these three dependent variables. The negative effect on the number of assessed agricultural acres (column 3) is in line with the findings by Manning and Ando (2022), who also found that producers decrease the number of agricultural acres in response to the loss of bats to WNS.

2.5. Robustness

2.5.1. Robustness of the main result

In Figure SI-2, we examine the robustness of our findings to treatment heterogeneity across cohorts, a concern emphasized in recent econometric studies (e.g., see Cunninham (2021) and Roth, Sant'Anna, Bilinski, and Poe (2023) for overviews). We plot the regression coefficients from four different regressions of our main dependent variables on year dummies relative to WNS arrival. The figure presents regression results from the two-way fixed effects (TWFE) model with and without a comprehensive set of controls, as well as from

two bias-correcting models that account for treatment heterogeneity (Borusyak, Jaravel, and Spiess (2024) and Cengiz, Dube, Lindner, and Zipperer (2019)). The findings are consistent across all four models, showing a pronounced, discontinuous increase in bond spreads (Panel A) that aligns with the arrival of WNS in a county. Panels B and C provide robustness graphs for property tax per capita and in own revenues per capita, respectively.

We conduct additional robustness and sensitivity tests of our main results. In Table SI-8, we address the concern that differential trends in the control group might be driving our inferences and re-estimate our main results on a sample that excludes states that never experienced WNS. Our results remain qualitatively unchanged.

Next, in Table SI-9, we present our main analyses using a more stringent definition of WNS arrival. In this analysis, we focus specifically on counties that have been classified as *WNS Positive* by the White Nose Syndrome Response Team. *WNS Positive* indicates that state, federal, or other wildlife management agencies have confirmed the presence of the disease. The results are similar to our main results.

Table SI-10 presents our analysis using a more stringent definition of a rural county. Specifically, we restrict our sample to those counties that have been classified by the USDA as (1) Nonmetro county completely rural or less than 2,500 urban population, not adj. to metro area, (2) Nonmetro county with urban population of 2,500-19,999, not adjacent to a metro area, or (3) Nonmetro county with urban population of 20,000 or more, not adjacent to a metro area. Although using this stricter definition significantly reduces our sample size, it yields results that confirm our main findings and show even larger effects. This stronger impact is consistent with our expectations, as smaller, more rural counties likely depend more heavily on agriculture.

We note that the Census population and financial data are fully complete only during mandatory Census years. In other years, some local governments opt not to complete the underlying survey. This means that our model with all statistical controls (column 6 of Table SI-4) is estimated on a limited sample. To better examine the role of controls on the magnitude of our estimate, Table SI-11 reports estimates using a sample that is restricted to non-missing population values. These regressions show that our results are not sensitive to the missing data.[10]

In Table SI-12, we present results using spreads calculated over Treasury yields rather than the Municipal Market Advisors (MMA) curve. While the MMA curve is typically preferred as a benchmark because it accounts for the institutional specificities of municipal bonds (Schwert, 2017), our findings remain robust when using Treasury yields as the risk-free rate benchmark. This consistency demonstrates that our main results are not sensitive to the choice of benchmark curve.

2.5.2. Urban counties

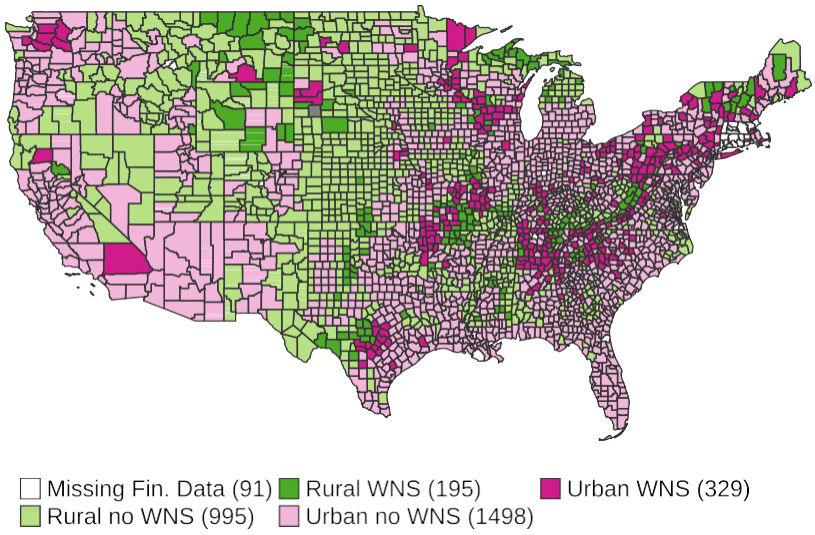
Another concern is that our results are spurious or driven by unobserved economic trends. To address this concern, we repeat our main analyses on a sample of urban counties (defined as non-rural counties). In Table SI-13, we find that the effect of WNS on urban counties' yield spreads, property taxes per capita, and total revenue per capita is substantially attenuated towards zero and, for bond yield spreads, is statistically indistinguishable from zero. These null results in urban areas, where the tax base is more diversified and less dependent on agriculture, help validate our main findings.

[10]The sample size and the estimates in Panel B of Table SI-11 are unchanged, because both financial and population variables come from the Census data. We report them for completeness.

2.5.3. Robustness for the financial results

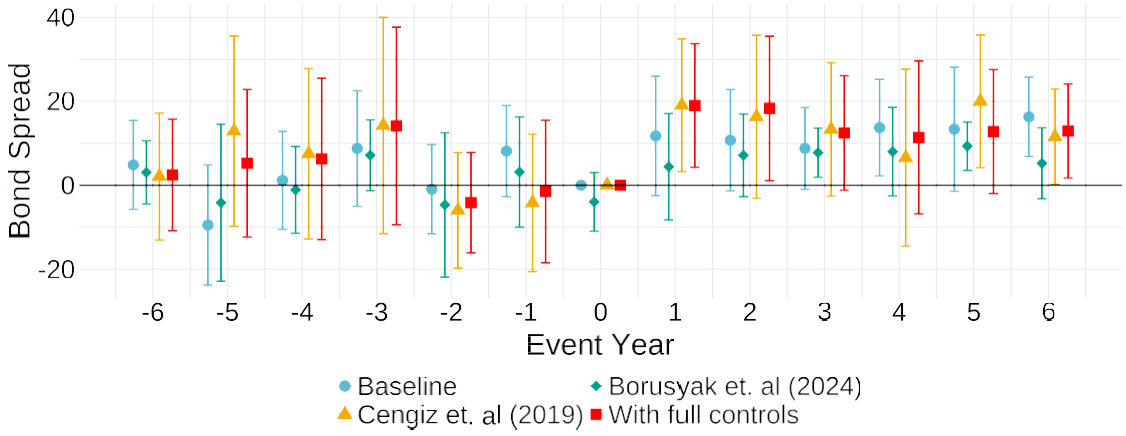
While reporting financial metrics on per capita items is a standard practice, we verify that our results are robust to alternative scaling methods. In Table SI-14, we scale property taxes and own revenues by the number of cropland acres, using USDA measurements from 1997 (closest measurement date before the beginning of our sample period). Due to the left-skewed distribution of these ratios, we apply a natural logarithm transformation before conducting our regression analyses. The results remain qualitatively consistent with our main findings, demonstrating that our conclusions are not sensitive to the choice of scaling variable.

Finally, Table SI-15 Panel A explores the impact of WNS on other county revenue measures, including total tax and total revenue. Both of these variables show a decrease after the arrival of WNS. Panel B presents our main revenue results but limits the sample of counties to those that issued bonds over the time-frame of our analysis. Again, our results remain similar, though slightly larger than our main results.

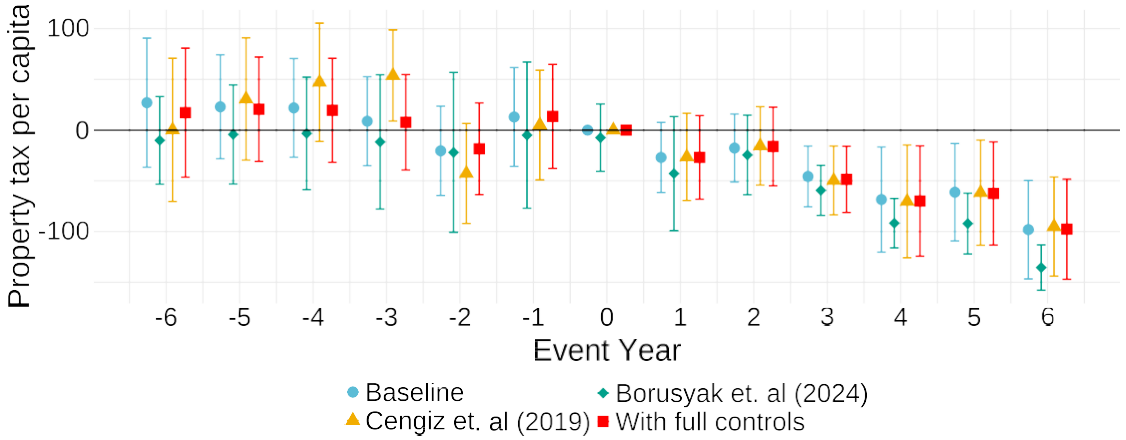


(a) Revenue Data Sample

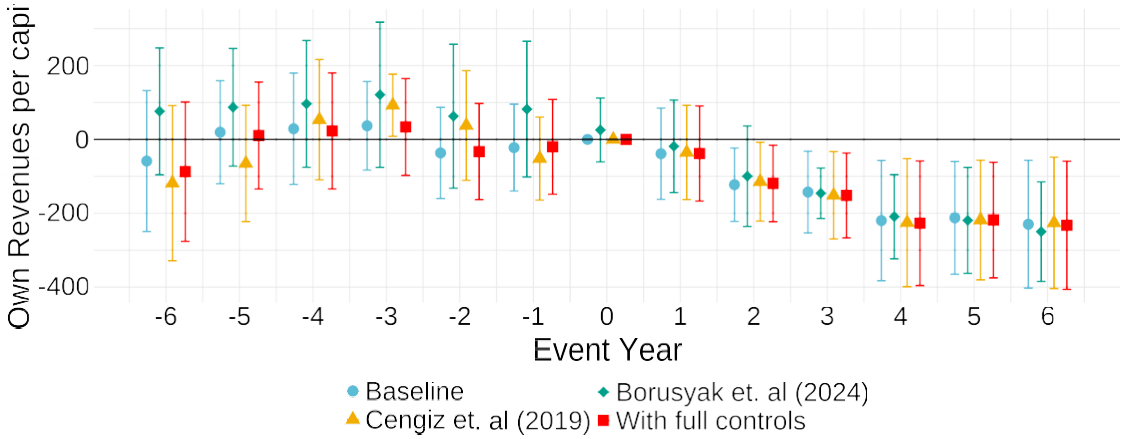
Fig. SI-1 Maps. This figure displays the map of rural and urban US counties and their respective WNS status. Rural counties are in shades of green, and urban counties are in shades of pink. Darker shades indicate the presence of WNS in a county as of 2022. Counties with missing data in our revenue analyses are shown in black (white) if they were (were not) affected by WNS. *Data Sources: whitenosesyndrome.org; USDA; Government Finance Database.*



(a) Bond Spreads



(b) Property Taxes per capita



(c) Own Revenues per capita

Fig. SI-2 Sensitivity to heterogeneity across cohorts. Panel (a) of this figure shows bond spreads (in basis points) in event time, Panel (b) displays property tax per capita in event time, and Panel (c) shows own revenues per capita in event time. The baseline two-way fixed effect model without any controls is reported in blue, the model that includes full controls is reported in red, and the two models allowing for treatment heterogeneity across cohorts (Borusyak et al. (2024) and Cengiz et al. (2019)), are reported in green and yellow, respectively.

Table SI-1

Summary statistics for main sample bond characteristics

Panel A: Descriptive Statistics

	Mean	StDev	$p^{10\%}$	$p^{25\%}$	$p^{50\%}$	$p^{75\%}$	$p^{90\%}$	Obs.
Post	0.11	0.31	0.00	0.00	0.00	0.00	1.00	41,268
Spread, bps	42.03	38.89	1.77	17.13	35.36	59.44	88.43	41,268
Bond Size, USD mln	0.55	0.70	0.09	0.17	0.33	0.61	1.23	41,172
Log(Bond Size)	12.69	1.04	11.41	12.04	12.69	13.32	14.03	41,172
Time to Maturity, years	8.85	5.53	2.00	4.00	8.00	12.00	17.00	41,268
Log(Maturity)	1.95	0.74	0.85	1.47	2.07	2.52	2.83	41,268
BQ	0.74	0.44	0.00	0.00	1.00	1.00	1.00	41,268
GO	0.73	0.44	0.00	0.00	1.00	1.00	1.00	41,268
Callable	0.46	0.50	0.00	0.00	0.00	1.00	1.00	41,268
Insured	0.36	0.48	0.00	0.00	0.00	1.00	1.00	41,268
Rating	9.50	8.30	3.00	3.00	5.00	22.00	22.00	41,268

Panel B: Correlations

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
[1] Post									
[2] Spread, bps	0.050								
[3] Log(Bond Size)	0.130	-0.010							
[4] Log(Maturity)	0.000	0.110	0.220						
[5] BQ	-0.100	-0.040	-0.440	-0.080					
[6] GO	0.090	-0.250	0.000	-0.020	0.020				
[7] Callable	0.010	0.130	0.140	0.720	0.010	-0.050			
[8] Insured	-0.010	-0.160	0.090	0.090	-0.130	0.080	0.010		
[9] Rating	-0.210	0.150	-0.340	-0.230	0.210	-0.060	-0.070	-0.140	

Panel C: Descriptive Statistics for Hypothetical Investment Example

	Mean	StDev	$p^{10\%}$	$p^{25\%}$	$p^{50\%}$	$p^{75\%}$	$p^{90\%}$	Obs.
Post	0.11	0.31	0.00	0.00	0.00	0.00	1.00	41,268
Spread, bps	42.03	38.89	1.77	17.13	35.36	59.44	88.43	41,268
Offering Yield, percent	2.75	1.26	1.05	1.70	2.77	3.80	4.35	41,268
MMA Yield, percent	2.50	1.29	0.79	1.42	2.45	3.64	4.21	41,268
Coupon Rate, percent	3.31	1.12	2.00	2.50	3.38	4.00	4.75	41,268
Bond Size, USD mln	0.55	0.70	0.09	0.17	0.33	0.61	1.23	41,172
Time to Maturity, years	8.85	5.53	2.00	4.00	8.00	12.00	17.00	41,268
Offering Size, USD mln	8.34	11.88	1.39	2.60	5.09	9.48	17.98	41,268

Panel A reports summary statistics for the rural county-issued bonds used in the paper. Panel B provides the pairwise Pearson correlations among our bond characteristics of interest in the lower triangular region. Panel C provides summary statistics for the hypothetical example. *Spread, bps* is the offering yield spread over the MMA AAA curve in basis points. *Bond Size, USD mln* is the bond size (measured in USD million), and *Log(Bond Size)* is its natural logarithm. *Time to Maturity, years* is the bond's time to maturity (measured in years), and *Log(Maturity)* is its natural logarithm. *BQ* is an indicator equal to one if the bond is bank-qualified, which means it has tax-advantaged status when purchased by commercial banks. *GO* is an indicator that equals one for the general obligation bonds backed by the issuer's full taxing authority rather than tied to a specific revenue stream (e.g., from utilities). *Insured* is an indicator variable equal to one for insured bonds, where the issuer has purchased a policy, meaning that bondholders will receive repayment of the principal and all interest payments from the insurer if the issuer defaults. *Callable* is an indicator variable equal to one for bonds with a call option, allowing the issuer to redeem the bond before its maturity date but only after a pre-set call date. *Rating* is the bond's underlying rating across Moody's, S&P, and Fitch (where available), increasing in value from 1 to 22. *Offering Yield, percent* is the bond's yield, in percent. *MMA Yield, percent* is the yield on MMA AAA curve, in percent. *Coupon Rate, percent* is the coupon rate, reported in percent. *Offering Size, USD mln* is the total amount borrowed in a single issue (an issue often offers multiple bonds).

Table SI-2

Summary statistics for main sample county revenue variables

Panel A: Descriptive Statistics

	Mean	StDev	$p^{10\%}$	$p^{25\%}$	$p^{50\%}$	$p^{75\%}$	$p^{90\%}$	Obs.
Post	0.05	0.22	0.00	0.00	0.00	0.00	0.00	12,181
Property tax p.c.	458.80	414.71	86.10	200.07	344.70	566.82	933.58	12,181
Total revenue own p.c.	1,088.89	1,109.84	253.83	400.95	684.73	1,304.93	2,521.69	12,181
Total tax p.c.	568.00	502.28	157.93	262.54	425.05	679.75	1,109.92	12,181
Revenue p.c.	1,602.47	1,475.91	400.50	606.40	1,082.33	2,075.07	3,520.35	12,181
Population	18,013.22	19,219.60	2,529.00	5,289.00	11,253.00	23,206.00	40,828.00	12,181
Log(Population)	9.29	1.06	7.84	8.57	9.33	10.05	10.62	12,181
Neighbors with WNS	0.14	0.43	0.00	0.00	0.00	0.00	1.00	12,181
Q1 avg. min. temp.	-5.20	6.08	-13.01	-9.65	-5.96	-0.44	3.44	12,181
Q2 avg. min. temp.	8.97	4.61	3.09	5.20	8.46	12.84	15.63	12,181
Q3 avg. min. temp.	14.67	4.18	9.00	11.50	14.49	18.26	20.45	12,181
Q4 avg. min. temp.	-0.80	4.97	-6.75	-4.87	-1.88	3.32	6.55	12,181
Q1 avg. precip.	51.82	46.49	9.18	16.12	33.17	78.93	123.44	12,181
Q2 avg. precip.	84.68	45.68	26.64	50.18	80.83	113.63	147.87	12,181
Q3 avg. precip.	75.39	43.80	20.29	42.86	70.66	102.46	135.19	12,181
Q4 avg. precip.	56.78	45.33	12.10	21.19	42.37	82.31	122.25	12,181

Panel B: Correlations

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]
[1] Post																
[2] Property tax p.c.	-0.08															
[3] Total revenue own p.c.	-0.05	0.67														
[4] Total tax p.c.	-0.06	0.95	0.71													
[5] Revenue p.c.	-0.04	0.67	0.90	0.70												
[6] Population	0.13	-0.29	-0.18	-0.24	-0.19											
[7] Log(Population)	0.15	-0.45	-0.26	-0.39	-0.30	0.83										
[8] Neighbors with WNS	0.42	-0.12	-0.08	-0.11	-0.05	0.13	0.12									
[9] Q1 avg. min. temp.	0.02	-0.17	-0.08	-0.11	-0.11	0.21	0.27	-0.02								
[10] Q2 avg. min. temp.	0.02	-0.23	-0.15	-0.20	-0.21	0.17	0.25	-0.00	0.82							
[11] Q3 avg. min. temp.	0.02	-0.22	-0.14	-0.19	-0.21	0.13	0.22	0.01	0.75	0.96						
[12] Q4 avg. min. temp.	0.06	-0.24	-0.13	-0.18	-0.17	0.26	0.33	0.03	0.91	0.90	0.86					
[13] Q1 avg. precip.	0.17	-0.28	-0.18	-0.23	-0.18	0.26	0.36	0.10	0.67	0.61	0.56	0.72				
[14] Q2 avg. precip.	0.18	-0.24	-0.19	-0.24	-0.24	0.14	0.24	0.14	0.31	0.54	0.54	0.46	0.52			
[15] Q3 avg. precip.	0.17	-0.20	-0.15	-0.19	-0.18	0.14	0.23	0.12	0.38	0.59	0.62	0.53	0.51	0.57		
[16] Q4 avg. precip.	0.17	-0.30	-0.19	-0.25	-0.18	0.28	0.38	0.14	0.51	0.53	0.47	0.64	0.77	0.52	0.48	

Panel A reports summary statistics for the revenue, socio-demographic, and weather characteristics of rural counties. Panel B provides the pairwise Pearson correlations among our revenue variables in the lower triangular region. *Property tax p.c.* is property taxes per capita. *Total revenue own p.c.* is the total revenue from own sources (i.e., excluding transfers from state and federal government), per capita. *Total tax p.c.* is total taxes per capita. *Revenue p.c.* is total revenue (from own sources and from intergovernmental transfers) per capita. *Population* is the population of the county. *Log(Population)* is the natural logarithm of the population of the county. *Neighbors with WNS* is the count of contiguous neighbor counties with WNS. *Q1, Q2, Q3, and Q4 avg. min. temp.* is the corresponding quartiles of the average minimum temperatures measured in Celcius. *Q1, Q2, Q3, and Q4 avg. precip.* is the corresponding quartiles of the average precipitation levels in mm.

Table SI-3

Summary statistics for the sample of urban counties and all counties

Panel A: Descriptive Statistics For Bond Variables

	Urban Counties				All Counties			
	Mean	StDev	Median	Obs.	Mean	StDev	Median	Obs.
Post	0.09	0.29	0.00	100,027	0.10	0.30	0.00	141,295
Spread, bps	34.76	40.01	26.84	100,027	36.90	39.95	29.18	141,295
Bond Size, USD mln	2.36	3.65	1.02	99,664	1.85	3.32	0.68	140,836
Log(Bond Size)	13.82	1.37	13.84	99,664	13.49	1.38	13.43	140,836
Time to Maturity, years	9.69	5.82	9.00	100,027	9.44	5.75	9.00	141,295
Log(Maturity)	2.04	0.73	2.19	100,027	2.01	0.74	2.15	141,295
BQ	0.19	0.39	0.00	100,027	0.35	0.48	0.00	141,295
GO	0.71	0.45	1.00	100,027	0.72	0.45	1.00	141,295
Callable	0.44	0.50	0.00	100,027	0.45	0.50	0.00	141,295
Insured	0.27	0.44	0.00	100,027	0.29	0.45	0.00	141,295
Rating	5.27	6.84	3.00	100,027	6.50	7.55	3.00	141,295

Panel B: Descriptive Statistics For Financial Variables

	Urban Counties				All Counties			
	Mean	StDev	Median	Obs.	Mean	StDev	Median	Obs.
Post	0.08	0.28	0.00	22,891	0.06	0.24	0.00	41,658
Property tax p.c.	341.14	280.18	272.86	22,891	368.01	337.30	282.01	41,658
Total revenue own p.c.	865.21	777.90	609.12	22,891	926.83	922.72	617.85	41,658
Total tax p.c.	489.94	417.67	373.04	22,891	500.87	440.21	376.46	41,658
Revenue p.c.	1,303.64	1,129.45	900.94	22,891	1,374.97	1,244.82	936.67	41,658
Population	191,420.85	486,691.82	64,296.00	22,891	127,950.07	374,583.90	37,279.00	41,658
Log(Population)	11.20	1.26	11.07	22,891	10.59	1.47	10.53	41,658
Neighbors with WNS	0.21	0.59	0.00	22,891	0.29	0.65	0.00	41,658
Q1 avg. min. temp.	-1.01	5.87	-1.02	22,891	-2.79	6.10	-2.80	41,658
Q2 avg. min. temp.	11.88	4.19	11.95	22,891	10.75	4.35	10.78	41,658
Q3 avg. min. temp.	17.15	3.79	17.42	22,891	16.20	3.91	16.30	41,658
Q4 avg. min. temp.	3.29	4.70	3.12	22,891	1.73	4.92	1.79	41,658
Q1 avg. precip.	75.38	42.22	71.77	22,891	69.07	44.21	65.09	41,658
Q2 avg. precip.	99.27	48.30	99.50	22,891	96.91	46.70	96.30	41,658
Q3 avg. precip.	97.85	54.70	94.38	22,891	92.16	50.57	88.68	41,658
Q4 avg. precip.	80.79	45.39	76.24	22,891	75.20	45.87	71.36	41,658

This table presents summary statistics for urban counties, as well as for all (both rural and urban) counties. Panel A reports basic summary statistics for the bond variables, while Panel B reports summary statistics for the financial, socio-demographic, and weather variables used in the paper. Variables are defined in Tables SI-1 and SI-2.

Table SI-4

Main Results

Panel A: WNS and municipal bond spreads.

	Spread					
	(1)	(2)	(3)	(4)	(5)	(6)
Post	10.320***	9.821***	9.516***	9.631***	9.294***	11.473***
	(2.709)	(2.791)	(2.804)	(2.896)	(2.751)	(3.525)
Neighbors with WNS		-0.656	-0.852	-0.790	-0.547	0.914
		(1.704)	(1.674)	(1.759)	(1.778)	(2.355)
Log(Bond Size)			-1.027	-1.836**	-1.845***	-1.818**
			(0.793)	(0.749)	(0.696)	(0.821)
Log(Maturity)			7.274***	6.367***	8.503***	8.902***
			(0.529)	(0.583)	(0.789)	(1.024)
BQ				-15.550***	-14.891***	-17.034***
				(2.339)	(2.083)	(2.488)
GO				-14.035***	-12.006***	-12.783***
				(2.965)	(2.556)	(3.628)
Callable				1.787**	1.179	2.100**
				(0.736)	(0.739)	(0.924)
Insured				-10.286***	-6.686***	-8.157***
				(2.019)	(2.010)	(2.702)
Log Population						-29.800**
						(13.403)
Weather controls	No	Yes	Yes	Yes	Yes	Yes
Mean dependent variable	42.03	42.03	42.03	42.03	42.03	42.03
Number of counties	944	944	943	924	924	697
County fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Rating fixed effects					Yes	Yes
Adjusted R^2	0.477	0.480	0.497	0.523	0.545	0.551
Observations	41,268	41,268	41,172	41,153	41,152	25,855

Panel B: Revenue analyses

	Property tax p.c.		Total revenue own sources p.c.	
	(1)	(2)	(3)	(4)
Post	-78.130***	-75.633***	-154.019***	-149.074**
	(16.103)	(15.859)	(59.381)	(59.487)
Log Population		-227.900**		-577.071*
		(89.056)		(301.018)
Neighbors with WNS		-3.191		13.757
		(10.473)		(18.095)
Weather controls	Yes	Yes	Yes	Yes
Mean dependent variable	459.05	459.05	1,089.13	1,089.13
Number of counties	1,029	1,029	1,029	1,029
Year fixed effects	Yes	Yes	Yes	Yes
County fixed effects	Yes	Yes	Yes	Yes
Adjusted R^2	0.824	0.825	0.801	0.801
Observations	12,180	12,180	12,180	12,180

This table repeats our main results. Panel A presents the results for the bond spreads, and Panel B presents the results for the revenue variables. Variables are defined in Tables SI-1 and SI-2. Levels of significance are presented as follows: *p<0.1; **p<0.05; ***p<0.01.

Table SI-5
Cross-sectional split by bats at risk.

Panel A: WNS and municipal bond spreads.

	Spread	
	High	Low
	(1)	(2)
Post	10.465**	7.744
	(4.142)	(8.496)
Neighbors with WNS	0.689	1.615
	(2.595)	(6.215)
Log(Bond Size)	-2.351**	-1.221
	(1.151)	(1.115)
Log(Maturity)	10.134***	8.041***
	(1.338)	(1.460)
BQ	-13.410***	-21.609***
	(3.164)	(3.839)
GO	-15.687**	-12.369***
	(6.967)	(4.092)
Callable	2.834**	1.318
	(1.223)	(1.361)
Log(Population)	-64.729***	-12.803
	(23.339)	(14.225)
Insured	-9.172*	-7.688**
	(4.812)	(3.116)
Weather controls	Yes	Yes
Mean dependent variable	43.31	41.15
Number of counties	318	373
County fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Rating fixed effects	Yes	Yes
Adjusted R^2	0.609	0.513
Observations	12,262	13,369

Panel B: Revenue analyses

	Property tax p.c.		Total revenue own sources p.c.	
	High	Low	High	Low
	(1)	(2)	(3)	(4)
Post	-66.796***	-7.543	-109.702*	-143.216
	(15.564)	(181.809)	(63.429)	(162.257)
Log Population	-117.612	-581.458***	-152.536	-1,457.099***
	(101.680)	(129.958)	(312.444)	(470.255)
Neighbors with WNS	3.995	-53.157	17.614	16.815
	(10.937)	(40.136)	(19.047)	(65.198)
Weather controls	Yes	Yes	Yes	Yes
Mean dependent variable	455.86	476.73	1,061.63	1,172.56
Number of counties	728	291	728	291
Year fixed effects	Yes	Yes	Yes	Yes
County fixed effects	Yes	Yes	Yes	Yes
Adjusted R^2	0.839	0.786	0.816	0.766
Observations	9,038	2,970	9,038	2,970

This table reports analyses by the number of at-risk bat species, with Panel A showing bond spread results and Panel B displaying revenue variable outcomes. Columns labeled *High* show regressions for counties with above-median WNS-susceptible bat species, while *Low* columns show those with below-median numbers. Variables are defined in Tables SI-1 and SI-2. Levels of significance are presented as follows: *p<0.1; **p<0.05; ***p<0.01.

Table SI-6
Cross-sectional split by assessment frequency.

Panel A: WNS and municipal bond spreads.

	Spread	
	High	Low
	(1)	(2)
Post	16.444***	7.190*
	(5.051)	(4.060)
Neighbors with WNS	2.751	0.610
	(3.587)	(2.688)
Log(Bond Size)	-2.759**	-0.586
	(1.288)	(0.854)
Log(Maturity)	9.419***	7.724***
	(1.471)	(0.945)
BQ	-18.874***	-16.228***
	(3.551)	(3.311)
GO	-14.617***	-4.277
	(4.305)	(3.827)
Callable	0.830	4.096***
	(1.216)	(1.363)
Insured	-12.793***	-1.313
	(3.447)	(3.259)
Log(Population)	-27.100	-36.724**
	(17.718)	(16.245)
Weather controls	Yes	Yes
Mean dependent variable	42.75	39.81
Number of counties	452	211
County fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Rating fixed effects	Yes	Yes
Adjusted R^2	0.543	0.582
Observations	15,857	9,165

Panel B: Revenue analyses

	Property tax p.c.		Total revenue own sources p.c.	
	High	Low	High	Low
	(1)	(2)	(3)	(4)
Post	-78.511***	-46.225**	-157.676*	-100.237*
	(19.646)	(21.511)	(87.425)	(54.821)
Log Population	-207.427*	-80.491	-561.582	-218.254
	(116.977)	(93.135)	(398.248)	(434.936)
Neighbors with WNS	-1.186	-15.741	10.973	-15.025
	(13.612)	(14.602)	(19.782)	(34.561)
Weather controls	Yes	Yes	Yes	Yes
Mean dependent variable	444.84	395.58	1,081.12	1,007.41
Number of counties	683	244	683	244
Year fixed effects	Yes	Yes	Yes	Yes
County fixed effects	Yes	Yes	Yes	Yes
Adjusted R^2	0.778	0.883	0.785	0.839
Observations	8,072	2,917	8,072	2,917

This table reports analyses by assessment frequency, with Panel A showing bond spread results and Panel B displaying revenue variable outcomes. Columns labeled *High* show regressions for counties that frequently update assessed values, while *Low* columns show those with less frequent assessment updates. Variables are defined in Tables SI-1 and SI-2. Levels of significance are presented as follows: *p<0.1; **p<0.05; ***p<0.01.

Table SI-7

WNS and assessed agricultural land taxes.

Panel A: Assessed taxes per capita

	Assessed taxes p.c.			
	(1)	(2)	(3)	(4)
Post	-15.343***	-14.903***	-20.545***	-26.988**
	(3.562)	(3.228)	(3.576)	(12.033)
Log Population		-51.235	-14.706	-49.592
		(34.978)	(32.350)	(67.047)
Neighbors with WNS		1.618	1.631	3.613
		(1.567)	(1.498)	(3.379)
Weather controls	Yes	Yes	Yes	Yes
Mean dependent variable	61.06	61.06	62.10	118.86
Number of counties	1,052	1,052	1,047	946
Land use more likely ag.	No	No	No	Yes
Post-2016 sample	No	No	Yes	No
Year fixed effects	Yes	Yes	Yes	Yes
County fixed effects	Yes	Yes	Yes	Yes
Land use code fixed effects	Yes	Yes	Yes	Yes
Adjusted R^2	0.531	0.530	0.531	0.674
Observations	18,841	18,841	17,421	7,884

Panel B: Alternative dependent variables

	Log(Assessed taxes)	Log(Assessed tax p.a.)	Log(Acres)
	(1)	(2)	(3)
Post	-0.260***	-0.231***	-0.289***
	(0.053)	(0.062)	(0.052)
Log Population	-0.544	-0.480	-0.163
	(0.762)	(0.752)	(0.710)
Neighbors with WNS	0.008	0.008	-0.028
	(0.037)	(0.036)	(0.039)
Weather controls	Yes	Yes	Yes
Mean dependent variable	10.97	-0.23	7.16
Number of counties	1,052	1,052	1,052
Land use more likely ag.	No	No	No
Post-2016 sample	No	No	No
Year fixed effects	Yes	Yes	Yes
County fixed effects	Yes	Yes	Yes
Land use code fixed effects	Yes	Yes	Yes
Adjusted R^2	0.465	0.493	0.605
Observations	18,841	18,841	18,744

This table presents robustness to the analyses of the impact of WNS on municipal revenues. Panel A presents the assessed taxes per capita as the dependent variable, with alternative sets of controls and fixed effects across the columns. In Panel B, column 1, our dependent variable is the natural logarithm of the absolute assessed taxes on agricultural land in a county. In column 2, our dependent variable is the natural logarithm of the assessed agricultural taxes per acre. In column 3, our dependent variable is the natural logarithm of the number of assessed agricultural acres. The remaining variables are defined in Tables SI-1 and SI-2. Standard errors are clustered by county. Levels of significance are presented as follows: *p<0.1; **p<0.05; ***p<0.01.

Table SI-8

Robustness: Dropping states never affected by WNS

Panel A: Bond spread analyses

	Spread					
	(1)	(2)	(3)	(4)	(5)	(6)
Post	12.596***	11.771***	11.230***	10.379***	10.485***	13.507***
	(2.876)	(3.046)	(3.057)	(3.099)	(2.937)	(4.105)
Neighbors with WNS		-0.169	-0.314	-0.283	0.097	0.694
		(1.805)	(1.764)	(1.820)	(1.810)	(2.407)
Log(Bond Size)			-0.767	-1.372*	-1.594**	-1.307
			(0.792)	(0.726)	(0.702)	(0.827)
Log(Maturity)			6.695***	6.074***	7.535***	7.522***
			(0.575)	(0.707)	(0.889)	(1.222)
BQ				-16.648***	-15.170***	-16.714***
				(2.933)	(2.517)	(3.183)
GO				-9.065***	-7.536***	-7.252*
				(3.017)	(2.624)	(3.911)
Callable				1.026	0.833	1.657
				(0.776)	(0.796)	(1.027)
Insured				-11.783***	-8.143***	-8.301***
				(2.147)	(2.181)	(2.819)
Log Population						-17.202
						(21.606)
Weather controls	No	Yes	Yes	Yes	Yes	Yes
Mean dependent variable	42.64	42.64	42.64	42.64	42.64	42.64
Number of counties	647	647	646	631	631	459
County fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Rating fixed effects					Yes	Yes
Adjusted R^2	0.499	0.501	0.517	0.542	0.565	0.567
Observations	29,549	29,549	29,481	29,466	29,465	16,777

Panel B: Revenue analyses

	Property tax p.c.		Total revenue own sources p.c.	
	(1)	(2)	(3)	(4)
Post	-81.934***	-77.644***	-156.986***	-147.136**
	(16.363)	(15.914)	(60.099)	(59.833)
Log Population		-252.736**		-695.154*
		(112.197)		(384.629)
Neighbors with WNS		-0.393		19.227
		(8.605)		(14.300)
Weather controls	Yes	Yes	Yes	Yes
Mean dependent variable	456.01	456.01	1,030.84	1,030.84
Number of counties	819	819	819	819
Year fixed effects	Yes	Yes	Yes	Yes
County fixed effects	Yes	Yes	Yes	Yes
Adjusted R^2	0.824	0.825	0.792	0.794
Observations	9,336	9,336	9,336	9,336

This table repeats our main results on a sample excluding states where WNS was never detected (as of 2022). Panel A presents the results for the bond spreads, and Panel B presents the results for the revenue variables. Variables are defined in Tables SI-1 and SI-2. Levels of significance are presented as follows: *p<0.1; **p<0.05;

***p<0.01.

Table SI-9
Robustness: Alternative definition of WNS

Panel A: Bond spread analyses

	Spread					
	(1)	(2)	(3)	(4)	(5)	(6)
Post	8.195***	7.559**	7.437**	6.725**	6.999**	8.967**
	(3.090)	(3.218)	(3.260)	(3.289)	(3.171)	(3.859)
Neighbors with WNS		-0.480	-0.690	-0.605	-0.385	0.999
		(1.714)	(1.681)	(1.755)	(1.769)	(2.296)
Log(Bond Size)			-1.061	-1.870**	-1.876***	-1.851**
			(0.796)	(0.753)	(0.699)	(0.825)
Log(Maturity)			7.296***	6.366***	8.513***	8.919***
			(0.530)	(0.584)	(0.791)	(1.024)
BQ				-15.528***	-14.887***	-16.983***
				(2.348)	(2.090)	(2.477)
GO				-13.894***	-11.872***	-12.628***
				(2.967)	(2.559)	(3.626)
Callable				1.836**	1.219*	2.118**
				(0.738)	(0.740)	(0.923)
Insured				-10.282***	-6.686***	-8.224***
				(2.024)	(2.012)	(2.721)
Log Population						-32.017**
						(13.318)
Weather controls	No	Yes	Yes	Yes	Yes	Yes
Mean dependent variable	42.03	42.03	42.03	42.03	42.03	42.03
Number of counties	944	944	943	924	924	697
County fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Rating fixed effects					Yes	Yes
Adjusted R^2	0.476	0.478	0.496	0.522	0.544	0.549
Observations	41,268	41,268	41,172	41,153	41,152	25,855

Panel B: Revenue analyses

	Property tax p.c.		Total revenue own sources p.c.	
	(1)	(2)	(3)	(4)
Post	-60.833***	-58.424***	-168.447***	-164.357**
	(17.970)	(17.823)	(63.951)	(64.222)
Log Population		-230.183***		-578.931*
		(89.051)		(301.755)
Neighbors with WNS		-3.811		14.918
		(10.527)		(18.375)
Weather controls	Yes	Yes	Yes	Yes
Mean dependent variable	459.05	459.05	1,089.13	1,089.13
Number of counties	1,029	1,029	1,029	1,029
Year fixed effects	Yes	Yes	Yes	Yes
County fixed effects	Yes	Yes	Yes	Yes
Adjusted R^2	0.823	0.824	0.801	0.801
Observations	12,180	12,180	12,180	12,180

This table repeats our main results, restricting WNS definition only to "WNS Positive" counties, as classified by whitenosesyndrome.org. Panel A presents the results for the bond spreads, and Panel B presents the results for the revenue variables. Variables are defined in Tables SI-1 and SI-2. Levels of significance are presented as follows: *p<0.1; **p<0.05; ***p<0.01.

Table SI-10

Robustness: Alternative definition of rural county

Panel A: Bond spread analyses

	Spread					
	(1)	(2)	(3)	(4)	(5)	(6)
Post	14.656**	14.326**	14.072**	13.997**	13.901**	16.018*
	(6.078)	(6.174)	(6.292)	(6.374)	(6.576)	(8.320)
Neighbors with WNS		1.358	0.920	0.660	0.204	-2.746
		(3.936)	(3.898)	(3.998)	(3.985)	(5.291)
Log(Bond Size)			-2.916*	-3.140**	-2.773**	-2.992**
			(1.484)	(1.341)	(1.158)	(1.313)
Log(Maturity)			7.650***	7.673***	9.860***	9.998***
			(0.856)	(0.898)	(1.029)	(1.337)
BQ				-17.316***	-16.702***	-18.048***
				(4.119)	(3.179)	(3.559)
GO				-11.017***	-8.776***	-8.351**
				(3.666)	(2.803)	(4.132)
Callable				-0.065	-0.496	0.437
				(1.148)	(1.012)	(1.393)
Insured				-14.842***	-10.803***	-13.417***
				(3.389)	(3.431)	(4.909)
Log Population						-37.307*
						(18.973)
Weather controls	No	Yes	Yes	Yes	Yes	Yes
Mean dependent variable	45.59	45.59	45.59	45.59	45.59	45.59
Number of counties	442	442	441	430	430	312
County fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Rating fixed effects					Yes	Yes
Adjusted R^2	0.480	0.488	0.504	0.529	0.565	0.583
Observations	17,419	17,419	17,363	17,352	17,351	10,500

Panel B: Revenue analyses

	Property tax p.c.		Total revenue own sources p.c.	
	(1)	(2)	(3)	(4)
Post	-86.818***	-84.512***	-154.352**	-150.074**
	(18.439)	(18.163)	(73.276)	(73.577)
Log Population		-196.552**		-513.734
		(98.413)		(334.408)
Neighbors with WNS		-3.960		13.273
		(11.586)		(20.640)
Weather controls	Yes	Yes	Yes	Yes
Mean dependent variable	458.49	458.49	1,125.34	1,125.34
Number of counties	831	831	831	831
Year fixed effects	Yes	Yes	Yes	Yes
County fixed effects	Yes	Yes	Yes	Yes
Adjusted R^2	0.823	0.824	0.800	0.801
Observations	10,171	10,171	10,171	10,171

the revenue variables. Variables are defined in Tables SI-1 and SI-2. Levels of significance are presented as follows: *p<0.1; **p<0.05; ***p<0.01.

This table replicates our main results using rural counties under a more stringent rural classification (defined in Section 2.5). Panel A presents the results for the bond spreads, and Panel B presents the results for the revenue variables. Variables are defined in Tables SI-1 and SI-2. Levels of significance are presented as follows: *p<0.1; **p<0.05; ***p<0.01.

Table SI-11

Robustness: Restricting sample to counties with complete population data

Panel A: Bond spread analyses

	Spread					
	(1)	(2)	(3)	(4)	(5)	(6)
Post	10.824***	10.267***	10.465***	11.177***	11.747***	11.473***
	(3.722)	(3.758)	(3.793)	(4.019)	(3.602)	(3.525)
Neighbors with WNS		-0.408	-0.648	0.954	0.898	0.914
		(2.196)	(2.158)	(2.427)	(2.357)	(2.355)
Log(Bond Size)			-0.617	-1.662*	-1.875**	-1.818**
			(1.027)	(0.937)	(0.854)	(0.821)
Log(Maturity)			7.982***	6.847***	8.937***	8.902***
			(0.668)	(0.708)	(1.040)	(1.024)
BQ				-17.609***	-17.026***	-17.034***
				(2.899)	(2.496)	(2.488)
GO				-16.399***	-13.075***	-12.783***
				(4.443)	(3.685)	(3.628)
Callable				2.443***	2.072**	2.100**
				(0.936)	(0.933)	(0.924)
Insured				-10.834***	-7.239***	-8.157***
				(2.723)	(2.597)	(2.702)
Log Population						-29.800**
						(13.403)
Weather controls	No	Yes	Yes	Yes	Yes	Yes
Mean dependent variable	40.26	40.26	40.26	40.26	40.26	40.26
Number of counties	719	719	718	697	697	697
County fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Rating fixed effects					Yes	Yes
Adjusted R^2	0.454	0.461	0.484	0.518	0.549	0.551
Observations	25,915	25,915	25,877	25,856	25,855	25,855

Panel B: Revenue analyses

	Property tax p.c.		Total revenue own sources p.c.	
	(1)	(2)	(3)	(4)
Post	-78.129***	-75.635***	-153.966***	-149.029**
	(16.103)	(15.860)	(59.383)	(59.490)
Log Population		-227.862**		-576.918*
		(89.058)		(301.019)
Neighbors with WNS		-3.190		13.756
		(10.473)		(18.096)
Weather controls	Yes	Yes	Yes	Yes
Mean dependent variable	459.05	459.05	1,089.13	1,089.13
Number of counties	1,029	1,029	1,029	1,029
Year fixed effects	Yes	Yes	Yes	Yes
County fixed effects	Yes	Yes	Yes	Yes
Adjusted R^2	0.824	0.825	0.801	0.801
Observations	12,180	12,180	12,180	12,180

the revenue variables. Variables are defined in Tables SI-1 and SI-2. Levels of significance are presented as follows: *p<0.1; **p<0.05; ***p<0.01.

This table repeats our main results on a sample of rural counties, focusing on a sample with non-missing population data. Panel A presents the results for the bond spreads, and Panel B presents the results for the revenue variables. Variables are defined in Tables SI-1 and SI-2. Levels of significance are presented as follows: *p<0.1; **p<0.05; ***p<0.01.

Table SI-12

Robustness: Spread over Treasury curve

	Spread over Treasury					
	(1)	(2)	(3)	(4)	(5)	(6)
Post	10.483***	10.331***	10.455***	9.782**	9.462**	12.170**
	(3.908)	(3.920)	(3.970)	(4.005)	(3.820)	(4.905)
Neighbors with WNS		-0.194	-0.216	-0.435	-0.298	0.989
		(2.482)	(2.346)	(2.530)	(2.511)	(3.822)
Log(Bond Size)			1.412	-0.231	-0.296	-0.186
			(0.861)	(0.832)	(0.790)	(0.912)
Log(Maturity)			16.631***	8.144***	10.031***	9.611***
			(0.673)	(0.648)	(0.817)	(1.001)
BQ				-18.151***	-17.497***	-20.849***
				(2.725)	(2.605)	(3.132)
GO				-12.139***	-10.358***	-12.953***
				(2.965)	(2.694)	(3.520)
Callable				21.201***	20.771***	21.447***
				(0.914)	(0.896)	(1.124)
Insured				-11.549***	-7.950***	-10.892***
				(2.617)	(2.556)	(3.374)
Log Population						-36.202**
						(15.719)
Weather controls	No	Yes	Yes	Yes	Yes	Yes
Mean dependent variable	7.34	7.34	7.34	7.34	7.34	7.34
Number of counties	946	946	945	925	925	700
County fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Rating fixed effects					Yes	Yes
Adjusted R^2	0.605	0.607	0.652	0.675	0.683	0.702
Observations	42,586	42,586	42,431	42,411	42,410	26,654

This table repeats our main bond results, with the dependent variable, *Spread over Treasury*, calculated as the offering yield spread over the Treasury curve and measured in basis points. The remaining variables are defined in Tables SI-1 and SI-2. Levels of significance are presented as follows: *p<0.1; **p<0.05; ***p<0.01.

Table SI-13
Robustness: Urban counties

Panel A: Bond spread analyses

	Spread				
	(1)	(2)	(3)	(4)	(5)
Post	0.307	0.858	1.150	1.397	1.452
	(2.838)	(2.825)	(2.810)	(2.875)	(2.723)
Neighbors with WNS		-0.587	-0.604	-0.649	-0.597
		(1.934)	(1.953)	(2.012)	(2.024)
Log(Bond Size)			-0.995**	-1.239***	-1.152***
			(0.438)	(0.388)	(0.349)
Log(Maturity)			12.168***	8.901***	12.141***
			(0.551)	(0.519)	(0.735)
BQ				-10.418***	-9.904***
				(1.602)	(1.562)
GO				-14.200***	-12.064***
				(1.819)	(1.502)
Callable				6.104***	4.735***
				(0.586)	(0.552)
Insured				-8.847***	-7.091***
				(1.693)	(1.689)
Weather controls	No	Yes	Yes	Yes	Yes
Mean dependent variable	34.80	34.80	34.80	34.80	34.80
Number of counties	672	672	672	663	663
County fixed effects	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Rating fixed effects					Yes
Adjusted R^2	0.428	0.429	0.474	0.497	0.518
Observations	100,027	100,027	99,664	99,655	99,655

Panel B: Revenue analyses

	Property tax p.c.		Total revenue own sources p.c.	
	(1)	(2)	(3)	(4)
Post	-16.414**	-17.661***	-45.078**	-48.559**
	(6.428)	(6.427)	(19.529)	(19.831)
Log Population		-98.434***		-235.559**
		(24.323)		(112.047)
Neighbors with WNS		1.806		12.561**
		(1.766)		(5.955)
Weather controls	Yes	Yes	Yes	Yes
Mean dependent variable	341.14	341.14	865.21	865.21
Number of counties	1,523	1,523	1,523	1,523
Year fixed effects	Yes	Yes	Yes	Yes
County fixed effects	Yes	Yes	Yes	Yes
Adjusted R^2	0.892	0.893	0.867	0.867
Observations	22,890	22,890	22,890	22,890

This table repeats our main results on a sample of urban counties. Panel A presents the results for the bond spreads, and Panel B presents the results for the revenue variables. Variables are defined in Tables SI-1 and SI-2. Levels of significance are presented as follows: *p<0.1; **p<0.05; ***p<0.01. ***p<0.01.

Table SI-14

Robustness: WNS and rural county revenues

	Log(Property tax per cropland)		Log(Total revenue own sources per cropland)	
	(1)	(2)	(3)	(4)
Post	-0.099**	-0.110**	-0.047	-0.057
	(0.049)	(0.049)	(0.043)	(0.042)
Log Population		0.753***		0.734***
		(0.160)		(0.205)
Neighbors with WNS		0.033		0.032**
		(0.021)		(0.016)
Weather controls	Yes	Yes	Yes	Yes
Mean dependent variable	3.41	3.41	4.24	4.24
Number of counties	997	997	997	997
Year fixed effects	Yes	Yes	Yes	Yes
County fixed effects	Yes	Yes	Yes	Yes
Adjusted R^2	0.958	0.958	0.965	0.965
Observations	11,860	11,860	11,859	11,859

This table assesses the sensitivity of our analyses of the impact of WNS on municipal revenues to alternative scaling of dependent variables. The dependent variable in columns (1) and (2), *Log(Property tax per cropland)*, is the natural logarithm of property tax collections, scaled by cropland acres in 1997. The dependent variable in columns (3) and (4), *Total revenue own sources p.c.*, is the natural logarithm of total revenue from own sources per capita, scaled by cropland acres in 1997. The remaining variables are defined in Tables SI-1 and SI-2. Standard errors are clustered by county. Levels of significance are presented as follows: *p<0.1; **p<0.05; ***p<0.01.

Table SI-15

Robustness: WNS and rural county revenues

Panel A: More aggregate outcome variables

	Total tax p.c.		Revenue p.c.	
	(1)	(2)	(3)	(4)
Post	-77.012***	-74.632***	-214.175***	-215.894***
	(20.398)	(20.236)	(60.582)	(59.920)
Log Population		-187.217*		134.382
		(103.383)		(643.874)
Neighbors with WNS		-7.836		5.787
		(14.158)		(23.356)
Weather controls	Yes	Yes	Yes	Yes
Mean dependent variable	568.41	568.41	1,602.91	1,602.91
Number of counties	1,029	1,029	1,029	1,029
Year fixed effects	Yes	Yes	Yes	Yes
County fixed effects	Yes	Yes	Yes	Yes
Adjusted R^2	0.814	0.815	0.817	0.817
Observations	12,180	12,180	12,180	12,180

Panel B: Restricting sample to counties with bond data

	Property tax p.c.		Total revenue own sources p.c.	
	(1)	(2)	(3)	(4)
Post	-121.812***	-116.620***	-294.996***	-277.352***
	(17.238)	(15.766)	(91.646)	(92.382)
Log Population		-215.050		-660.845
		(135.569)		(506.664)
Neighbors with WNS		14.335		23.361
		(9.402)		(22.624)
Weather controls	Yes	Yes	Yes	Yes
Mean dependent variable	434.23	434.23	1,148.52	1,148.52
Number of counties	528	528	528	528
Year fixed effects	Yes	Yes	Yes	Yes
County fixed effects	Yes	Yes	Yes	Yes
Adjusted R^2	0.832	0.833	0.801	0.802
Observations	6,355	6,355	6,355	6,355

This table presents robustness to the analyses of the impact of WNS on municipal revenues to using more aggregated dependent variables and to restricting the sample to counties with available bond data. Panel A repeats our main results using total taxes per capita, *Total tax p.c.*, (columns 1 and 2) and total revenue per capita, *Total revenue p.c.*, (columns 3 and 4). Panel B repeats our main revenue regressions using a restricted sample that includes only the counties for which we have bond data. The remaining variables are defined in Tables SI-1 and SI-2. Standard errors are clustered by county. Levels of significance are presented as follows:
*p<0.1; **p<0.05; ***p<0.01

[i] The GBF is an international agreement negotiated within the Convention on Biodiversity, https://www.cbd.int/doc/decisions/cop-15/cop-15-dec-04-en.pdf.

[ii] In some cases, natural assets and physical or financial assets may be sufficiently connected to incentivize investment in conservation. Some firms have begun hedging against biodiversity risks (*5*), but this is mostly regulatory risk rather than generating incentives to conserve biodiversity.

[iii] Municipal borrowing costs reflect the interest on municipal bonds issued by counties and are usually backed by future tax revenues.

[iv] For a review of municipal bonds and the municipal bond market, see Cestauet al. (*27*).

[v] Municipal securities are exempt from capital gains taxes. Therefore, if investors' opportunity cost was to raise equivalent funds through alternative investments, they would require a payoff of approximately $17{,}655 = \frac{14{,}124}{1-0.2}$ to generate a comparable after-tax return.