Perverse incentives created by tree protection ordinances[*]

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Abstract

Since 2000, the United States has seen a rapid proliferation of municipal tree protection ordinances, with 750+ cities adopting one by 2024. Yet, little is known about the efficacy of these policies, and no prior literature speaks to the economic incentives they create. In particular, 63% of ordinances utilize trunk diameter-based thresholds to preserve larger trees. These thresholds could result in landowners strategically cutting down trees before they reach protected status to avoid future regulatory hurdles and preserve option value associated with potential development. Focusing on one such ordinance in Austin, TX, our study is the first to document bunching in the distribution of tree removal permits for protected tree species just below cutoff diameters, indicating preemptive cutting. We estimate that 5-6% of permits just below diameter thresholds are due to preemptive cutting. We do not find evidence of tree preservation or dishonest claims of dead, hazardous, or encroaching trees.

JEL Classifications: Q58, Q20, Q28, Q57, R22, R52

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1 Introduction

Tree cover in urban and community areas of the United States is on the decline at a rate of about 175,000 acres per year, with associated losses conservatively valued at 96 million dollars per year (Nowak and Greenfield, 2018). One potential solution is municipal tree protection policies, which aim to preserve city trees and their benefits such as carbon sequestration, stormwater management, cooling, energy savings, improved air quality, better health, aesthetic value, reduced light pollution, and sediment regulation.[1]

A common way that municipal tree protection ordinances are implemented in the United States is by specifying a series of cutoff threshold trunk diameters that determine how difficult it is to remove a tree legally. The idea is to preserve larger trees, which generally provide more benefits.[2] We ask whether the presence of these thresholds generates perverse incentives for preemptive cutting, since homeowners might wish to avoid future regulatory hurdles for removing larger trees.

We analyze tree removal permit data in Austin, TX, where the tree protection ordinance establishes two trunk diameter thresholds (24" and 30") that apply to specific "heritage" species. Trees exceeding these thresholds face increasingly stringent removal requirements. By examining the distribution of removal permits around the thresholds, we provide statistically significant evidence of preemptive cutting for trees on private land, with public tree removal permits serving as a placebo. We estimate that 5-6% of private trees removed just below the thresholds are preemptively cut down. Importantly, we find no evidence that the policy achieves its intended goal of tree preservation—conditional on reaching threshold diameters, private heritage trees are not removed at larger diameters than comparable public trees. We also find no evidence of increased dishonest reporting of tree conditions around the thresholds, suggesting the perverse incentives operate through actual preemptive removal rather than fraudulent permit claims.

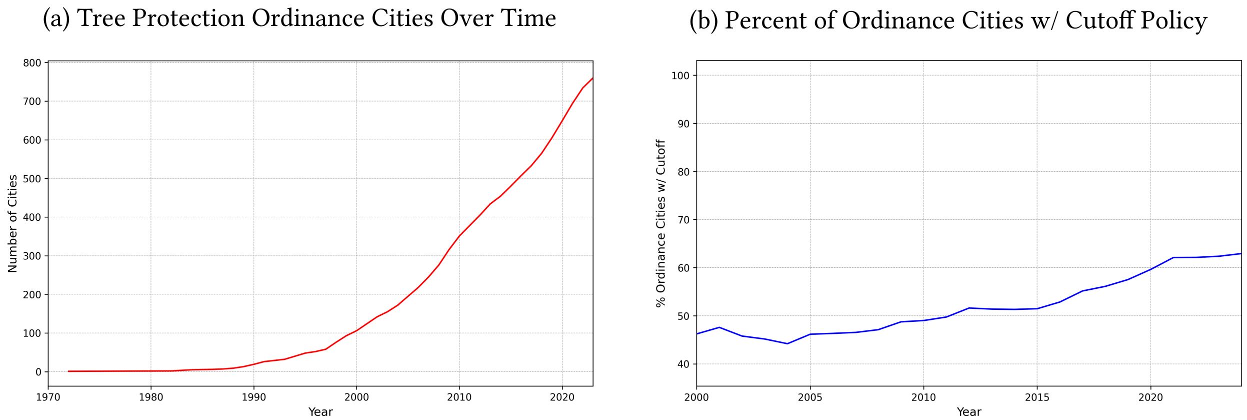
Our findings are particularly troubling given that tree protection ordinances of this form are ubiquitous in the United States. Figure 1 shows that the number of cities with a tree protection ordinance has been rapidly rising since 2000. As of September 2024, 766 cities had adopted a tree protection ordinance in the US alone. Cutoff policies are also commonplace, with 63% of those exhibiting a cutoff policy.

Ours is the first study to investigate incentives created by municipal tree protection ordinances. While

[1] See: Li, Svenning, Zhou, Zhu, Abrams, Lenton, Ripple, Yu, Teng, Dunn et al. (2024); Chung, Frank, Pokhrel, Dietz and Liu (2021); Rodriguez Mendez, Fuss, Lück and Creutzig (2024); Silvera Seamans (2013); Giacinto, Fricker, Ritter, Yost and Doremus (2021); Nowak and Crane (2002); Diringer, Morgan, Heather, Madeline, Jennifer and Sharlene (2020); Sung and Kim (2024).

[2] For example, Nowak, Bodine, Hoehn, Edgar, Hartel, Lister and Brandeis (2016) finds that trees over 30" sequester the most carbon in Austin. Larger trees also provide more shade and cooling.

Figure 1: Municipal Tree Protection Ordinances in the USA



Notes: Panel (a) depicts authors' compilation of municipal tree protection ordinances over time from LexisNexis. Panel (b) depicts the percent of those ordinances exhibiting a cutoff threshold beyond which it is more difficult to cut down a tree. See Appendix Section A-1 for more details on our procedure.

substantial research has examined conservation incentives for natural forests, managed forestlands, and agroforestry systems (e.g. Coffield, Vo, Wang, Badgley, Goulden, Cullenward, Anderegg and Randerson, 2022; Alix-Garcia, Sims and Yanez-Pagans, 2015; Jayachandran, 2013; Neal, 2024), urban tree conservation has received comparatively less attention despite its significant environmental, social, and economic benefits. A few studies evaluate tree protection ordinances by examining impacts on urban canopy cover, with mixed or inconclusive results. Galenieks (2017) attributes differences in tree cover in two cities in California to more stringent tree protection in one of them, but focuses on street trees. Hill, Dorfman and Kramer (2010) find no preservation impact from simply having a tree ordinance, but finds that ordinances with more clauses are associated with more trees. Hilbert, Koeser, Roman, Hamilton, Landry, Hauer, Campanella, McLean, Andreu and Perez (2019) find that heritage tree ordinances of the form we study here are associated with more tree cover in Florida, but no predictive power for tree protection ordinances in general. Salisbury, Koeser, Hauer, Hilbert, Abd-Elrahman, Andreu, Britt, Landry, Lusk, Miesbauer et al. (2022) find that heritage tree ordinances are associated with more tree cover among 300 cities in Florida, but tree protection ordinances in general had the opposite effect. In contrast to these studies, our focus is on *economic incentives* generated by urban tree protection. We are also the first to exploit the threshold structure setup– a common design in the United States– to provide causal evidence on perverse incentives generated.

In that vein, we also contribute to a broader literature on environmental policies, which demonstrates that well-meaning cutoff rules can sometimes go awry and create perverse incentives counter to the intended outcomes- contexts explored include habitat for endangered species (Langpap and Wu, 2017), appliance energy efficiency certifications (Houde, 2022), home energy efficiency letter grades (Lu and Spaenjers, 2023; Collins and Curtis, 2018), air quality designations (Ghanem, Shen and Zhang, 2020), and automobile fuel economy standards (Wu, Zhang and Liao, 2024; Whitefoot and Skerlos, 2012).

2 Threshold policy context and data

Austin's Tree Protection Ordinance, established in 1983, aims to preserve the city's urban forest, with particular emphasis on heritage trees (City of Austin, 2021). The ordinance consists of three parts: (i) Trees over 19" diameter at breast height (DBH; defined as 4.5 feet above natural grade) require a permit for removal. This rule applies to all species. (ii) Certain native species are designated as protected "heritage trees." Heritage trees over 24" DBH need a variance approved for removal. Valid reasons include if the tree is dead, hazardous, or preventing reasonable use of the property. (iii) Any heritage trees over 30" DBH require full city council approval to cut down. See Appendix Section A-2 for an infographic from the City of Austin, as well as more details on benefits and controversies related to Austin's policy.

Our analysis uses tree removal permit data from Austin Open Data spanning the years 2006–2021.[3] Each record contains details on tree size, species, reason given for cutting, property ownership category (public, residential, commercial), date, and whether the permit was approved. Trees below 19" do not necessitate a permit in many cases, so we exclude them from our analysis.

We classify species by whether they are a species regulated by the policy ("Heritage Species") or not.[4] Appendix Section A-4 presents summary statistics by species and whether the permit is from a tree on public or private land, as well as figures depicting trends over time.

Private heritage trees could experience two effects. First, trees may be preemptively cut since landowners face a larger cost of cutting after the threshold diameter is reached. Removing the tree means preserving the option value associated with future development, including building new structures and modifying existing structures and landscaping. Second, once the diameter is reached, private landowners either will have their permits denied (except in the case of dead or diseased trees), face fines/fees, or would need to go before a city council to get special approval to cut down the tree.

Public heritage trees are unlikely to respond to the thresholds because public officials do not need to preserve option value associated with future development since the trees are primarily located in parks

[3]The tree removal permits data were downloaded from Austin Open Data (URL: https://data.austintexas.gov/Building-and-Development/Issued-Tree-Permits/ac2h-ha3r) on March 31, 2021.

[4]We describe our procedure for determining tree species from string inputs in Appendix Section A-3.1.

or street medians. Additionally, the policy appears not to be enforced stringently for public permits, as evidenced by the flat and low denial rate for public permits (Figure A-7). The denial rate is not higher for heritage species, and permits for even the largest trees (>30") seem to rarely be denied if the tree is on public land. This suggests that government employees face no incentive to change their behavior due to this policy- they can cut down trees regardless of species and diameter.

Given these differential incentives between public and private heritage trees, throughout the paper, we will use public heritage species permits as a counterfactual for private heritage species permits. These groups consist of the same species of trees and thus have similar growth curves. The comparison of public and private non-heritage species will be used in a series of placebo-like tests to ensure our assumptions are plausible. For more on the choice of counterfactual, see Appendix Section A-6.1.[5]

For analyses in the remainder of the paper, we restrict our sample to non-denied permits because our goal is to capture tree removals. We describe our trunk diameter data in detail in Section A-5, where we document mass points due to rounding to whole numbers, and also explain our trunk diameter rounding procedure.[6]

Can we trust the trunk diameter measurements? In other contexts, one might reasonably question whether bunching in the distribution of a variable of interest simply indicates strategic misreporting. However, dishonesty about tree size is unlikely in this case given the sizes we focus on and the laws in place in Austin. It would be unsafe to remove the type of trees we study (19"+) without a professional. Thus, homeowners typically work with tree removal companies for non-development related tree removals. Further, the tree ordinance review application requires details that most citizens would not be able to come up with on their own.[7] Therefore, tree removal companies typically will work with the homeowners to fill out paperwork.[8] For development-related work, the developer typically handles the removal permits along

[5]An alternative approach could be to compare with a similar city with no ordinance in place, but for which permitting is required for removal of all trees at least 19". The authors are not aware of any such city. Usually, permitting requirements that would generate the type of detailed data we need are put in place to enforce an ordinance or other tree-related legislation.

[6]This procedure groups the tenths digits to facilitate the propensity score estimation detailed in (7) below.

[7]For a look at the type of details required, see the residential tree review checklist: https://www.austintexas.gov/sites/default/files/files/Development_Services/RES_ResidentialTreeReviewChecklist.pdf

[8]For a few examples, Certified Arbor Care's website says, under frequently asked questions: "Does Certified Arbor Care provide permit submittal services to municipalities for removals, root encroachment, or pruning? Yes, we can help assist with permitting. This is a fee based service and varies from project to project. Call or fill out our contact form today to setup an appointment." (https://certifiedarborcare.net/) Heritage Tree Care offers permitting- their website states specifically referring to the city ordinance, "Heritage Tree Care is familiar with complicated regulations" (https://txheritagetreecare.com/residential/arborist-austin/) Tree Amigos Website offers to "act as your tree ambassador to the City of Austin" Their website continues, "By interfacing with city staff as arborists, we can do what it takes to get your project approved and underway, while also maintaining the health of your valuable trees during construction. (https://austintreeamigos.com/services)

with other building permits (but may contract out the tree removal). After the application is submitted, it is reviewed by the city, which has the power to require a tree inspection by the city arborist's office. No matter whether development or non-development related, it's required to get an arborist to write a letter detailing reasons if the heritage tree greater than 24" is removed.[9] Given that arborists and developers have their licenses and reputations on the line, it is unlikely that they would intentionally misreport something as easily verifiable as tree diameter, but even if they had such an incentive, they could be caught by the city arborist's office. Nevertheless, we check for strategic rounding in Appendix Section A-5.2.

The one potential reporting loophole, however, is the case of dead, diseased, or hazardous trees. The law says that "A person may, without a variance, remove a damaged heritage tree that is an imminent hazard to life or property if the tree is removed within seven days of being damaged. The director may extend this deadline for widespread and extensive storm damage."[10] Even if the tree is not removed under this particular clause, it is plausible that there is less oversight or verification when citizens say the trees are dead, diseased, or hazardous. For example, in a situation where the arborist's office is backlogged, they may take developers' word for it regarding hazardous trees. Therefore, we probe for dishonesty by examining the prevalence of trees classified as dead, hazardous, and encroaching around the thresholds.

3 Empirical approach

3.1 Tests of stochastic dominance to explore tree preservation

The policy is intended to preserve trees. Since all trees are eventually removed, we define preservation as delay of cutting. In general, a finding that the trunk diameter of private heritage tree removal permits was larger than public heritage tree removal permits would confirm tree preservation. Therefore, to probe potential tree preservation, we test for first order stochastic dominance in the underlying empirical cumulative distribution functions (CDFs) using Kolmogorov-Smirnov tests (Schröer and Trenkler, 1995).[11]

[9] This applies whenever there is proposed construction within the 1/2 CRZ of a Protected Tree and/or if there are obvious conflicts between the tree(s) and the proposed construction.) https://www.austintexas.gov/sites/default/files/files/Development_Services/RES_ResidentialTreeReviewChecklist.pdf

[10] See: https://services.austintexas.gov/edims/document.cfm?id=134292

[11] The test statistic D is defined as

$$D = \max\left(|D^+|, |D^-|\right) \tag{1}$$

where

$$D^+ = \max_x \{F(x) - G(x)\} \tag{2}$$

and

$$D^- = \min_x \{F(x) - G(x)\} \tag{3}$$

In the above, $F(x)$ is the CDF for one of the distributions we compare, and $G(x)$ is the CDF for the other. We compute p-values following Smirnov (1933).

Since incentives start at the 24" and 30" cutoffs, we specifically focus on testing whether private heritage tree diameters at removal are larger than those of public heritage trees *conditional* on surviving to a given policy cutoff. This guarantees that any preemptive cutting prior to a given cutoff, which should also affect private but not public tree removal, does not contaminate the test for tree preservation (i.e. trees cannot be cut down twice).

3.2 Manipulation tests to detect statistical evidence of preemptive cutting

To test for manipulation in the distribution of tree diameters just below the 24 and 30" regulatory thresholds, we implemented nonparametric manipulation tests using the local polynomial density estimation approach developed by Cattaneo, Jansson and Ma (2020, 2024) to estimate the density of the running variable (trunk diameter) on both sides of the regulatory threshold. This methodology improves upon previous manipulation tests (e.g., McCrary (2008)) by avoiding pre-binning of the data and accommodating mass points in the distribution—a critical feature given the prevalence of rounding in diameter measurements (see Appendix Section A-5 for more in our context).[12]

Bandwidths were selected using the integrated mean squared error (IMSE) with regularization in the optimal bandwidth selection (IMSE-ROT option). This is based on a Gaussian reference model which is common for all grid points. For inference, we used the robust bias-corrected procedure with jackknife variance estimation, which provides improved finite sample performance.

Our goal is to examine whether there is a discontinuity in the density of the running variable (trunk diameter) at the regulatory threshold. We test this for both the 24" and 30" cutoffs, focusing on private heritage trees, and leaving aside public heritage trees as a placebo.[13]

[12]Specifically, we employed the `rddensity` command in Stata with the settings recommended by Cattaneo, Jansson and Ma (2018): triangular kernel, second-order local polynomial for density estimation (p=2), and third-order polynomial for bias correction (q=3).

[13]Formally, this involves testing the two-sided hypothesis:

$$H_0 : \lim_{x \uparrow c} f(x) = \lim_{x \downarrow c} f(x) \quad \text{versus} \quad H_a : \lim_{x \uparrow c} f(x) \neq \lim_{x \downarrow c} f(x) \tag{4}$$

where c is the cutoff of interest (either 24 or 30") and $f(x)$ is the density function of the running variable.

We formally test the null hypothesis given in (4) for private heritage species permits around the 24" and 30" thresholds. Denote $\hat{f}_+(h) = \lim_{x\downarrow c} f(x)$ and $\hat{f}_-(h) = \lim_{x\uparrow c} f(x)$. Following Cattaneo et al. (2018), the manipulation test statistic is:

$$T(h) = \frac{\hat{f}_+(h) - \hat{f}_-(h)}{\hat{V}(h)} \tag{5}$$

The parameter h is the bandwidth(s) used to localize the estimation and inference procedures near the cutoff point x. $\hat{V}(h)$ is defined such that

$$\hat{V}^2(h) = \mathbb{V}(\hat{f}_+(h) - \hat{f}_-(h)) \tag{6}$$

where $\mathbb{V}$ is a consistent estimator of the population variance. Under these assumptions, Cattaneo et al. (2020) show that

We use the restricted version of the test, which constrains the estimation such that the cumulative distribution and certain derivatives are continuous across the threshold.

3.3 Local polynomial density estimation to quantify a lower bound on preemptive cutting

Though the methods described in Section 3.2 allow us to test for discontinuities in the distribution, they do not quantify the extent to which private heritage species exhibit removals just below the cutoff. To quantify a lower bound on the extent of preemptive cutting, we employ local polynomial density estimation methods following Cattaneo et al. (2020) and Cattaneo et al. (2024).[14]

For this analysis, we limited the sample to heritage species only and used public heritage trees as a counterfactual for private heritage trees. We applied propensity score weighting to ensure comparability, using probit models with year-issued, tenth-digit, and species fixed effects. Let T_i denote treatment status (1 for private heritage, 0 for public heritage). The propensity score was modeled as:

$$\Pr(T_i = 1|\text{year, tenths digit, species}) = \Phi(\tau_y + \theta_d + \sigma_s) \tag{7}$$

In the above, τ_y is a fixed effect for year, θ_d is a fixed effect for tenths digit, and σ_s is a fixed effect for species group. We plugged the estimates for $\hat{\tau}$, $\hat{\theta}$ and $\hat{\sigma}$ in to predict $\hat{\Phi}$.

The counterfactual weights for constructing the private tree distribution were then calculated as:

$$w_i = T_i \cdot \frac{1 - \hat{\Phi}}{\hat{\Phi}} \tag{8}$$

Then, we estimated the local polynomial density by plugging in these weights, and employing a triangular kernel, quadratic local polynomial regression for the point estimates, and a third order local polynomial for bias correction to construct the confidence intervals (all following best practices; see Cattaneo et al. (2018); Cattaneo, Jansson and Ma (2022)). Our optimal bandwidth selection procedure is an integrated rule-of-thumb bandwidth based on a Gaussian reference model which is common for all grid points.

Two estimation challenges that stood out to us during implementation were that the optimal bandwidth differed between public and private heritage species and the grid at which the local polynomial density was computed also differed slightly. We opted to use the optimal bandwidth for the treated species to avoid

$T(h) \sim N(0,1)$.

[14] These are implemented through the `lpdensity` Stata package.

over-smoothing. The grid chosen by the procedure could also differ, despite our starting with all trunk diameter values rounded to nearest tenth digit. To remedy this potential inconsistency between the two groups, we follow a three-step procedure. First, we estimate the control optimal bandwidth, starting with all of our trunk diameters (grouped by tenth digit). This gives us a grid for the control units. Next, we use this grid to estimate the treatment units, establishing optimal bandwidth for the treated units. In a third step, we again estimate the control density, but using the treatment optimal bandwidth and the grid outputted by the second step.

To quantify the bunching behavior in private heritage permits, we identified the point x_b where the private and public density functions begin to diverge below the threshold. The target estimand is the excess mass between x_b and the cutoff c:

$$\text{Excess Mass} = \int_{x_b}^{c} \left(\hat{f}_{\text{private}}(x) - \hat{f}_{\text{public}}(x) dx \right) \tag{9}$$

This difference represents the excess mass of private heritage trees just below the threshold, providing a lower bound estimate on the percentage of permits that likely represent preemptive cutting; this is conceptually similar to Kleven and Waseem (2013) and others in the bunching literature.

To approximate (9), we estimated $\hat{f}_l(x)$, for $l \in \{\text{private, public}\}$ at each grid point used in the three-step procedure detailed above. To convert that to percentage terms, we divided by the sum of $\hat{f}_{\text{private}}(x)$ over the range $[x_b, c)$.

3.4 Exploring dishonesty

To examine whether the policy cutoffs are associated with lying about the condition of their trees, we examine the share citing "dead," "hazardous," and "encroaching" trees as the removal reason around the cutoffs. The general idea is that we might expect a jump in trees reported as being problematic at each threshold, since more justification will be needed to cut down a tree just above the threshold. The jump would be present for private heritage trees, but not public heritage trees, since public officials have no incentive to lie about whether their trees are hazardous, as they will not be denied either way.

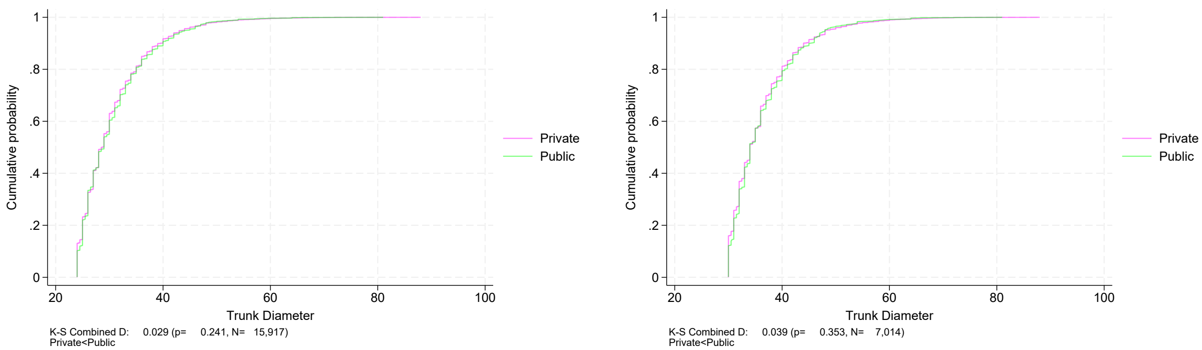
4 Results

4.1 We find no evidence of tree preservation.

To visualize potential tree preservation, we present the empirical cumulative distribution functions (CDFs) comparing heritage private and public permits in Figure 2. The empirical CDFs are nearly identical, visually indicating no evidence of tree preservation. Kolmogorov-Smirnov joint p-values do not reject the null hypothesis of no stochastic dominance, confirming statistically that there is no evidence of tree preservation.

Figure 2: Empirical CDFs for Heritage Species, Conditional on Reaching 24 or 30"

(a) ≥ 24" (b) ≥ 30"



Notes: This figure compares the empirical cumulative distributions for public (lime) and private (magenta) heritage species. Panel (a) shows the empirical CDFs for all trees surviving to at least 24", whereas panel (b) shows the same for all trees surviving to at least 30". The two-sided Kolmogorov-Smirnov joint p-value is shown at the bottom of each figure. The sample includes only non-denied permits. A sensitivity check for this figure is presented in Appendix Figure A-17.

Two reasonable concerns stand out here. The first is that perhaps public and private trees are fundamentally different- for example, the city takes better care of trees. These differences could mask a situation where, in the absence of the policy, we would find that the private trees do not live as long as public, but with the policy in effect, the private trees are preserved and "catch up" to public trees. This would lead us to find there is no tree preservation occurring when there is. To allay this concern, we additionally present Figure A-18 in the appendix, which conducts the same comparisons but for non-heritage species. If the city takes better care of trees in general, we would expect for the non-heritage public tree permits to be located to the left of the non-heritage private tree permits. While there is a limited amount of visual evidence for this in the case of the 30" cutoff, we cannot reject the null hypothesis of no stochastic dominance. And, for the 24" cutoff, we find no evidence that private non-heritage trees have shorter lifespans than public non-heritage trees.

Another possibility is that there also was a saving effect for public trees. In that case, we would see denials for public heritage trees at the same rate as private heritage trees, and we would also expect that denied permits grow with trunk diameter for public heritage species. Figure A-7 shows that Heritage Species are more likely to be denied, and indicates that this is in particular true for private trees. Denials depend positively on trunk diameter only for private heritage species. In fact, for the largest public trees, we see very few denials, and at the 30" cutoff, the fraction of permits denied *falls* for public heritage species. This suggests that the policy is not imposing a binding constraint on public tree removal.

4.2 We find statistical evidence of preemptive cutting.

We employ manipulation tests to provide statistical evidence of discontinuities in the distribution of private heritage tree removal permits at the threshold diameters of 24" and 30", as described in Section 3.2. Before implementing the manipulation tests, we round the trunk diameter variable to tenths digits as described and justified in Appendix Section A-5.

Table 1: Statistical Tests of Preemptive Cutting Just Under Thresholds

	24"		30"	
	Private	Public	Private	Public
t -stat	-13.206	1.675	-6.065	1.353
p-val	0.000	0.094	0.000	0.176
Trunk Diameter Range	[19,29]	[19,29]	[25,40]	[25,40]
Obs.	19,909	1,767	11,251	1,058

Notes: This table presents test statistics using the methodology of Cattaneo et al. (2020, 2024). In the first column, we show the $t-$statistic and $p-$ value associated with the two-sided test that there is a discontinuity at the 24" threshold for private heritage trees. In the second column, we show the same for public heritage trees (a placebo). In the third column, we present the t-statistic and p-value for the 2-sided test of manipulation around the 30" cutoff for private heritage trees. In the fourth column, we show the same for public heritage trees (a placebo).

The results are presented in Table 1, and indicate a highly statistically significant discontinuity for private heritage species, at both the 24" and the 30" threshold (p <0.001 in both cases). Public heritage trees serve as a placebo, and we see no evidence of a downward jump for those- the sign of the t-statistic is in fact positive. The 24" threshold shows a discontinuity that is only marginally significant with $p = 0.094$. The 30" threshold is not significant.

Whole number rounding in our data means that traditional manipulation tests, like McCrary (2008), might falsely detect a jump in the density even when none exists. The method we use, due to Cattaneo et al. (2020) and Cattaneo et al. (2024), is suitable for several reasons. First of all, it is boundary adaptive, meaning that all inference is valid at any point, including endpoints of the distribution or thresholds at which discontinuities may occur. It chooses an optimal bandwidth at the boundaries of the distribution and also at all points in the interior. Secondly, the method automatically accounts for mass points (whole numbers, in our case) by expanding the window of points that is used to construct the smoothed density whenever repeat observations are detected. Lastly, the manipulation tests treat each side of a given threshold symmetrically (e.g. so that they both include 24" in the estimation), so it is unlikely that we would find a break in the density if there were none.

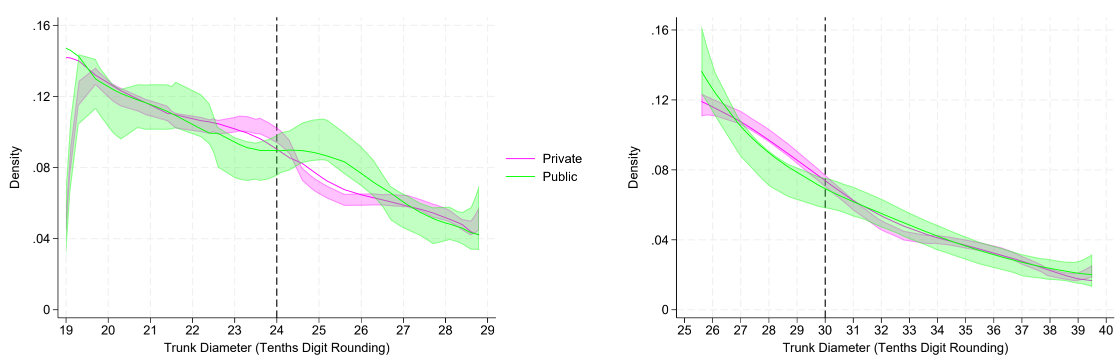
4.3 We quantify a lower bound on the extent of preemptive cutting.

While instructive as to the strength of statistical evidence on preemptive cutting, the manipulation tests presented in Table 1 do not quantify the extent of preemptive cutting in an intuitive way. To address this, in Figure 3, we employ local polynomial density estimation due to Cattaneo et al. (2020), as implemented in Cattaneo et al. (2024). We implement the optimal bandwidth and smooth across diameters in either [19,29] (for the 24" cutoff) or [25,40] (for the 30" cutoff).

For this analysis, we limit the sample to only heritage species, and use the public heritage trees to construct a counterfactual density for private heritage trees. In order to ensure they are comparable, we utilize weights constructed from a probit propensity score model, which consists of three sets of dummy variables: year issued, tenth digit, and species.

Figure 3: Quantifying a Lower Bound on Preemptive Cutting Just Under Thresholds

(a) 24" Threshold (b) 30" Threshold



Notes: Panel (a) shows the estimated local polynomial densities for private heritage (magenta) and public heritage (lime) species, including trunk diameters ∈ [19,29]. Solid lines are point estimates and transparent regions are confidence bands. Panel (b) shows the same, but for trunk diameters ∈ [25,40]. The dashed vertical line is the threshold we examine. Both plots suggest preemptive cutting for private heritage species just under the threshold. The sample includes only non-denied permits.

As described in Section 3, we standardized the bandwidth and grid (the grid is the points at which the local polynomial density is computed) across private heritage trees (our treatment group) and public heritage trees (the comparison group).

Despite not explicitly modeling a discontinuity at the cutoff, Figure 3 presents strong evidence that these cutoffs are points around which the two distributions tend to diverge in ways consistent with preemptively cut trees. In particular, the density of private trees exceeds that of public trees just below each threshold. Also consistent with preemptive cutting, we find that there is a dip in the private density relative to the public density just above each threshold (though it is not significant for the 30” threshold). Furthermore, the solid lines, which represent point estimates, cross near the threshold, confirming that the thresholds skew tree removal behavior differentially for these two groups.[15]

Confidence intervals sometimes diverge from point estimates in Figure 3 because bias correction is only used for the construction of confidence bands, but not for point estimation. Additionally, point estimates could lie outside the confidence bands with this procedure because of high curvature at certain evaluation points, which is expected when there is a large bunching effect. The analysis depicted here uses an optimal bandwidth selection procedure throughout, ensuring that we do not choose too large of a bandwidth, which could manufacture such a situation.

Our procedure for quantifying the extent of preemptive cutting follows the intuition of Kleven and Waseem (2013), but uses the estimated density from Cattaneo et al. (2024) described above. We linearly interpolate the densities to connect the grid points for each group. Then, we locate the point at which the two lines cross, x_b, an often-sought parameter in the bunching literature that quantifies at which diameter the bunching begins. We sum the mass between the two lines over the entire bunching region $[x_b,c)$, where c is the cutoff (either 24 or 30”). To make it tangible, we divide that area by the entire area under the empirical PDF over the range $[x_b,c)$ for the treated group. This yields the estimated percent of permits with trunk diameters just below the threshold that are preemptive cuttings.

For the 24” threshold, we find $\hat{x_b} = 21.6$, and we estimate that 5.03% of permits in the range [21.6,24) are preemptively cut trees. For the 30” threshold, $\hat{x_b} = 26.8$, and we estimate that 6.36% of permits in the range [26.8,30) are preemptive tree removals.

These percentages are likely to be conservative for a couple of reasons. First, we smoothed across the cutoff, attenuating the discontinuity. Second, as can be seen on the plot, the confidence bands tell a starker picture than the point estimates we use do, because the latter are not bias corrected. Thus, they may not fully account for the mass point at 24”, which would exaggerate the number of permits just above the policy

[15]We are also reassured that the visual evidence is entirely consistent with a very simple sensitivity check that we present in Appendix Section A-5.1.

threshold. Therefore, we interpret our estimates as a lower bound on the extent of preemptive cutting.

4.4 We find no visual evidence of dishonesty.

To probe dishonesty, we plot the fraction of trees reported dead, hazardous, and encroaching by trunk diameter. Though we find a slight uptick of heritage trees being reported encroaching from before to after 24", we found no *differential* visual evidence of manipulation around the cutoffs when comparing private and public heritage species (Figure 4).

5 Conclusion

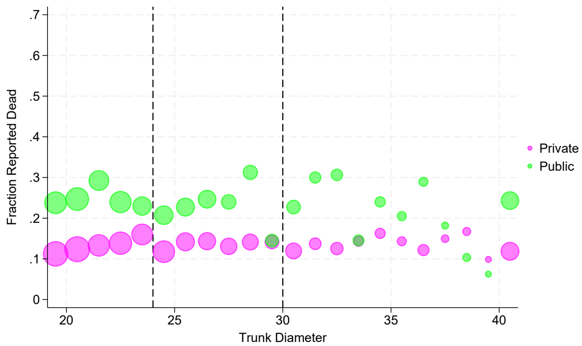
Tree protection is popular among municipal governments for a reason- homeowners value trees in their neighborhoods (Sander, Polasky and Haight, 2010; Han, Heblich, Timmins and Zylberberg, 2024; Siriwardena, Boyle, Holmes and Wiseman, 2016), and residents support tree protection (Koeser, Hauer, Andreu, Northrop and Hilbert, 2023). Thus, it is imperative that municipal ordinances are designed in a manner that promotes tree preservation, rather than undermines it. Two alternative tree protection policy setups might be considered: 1. a system of tax credits for tree preservation, with tiers set according to DBH, as suggested by Willis, Koeser, Clarke, Hansen, Hilbert, Lusk, Roman and Warner (2024), and 2. re-planting campaigns, as advocated for by Ordóñez-Barona, Bush, Hurley, Amati, Juhola, Frank, Ritchie, Clark, English, Hertzog, Caffin, Watt and Livesley (2021).

Our results reveal previously undocumented economic incentives for tree removal. Others have characterized removal incentives such as aesthetics and hazards (Ossola and Hopton, 2018), as well as development (Pike, O'Herrin, Klimas and Vogt, 2021) and redevelopment (Willis et al., 2024; Lavy and Hagelman III, 2017; Morgenroth, O'Neil-Dunne and Apiolaza, 2017; Lee, Longcore, Rich and Wilson, 2017). It is plausible that these other incentives interact with those we document; we leave this exploration to future research.

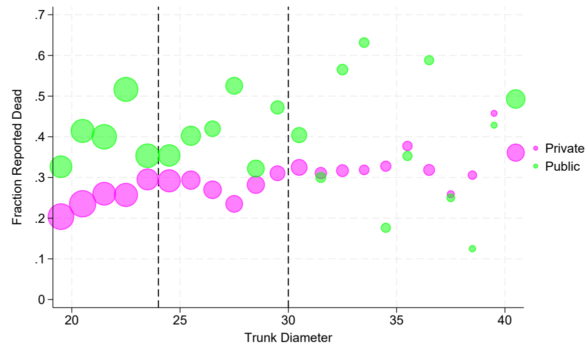
Surprisingly, our results do not raise concerns that the ordinance triggers dishonest permit claims about protected trees. Since we focused on the reporting of dead, hazardous, and encroaching trees, we cannot speak to the other issues inherent to these policies, including those documented by Clark, Ordóñez and Livesley (2020), who find that tree ordinances in Australia are undermined by exemptions, lack of enforcement, and inadequate penalties. Indeed, Lavy and Hagelman III (2017) confirm that exemptions are common and counter to policy objectives. Others have pointed out that enforcement is lacking, especially with regard to trees on private property, including Coughlin, Mendes and Strong (1988). We did not study

Figure 4: Fraction Reported Dead, Hazardous and Encroaching by Diameter

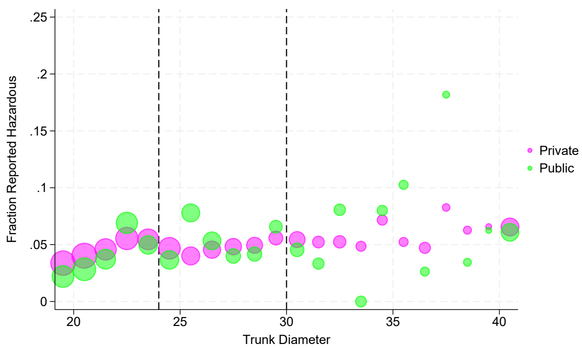
(a) Heritage Species, Dead



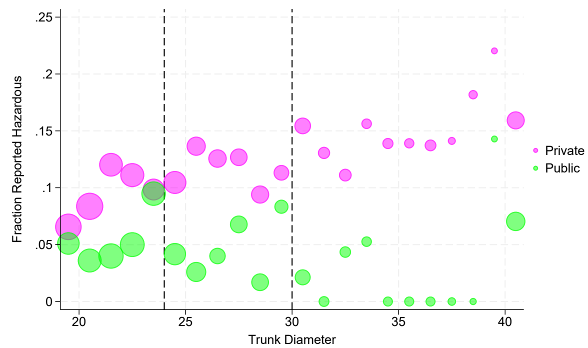
(b) Non-Heritage Species, Dead



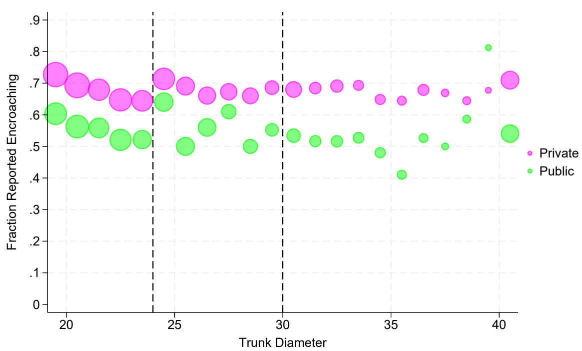
(c) Heritage Species, Hazardous



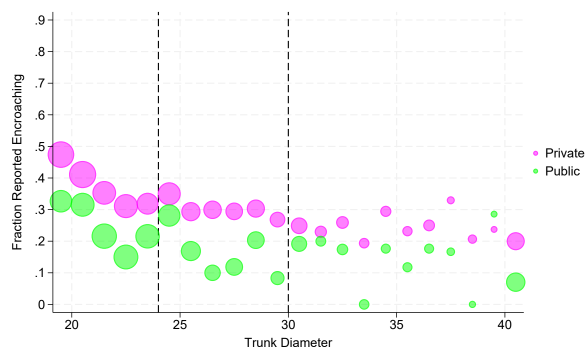
(d) Non-Heritage Species, Hazardous



(e) Heritage Species, Encroaching



(f) Non-Heritage Species, Encroaching



Notes: In Panel (a), we show the fraction reported dead for Heritage Species, whereas Panel (b) shows the fraction reported dead for Non-Heritage Species. In Panel (c), we show the fraction reported hazardous for Heritage Species, and Panel (d) shows the fraction reported hazardous for Non-Heritage Species. Panel (e) and (f) present the fraction reported encroaching for Heritage and Non-Heritage Species, respectively. The size of the dots depict counts of observations. In the figure, all permits with trunk diameter 40+ have been grouped for ease of interpretation. The sample includes only non-denied permits.

enforcement, but note that it is a fruitful topic for future research.

In sum, the results indicate that Austin's ordinance may not protect larger and heritage trees as intended. This is because the policy is undermined by preemptive cutting prior to reaching protected sizes. The perverse incentives we document are less likely to be generated by alternative policies like tax credits for preservation and re-planting campaigns. More broadly, our results highlight the importance of careful policy design in municipal environmental regulation, with implications for the 766 cities that have adopted similar ordinance structures. Moreover, the unintended impacts highlight the importance of empirical ex post analysis of environmental regulations, and of careful thought about the consequences of cutoff thresholds in policymaking more generally.

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Supplementary Appendix

A-1 Municipal Code Classification Procedures

We employed a natural language search for “tree protection ordinance” on NexisUni. We narrowed the results to municipal codes. We downloaded and processed all documents, in batches of 500, state by state. Not all of these documents were tree protection ordinances, however, since these three terms occurring anywhere in a document means it is downloaded.[16]

We determined whether a document is a tree protection ordinance using a list of phrases compiled based on reading the documents, including “heritage tree,” “rare tree,” “protected tree,” “notable tree,” and “landmark tree.”

To quantify the percent of tree ordinances characterized by a cutoff girth policy, we explored a broad set of phrases indicating both comparisons (e.g. “greater than”) and measurements (e.g. “feet”). The idea was to find such a phrase and identify a number in close proximity to it, and capture the text around it for inspection. Upon inspecting the output, we determined that the algorithm captured much irrelevant information.[17]

In light of this, we conducted a much narrower search for cutoff policies, using only the phrases “in.,” “inches,” “dbh,” ”diameter at breast height,” and double quotations, and requiring that they be preceded by a number between 5 and 50, reflecting realistic inch values for tree diameters.

The probable consequence of our narrower definition of what constitutes a cutoff tree girth is that our count of the number of tree policies characterized by such cutoffs is an underestimate, and thus the percentages of cities having such a cutoff policy (or of ordinance documents with this feature) are lower than the true percentages.

A-2 The Austin Tree Context

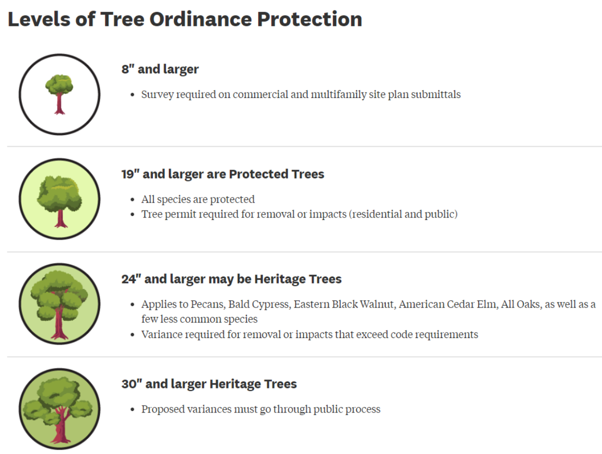
Figure A-1 shows a simple diagram designed to summarize the information on tree cutoffs and heritage trees for consumers.

Protecting Austin’s trees is a worthwhile goal. Nowak et al. (2016) conducted an inventory of trees in Austin, documenting city-specific ecosystem services provided by 33.8 million trees. They find that

[16] For example, the 1499th record from Alabama extracts a document called “Huntsville, Alabama Code of Ordinances Sec. 23-439 CODE OF ORDINANCES City of HUNTSVILLE, ALABAMA Codified through Ordinance No. 23-74, adopted February 9, 2023. (Supp. No. 26, Update 2).” This document is part of a municipal ordinance entitled ”Chapter 23 - STREETS, SIDEWALKS AND OTHER PUBLIC PLACES, ARTICLE VII., COMMUNICATIONS PROVIDERS, DIVISION, 3. SMALL CELL WIRELESS FACILITIES” Trees and protection are both pertinent to telecommunications infrastructure.

[17] For example, describing required distance from a driveway.

Figure A-1: Tree Protection Summary Graphic



Notes: This figure shows the graphic provided on City of Austin's Website to summarize the policy.

trees in Austin remove 1,300 tons of pollution a year (valued at $2.8 million/year), mitigate 5,900 tons of VOC exposure, store 1.9 million tons of carbon ($242 million), sequester 92,000 tons of carbon ($11.6 million/year). The total value of carbon emissions reductions is $4.9 million/year and they also conserve $18.9 million/year worth of energy in buildings.

Despite the benefits of preserving trees in Austin, the ordinance has not been without controversy. Famously, the governor of Texas opposed the policies because he needed to remove a tree to construct his pool. According to a 2017 news article featured in the Austin American-Statesman, "Abbott's tree chagrin apparently dates to 2011, when two large pecan trees stood in an area of the Central Austin property he owned while he was attorney general. He built a new home in 2011 and a pool in 2012, according to city records." (Findell, 2017) In a radio interview with Fort Worth's WBAP-AM, the governor expressed dismay that "Austin, Texas owns your trees. That is insanity" and referred to the protection ordinance as "socialistic." (Selby, 2017)

A-3 Data Details

A-3.1 Species Classification

According to the 2010 Tree Ordinance, which was built off of the 2006 Tree Ordinance (list below of species unchanged),

> HERITAGE TREE means a tree that has a diameter of 24" or more, measured four and one-half feet above natural grade, and is one of the following species: (a) Ash, Texas (b) Cypress. Bald (c) Elm, American (d) Elm, Cedar Pagel of 13 (e) Madrone, Texas (f) Maple. Bigtooth (g) All

Oaks (h) Pecan (i) Walnut, Arizona (j) Walnut, Eastern Black

Here, we outline our process for cleaning the tree species names in our permit data. First, we standardized the names by de-spacing, lower-casing and removing special characters. Then, tree names containing any of the following de-spaced phrases were designated as heritage species:

- americanelm
- arizonablackwalnut
- arizonawalnut
- armericanelm
- baldcypress
- bigtoothmaple
- caryaillinoensis
- cedarelm
- easternblackwalnut
- oak
- pecan
- texasash
- texasmadrone

Tree names containing any of the following de-spaced phrases were designated as non-heritage species:

- acacia
- airzonaash
- americanpersimmon
- anacua
- arizonaash
- arizonacypress
- arizonaelm
- boxelder
- bradfordpear
- brasil
- buckeye
- bumelia
- carolinaash
- carolinaash
- catalapa
- catalpa
- cedar
- cherrylaurel
- chinaberry
- chineseelm
- chineseparasol
- chinesepistache
- chinesetallow
- cottonwood
- crepemyrtle
- dogwood
- elder
- evergreen
- fig
- goldenrain
- greenash
- gumbumelia
- hackberry
- hickory
- holly
- japaneseparasol
- juniper
- kumquat
- lacebarkelm
- laurel
- ligustrum
- lilac
- locust
- londonplanetree
- magnolia
- mequite
- mesquite
- mexicanash
- mimosa
- mulberry
- mullberry
- palm
- paradise
- pear
- persimmon
- pine
- pomegranite

- poplar
- redbud
- siberianelm
- silvermaple
- soapberry
- sugarberry
- sweetgum
- sycamore
- tallow
- treeofheaven
- tulippoplar
- waferash
- willow

We designated the following tree descriptions as disambiguations:

- ash
- blackwalnut
- cypress
- elm
- maple

The results are presented in Table A-1. Unclassified/Unknown refers to those observations that did not fall in the above designations; the vast majority of these are either labelled as "unknown" or otherwise missing a description.

Table A-1: Counts of Classifications

	Count
Disambiguation	1,482
Heritage	32,995
Non-Heritage	14,049
Unclassified/Unknown	939

Notes: This is the result of the classifications of tree species into heritage and non-heritage species.

It remained unclear to us whether disambiguations should be classified as heritage trees. For this, we used the self-reported heritage tree variable, which is subject to error. This category would only apply in the dataset when the tree is >24" in diameter, so we present statistics on this subset of larger trees.

Table A-2 gives an initial sense of how disambiguations compare to the non-ambiguous species classifications.

Table A-2: Fraction of Each Disambiguation Category that is Reported as Heritage

	Fraction	*Count*
Disambiguation	0.473	484
Heritage	0.897	14,756
Non-Heritage	0.124	6,048
Unclassified/Unknown	0.419	93

Notes: This table depicts the percent of each of the above designations that is reported as heritage in the self-reported heritage tree variable.

The percent does vary by disambiguation category, though. See Table A-3.

Table A-3: Fraction of Each Disambiguation Category that is Reported as Heritage

	Fraction	*Count*
ash	0.175	252
blackwalnut	0.951	41
cypress	0.882	17
elm	0.777	166
maple	0.250	8

Notes: This table depicts the percent of each disambiguation category that is reported as heritage in the self-reported heritage tree variable.

Comparing Tables A-2 and A-3, we decided to not classify the disambiguations into either heritage or non-heritage. Maple trees might be most likely to be non-heritage, but with just 31 observations, it seemed most reasonable to simply exclude disambiguations since their fraction is very different than Heritage and also very different from Non-Heritage.

A-4 General Summary Statistics

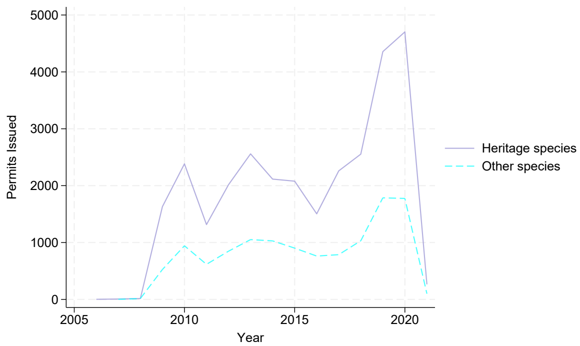
In Table A-4, we present summary statistics by whether the tree was a heritage species, broken out by private/public land and then pooled across land types. Figures A-2 through A-6 document general trends over time in the count of permits and each of the permit characteristics depicted in Table A-4. Lastly, Figure A-7 presents denials by diameter for both heritage and non-heritage species, broken out by private and public land.

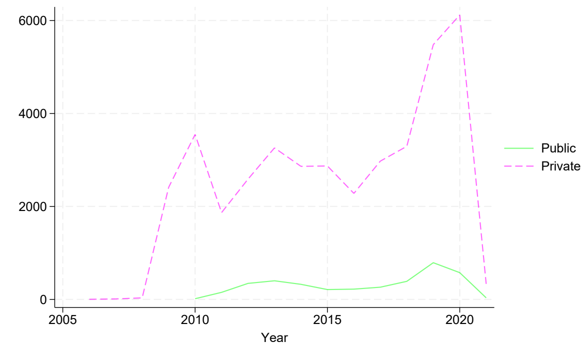
Table A-4: Summary Statistics by Whether Heritage Species

	Heritage Species					Non-Heritage Species				
	Mean	St. Dev.	Min	Max	Count	Mean	St. Dev.	Min	Max	Count
Private:										
Dead	0.133	0.339	0.000	1.000	27,349	0.276	0.447	0.000	1.000	10,948
Denied	0.028	0.164	0.000	1.000	27,349	0.015	0.121	0.000	1.000	10,948
Development-Related	0.736	0.441	0.000	1.000	27,349	0.400	0.490	0.000	1.000	10,948
Encroaching	0.675	0.468	0.000	1.000	27,349	0.323	0.468	0.000	1.000	10,948
Fee Required	0.656	0.475	0.000	1.000	27,349	0.381	0.486	0.000	1.000	10,948
Good Condition	0.512	0.500	0.000	1.000	27,211	0.178	0.382	0.000	1.000	10,888
Hazardous	0.049	0.216	0.000	1.000	27,349	0.113	0.316	0.000	1.000	10,948
Residential	0.946	0.225	0.000	1.000	20,036	0.912	0.283	0.000	1.000	8,238
Trunk Diameter	26.223	7.002	19.000	88.000	27,182	25.880	6.710	19.000	78.000	10,921
Public:										
Dead	0.238	0.426	0.000	1.000	2,419	0.404	0.491	0.000	1.000	1,227
Denied	0.007	0.086	0.000	1.000	2,419	0.011	0.106	0.000	1.000	1,227
Development-Related	0.570	0.495	0.000	1.000	2,419	0.225	0.418	0.000	1.000	1,227
Encroaching	0.551	0.497	0.000	1.000	2,419	0.202	0.402	0.000	1.000	1,227
Fee Required	0.555	0.497	0.000	1.000	2,419	0.211	0.408	0.000	1.000	1,227
Good Condition	0.392	0.488	0.000	1.000	2,413	0.103	0.304	0.000	1.000	1,226
Hazardous	0.048	0.215	0.000	1.000	2,419	0.046	0.211	0.000	1.000	1,227
Residential	0.703	0.457	0.000	1.000	2,115	0.403	0.491	0.000	1.000	1,078
Trunk Diameter	26.449	7.107	19.000	81.000	2,404	26.042	6.887	19.000	75.000	1,219
All:										
Dead	0.141	0.348	0.000	1.000	29,768	0.289	0.453	0.000	1.000	12,175
Denied	0.026	0.159	0.000	1.000	29,768	0.015	0.120	0.000	1.000	12,175
Development-Related	0.722	0.448	0.000	1.000	29,768	0.382	0.486	0.000	1.000	12,175
Encroaching	0.665	0.472	0.000	1.000	29,768	0.311	0.463	0.000	1.000	12,175
Fee Required	0.647	0.478	0.000	1.000	29,768	0.364	0.481	0.000	1.000	12,175
Good Condition	0.502	0.500	0.000	1.000	29,624	0.170	0.376	0.000	1.000	12,114
Hazardous	0.049	0.216	0.000	1.000	29,768	0.106	0.308	0.000	1.000	12,175
Residential	0.923	0.266	0.000	1.000	22,151	0.853	0.354	0.000	1.000	9,316
Trunk Diameter	26.241	7.011	19.000	88.000	29,586	25.897	6.728	19.000	78.000	12,140

Notes: This table presents summary statistics for all variables in our analysis, first for private land only (under "Private" subheading), then for public land ("Public" subheading), and then for all types of land ("All" subheading). The first 5 columns summarize each variable for Heritage Species, whereas the last 5 columns summarize the same for Non-Heritage Species.

Figure A-2: Trends in Permit Counts

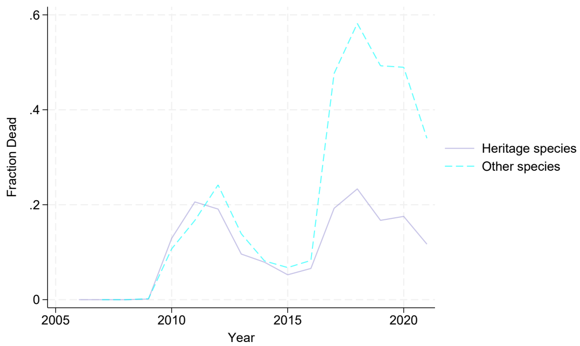




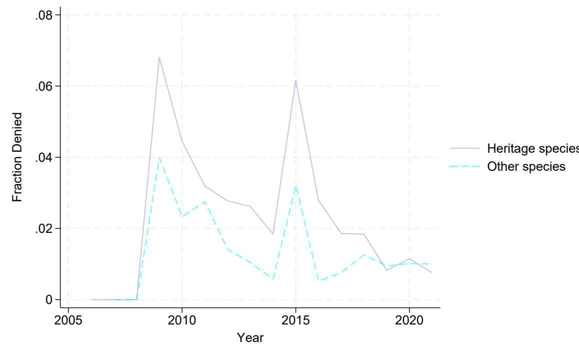
Notes: This figure presents the count of issued permits over time. Panel (a) compares permits across heritage and non-heritage species. Panel (b) compares permits across public and private land.

Figure A-3: Trends in Permit Characteristics by Whether Heritage Species

(a) Fraction Dead

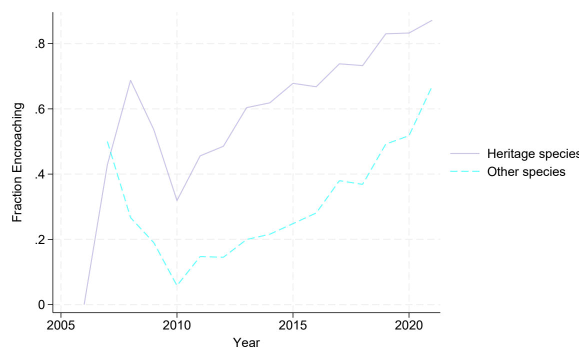


(b) Fraction Denied



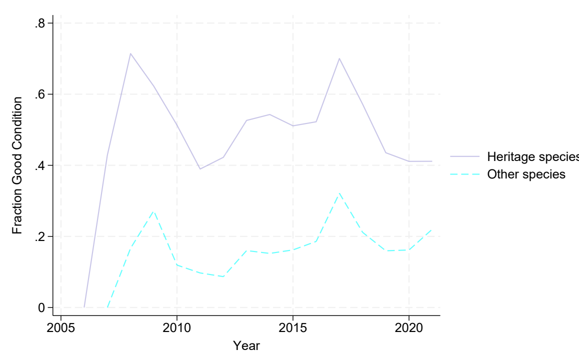
(c) Fraction Development-Related

(d) Fraction Encroaching



(e) Fraction Fee Required

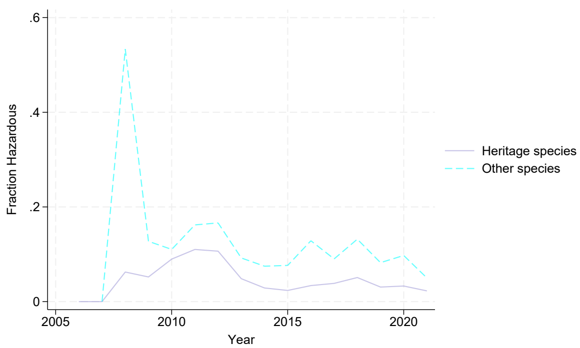
(f) Fraction Good Condition



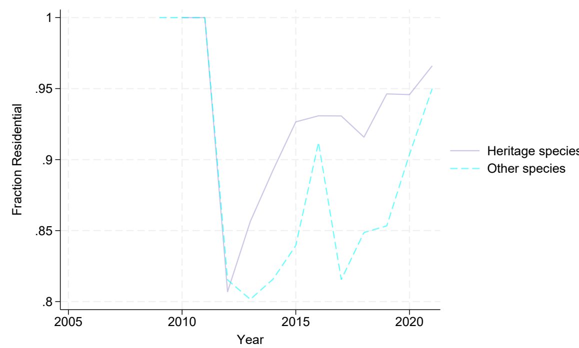
Notes: This table presents trends over time for heritage vs non-heritage species. In panel (a), we show the fraction of permits where the tree was reported dead. Panel (b) reports the fraction of permits denied over time. Panel (c) presents the fraction of permits related to development over time. Panel (d) depicts the fraction reported to be encroaching. Panel (e) depicts the fraction for which fees were required over time. Panel (f) presents the fraction reported to be in good condition.

Figure A-4: Trends in Permit Characteristics by Whether Heritage Species, Continued

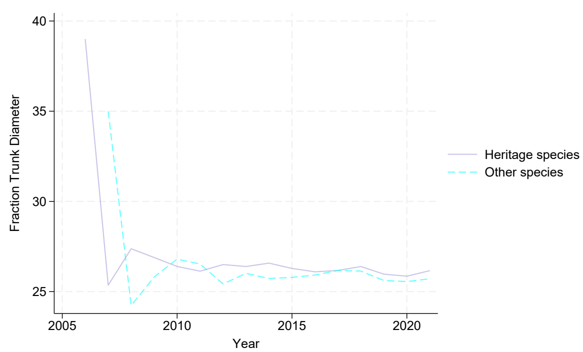
(a) Fraction Hazardous



(b) Fraction Residential

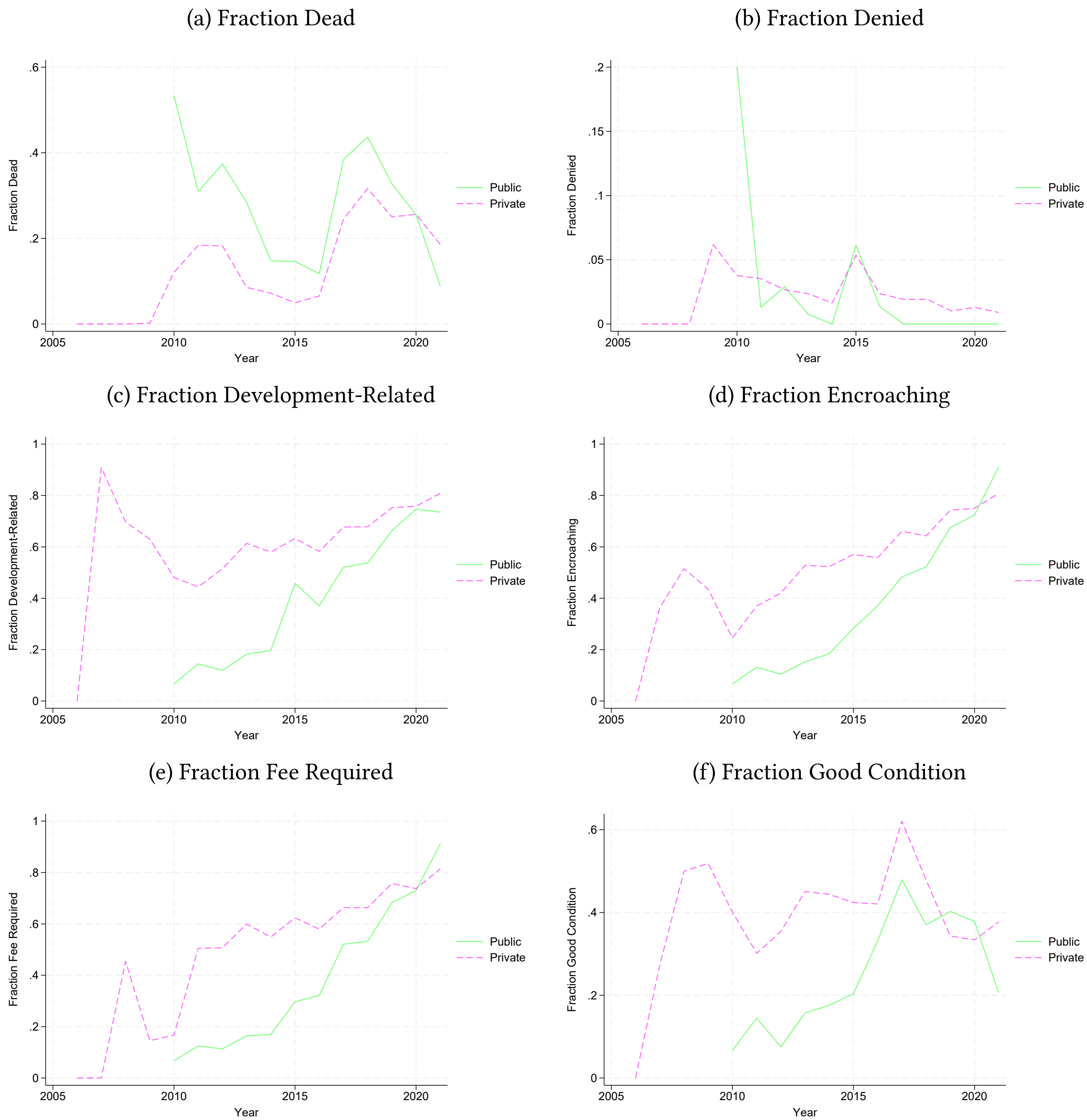


(c) Trunk Diameter



Notes: This table continues the presentation of trends over time for heritage vs non-heritage species (Figure A-3). In panel (a), we show the fraction reported to be hazardous over time. Panel (b) presents the fraction of residential permits. Panel (c) depicts the average trunk diameter over time.

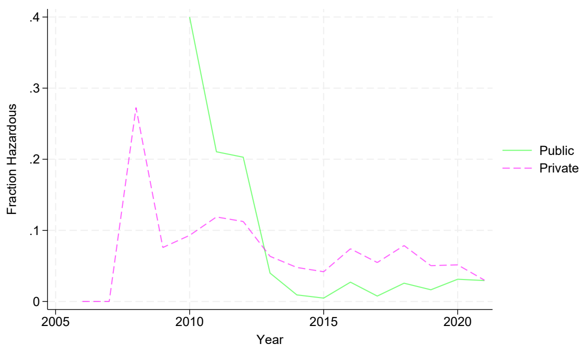
Figure A-5: Trends in Permit Characteristics by Private-Public



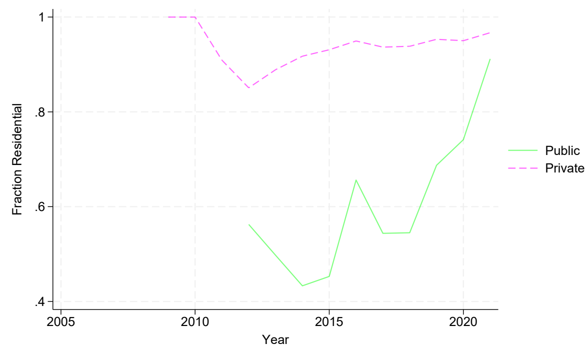
Notes: This table presents trends over time for private vs. public trees. In panel (a), we show the fraction of permits where the tree was reported dead. Panel (b) reports the fraction of permits denied over time. Panel (c) presents the fraction of permits related to development over time. Panel (d) depicts the fraction reported to be encroaching. Panel (e) depicts the fraction for which fees were required over time. Panel (f) presents the fraction reported to be in good condition.

Figure A-6: Trends in Permit Characteristics by Private-Public, Continued

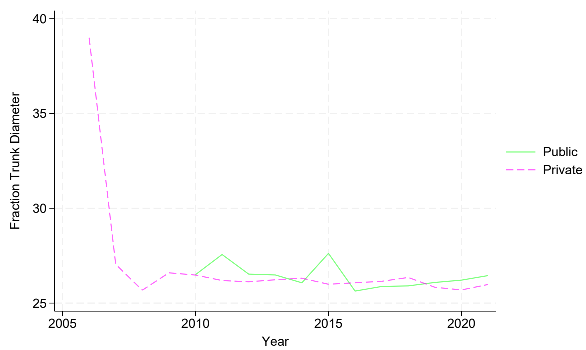
(a) Fraction Hazardous



(b) Fraction Residential



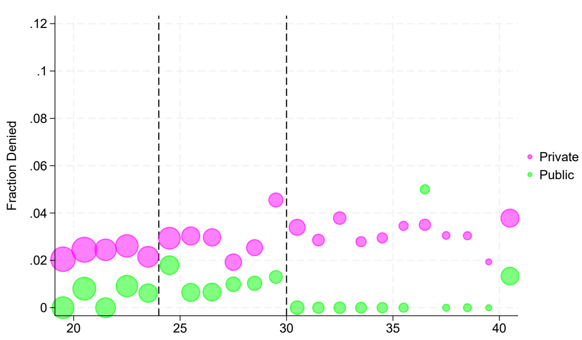
(c) Trunk Diameter



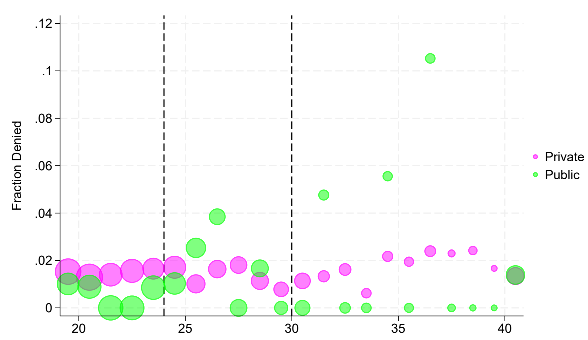
Notes: This table continues the presentation of trends over time for private vs. public trees (Figure A-5). In panel (a), we show the fraction reported to be hazardous over time. Panel (b) presents the fraction of residential permits. Panel (c) depicts the average trunk diameter over time.

Figure A-7: Fraction Denied by Diameter

(a) Heritage Species



(b) Non-Heritage Species

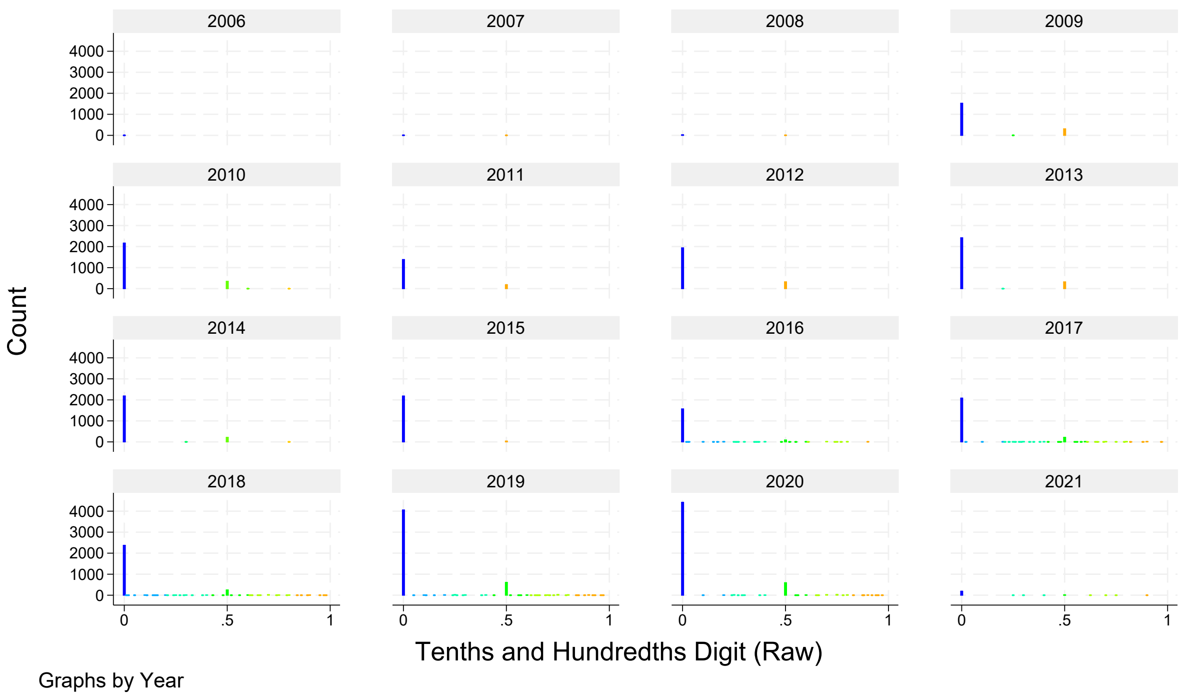


Notes: In Panel (a), we show the fraction denied for Heritage Species, whereas Panel (b) shows the fraction denied for Non-Heritage Species. The size of the dots depict counts of observations. In the figure, all permits with trunk diameter 40+ have been grouped for ease of interpretation.

A-5 Round numbers and Trunk Diameter Rounding Procedure

Our tree diameter data has at most 2 digits after the decimal point, and exhibits mass points at whole numbers and half numbers. The extent of the rounding is greater in earlier years (Figure A-8).

Figure A-8: Hundredths and Tenths Digit by Year

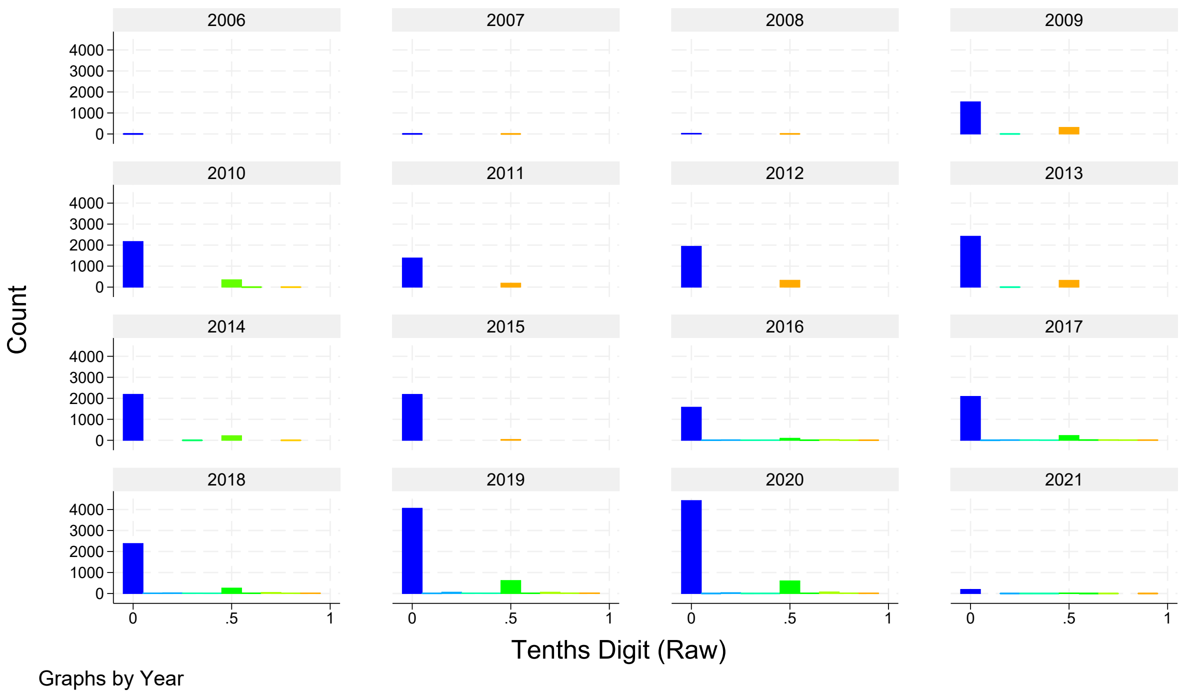


Notes: This figure shows the tenths and hundredths digit by year for all non-denied permits.

One practical challenge is the extent of round-number bunching, which can bias analyses relying on manipulation testing with techniques like McCrary (2008). We make use of techniques that adjust for mass points, but before doing so, we adjust the trunk diameter values so that within each integer trunk diameter, we have 9 tenths digit groups.[18] The natural way to do this is to create groups by rounding down, e.g. [0,.1),[0.1,.2),...,[0.9,next integer). But, we want to distinguish between values at a mass point vs. above the mass point, so we instead round down for all tenths digits after the first, but round up before the first. Thus, our categories are: 0, (0,.2), [.2,.3),...,[0.9,next integer). We refer to this altered variable in our paper as "Trunk Diameter (Tenths Digit Rounding)." To understand the changes in the distribution of tenths digits due to this rounding technique, we present Figure A-9 (traditional tenths digit categories) as well as Figure A-10 (our rounding scheme). The rounding up to distinguish between 0 and (0,.1) only affects 12

[18]We need a tractable number of tenths digit groups for our estimation of the propensity score to construct weights prior to local polynomial density estimation.

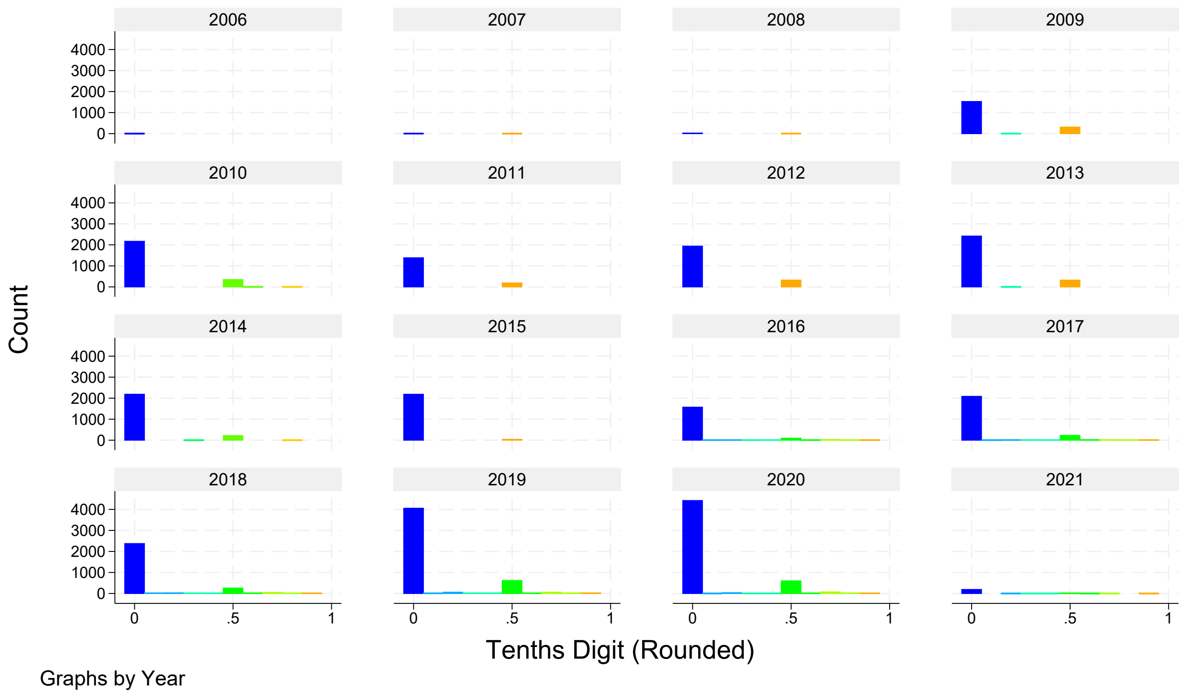
Figure A-9: Tenths Digit by Year



Notes: This figure shows the tenths digit by year for all non-denied permits, before the tenths digit is rounded such that all permits such that the digits after the decimal are ∈ (0,.1] are rounded up, and all other situations are rounded down to the nearest tenths digit.

observations, so the differences are imperceptible between the two figures.

Figure A-10: Tenths Digit by Year, With Rounding



Notes: This figure shows the tenths digit by year for all non-denied permits, after the tenths digit is rounded such that all permits such that the digits after the decimal are ∈ (0,.1] are rounded up, and all other situations are rounded down to the nearest tenths digit.

To visualize the mass points, we provide Figure A-11. Note that the number of public trees is lower.

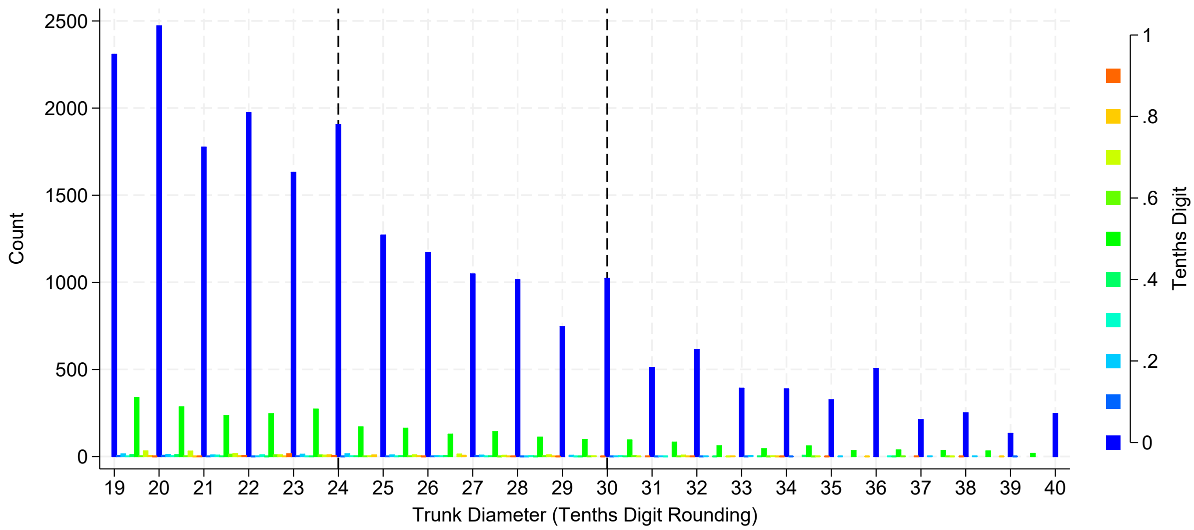
Next, we restrict to non-integer values (Figure A-12). This was done to probe the feasibility of omitting these numbers to address round numbers, as advocated by Kranz and Pütz (2022). We lose most of our sample when omitting integers.

A-5.1 Simple Histograms with 1-inch bins designed to exclude the thresholds

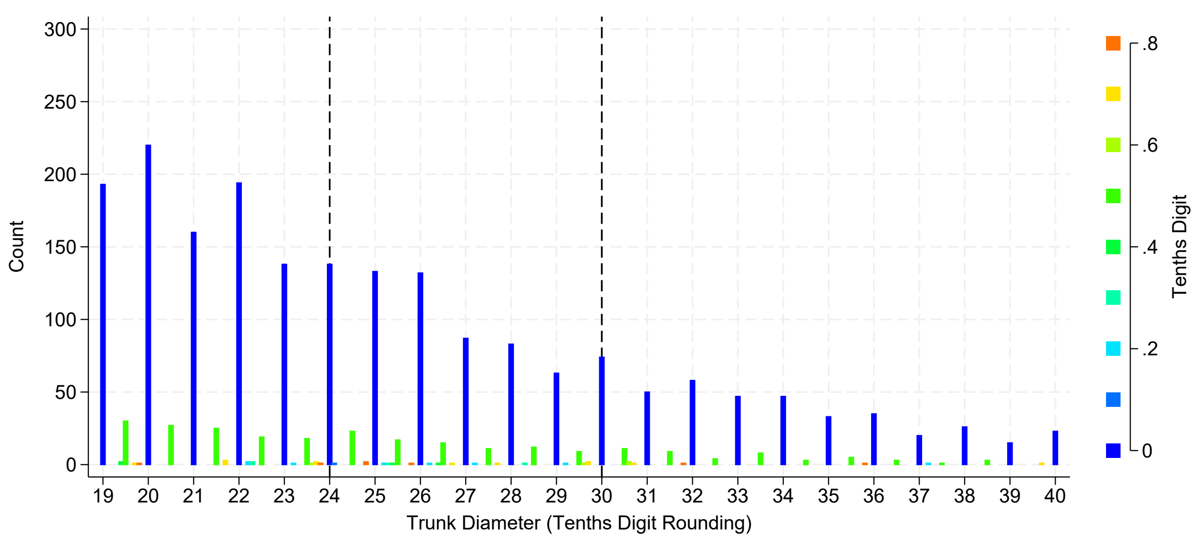
Since the data exhibits rounding and much rounding occurs at the 24" cutoff, we produce the histograms with 1-inch bins chosen such that none includes the threshold values in Figure A-13. The idea here is not to take a stand on how to group the values rounded to the thresholds, and to use the fact that the round number bunching can be handled by ensuring that all groups have length 1. The visual conclusion is very similar to what we see in Figure 3.

Figure A-11: Distribution of Heritage Species Permits by Private-Public

(a) Private



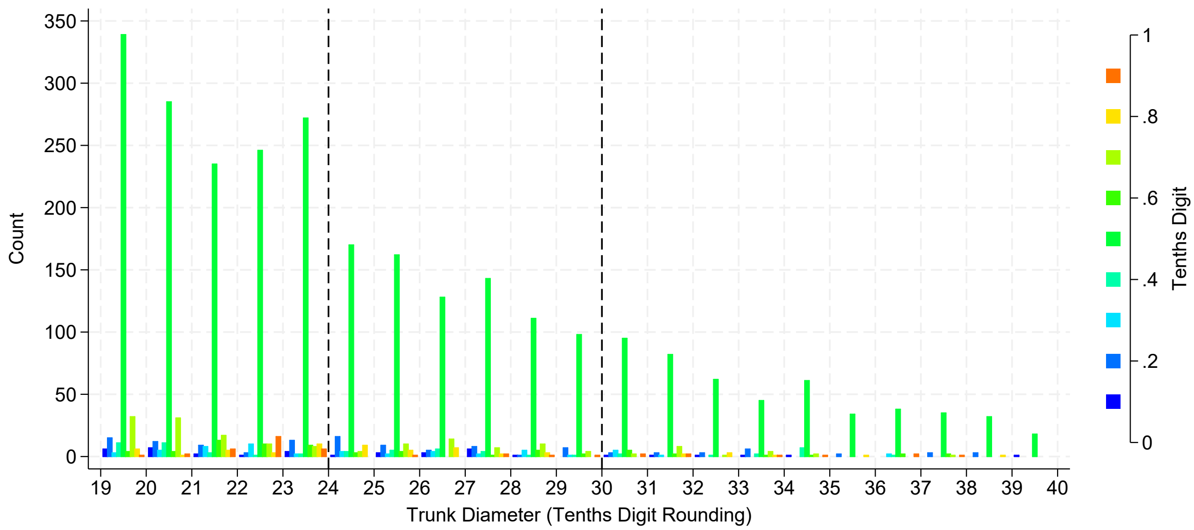
(b) Public



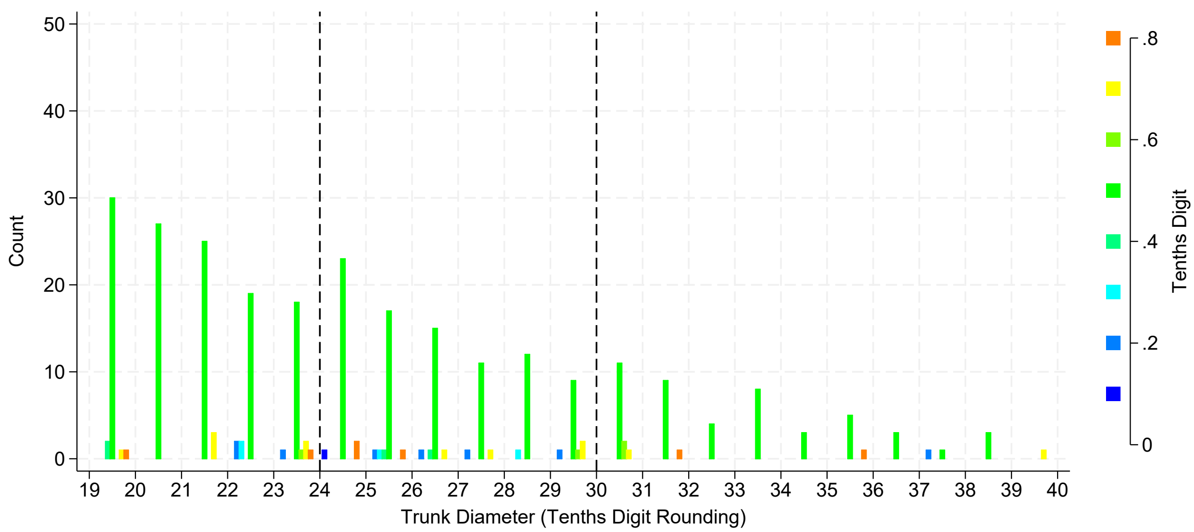
Notes: This figure shows counts of non-denied, non-development related tree permits with each diameter, where diameters are grouped by their first digit after the decimal to determine the color scheme. The sample in panel (a) is private heritage species and the sample in panel (b) is public heritage species. For readability, we present only diameters between 19 and 40 (inclusive of those endpoints). To differentiate between true mass points and non-mass points, we have grouped observations with tenths digit of 0 that are not integers with the 0.1 tenths digit group.

Figure A-12: Distribution of Heritage Species Permits by Private-Public, Non-integer Only

(a) Private



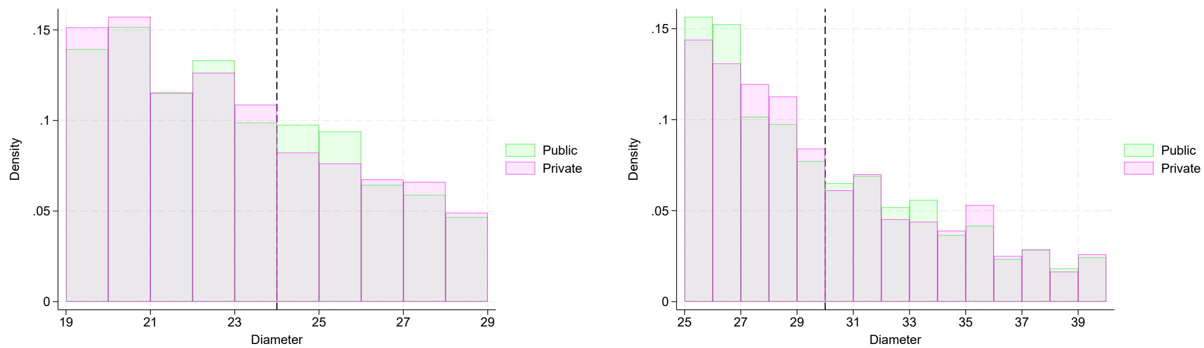
(b) Public



Notes: This figure shows counts of non-denied tree permits with each diameter, where diameters are grouped by their first digit after the decimal to determine the color scheme. The sample in panel (a) is private heritage species and the sample in panel (b) is public heritage species. For readability, we present only diameters between 19 and 40 (inclusive of those endpoints To differentiate between true mass points and non-mass points, we have grouped observations with tenths digit of 0 that are not integers with the 0.1 tenths digit group.

Figure A-13: Distribution of Private vs. Public Heritage Species, Excluding Thresholds

(a) 24” (b) 30”

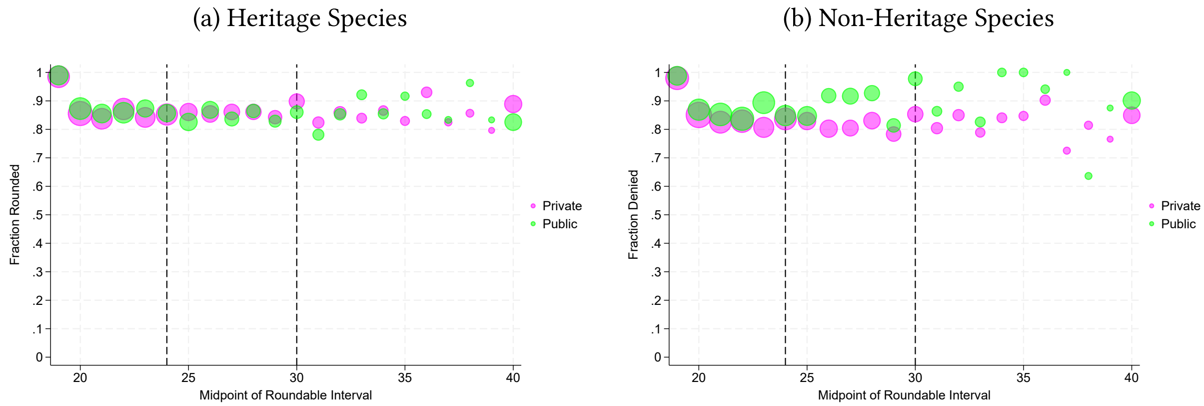


Notes: This figure shows histograms of private heritage and non-heritage species permits, excluding denied permits, by trunk diameter. The trunk diameter bins are constructed such that they each have width one and that none contains the cutoff value. That is, for panel (a), which examines the 24” threshold, the values are grouped as: [19,20)...[23,24), (24,25],...,(28,29]. For panel (b), which examines the 30” threshold, the values are grouped as [25,26)...[29,30), (30,31],...,(39,40].

A-5.2 Strategic Rounding

One might be concerned that some area around our two thresholds is subject to strategic rounding. To address this, we adapted the technique found in Andarge, Ghanem, Keiser and Lade (2024) to our 2-threshold context, but could not produce estimates due to convergence issues with the maximum likelihood. In lieu of their more formal approach, we simply present the fraction rounded by roundable interval in Figure A-14. A roundable interval with midpoint m is defined to be $[m-.5, m+.5)$. We do not find any visual evidence of excess rounding of private Heritage Species at the 24” or 30” thresholds. This is not surprising in our context, since there is no incentive to round differently near the threshold than when a tree’s diameter is not near the threshold. This is because the policy applies to trees 24” *and larger* and 30” *and larger*. So, purposeful rounding on the part of homeowners below the threshold would be rounding *up*, and would only increase the chance with which the tree faces additional hurdles to removal. And, purposeful rounding down would not exempt a larger tree from the same additional hurdles. This is in contrast with the situations in most other studies, where there are clear incentives to round either up or down, including: Andarge et al. (2024), Breunig, Deutscher and Hamilton (2024), Mikhed, Raina, Scholnick and Zhang (2024), and Ghanem et al. (2020). Instead, in our context, the trunk diameter data is rounded after it is determined whether it exceeds the threshold.

Figure A-14: Fraction Rounded by Roundable Interval



Notes: In Panel (a), we show the fraction rounded for Heritage Species, whereas Panel (b) shows the fraction rounded for Non-Heritage Species. The horizontal axis is the midpoint m of each roundable interval- that is, each dot groups all values in the range$[m - .5, m + .5)$. The size of the dots depict counts of observations. In the figure, all permits with trunk diameter roundable interval 40+ have been grouped for ease of interpretation.

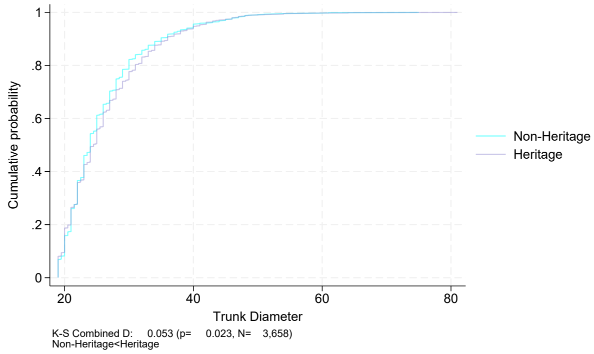
A-6 Analysis Details and Sensitivity Checks

A-6.1 Why not compare private heritage and private non-heritage?

Heritage and non-heritage species have different growth curves. To see whether private heritage and private non-heritage species are comparable in the absence of the perverse incentives created by the policy, we compare the overall empirical CDF for public heritage and public non-heritage trees. If one stochastically dominates the other according to the Kolmogorov-Smirnov test, then they are not comparable and we cannot use non-heritage species as a counterfactual for heritage species. We find a K-S combined p-value of 0.023, indicating that heritage species typically are cut at larger diameters, and the two groups are not comparable, establishing that non-heritage trees are not a valid counterfactual for heritage trees.

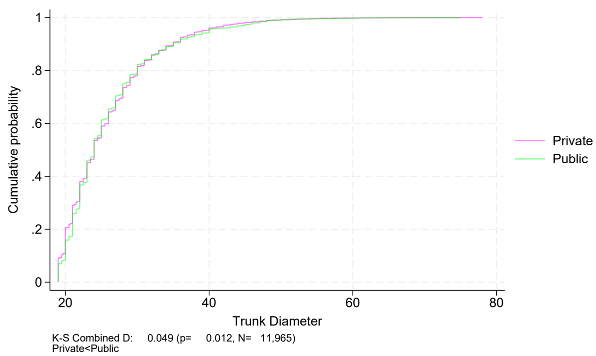
We additionally present the same for non-heritage species to compare public and private trees. This is a sort of placebo test since our treatment group is private heritage and our control group is public heritage. The D-value is slightly lower, indicating that comparing across public vs. private makes more sense than across non-heritage vs. heritage. The visual story also indicates that the comparison of public and private is more compelling.

Figure A-15: Empirical CDFs for Public Heritage and Non-Heritage Trees, all >= 19”



Notes: This figure presents the empirical CDFs for public heritage (lavender) vs. private heritage (cyan).

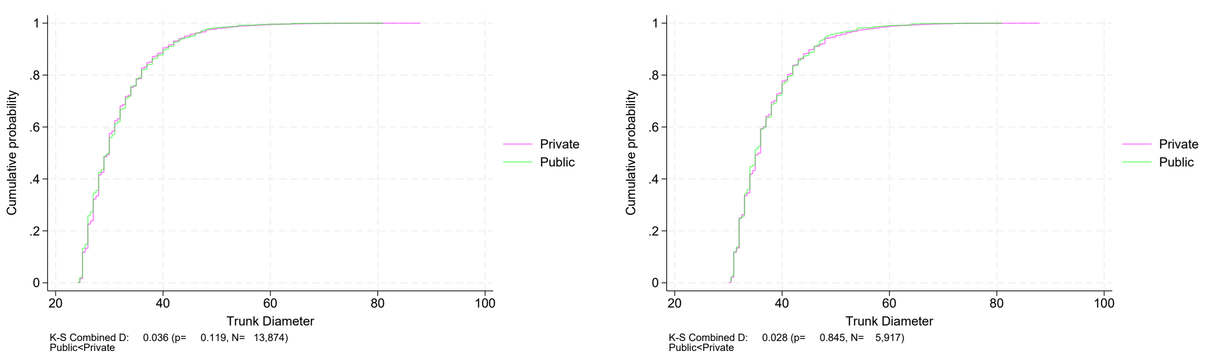
Figure A-16: Empirical CDFs for Non-Heritage Public and Private Trees, all >= 19”



Notes: This figure presents the empirical CDFs for non-heritage private (magenta) vs. public (lime).

Figure A-17: Sensitivity Check for Figure 2

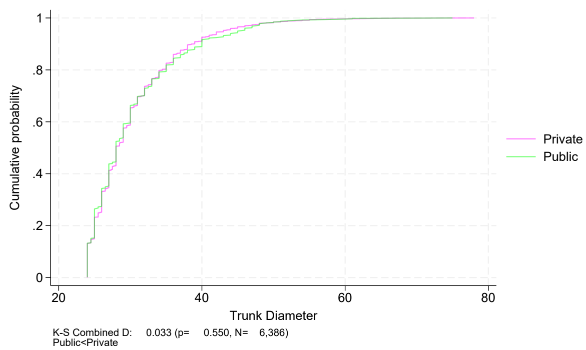
(a) >24” (b) >30”



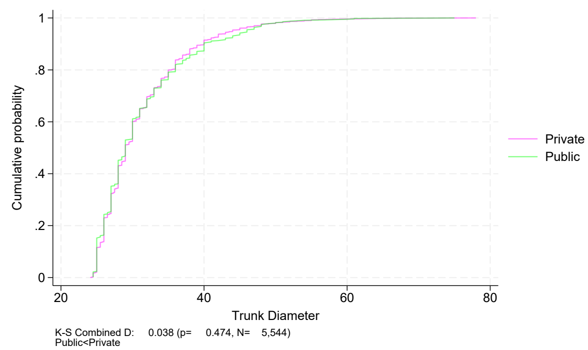
Notes: This figure compares the empirical cumulative distributions for public (lime) and private (magenta) heritage species. Whereas Figure 2 includes the relevant thresholds, here we exclude the relevant thresholds since the presence of whole number mass points could theoretically impact the results (but does not in this case). The Kolmogorov-Smirnov joint p-value is shown at the bottom of each figure. The sample includes only non-denied permits.

Figure A-18: Empirical CDFs for Non-Heritage Species, Conditional on Reaching 24 or 30”

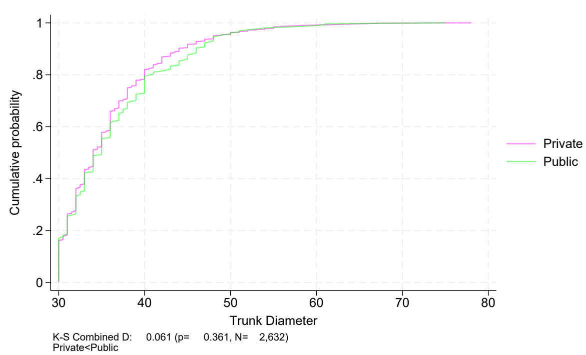
(a) ≥ 24”



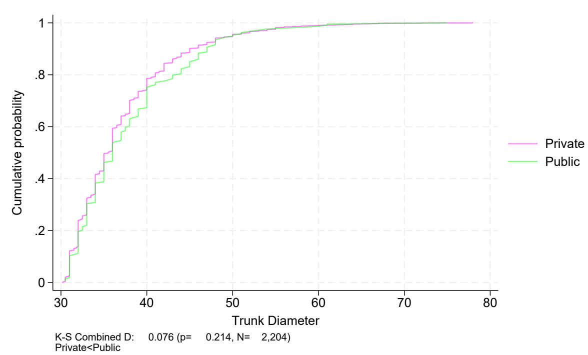
(b) >24”



(c) ≥ 30”



(d) >30”



Notes: This figure compares the empirical cumulative distributions for public (lime) and private (magenta) non-heritage species. The Kolmogorov-Smirnov joint p-value is shown at the bottom of each figure. We present the figures separately both including and excluding the relevant thresholds since the presence of whole number mass points could theoretically impact the results (but does not in this case).