The Political Economy of Conservation Buyouts

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Abstract

The federal government spends billions of dollars to induce additional conservation on private land annually, yet privately funded payments not to extract most federally-managed resources are forbidden by nineteenth-century "use-it-or-lose-it" statutes. Recent attempts to change these rules to allow private interests to advance voluntary "Coasean provision" of conservation on public lands have generated strong political backlash, despite the fact that they are based on voluntary exchange. We develop a model of public-resource governance with three parties (user, conservationist, government) that matches the institutional features of U.S. federal land management and characterize the distributional and welfare implications of allowing conservationists to acquire resource rights. We find that conservationists always gain from being allowed to trade, but that the impact on resource users, governments, and overall welfare depends on the interaction of several factors. Aggregate welfare can fall if government implicitly over-subsidizes conservation by setting conservation fees less than resource user fees. The extent to which these losses are borne by resource users vs. the government depends on how rights are initially allocated. Crucially, free allocation of initial rights paired with conservation fees set equivalent to extraction fees is Pareto-improving and unambiguously welfare-improving. Calibrations to federal grazing and federal timber suggest that allowing buyouts could be welfare improving within the range of plausible damage estimates, and the incidence of gains and losses is consistent with the political economy of recent federal policy debates.

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1 Introduction

Market-based approaches to environmental regulation have gained ground steadily over the past five decades. Where command-and-control rules mandate specific technologies, inputs, or processes, market-based instruments in the tradition of Coase (1960) and Pigou (1932) either price the externality or cap the activity that produces it and rely on agents' optimizing behavior to deliver cost-effective abatement (Weitzman, 1974; Banzhaf et al., 2013; Stavins, 1995, 2003). In the context of natural resources, voluntary trade is celebrated in environmental economics as a leading instrument for addressing externalities generated by *private* resource use via mechanisms including conservation easements, payments for ecosystem services, and outright land acquisition and preservation (Parker, 2004; Anderson and Libecap, 2014; Salzman et al., 2018). The concern with market approaches is not that they are ineffective, but that they may be under-supplied without government intervention.

However, recent literature has emphasized that voluntary contributions to environmental public goods—by donors, environmental NGOs, and conservation-minded firms—are widespread and growing in prevalence, contrary to the standing assumption in classical Pigouvian analysis that voluntary abatement is negligible (Bergstrom et al., 1986; Andreoni, 1990; Kotchen, 2006). Recent theoretical work has accordingly revisited optimal instrument choice in settings where conservationists can directly intervene to lessen externality-generating activity or compensate extractors not to extract, a phenomenon termed *Coasean provision* (Costello and Kotchen, 2022; Chan, 2024; Chan and Kotchen, 2014, 2022). Working examples are by now varied: whale-protection contracts (Costello et al., 2012; Huang et al., 2017), supply-side carbon buyouts (Harstad, 2012; Asheim et al., 2019), and donor-funded freshwater transfers (Leonard et al., 2020).

We study Coasean provision in the context of *public natural resource* governance, where two features of the institutional environment make voluntary provision a different problem than has previously been studied. First, publicly owned natural resources are subject to *both* a quantity cap and a per-unit fee whose levels are set politically rather than optimally—federal grazing, timber, and oil-and-gas lease offerings (and prior-appropriation water rights) all share this structure (Leshy et al., 2021). Second, "use-it-or-lose-it" requirements written into still-prevailing nineteenth-century statutes preclude conservationists from acquiring extraction rights for the express purpose of holding them out of production (Leonard and Regan, 2019; Leonard et al., 2021).

Even as the federal government spends over \$10 billion annually paying private landowners to supply environmental public goods—through tools such as subsidized conservation easements (Parker and Thurman, 2018), the Conservation Reserve Program, and the Environmental Quality Incentives program—this approach is structurally forbidden on federal land.[1] Unlike for most externalities where voluntary provision is allowed but potentially under-supplied, voluntary Coasean provision is itself a policy parameter on federal lands. Moreover, recent attempts to

[1] It is estimated that annual foregone revenues from federal tax incentives for conservation easements are \$6.5 billion (Basche et al., 2020), while annual spending under the CRP reaches \$1.8 billion (Cramton et al., 2021) and EQIP spending exceeds \$2 billion annually (Feld et al., 2022).

allow such provision have proven politically fraught.

The "Public Lands Rule" initially adopted by BLM in 2024 provides an illustrative example. The rule explicitly recognized conservation as a valid "use" of federal land on par with activities like grazing and oil and gas extraction, and created a loose framework for Coasean provision-like arrangements through "conservation leases" and "restoration leases" (Ruple et al., 2023; Bureau of Land Management, 2024). Extractive industries, agricultural groups, and Western state governors staunchly condemned the rule, arguing that by allowing third parties to effectively lock up public acreage, the Biden administration was orchestrating a zero-sum transfer of land control that posed an existential threat to grazing rights, energy development, and the economic survival of rural communities (Ruple et al., 2023). The new Trump administration signaled rescission of the rule as one of its top priorities, and in April 2026 the White House Office of Information and Regulatory Affairs (OIRA) officially concluded its review, clearing the final regulatory pathway to formally revoke the rule's market-based provisions Stevenson (2026).

This saga—and the broader dynamic it illustrates—raises several important questions about Coasean provision for publicly managed natural resources, often termed "non-use" rights in this context. First, given the *voluntary* nature of Coasean provision, why does it generate such fierce opposition? Specifically, who wins and who loses from allowing conservation interests to acquire "non-use" rights, and under what conditions? Second, how do these distributional gains and losses aggregate into overall welfare? We show that the answer to both questions—and the connection between them—depends critically on the interplay of two institutional parameters for public natural resources: the mechanism for initially allocation rights and the implicit subsidy to conservation contained in administratively set fees.

We model three parties—the resource user U, the conservationist C, and the government G—and parameterize the policy environment with three levers: an overall extraction cap, the allocation regime (rights are either freely allocated to U or sold via auction) and the relative magnitudes of the per-unit fees charged to resource users (f) vs. conservationists (k). We model equilibrium resource use and the distribution of welfare without Coasean provision and then characterize impacts to each party and to overall welfare if Coasean provision is allowed. We do not assume that policy is initially calibrated optimally. Four results follow. First, the distributional incidence of Coasean provision is as follows: conservationists always gain, resource users gain under free allocation and lose under auction, the government weakly loses under free allocation (with ambiguous implications under auction). Second, aggregate welfare can fall due to Coasean provision for the same reason emphasized by Costello and Kotchen (2022): if $k < f$ then the government may be over-subsidizing conservation, leading to welfare-reducing "overshoot" whereby extraction falls below the optimal level.

Our third core result is that aggregate welfare is *allocation-invariant*: free allocation and auction yield identical welfare at any particular f vs. k fee wedge. This is because aggregate welfare depends only on the equilibrium extraction quantity, which is determined entirely by f vs. k, not the allocation mechanism. Finally, we show how the two pieces fit together. While aggregate welfare does not depend on the allocation mechanism, its incidence does. In the welfare-reducing overshoot regime, the loss falls uniquely on the government under free allocation. Under an auction, welfare losses are either split between resource users and the government ($k < f$) or borne entirely by resource users ($k = f$). Jointly, these results yield a direct policy implication: free allocation paired with $k = f$ is the unique configuration that is both unambiguously welfare-improving and Pareto-improving.

We provide two extensions to the model to show how the core results are affected by real-world considerations such as free-riding and transaction costs. We then illustrate the framework with calibrations to federal grazing and federal timber. We find that allowing Coasean provision is likely to increase overall welfare for both resources. The distributional implications are more nuanced. For grazing rights, which are freely allocated, the government loses revenue when $k = 0$, but these losses can be averted by charging conservationists for foregone grazing fees ($k = f$), yielding a weak Pareto improvement. For timber, which is auctioned, existing resource users suffer losses regardless of the level of k because equilibrium prices rise due to the entrance of conservationists as competitive bidders.

We extend the emerging literature on voluntary Coasean provision in two directions. First, we shift the focus from welfare to distributional incidence: holding aggregate welfare fixed by allocation invariance, we ask which party bears the welfare change at each fee wedge, and find that the loss-incidence pattern depends on allocation regimes (auctions vs. free allocation). Second, recent work demonstrates that optimal policy differs in the presence of voluntary contribution to environmental public goods (Costello and Kotchen, 2022; Chan, 2024), but we ask a different question. Rather than characterize optimal policy with vs. without Coasean provision, we study the distributional and welfare implications of allowing Coasean provision in the context of policy that is not calibrated optimally *ex ante*. Our framework generalizes to any cap-and-fee setting where voluntary contributions to a public good interact with a regulatory quantity instrument, including fishery-quota retirements and supply-side carbon buyouts.

2 Background and Model

2.1 Context

Many natural resource stocks are owned and managed by governments. One reason for this is widespread government ownership of land. In the United States the federal government owns roughly 30% of the land, including about half the land in the American West. As a result, government manages considerable oil, gas, and mineral deposits, timber, and grazing resources across agencies including the Bureau of Land Management, the U.S. Forest Service, and various state governments. In addition, federal and state governments manage surface water and marine ecosystems. Globally, most governments retain ownership and management of subsurface resources, even when land is privatized (unlike in the United States). Finally, externality-related cap-and-trade markets can be thought of within this framework, to the extent that the government initially owns all the pollution permits it creates before allocating them to firms.

In the United States, the statutory rules governing each of these resources entails both a quantity instrument and a per-unit fee (Leshy et al., 2021). The Bureau of Land Management (BLM) sets the annual ceiling on authorized animal-unit months for federal grazing and charges $1.35/AUM under a statutory formula (Vincent, 2019). The U.S. Forest Service sets allowable cut and recovers per-MBF administrative costs on each sale, with bid premia layered on top in competitive auctions (Athey et al., 2011). BLM determines lease offerings for federal oil and gas, allocates them via competitive auctions, and collects production-stage royalties. None of these quantity-and-fee parameters is set by an externality calculation; instead, they are institutional hangovers—e.g, the 1934 Taylor Grazing Act fee formula, the multiple-use mandates of the National Forest Management Act, the 1920 Mineral Leasing Act royalty structure, and a century of state-by-state water adjudications—that were geared toward promoting resource use during Westward expansion, rather than aligning marginal social cost of extraction with the price that resource users face (Leshy et al., 2021; Leonard and Regan, 2019).

The historical desire to promote development of the nation's resources has a second important legacy still shaping resource allocation. Statutory "beneficial-use" and "diligent-development" requirements bar the acquisition of extraction rights for the express purpose of holding them out of production: a permit or lease must be grazed, drilled, or harvested or it can be canceled and reissued to another party. The legal genealogy traces to the General Mining Law of 1872, the Mineral Leasing Act of 1920, the Taylor Grazing Act of 1934, and the prior appropriation doctrine for surface water, which together were designed to prevent speculation and absentee ownership during westward expansion (Leonard and Regan, 2019; Leonard et al., 2021). These requirements forced productive entry and limited the monopolistic rent-extraction strategies that nineteenth-century land speculators had used elsewhere. Their consequence today is that conservation organizations cannot acquire and retire extraction rights even when their willingness to pay strictly exceeds the resource users' reservation price.

There have been recent attempts to address the structural barriers to voluntary, privately funded conservation of federal resources, but they have proven to be politically contentious. For example, the 2024 Public Lands Rule (Bureau of Land Management, 2024) redefined conservation as a legitimate "use" of federal land for purposes of grazing-permit eligibility and introduced "restoration leases" and "mitigation leases" as new use categories that place rangeland in non-extractive status under regulator approval—a partial relaxation of beneficial-use, limited to the BLM grazing side (Ruple et al., 2023; Henderson, 2025). Within months, Wyoming and Utah filed federal-court challenges (State of Wyoming, 2024; State of Utah, 2024), an industry coalition led by the Public Lands Council filed in parallel (Public Lands Council, 2024), and Congressional reversal proposals followed (U.S. Congress, 2024). The opposition's economic logic centered on lost state revenue from grazing permits and on the prospect of conservation buyers entering rangeland markets at scale. The rule, which is being formally rescinded by the BLM (Stevenson, 2026), diverged in important ways from the idealized model we present below. Nevertheless, the dramatic political reaction to a rule that would have expanded the scope for *voluntary* trades help provide motivation for our model. Our goal is to provide the analytic structure to better understand which parties gain, which lose, and whether aggregate welfare improves under any candidate configuration of allocation and fees.

2.2 Model setup

The model has three actors. A resource user U derives benefits from the consumptive use or extraction of a publicly owned natural resource, denoted Q. The aggregate marginal benefit of extraction $MB(Q)$ is the horizontal sum of users' willingness to pay across marginal units; we assume $MB(Q)$ is positive and weakly decreasing on the relevant range. A conservationist C faces marginal damages from extraction, which could include ecological loss, foregone non-use value, climate damages. Conservation impacts are represented by damage function $MD(Q)$, which we assume is weakly increasing (Krutilla, 1967). A government G owns the underlying resource and sets the policy environment.

There are two critical policy levers. The first is a quantity cap $\bar{Q}$, exogenously set, on the maximum allowable extraction. The second is a fee schedule: a per-unit extraction fee f collected from U and, when buyouts are permitted, a per-unit conservation fee k collected from C on each conserved unit. We treat $0 \leq k \leq f$ as the policy-relevant range. Orthogonal to the fee schedule is the allocation regime—the mechanism that initially distributes extraction rights. Under *free allocation*, U receives all $\bar{Q}$ rights at no cost (subject to paying f on each extracted unit) and may sell unused rights to C at the market-clearing price. Under *auction*, the government allocates rights via uniform-price auction; U and C bid against one another, the rights clear at the highest losing bid, and revenue accrues to G. The two regimes correspond loosely to the status quo for federal grazing (free allocation) and federal timber (auction); they can be though of as two natural benchmarks rather than as the universe of possibilities.

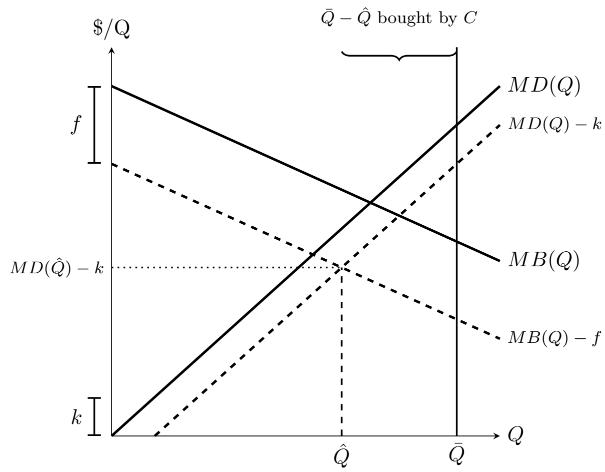
We begin with general functional forms to establish the properties of potential conservation buyouts. Figure 1 below uses a linearized parameterization for visual clarity, but Propositions 1–5 hold for any MB, MD satisfying the monotonicity assumptions.

2.3 Equilibrium with vs. without non-use rights

Without buyouts, the extraction cap binds whenever U's marginal benefit at $\bar{Q}$ exceeds the fee, $MB(\bar{Q}) > f$, and equilibrium extraction is $\bar{Q}$. The case $MB(\bar{Q}) \leq f$ collapses to a fee-only regime in which the cap is slack; we treat this as outside the scope of the analysis and focus on the binding-cap case throughout. When buyouts are permitted, C purchases extraction rights as long as the per-unit cost of acquiring a right falls below the marginal damage avoided by conserving it. C's effective per-unit cost is the price paid to U plus the conservation fee paid to G, and U's reservation price is the marginal extraction profit forgone, $MB(Q) - f$. The marginal trade clears where C's willingness to pay equals U's reservation price—equation (1) below defines the equilibrium extraction quantity $\hat{Q}$. At this equilibrium, C purchases $\bar{Q} - \hat{Q}$ rights (either from U or G and withholds them from production.

$$MB(\hat{Q}) - f \;=\; MD(\hat{Q}) - k. \tag{1}$$

Figure 1. Equilibrium with non-use rights



Notes: The cap $\bar{Q}$ would bind in the absence of buyouts. The per-unit price line $MD(\hat{Q}) - k = MB(\hat{Q}) - f$ defines the equilibrium extraction quantity $\hat{Q} < \bar{Q}$. Conservationists buy the rights to $\bar{Q} - \hat{Q}$ units at the equilibrium price.

Three regimes are possible depending on where $\hat{Q}$ falls relative to the cap and to the social optimum Q^* (the unique quantity solving $MB(Q^*) = MD(Q^*)$). We refer to them as the *irrelevance regime* ($\hat{Q} = \bar{Q}$, no buyouts occur), the *improvement regime* ($Q^* \leq \hat{Q} < \bar{Q}$, buyouts conserve units that should not be extracted), and the *overshoot regime* ($\hat{Q} < Q^*$, buyouts conserve units beyond the social optimum). Whether the equilibrium falls in the improvement or the overshoot regime depends entirely on the magnitude of the fee wedge $f - k$, as Proposition 1 makes precise.

Proposition 1 (Equilibrium characterization)**.** *Suppose $MB' < 0 < MD'$ and $MB(\bar{Q}) - MD(\bar{Q}) < f - k$. Then there exists a unique $\hat{Q} < \bar{Q}$ satisfying* (1)*, and*

$$\frac{\partial \hat{Q}}{\partial f} = \frac{1}{MB'(\hat{Q}) - MD'(\hat{Q})} < 0, \qquad \frac{\partial \hat{Q}}{\partial k} = -\frac{1}{MB'(\hat{Q}) - MD'(\hat{Q})} > 0, \qquad \frac{\partial \hat{Q}}{\partial \bar{Q}} = 0.$$

If instead $MB(\bar{Q}) - MD(\bar{Q}) \geq f - k$, then $\hat{Q} = \bar{Q}$ and no buyouts occur. (Proof in Appendix A.1.)

There are several important implications of Proposition 1. First, raising the extraction fee f lowers U's reservation price for selling rights and so contracts equilibrium extraction; raising the conservation fee k lowers C's effective willingness to pay and so expands extraction. Second, the cap $\bar{Q}$ does not appear in the interior equilibrium condition—once buyouts are active, the cap is no longer the binding constraint on extraction. This is a basic consequence of allowing voluntary trade on top of regulatory quantity instruments: the equilibrium extraction quantity is determined by relative prices, with the cap serving as a boundary condition that determines whether trade occurs at all.

Corollary 1.1 (Welfare-irrelevance regime)**.** *If $f - k \leq MB(\bar{Q}) - MD(\bar{Q})$, then $\hat{Q} = \bar{Q}$, no buyouts occur, and $\Delta W = \Delta C = \Delta U = \Delta G = 0$. (Proof in Appendix A.1.)*

Corollary 1.1 identifies the boundary at which Coasean provision is effectively foreclosed by the policy environment. When the fee wedge $f-k$ is too small relative to the gap between marginal benefit and marginal damage at the cap, C's willingness to pay never exceeds U's reservation price, and no trade occurs even when the law permits it. An extreme case would be one where the cap is set efficiently ex ante ($\bar{Q} = Q^*$) and conservationists are charged equivalent fees to users ($f = k$). As the f vs. k wedge increases, so does the scope for transactions. As we show below, whether these transactions increase or decrease welfare depend on the stringency of the cap relative to optimal extraction. Before turning to aggregate welfare, we characterize the distributional incidence of the gains and losses from allowing Coasean provision.

3 Distributional implications

3.1 Allocation mechanisms

The allocation regime—the mechanism by which the government distributes initial extraction rights—plays a central role in shaping the distributional implications of allowing Coaseian provision. This choice is orthogonal to the fee schedule, and the two regimes we consider correspond to the two natural benchmarks in U.S. public-resource policy. Under *free allocation*, the government grants extraction rights to U at zero cost. U is then free to extract or to sell unused rights to C at the market-clearing price; a conservationist who acquires a right pays the market price p to U and the conservation fee k to G for a total per-unit cost of $p + k$. The current federal grazing regime is the closest empirical analog—ranchers must hold permits corresponding to a certain amount of grazing (denominated in animal unit months). These permits were initially allocated under the Taylor Grazing Act in 1934 and are grandfathered to ranching operations. However, in addition to the necessary permits, ranchers pay a fee per unit of actual grazing that has hovered around \$1.35/AUM for decades (Leshy et al., 2021).

Under *auction*, the government allocates all $\bar{Q}$ rights through an auction in which U and C both bid; the rights clear at the marginal-loser bid (a second-price auction), revenue accrues to G, and successful bidders pay any extraction or conservation fees in addition to the auction price.[2]

[2] The auction expressions in Proposition 2(b)–(c) assume a uniform-price auction with marginal-loser pricing and price-taking by U and C. Demand reduction by strategic bidders (Ausubel et al., 2014), pay-as-bid rules, and reserve prices below marginal cost can each break the clean expressions below; the qualitative result—that U's welfare falls and G's welfare picks up an auction-revenue rebound—is robust, but the magnitudes depend on the auction format. Federal timber sales clear at competitive auction (Athey et al., 2011) with administrative cost-recovery fees layered on top, but use sale-by-sale oral or sealed-bid procedures rather than a uniform-price auction over an aggregate $\bar{Q}$; the calibration in Section 6.3 accordingly approximates rather than implements the model auction.

Federal timber sales are one example: stumpage rights clear at a competitive price, with administrative cost-recovery fees layered on top. Oil and gas leases are another: leases are allocated via competitive bids paid as an up-front "bonus," and producers subsequently pay a statutorily set royalty on any production.

A key feature of equilibrium under both regimes is that the equilibrium extraction quantity $\hat{Q}$ is determined by the same condition—the marginal-trade indifference described in Equation (1)—and is therefore identical across allocation regimes. Allocation determines who captures the surplus on the $\bar{Q}-\hat{Q}$ traded units, but it does not determine the location of the marginal trade. We use this lemma throughout: the welfare results in Section 4 aggregate over U, C, and G in a way that is allocation-invariant, but the distributional results in this section depend critically on whether rights are auctioned or grandfathered.

3.2 Per-party welfare changes

The change in each party's welfare from allowing buyouts is the difference between its with-buyouts and without-buyouts payoffs. Without buyouts, U extracts $\bar{Q}$ and pays $f\bar{Q}$ in extraction fees; C bears damage $\int_0^{\bar{Q}} MD(q)\,dq$ and makes no payments; G collects $f\bar{Q}$ in fees under free allocation, or $\bar{Q}\,MB(\bar{Q})$ in auction revenue plus extraction fees under auction. With buyouts, U extracts only $\hat{Q}$ and (under free allocation) sells the remaining $\bar{Q}-\hat{Q}$ rights to C at price $MB(\hat{Q})-f$; C bears damage $\int_0^{\hat{Q}} MD(q)\,dq$ and pays a per-unit cost equal to $MD(\hat{Q})$ on each conserved unit (in equilibrium); G collects fees on remaining extraction plus k on each conserved unit, with auction revenue adjusting accordingly under auction. Proposition 2 states the change in each party's welfare in closed form.

Proposition 2 (Distributional incidence)**.** *Let $\hat{Q} < \bar{Q}$ be the buyout equilibrium. Then:*

(a) $\Delta C = \int_{\hat{Q}}^{\bar{Q}} \big(MD(q) - MD(\hat{Q})\big)\,dq > 0$ *for any allocation regime.*

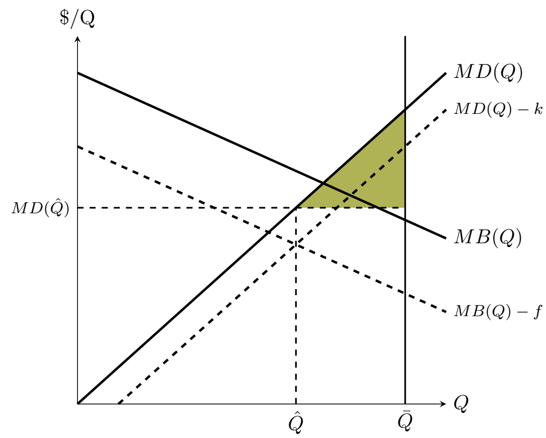
(b) $$\Delta U^{free} = \int_{\hat{Q}}^{\bar{Q}} \big(MB(\hat{Q}) - MB(q)\big)\,dq > 0,$$
$$\Delta U^{auct} = -\hat{Q}\big(MB(\hat{Q}) - MB(\bar{Q})\big) - \int_{\hat{Q}}^{\bar{Q}} \big(MB(q) - MB(\bar{Q})\big)\,dq < 0.$$

(c) $\Delta G^{free} = (k-f)(\bar{Q}-\hat{Q}) \leq 0$, *with equality iff* $k = f$.
$\Delta G^{auct} = \big(MB(\hat{Q}) - MB(\bar{Q})\big)\bar{Q} - (\bar{Q}-\hat{Q})(f-k)$, *of ambiguous sign.*

(Proof in Appendix A.2.)

The first part of the proposition establishes that the conservationist always gains. In equilibrium, C's effective per-unit cost for a conserved unit is $MD(\hat{Q})$—the price paid to U plus the conservation fee paid to G exactly equal the marginal damage at the equilibrium quantity. Each unit conserved between $\hat{Q}$ and $\bar{Q}$ delivers a per-unit gain of $MD(q) - MD(\hat{Q})$, which is positive because MD is strictly increasing. The integral aggregates these unit-by-unit gains into the area shaded in Figure 2. No allocation parameter enters this calculation; hence C's gain is identical under free allocation and under auction.

Figure 2. Conservationist's gain ΔC

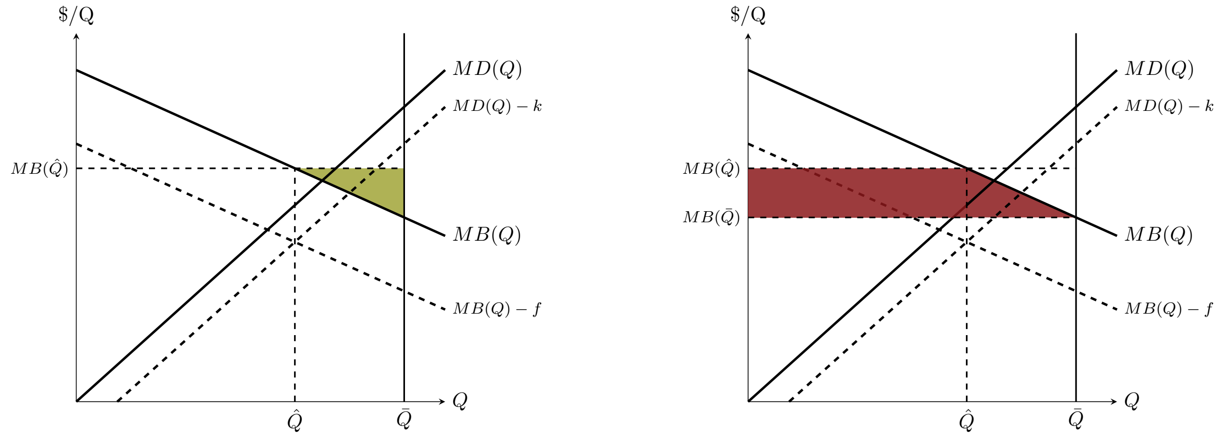


Notes: The shaded region is the integral in Proposition 2 under both free allocation and under auction.

The second part of Proposition 2 shows that U's welfare change depends on the allocation regime. Under free allocation, U enters with all $\bar{Q}$ rights at zero cost and sells $\bar{Q} - \hat{Q}$ rights at the equilibrium price $MB(\hat{Q}) - f$. Because MB is downward-sloping and $\hat{Q} < \bar{Q}$, the per-unit sale price exceeds U's reservation price for marginal units close to $\bar{Q}$, where U's extraction rents had been lowest; the area between the horizontal line at $MB(\hat{Q})$ and the marginal-benefit curve over $[\hat{Q}, \bar{Q}]$ is U's gain (Figure 3, Panel A). Under auction, the picture is reversed. Without buyouts, U wins all $\bar{Q}$ rights at the auction-clearing price $MB(\bar{Q}) - f$; with buyouts, C enters the auction and pushes the clearing price up to $MB(\hat{Q}) - f$. There are two consequences: U now pays a strictly higher auction price on the $\hat{Q}$ units it still acquires, and it loses the rent it had been earning on the $\bar{Q} - \hat{Q}$ units that C now wins (Figure 3, Panel B). Both effects reduce U's welfare, and the sign is unambiguous: U loses under auction whenever buyouts occur. The reversal is driven entirely by the allocation regime; the equilibrium quantity $\hat{Q}$ is identical across regimes.

The third part of Proposition 2 shows that the government's revenue change is qualitatively different across allocation regimes. Under free allocation, G collects a per-unit extraction fee f on every unit U extracts and a per-unit conservation fee k on every unit C acquires. The change in revenue is $(k - f)(\bar{Q} - \hat{Q})$, which is weakly negative and equal to zero only in the knife-edge case $k = f$. Under auction, the algebra has two competing terms. The auction-revenue effect, $(MB(\hat{Q}) - MB(\bar{Q}))\bar{Q}$, is strictly positive: every unit now clears at a higher price. The fee-revenue loss on conserved units, $(\bar{Q} - \hat{Q})(f - k)$, is weakly positive and enters with a negative sign. Whether the gain dominates the loss depends on the parameter values—specifically, on the curvature of MB and the relative magnitudes of $\bar{Q} - \hat{Q}$ and $f - k$. Consider two limit cases. When $k = f$, the fee-revenue loss vanishes and G strictly gains under auction. When $k = 0$, the algebra reduces to $(MB(\hat{Q}) - MB(\bar{Q}))\bar{Q} - f(\bar{Q} - \hat{Q})$, which is of ambiguous sign in general.

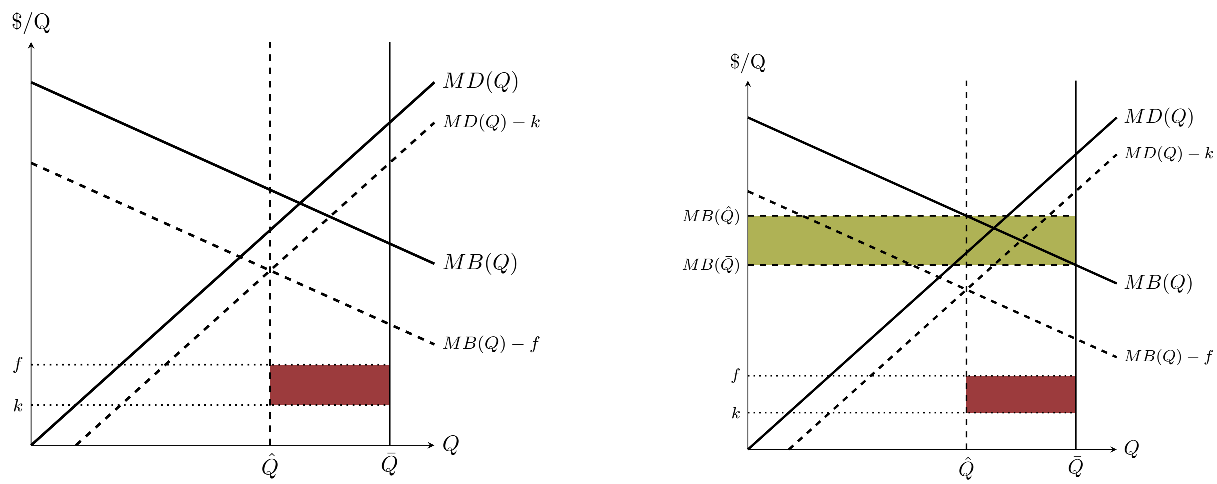
Figure 3. Resource user's welfare change ΔU



(A) Free allocation: $\Delta U^{\text{free}} > 0$ **(B) Auction: $\Delta U^{\text{auct}} < 0$**

Notes: Panel A illustrates the free-allocation case (Proposition 2(b), gain region): U sells $\bar{Q} - \hat{Q}$ rights at the equilibrium price $MB(\hat{Q}) - f$. Panel B illustrates the auction case (loss regions): U pays a higher auction price on retained units *and* loses rent on the units bought by C.

Figure 4. Government's revenue change ΔG



(A) Free allocation: $\Delta G^{\text{free}} \leq 0$ **(B) Auction: ΔG^{auct} ambiguous**

Notes: Panel A: pure fee-revenue loss under free allocation (Proposition 2(c)). Panel B: auction-revenue gain (green) net of fee-revenue loss (red); sign is ambiguous in general.

4 Aggregate welfare

4.1 The role of G in aggregate welfare

Aggregate welfare in this setting is the sum of payoffs across the three parties, $W = U_{\text{surplus}} + C_{\text{surplus}} + G_{\text{revenue}}$. It is worth emphasizing that the government is included in the welfare aggregation; the welfare results below do not implicitly weight G's revenue at zero. This approach allows us to more directly map the distributional implications to the aggregate welfare implications. It also enables consideration of a case where the marginal cost of public funds is greater than one, as discussed below.

Although we explicitly include government revenue in our general welfare calculation, it often nets out through transfers. Two transfers cancel completely. The extraction fee f enters ΔU as $-f$ on each retained unit and ΔG as $+f$ on the same units, so the two entries sum to zero. Likewise, the conservation payment $p = MD(\hat{Q}) - k$ enters ΔC as $-p$ on each conserved unit and (under free allocation) ΔU as $+p$. By contrast, the auction-induced price rise ΔP does not cancel completely: it enters ΔU as $-\Delta P \cdot \hat{Q}$ (paid on the units U still acquires) but enters ΔG as $+\Delta P \cdot \bar{Q}$ (collected on every unit auctioned, including the $\bar{Q} - \hat{Q}$ units C wins). The mismatch leaves a residual difference of $\Delta P \cdot (\bar{Q} - \hat{Q})$ that distinguishes auction from free allocation in the per-party algebra; this is the term behind the ambiguous sign of ΔG^{auct} in Proposition 2(c). Adding $\Delta U + \Delta C + \Delta G$ collapses the first two transfers to zero in the sum—they cancel because they appear on opposite sides of pairs of parties' balance sheets, not because they have been excluded from welfare—while the residual term remains and contributes to the welfare integral via its effect on the equilibrium quantity $\hat{Q}$.

The welfare identity (which Proposition 3 below derives formally),

$$\Delta W \;=\; \Delta U + \Delta C + \Delta G \;=\; \int_{\hat{Q}}^{\bar{Q}} \big(MD(q) - MB(q)\big)\, dq, \tag{2}$$

holds by construction. When the welfare result yields $\Delta W < 0$ and the distributional result yields $\Delta C > 0$, the deficit $\Delta U + \Delta G < -\Delta C < 0$ must be absorbed by some combination of U and G. Which party bears the loss depends on the allocation regime, by Proposition 2(b)–(c). We note that this expression weights G's revenue at par with the surplus accruing to private parties. If public funds carry a marginal cost above unity—as they typically do when raising tax revenue distorts other margins (Browning, 1976; Bastani, 2024)—a dollar of G's revenue is worth more than a dollar of U's or C's surplus, and overshoot welfare losses borne by G are larger in social terms than the linear sum suggests. We return to this point later.

4.2 General welfare result

Our next proposition characterizes the overall welfare implications of allowing Coasean provision for public natural resources.

Proposition 3 (General welfare change)**.** *Suppose $\hat{Q} < \bar{Q}$. Then ΔW is given by (2), depends only on $(\hat{Q}, \bar{Q}, MB, MD)$, and:*

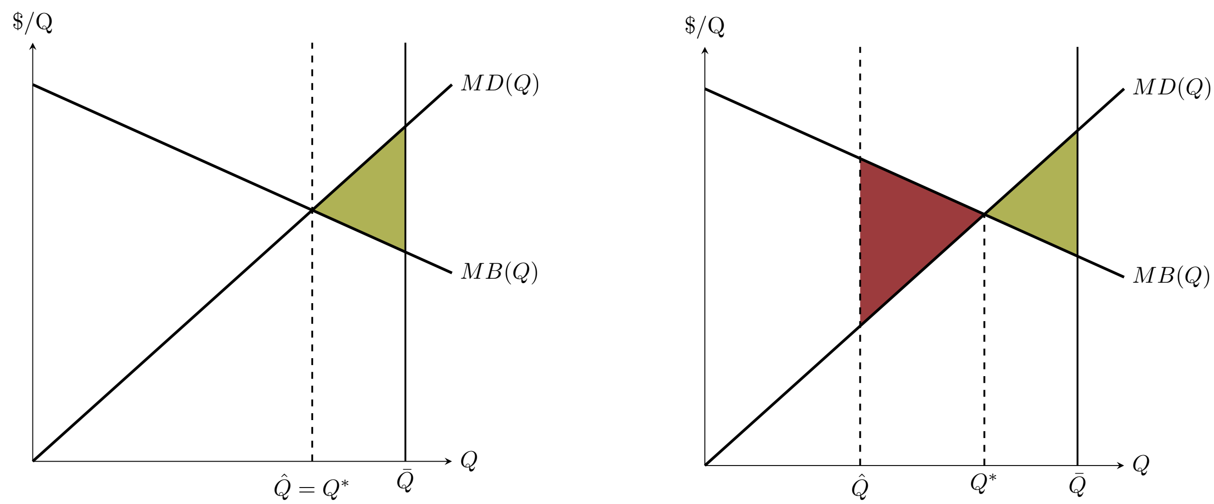
1. *If $\hat{Q} \geq Q^*$ (improvement or irrelevance regime), the integrand is non-negative and $\Delta W \geq 0$.*
2. *If $\hat{Q} < Q^*$ (overshoot regime), the integrand changes sign at Q^*; ΔW may be of either sign and is positive iff the gain on $[Q^*, \bar{Q}]$ exceeds the loss on $[\hat{Q}, Q^*]$.*

A sufficient condition for $\Delta W > 0$ is $MB(\bar{Q}) - MD(\bar{Q}) < f - k \leq MB(Q^*) - MD(Q^*)$. (Proof in Appendix A.3.)

The proposition has two components. The integrand $MD(q) - MB(q)$ measures the net social value of conserving each unit between $\hat{Q}$ and $\bar{Q}$: $MD(q)$ is the damage avoided, $MB(q)$ the surplus forgone. The sign of the integrand changes at the social optimum Q^*, and the geometry of the integral determines the sign of ΔW. In the improvement regime $\hat{Q} \geq Q^*$, the integrand is nonnegative throughout the conserved range and welfare weakly improves; the boundary case $\hat{Q} = Q^*$ corresponds to $k = f$ and yields the maximum welfare gain achievable through buyouts. However, it is also possible that $\hat{Q} < Q^*$, so that the integral contains both positive and negative regions.

Figure 5 illustrates the two regimes. In the overshoot regime $\hat{Q} < Q^*$, the integrand is negative on $[\hat{Q}, Q^*]$ and positive on $[Q^*, \bar{Q}]$, and the net sign of ΔW depends on whether the gain on the second sub-interval exceeds the loss on the first. This is the same Pigouvian-overshoot logic identified by Costello and Kotchen (2022): the under-priced extraction fee acts as an implicit subsidy on conservation buyouts, and C's effective willingness to pay exceeds the social value of avoided damage on units below Q^*. The sufficient condition in Proposition 3 translates this geometry into a condition on the fee wedge: $f - k$ must be large enough to trigger buyouts—above the irrelevance threshold from Corollary 1.1—but small enough to avoid pushing $\hat{Q}$ below Q^*. When $f = k$, no overshoot is possible and aggregate welfare weakly improves from allowing buyouts.

Figure 5. Welfare improvement vs. welfare-reducing overshoot



(A) Welfare improvement **(B) Welfare-reducing overshoot**

Notes: Geometric decomposition of $\Delta W = \int_{\hat{Q}}^{\bar{Q}} (MD(q) - MB(q))\, dq$. Panel A: when $\hat{Q} \geq Q^*$, $MD > MB$ throughout the conserved range; the gain triangle (green) is the entire welfare change and $\Delta W \geq 0$. The boundary case $\hat{Q} = Q^*$ obtains under $k = f$. Panel B: when $\hat{Q} < Q^*$, the conserved range splits into a loss subregion $[\hat{Q}, Q^*]$ where $MB > MD$ (red) and a gain subregion $[Q^*, \bar{Q}]$ where $MD > MB$ (green). A large enough fee wedge $f - k$ pushes $\hat{Q}$ far enough below Q^* that the red loss exceeds the green gain, and $\Delta W < 0$.

Corollary 3.1 (Allocation invariance). *ΔW depends only on $(\hat{Q}, \bar{Q}, MB, MD)$ and is identical under free allocation and under auction. (Proof in Appendix A.3.)*

Allocation invariance follows immediately from the welfare identity because the integrand contains no allocation argument, and the equilibrium quantity $\hat{Q}$ is determined by Equation (1), which also contains no allocation argument. Allocation determines only the distribution of surplus across parties; total welfare depends solely on the cap, the equilibrium quantity, and the underlying cost and benefit curves. The distributional results of Proposition 2 and the welfare result of Proposition 3 are therefore complementary: changing the allocation reshuffles the payoffs across U, C, and G without changing the total.

The policy debate over conservation buyouts often conflates two questions—"are buyouts good or bad?" and "who wins or loses?"—but they have different answers and depend on different policy parameters. The first is a function of $\hat{Q}$ and hence of $f - k$; the second is a function of the allocation regime. This is an application of the Coase theorem to the specific cap-and-fee public-resource structure in which G enters aggregate welfare W as a budget-constrained party rather than as a Pigouvian planner.

Our next Corollary emphasizes the unique features of the Coasean logic in this setting—an aggregate-welfare statement on its own is fairly ambiguous, but combined with regime-specific incidence it identifies the policy levers that can redistribute losses to make welfare improvements politically feasible.

Corollary 3.2 (Loss-incidence decomposition under overshoot)**.** *Suppose the overshoot regime obtains, $\Delta W < 0$. Then $\Delta C > 0$ (Prop 2(a)), and the welfare loss decomposes as follows.*
(a) Free allocation. *U enjoys a strict surplus transfer, $\Delta U^{free} = \int_{\hat{Q}}^{\bar{Q}} \big(MB(\hat{Q}) - MB(q)\big)\, dq > 0$, and G bears the entire welfare loss plus the transfer:*

$$\Delta G^{free} \;=\; -(f-k)(\bar{Q}-\hat{Q}) \;=\; \Delta W - \Delta C - \Delta U^{free} \;<\; \Delta W \;<\; 0.$$

The share of $|\Delta W|$ borne by G exceeds unity, $-\Delta G^{free}/|\Delta W| > 1$; the excess $-\Delta G^{free} - |\Delta W| = \Delta C + \Delta U^{free} > 0$ is the surplus transferred from G to C and U.

(b) Auction. *U loses, $\Delta U^{auct} = -\hat{Q}\big(MB(\hat{Q}) - MB(\bar{Q})\big) - \int_{\hat{Q}}^{\bar{Q}} \big(MB(q) - MB(\bar{Q})\big)\, dq < 0$, and the loss is split between U and G in shares*

$$s_U^{auct} \;=\; \frac{-\Delta U^{auct}}{|\Delta W| + \Delta C}, \qquad s_G^{auct} \;=\; \frac{-\Delta G^{auct}}{|\Delta W| + \Delta C}, \qquad s_U^{auct} + s_G^{auct} = 1,$$

where $\Delta G^{auct} = \bar{Q}\big(MB(\hat{Q}) - MB(\bar{Q})\big) - (\bar{Q}-\hat{Q})(f-k)$ and $\operatorname{sign}(s_G^{auct})$ is determined by whether the auction-revenue rebound $\bar{Q}\big(MB(\hat{Q}) - MB(\bar{Q})\big)$ exceeds the fee-revenue loss $(\bar{Q}-\hat{Q})(f-k)$. (Proof in Appendix A.3.)

The connection between distribution incidence and aggregate welfare arises from combining the welfare identity, the conservationist's gain (Proposition 2(a)), and the user's incidence under each allocation regime (Proposition 2(b)). Because C always gains, any welfare loss in the overshoot regime falls on the sum $\Delta U + \Delta G$. Under free allocation, U also gains, so the entire welfare loss is absorbed by G—the magnitude of G's loss strictly exceeds $|\Delta W|$ because it must also cover the surplus transferred to C and U, formalized in Cor 3.2(a). Under auction, U loses, so the welfare loss is split between U and G in the shares stated in Cor 3.2(b), with the sign of ΔG^{auct} determined by whether the auction-revenue gain covers the fee-revenue loss.

So far, our analysis weights G's revenue at par with private surplus, but the policy ranking strengthens under a plausible marginal cost of public funds (MCPF) above unity. Under free allocation, G bears the entire welfare loss plus the transfer to U, so a dollar of ΔG^{free} counts as MCPF $\cdot \Delta G^{\text{free}}$ in social terms; the welfare-reducing region widens monotonically in MCPF, and the status-quo $k = 0$ regime worsens relative to $k = f$. However, if $k = f$, then $\Delta G^{\text{free}} = 0$ by Proposition 2(c), so the MCPF weight is irrelevant. Under auction, an increase in MCPF affects both the auction-revenue gain and the fee-revenue loss for G equally. However, setting $k = f$ eliminates the fee-revenue loss and implies that increases MCPF would strictly increase G's welfare through the auction revenue gain. The upshot is that the policy ranking $k = f$ over $k = 0$ strengthens as MCPF rises, regardless of the allocation mechanism. Appendix B illustrates this for the grazing and timber calibrations.

Table 1 summarizes the qualitative pattern across the four boundary (allocation × fee) configurations, with precise magnitudes in Table A1. State and industry opposition to conservation buyouts is rational under a $k = 0$ regime that offers a subsidy to conservation, or under an auction regime where U's welfare decreases. In contrast, under $k = f$ and free allocation, U gains from voluntary trade and G's revenue is unaffected. The political-economy obstacles are therefore eliminated. Objections to non-use rights that lie outside the scope of MB and MD—non-pecuniary attachment to ranching as a way of life, fairness-of-process concerns, or fear of NGO entry into rangeland governance—are not represented in the model and may persist under any cap-and-fee regime. Section 6 below illustrates these patterns numerically in calibrations of federal grazing and federal timber.

Table 1. Distributional Incidence and Welfare Effects Under Boundary Conditions

	Free allocation	**Auction**
$k = 0$	$\Delta C > 0$ $\Delta U > 0$ $\Delta G < 0$ ΔW depends on $f - k$	$\Delta C > 0$ $\Delta U < 0$ ΔG ambiguous ΔW same as free (Cor. 3.1)
$k = f$	$\Delta C > 0$ $\Delta U > 0$ $\Delta G = 0$ *Pareto-improving;* $\Delta W > 0$	$\Delta C > 0$ $\Delta U < 0$ $\Delta G > 0$ $\Delta W > 0$ (improvement regime)

Notes: Signs follow from Proposition 2 and Corollary 3.2. Free allocation paired with $k = f$ is the unique Pareto-improving cell. Linear closed forms for each cell are collected in Appendix Table A1.

5 Extensions

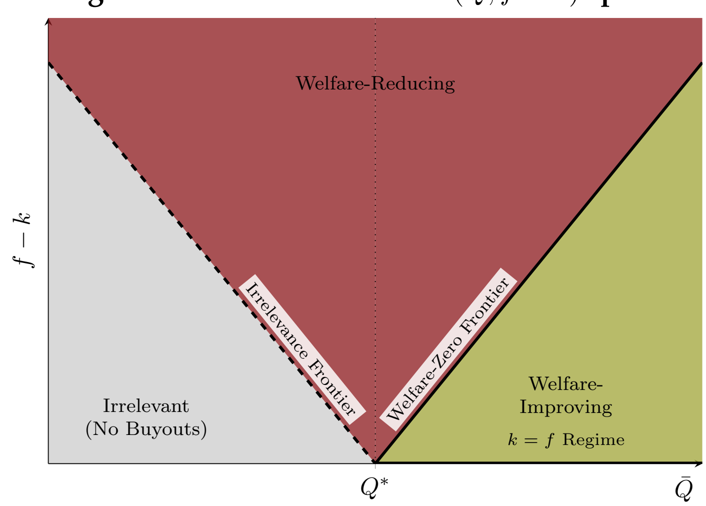
5.1 Linearization and the welfare frontier

The propositions and corollaries above hold for arbitrary MB and MD satisfying the monotonicity assumptions. To draw out the comparative statics in closed form and to anchor the calibration in Section 6, we now adopt the linearization $MB(Q) = a - bQ$ and $MD(Q) = c + dQ$ with $a, b, c, d > 0$ and $a > c$ to ensure an interior social optimum. Under linearization, the social optimum is $Q^* = (a-c)/(b+d)$ and the buyout equilibrium is $\hat{Q} = (a-c+k-f)/(b+d)$. Substituting into the welfare integral and simplifying yields a closed form for the welfare change,

$$\Delta W \;=\; (\bar{Q} - \hat{Q})\Big[\tfrac{1}{2}(b+d)(\bar{Q} - \hat{Q}) - (f-k)\Big],$$

Solving for the fee wedge that delivers $\Delta W = 0$ yields: $(f-k)^* \;=\; (b+d)\bar{Q} - (a-c)$. This equation defines the frontier for conservation buyouts reducing vs. improving welfare, corresponding to whether or not overshoot occurs. The fee gap $f - k$ is bounded from below by zero at Q^* and is increasing in $\hat{Q}$. As the initial cap becomes more lax relative to the social optimum, the scope for overshoot from an implicit conservation subsidy $f - k$ declines, but if the initial cap is close to Q^*, the fee gap must shrink to avoid welfare-reducing overshoot. Figure 6 illustrates.

Figure 6. Welfare frontiers in $(\bar{Q}, f-k)$ space



Notes: Linearized model: $MB = a - bQ$, $MD = c + dQ$. Above the welfare-zero frontier (overshoot regime) buyouts reduce welfare; between the welfare-zero frontier and the irrelevance frontier, buyouts strictly improve welfare; at or below the irrelevance frontier, no buyouts occur.

We can also derive an analogous frontier from Corollary 1.1: the line $f - k = (a-c) - (b+d)\bar{Q}$ defines when conservation buyouts are welfare-irrelevant (no buyouts occur). The two frontiers cross at $(\bar{Q}, f-k) = (Q^*, 0)$ and partition the $(\bar{Q}, f-k)$ plane into three regions: a welfare-improving region between the two frontiers, an irrelevance region below, and a welfare-reducing region above. Figure 6 depicts these frontiers and illustrates the central comparative-statics insight: the welfare effect of buyouts depends jointly on the cap and the fee wedge, and small changes in either can move the policy regime across frontiers. The figure also underscores the fact that it is not possible for Coaseean provision to increase welfare if the initial cap is set at or below the social optimum. In this scenario, trades will either not occur, or will necessarily result in overshoot that reduces $\hat{Q}$ below the social optimum.

5.2 Free-riding

The baseline analysis focuses only on C's marginal damage function. In this conceptualization, marginal damages would reflect a specific NGO or individual's willingness-to-pay to avoid extraction. Hence, our statements about total welfare are confined to the transacting parties and do not reflect the broader social implications of conservation and non-use. In practice, environmental NGOs and individual donors capture only a fraction of the social benefit from conservation, with the rest accuring to other beneficiaries who do not contribute (Andreoni, 1990; Kotchen, 2006; Bergstrom et al., 1986). We follow Costello and Kotchen (2022) and model this by writing the conservationist's effective marginal damage function as $MD_C(Q) = \beta\, MD_S(Q)$, where $\beta \in (0,1]$ denotes the share of social damages that are internalized by C and MD_S is the underlying social marginal damage function. The case $\beta = 1$ recovers the baseline where there are no social benefits external to C; the case $\beta < 1$ captures partial free-riding.

With free-riding, the cap-and-fee equilibrium condition becomes $MB(\hat{Q}) - f = \beta\, MD_S(\hat{Q}) - k$. Two reference quantities help frame implications. We write $\tilde{Q}(\beta)$ for the unsubsidized free-riding equilibrium that solves $MB(Q) = \beta\, MD_S(Q)$—the cap-and-fee equilibrium evaluated at $f = k$, which collapses to the no-fee Coase outcome—to keep it visually distinct from the main-text cap-and-fee equilibrium $\hat{Q}$ ($\beta = 1$, $f - k > 0$). The social optimum Q_S^* solves $MB(Q) = MD_S(Q)$. With MB strictly decreasing and MD_S strictly increasing, both reference quantities are unique by single-crossing. At Q_S^*, $MB(Q_S^*) = MD_S(Q_S^*) > \beta\, MD_S(Q_S^*)$ whenever $\beta < 1$, so $\tilde{Q}(\beta) > Q_S^*$: private conservation underprovides relative to the social optimum, and the gap is governed by β together with the curvature of MB and MD_S. Proposition 4 states the unique fee wedge that closes this gap, for general monotone marginal benefit and damage functions.

Proposition 4 (Free-riding wedge)**.** *Let MB be continuous and strictly decreasing and MD_S continuous and strictly increasing on $[0, \bar{Q}]$, with $MD_C(Q) = \beta\, MD_S(Q)$ for $\beta \in (0,1]$. The fee wedge that induces $\hat{Q} = Q_S^*$ is*

$$(f-k)^{opt}(\beta) \;=\; (1-\beta)\, MD_S(Q_S^*),$$

strictly positive whenever $\beta < 1$ and $MD_S(Q_S^*) > 0$. (Proof in Appendix A.4.)

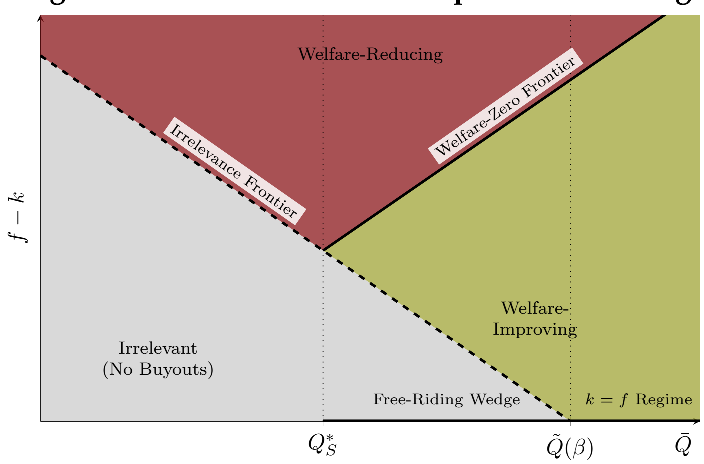
Corollary 4.1 (Linear closed form)**.** *Under linearization $MB(Q) = a - bQ$, $MD_S(Q) = c + dQ$ (with $b, d > 0$), the wedge in Proposition 4 admits the closed form*

$$(f-k)^{opt}(\beta) \;=\; (b + \beta d)\left(\tilde{Q}(\beta) - Q_S^*\right) \;=\; (1-\beta)\,(c + d\, Q_S^*),$$

where $Q_S^* = (a-c)/(b+d)$ *and* $\tilde{Q}(\beta) = (a-\beta c)/(b+\beta d)$. *(Proof in Appendix A.4.)*

The fee wedge $(1-\beta)\,MD_S(Q_S^*)$ is a Pigouvian correction for the externality that C's free-riding imposes on the rest of society. It equals the social marginal damage at the social optimum, scaled by the share of damages C does not internalize. This result is general—it does not depend on linear MB or linear MD_S, only on monotonicity—and reduces to the baseline result $(f-k)^{\text{opt}}(1) = 0$ when conservation buyers fully internalize social damages. In the linearization (Corollary 4.1), the wedge can be written in closed form as $(b+\beta d)(\tilde{Q}(\beta) - Q_S^*)$, which scales with the gap between private and social equilibria.[3] As Figure 7 illustrates, free-riding shifts the welfare-zero frontier outward in $(\bar{Q}, f-k)$ space. In other words, a larger fee wedge is required to reach any given welfare level when C's effective demand is attenuated.

Figure 7. Welfare frontier under partial free-riding



Notes: Same axes as Figure 6 but with $\beta < 1$, so C captures only fraction β of social conservation value. The welfare-zero frontier shifts outward and the welfare-improving region shrinks.

5.3 Transaction costs as a symmetric filter

Conservation buyouts in practice involve substantial fixed costs of contracting, due-diligence, brokering, and legal review (Stavins, 1995; Anderson and Parker, 2013), which our model abstracts away. Adding them back delivers a result that is in the spirit of Coase (1960): fixed transaction costs filter out small welfare-changing trades regardless of sign. Small welfare-reducing trades—overshoots that occur when $\hat{Q}$ falls just below Q^*—are blocked because the conservationist's gain is too small to cover the transaction cost T. So are small welfare-improving trades just above the irrelevance frontier, where the per-unit damage avoided is barely above the per-unit reservation cost. Transaction costs are usually thought of as friction that prevents efficient trade; here they double as a filter that screens out trades whose welfare effect is too small to justify the fixed cost of executing them, in either direction.

[3]This can be rewritten as $(1-\beta)(c + dQ_S^*)$, which illustrates the share-of-damages interpretation.

We model fixed transaction costs as a single $T \geq 0$ borne by C per buyout transaction. The conservationist participates only if the gross gain—the integral $\int_{\hat{Q}}^{\bar{Q}} (MD(q) - MD(\hat{Q}))\, dq$ from Proposition 2(a)—exceeds T. Under linearization, this gross gain equals $\frac{1}{2}d(\bar{Q} - \hat{Q})^2$, and the participation condition simplifies to $\bar{Q} - \hat{Q} \geq \sqrt{2T/d}$.

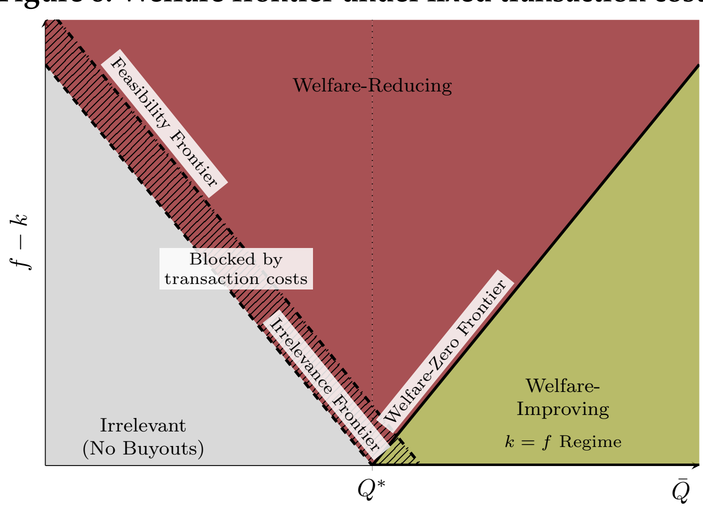
Proposition 5 (Symmetric blocking under fixed transaction costs)**.** *Under linearization, with fixed transaction cost $T \geq 0$ borne by C, buyouts are feasible iff*

$$\bar{Q} - \hat{Q} \;\geq\; \sqrt{2T/d},$$

equivalently $f - k \;\geq\; (a - c) - (b + d)\bar{Q} + (b + d)\sqrt{2T/d}$. The feasibility frontier is parallel to the irrelevance frontier, shifted upward by $(b + d)\sqrt{2T/d}$. Trades with welfare impact $|\Delta W| \leq (b + d)T/d$ are blocked, regardless of whether the welfare effect is positive or negative. (Proof in Appendix A.4.)

Figure 8 illustrates Proposition 5. The feasibility frontier is parallel to the irrelevance frontier and shifted upward by $(b + d)\sqrt{2T/d}$; the hatched band between the two parallel lines contains the trades that would have occurred without transaction costs but are now blocked. For $\bar{Q} < Q^*$, the band sits in the welfare-reducing region (small overshoots blocked); for $\bar{Q} > Q^*$, it sits in the welfare-improving region (small welfare-improving trades blocked). Although transaction costs are symmetric in the sense that they can block trades on either side of Q^*, they affect the welfare implications of allowing Coasean provision asymmetrically. As Figure 8 illustrates, transaction costs block some number of welfare-reducing trades regardless of $f - k$, but they only block welfare-enhancing trades when $f - k$ approaches zero. The net effect is to reduce the welfare-reducing region (by correspondingly increasing the welfare-irrelevant region), making net losses to society from allowing Coasean provision less likely in the presence of transaction costs.

Figure 8. Welfare frontier under fixed transaction costs



Notes: The hatched band between them is the set of $(\bar{Q}, f - k)$ pairs at which a trade would have occurred without T but is blocked by it; the band crosses both the welfare-reducing and welfare-improving regions.

Two additional implications are worth noting. First, the symmetric-blocking effect of transaction costs interacts with free-riding from Section 5.2. The effective transaction cost scales as T/β, so the filter is wider when conservation buyers internalize a smaller share of social damages. Second, the welfare effect of allowing buyouts is asymmetric in expectation if MD is uncertain: blocking the overshoots is more valuable when expected MD is low, because the welfare-reducing region is wider in $(\bar{Q}, f-k)$ space when damages are smaller.

6 Calibration

6.1 General Approach

The propositions above identify the conditions under which conservation buyouts improve welfare. While the results hold for general functional forms, an advantage of the linearization is that most of the parameters can be anchored in observable data. The reservation value a corresponds to the highest willingness to pay among extractors; the average slope b can be backed out from the market price at the cap and the reservation value; the cap $\bar{Q}$ and the fees f and k are administrative variables. The marginal-damage parameters c and d are by contrast difficult to pin down, particularly for resources whose damages include multiple nonmarket services such as ecosystem function, watershed protection, or carbon storage.

We sidestep this difficulty by inverting the question. Our approach instead holds the observable parameters fixed, estimates $md_{\max} = c + d\bar{Q}$ (the marginal damage at the cap) across a plausible range, and computes ΔW, ΔC, ΔU, and ΔG for each value. The break-even $md^*_{\max}$ at which ΔW crosses zero is the threshold marginal damage above which buyouts deliver welfare gains (under linearization). It has the closed form

$$md^*_{\max} \;=\; (a - c + f - k) - b\,\bar{Q}.$$

As a credibility check, we then ask whether $md^*_{\max}$ lies inside or outside the literature-supported range for the resource: if the threshold sits comfortably below the lowest plausible marginal damage, buyouts robustly improve welfare; if it sits above the highest plausible value, they robustly reduce welfare; if it falls inside the range, the conclusion is sensitive to the marginal-damage estimate. We apply this approach to two settings below.

Table 2 summarizes the calibration parameters for the two settings. Sections 6.2 (grazing) and 6.3 (timber) discuss the choice of each parameter and associated sources, as well as the results of the calibrations. Appendix B demonstrates the robustness of both calibrations across a broad range of parameters. In both calibrations we set $c = 0$, implying zero marginal damage when there is no extraction. Substituting $b = (a - p_{\bar{Q}})/\bar{Q}$ collapses the closed form to $md^*_{\max} = p_{\bar{Q}} + f - k$, so the break-even threshold itself does not depend on c. Allowing $c > 0$ shifts the social optimum $Q^* = (a-c)/(b+d)$ leftward and, for a given $md_{\max}$, implies a flatter marginal-damage slope $d = (md_{\max} - c)/\bar{Q}$; both effects narrow the welfare-reducing region in $(\bar{Q}, f-k)$ space and reduce the welfare loss conditional on overshoot. The thresholds reported below are therefore weakly conservative *against* allowing buyouts.

Table 2. Calibration parameters for federal grazing and federal timber

Parameter	Federal grazing	Federal timber
Cap, $\bar{Q}$	12.3 million AUMs	3.0 million MBF
Extraction fee, f	\$1.35/AUM	\$4/MBF
Reservation value, a	\$30/AUM	\$100/MBF
Price at the cap, $p_{\bar{Q}}$	\$23.40/AUM	\$70/MBF
Slope, $b = (a - p_{\bar{Q}})/\bar{Q}$	\$0.537/AUM per million AUMs	\$10/MBF per million MBF
MD intercept, c	0	0
$md_{\max}$ sweep range	$[\$5, \$40]$/AUM	$[\$40, \$7{,}000]$/MBF
Allocation regime	Free allocation	Auction
Break-even $md^*_{\max}$ at $k = 0$	\$24.75/AUM	\$74/MBF
Break-even $md^*_{\max}$ at $k = f$	\$23.40/AUM	\$70/MBF

Notes: Sources: federal grazing fee under PRIA (Vincent, 2019); private grazing-lease rates from USDA-NASS Quick Stats, 17-state average (USDA National Agricultural Statistics Service, 2024); federal stumpage prices and allowable cut from USFS Cut and Sold reports; competitive-auction format for federal timber follows Athey et al. (2011). The closed-form break-even $md^*_{\max} = p_{\bar{Q}} + f - k$ implies $md^*_{\max}$ is invariant to a and $\bar{Q}$ (Appendix E.1). At $k = f$, the threshold collapses to the irrelevance boundary $md^*_{\max} = p_{\bar{Q}}$ for both settings.

6.2 Federal Grazing AUMs (Free Allocation)

We parameterize the model for federal grazing using publicly available administrative data and the private grazing-lease market. The cap is $\bar{Q} = 12.3$ million animal-unit months, corresponding to BLM-authorized AUMs in force on federal rangeland (Vincent, 2019).[4] The federal grazing fee is $f = \$1.35$/AUM, set by formula under the Public Rangelands Improvement Act and updated annually (Vincent, 2019). The reservation value $a = \$30$/AUM is anchored at the upper end of private grazing-lease rates on high-productivity allotments. The market price at the cap, $p_{\bar{Q}} \approx \$23.40$/AUM, is the 17-state average private-leasing rate reported by USDA-NASS for comparable rangeland (USDA National Agricultural Statistics Service, 2024); combined with a and $\bar{Q}$, this implies a slope $b = (a - p_{\bar{Q}})/\bar{Q} \approx \$0.537$ per million AUMs. We set $c = 0$ (no intercept for the MD function) for simplicity and calibrate $md_{\max}$ across $[\$5, \$40]$/AUM, a range that brackets carbon-only damages at the low end and combined carbon-plus-ecosystem damages at the high end, as described below.

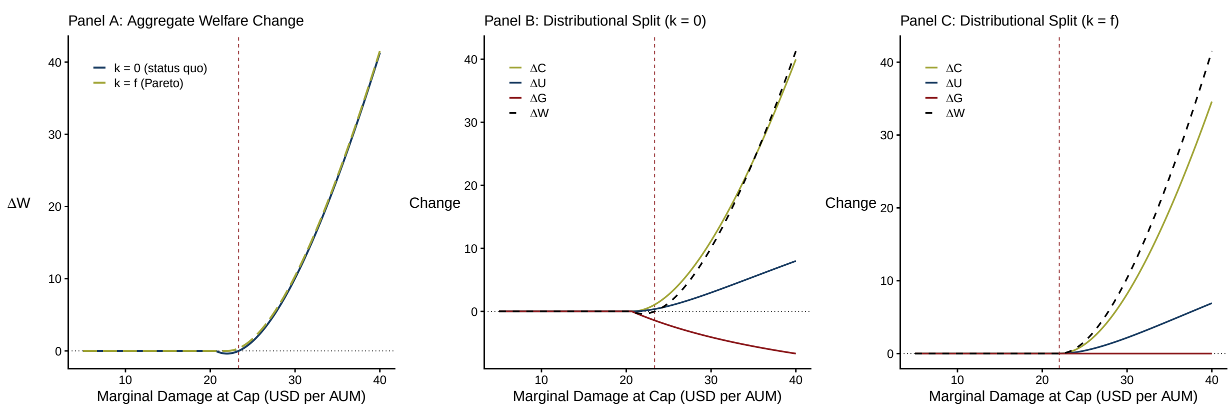
The closed-form break-even thresholds are $md^*_{\max}(k = 0) = 30 + 1.35 - 6.60 \approx \$24.75$/AUM under the status-quo regime and $md^*_{\max}(k = f) = \$23.40$/AUM at the Pareto-improving fee setting level (where the threshold collapses to the irrelevance boundary). The closed-form expression simplifies further by recognizing that our estimate of the slope b is itself a function of other parameters. Substituting $b = (a - p_{\bar{Q}})/\bar{Q}$ into $md^*_{\max} = a + f - k - b\bar{Q}$ delivers $md^*_{\max} = p_{\bar{Q}} + f - k$, so the

[4] The 12.3-million-AUM figure is the BLM "AUMs in force" total reported by CRS for FY2017; USFS rangeland adds roughly 1–2 million authorized AUMs annually but is treated as out-of-scope here. The closed-form break-even derived below is invariant to $\bar{Q}$ once the private lease rate is held fixed (Appendix E.1), so the calibration is insensitive to whether USFS rangeland is included.

welfare threshold depends only on the private lease rate, the federal fee, and the conservation-fee setting—not on a or $\bar{Q}$ directly.

Figure 9 shows the results of the calibration. Panel A traces ΔW as a function of $md_{\max}$ under both regimes. Under $k = 0$, the curve crosses zero from below at $md^*_{\max} \approx \$24.75/\text{AUM}$, indicating welfare gains for marginal damages above this threshold; under $k = f$, ΔW is everywhere weakly positive, with the boundary at the irrelevance threshold $md_{\max} = \$23.40/\text{AUM}$. Panel B decomposes the $k = 0$ welfare effect into its distributional components and matches Corollary 3.2 directly: $\Delta C > 0$ throughout the active range, $\Delta U > 0$ (free allocation), and $\Delta G < 0$, with the magnitude of the government's loss exactly accounting for the welfare loss in the (small) overshoot region. The policy implication is that if the marginal damage from federal grazing exceeds \$24.75/AUM, buyouts can improve welfare under the status-quo regime. Raising k to f removes the overshoot region entirely.

Figure 9. Federal grazing AUMs — inverted-MD calibration (free allocation)



Notes: Panel A: aggregate welfare change ΔW as a function of assumed marginal damage at the cap $md_{\max}$, under $k = 0$ (status quo, solid) and $k = f$ (Pareto regime, dashed). Panel B: distributional split under $k = 0$ — $\Delta C > 0$, $\Delta U > 0$ (free allocation), $\Delta G < 0$. Visualizes Corollary 3.2: under overshoot+free allocation, G is the unique net loser. Panel C: distributional split under $k = f$ (Pareto regime) — $\Delta C > 0$, $\Delta U > 0$, $\Delta G = 0$ by Proposition 2(c); G is held harmless and aggregate welfare equals $\Delta C + \Delta U$.

How does the break-even threshold compare to existing estimates of grazing damages? Kauffman et al. (2022) measure per-AUM emissions from enteric fermentation and manure deposition alone of 875 $kgCO_2e$ at a 20-year GWP and 391 $kgCO_2e$ at a 100-year GWP, not accounting for land-use change and lost sequestration. At the EPA 2023 SC-GHG estimate of \$380/tCO_2e for 2030 emissions at a 1.5% discount rate (U.S. Environmental Protection Agency, 2023), that gives carbon-only damages of \$149–\$333/AUM across the two horizons; at the IWG 2021 SC-GHG of \$51/tCO_2e, the corresponding range is \$20–\$45/AUM. Damage-function approaches that bypass a single SC-GHG point estimate (Kauffman et al., 2023) report \$72–\$166/AUM. The status-quo break-even threshold is $md^*_{\max} = \$24.75/\text{AUM}$. Nearly every estimate from the literature exceeds this cutoff except the IWG 2021 anchor at the 100-year GWP horizon (\$20/AUM), which sits a few dollars below the threshold before land-use-change channels (lost soil-carbon stocks, foregone vegetation-carbon sequestration) and ecosystem-service damages on water yield and biodiversity are added.

Section 4.1 flagged that aggregating G's revenue at par with private surplus is conservative when public funds carry a marginal cost above unity. Applying a marginal cost of public funds (MCPF) above unity widens the welfare-reducing region under $k = 0$ by amplifying G's revenue loss in social terms, but leaves the Pareto regime untouched: under $k = f$ free allocation, $\Delta G = 0$ by construction so the MCPF weight is inert, and the policy ranking $k = f > k = 0$ strengthens, not weakens, as MCPF rises. See Figure B1.

6.3 Federal Timber (Auction)

We also develop a federal-timber calibration to illustrate the other allocation regime. We set the cap at $\bar{Q} = 3.0$ million thousand-board-feet (MBF), corresponding to roughly the 3 billion board-feet allowable cut authorized by the U.S. Forest Service in recent years. We set the administrative-cost-recovery fee at $f = \$4$/MBF.[5] The reservation value is $a = \$100$/MBF, anchored on the upper end of stumpage prices for high-quality timber, and the price at the cap is $p_{\bar{Q}} = \$70$/MBF, the average federal stumpage price across recent USFS sales.[6] These imply a slope $b = (a - p_{\bar{Q}})/\bar{Q} = \$10$ per MBF per million MBF. As with grazing, we make the simplifying assumption that $c = 0$. We vary $md_{\max}$ over $[\$40, \$7{,}000]$/MBF, a range chosen to span the full-accounting carbon-damage estimates discussed below. Federal timber is sold via competitive auction, so we apply the auction expressions from Proposition 2 rather than the free-allocation expressions.

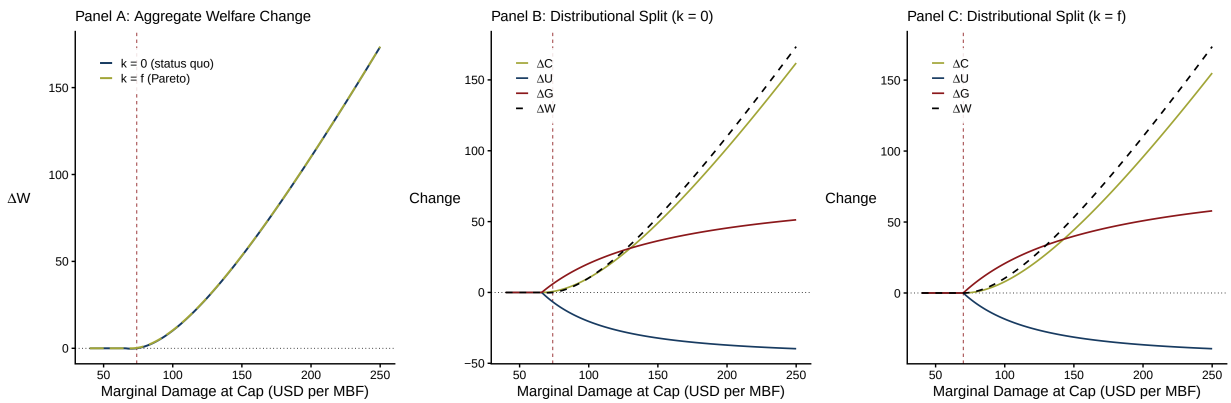
The closed-form break-even threshold is $md^*_{\max} = 100 + 4 - 30 = \$74$/MBF. Figure 10 depicts the full results. Panel A traces ΔW as a function of $md_{\max}$, with the curve crossing zero from below at approximately $\$74$/MBF. Panel B decomposes the welfare effect under auction, $k = 0$: $\Delta C > 0$ throughout the active range, $\Delta U < 0$ (auction lowers U's payoff), and $\Delta G > 0$. The positive sign on ΔG is consistent with Corollary 3.2's second case—the auction-revenue rebound dominates the fee-revenue loss in this calibration, so the welfare loss in the overshoot region falls entirely on U. The policy implications parallels those for grazing: if the marginal damage from a marginal MBF of federal timber harvest plausibly exceeds $\$74$/MBF, then buyouts improve welfare under the status-quo auction regime.

Finally, we compare the break-even threshold to existing estimates of timber-harvest damages. Talberth and Carlson (2024) report net forest-sector emissions of 9.29–16.74 tCO_2e per MBF for federal-style harvest, drawing on full-accounting estimates that include foregone above-ground sequestration, soil-carbon pulse, slash decomposition, and operational emissions in addition to

[5]The $4/MBF figure is an approximation averaged across USFS regions and sale types; the agency does not publish a single nationwide per-MBF administrative-cost number, and actual cost recovery varies with sale size and contract structure. The model maps f to the per-unit charge actually collected on each sold unit, which the average captures adequately for the calibration's threshold purpose.

[6]The $70/MBF figure is averaged across USFS regions and species categories; recent Northwest-region softwood sawtimber prices on USFS land are in this range, but actual stumpage varies substantially by region, species, and sale type (USFS Cut and Sold reports).

Figure 10. Federal timber — inverted-MD calibration (auction regime)



Notes: Panel A: aggregate welfare change as a function of $md_{\max}$, under $k = 0$ (status quo, solid) and $k = f$ (Pareto regime, dashed). Panel B: distributional split under $k = 0$ — $\Delta C > 0$, $\Delta U < 0$ (auction), $\Delta G > 0$ (auction-revenue rebound dominates fee-revenue loss). Panel C: distributional split under $k = f$ — same qualitative pattern with smaller ΔU loss because the fee wedge $f - k = 0$ removes the additional cost on retained units.

the wood-product carbon balance (Hudiburg et al., 2019). At the EPA 2023 SC-GHG estimate of \$380/tCO$_2$e for 2030 emissions at a 1.5% discount rate (U.S. Environmental Protection Agency, 2023), that gives carbon-only damages of roughly \$3,500–\$6,400/MBF, well above the break-even threshold $md^*_{\max} = \$74$/MBF. Watershed services—sediment delivery, peak-flow attenuation, late-season streamflow—and habitat or biodiversity damages associated with intact stands add further damages that vary widely by location and stand condition (Brown et al., 2007; Krieger, 2001; Polasky et al., 2008). As with grazing, the welfare-improving conclusion under buyouts is robust to the SC-GHG and emissions-factor variation we observe in the literature; even under the lower end of the Talberth–Carlson range and a lower SC-GHG anchor, carbon-only damages clear the threshold. Figure B2 demonstrates that these findings are robust to alternative MCPFs.

6.4 Robustness of Calibration Exercises

Appendix B.1 reports the local sensitivity of the break-even threshold $md^*_{\max}$ to each calibration primitive. Working from the closed form $md^*_{\max} = a + f - k - b\bar{Q}$ together with the slope restriction $b = (a - p_{\bar{Q}})/\bar{Q}$, the threshold collapses to $md^*_{\max} = p_{\bar{Q}} + f - k$ — only the private lease rate at the cap and the fee setting (f, k) matter; the reservation value a and the cap $\bar{Q}$ drop out by construction. Table B1 confirms this in numbers: $\partial md^*_{\max}/\partial a = 0$ and $\partial md^*_{\max}/\partial \bar{Q} = 0$ at both the grazing and the timber calibration points, while the elasticity with respect to $p_{\bar{Q}}$ approaches unity. The break-even threshold therefore derives entirely from a single, market-observed quantity — the private grazing-lease rate or the federal stumpage price — rather than from less-observable demand intercepts or capacity choices. What this local exercise cannot, on its own, rule out is joint movement of multiple primitives away from the calibration point.

Appendix B.3 demonstrates the robustness of the calibration along broader two-dimensional planes for each setting. In Panel A of Figures B3 (grazing) and B4 (timber), we trace the break-even damage threshold $md^*_{\max}$ over $(p_{\bar{Q}}, \bar{Q})$ holding a fixed; the contours come out vertical, visually confirming the closed-form result $md^*_{\max} = p_{\bar{Q}} + f - k$ derived in Section 6.1 — the threshold tracks the market price at the cap and is invariant in $\bar{Q}$. In Panel B, we trace aggregate welfare ΔW over $(a, \bar{Q})$ at an above-threshold damage value ($30/AUM for grazing; $500/MBF for timber), holding $p_{\bar{Q}}$ at its calibration value. ΔW stays strictly positive across the full neighborhood (between roughly $5M and $15M per year in the grazing context) and the $\Delta W = 0$ contour lies entirely outside the relevant region in both settings. The welfare conclusion supporting buyouts therefore does not flip under joint perturbations of the demand intercept, the cap, or the market price; the headline claim survives along the planes that the one-dimensional exercise in Appendix B.1 could not, by construction, rule out.

6.5 Oil and Gas

The same approach in principle extends to federal oil and gas leasing, but several features of that setting complicate a direct application. The lease pricing structure is not a simple per-unit fee: federal oil and gas leases combine a bonus bid (paid up front), a royalty on production (a percentage of gross revenue), and administrative cost recovery, none of which maps cleanly onto our f. When fees are fixed per unit, setting $k = f$ is trivial. But in the oil and gas context $f = \theta P$, where θ is the federal royalty rate (currently 12.5%), and P is the price of oil. Because P is unknown, it would be difficult to price conservation on par with extraction *ex ante*. Second, a compounding factor is that unlike timber and grazing where quantities are estimated or administratively set *ex ante*, oil and gas production is highly uncertain. Hence, obtaining the $k = f$ equivalence in oil and gas would be practically challenging. Finally, oil and gas leases run for decades, with declining-well dynamics, abandonment liability, and option value of delayed development—margins that a static cap-and-fee model does not capture (Harstad, 2012; Asheim et al., 2019). We accordingly leave a calibration of oil and gas to future work, with a dynamic extension of the model and a richer mapping from lease primitives to the policy variables $(f, k, \bar{Q})$ as the natural next step.

7 Conclusion

This paper sheds new light on the welfare implications of extending voluntary Coasean provision, or "non-use rights" to natural resources on U.S. public lands. Recent proposals and attempts to allow conservation interests to acquire federal grazing permits, oil and gas leases, and timber leases for the purposes of "non-use" have been strongly opposed by resource users, state governments, and local communities (Ruple et al., 2023). The existing literature on Coasean provision focuses on aggregate welfare in the context of purely private provision, and is thus not equipped to understand the distributional implications of changing key features of public natural resource governance.

We have shown that the controversy over buyouts is fundamentally distributional, and that the distributional structure depends on two policy levers—how rights are initially allocated, and what fee conservation buyers are charged. We find that the question of *whether* buyouts improve welfare is governed by the equilibrium extraction quantity, while the question of *who* gains and loses is governed by the allocation regime. Understanding why requires careful mapping of the distributional impacts.

Conservationists always gain from being allowed to participate. Resource users gain when rights are freely allocated and lose when rights are auctioned. In contrast, the government's revenue weakly falls under free allocation and is ambiguous under auction; the only configuration in which government is held harmless is free allocation paired with $k = f$, which is also the unique Pareto-improving regime and the only configuration that delivers an unambiguous welfare improvement. A standard marginal-cost-of-public-funds correction (MCPF > 1) amplifies the free-allocation loss to G and strengthens the policy ranking $k = f$ over $k = 0$.

Our analysis adds nuance to the prevailing rhetoric in policy debates. Resource users' opposition to buyouts is rational under an auction regime but *not* under free allocation; states' concern about lost revenue is legitimate under a $k = 0$ regime but disappears under $k = f$.[7] The U.S. debate over the Public Lands Rule has largely conflated these dimensions, treating "allowing buyouts" as a single policy choice rather than a parameterized family of regimes with very different distributional consequences. Our analysis suggests that a buyouts regime that paired free initial allocation with $k = f$ would simultaneously address the principal objections of resource users and revenue-collecting agencies while still delivering net welfare gains.

Several caveats warrant emphasis. The analysis is partial-equilibrium and abstracts from dynamics, market power, and the possibility that conservation organizations themselves face budget constraints that limit their effective demand. The extensions in Section 5 relax the assumption of full preference aggregation by C and allow for fixed transaction costs, but a full treatment of the relevant frictions in any specific empirical setting—grazing AUMs, oil-and-gas leases, water rights, fishery quotas—requires application-specific calibration that we leave to future work. The framework also captures political economy only to the extent it operates through the surplus channels of U, C, and G in the MB/MD structure. Objections to non-use rights that lie outside that structure—cultural, identity-based, fairness-of-process, or concerns about non-governmental entry into rangeland governance—are not represented in the model and may persist under any cap-and-fee regime. Future research by economists and others should attempt to grapple with these other factors more directly. The framework here provides clarity to the debate by precisely characterizing the direct, strictly economic gains and losses from allowing Coasean provision for public natural resources. The central message is that conservation buyouts are a parameterized family of policies rather than a single policy, and the choice of allocation and fee structure determines the magnitude of total social gains and losses, as well as who bears them.

[7] While fees are collected by the federal government, a fraction of the revenues is often shared with states, especially for resources like oil, gas, and timber.

References

Anderson, T. L. and G. D. Libecap (2014). *Environmental Markets: A Property Rights Approach*. Cambridge: Cambridge University Press.

Anderson, T. L. and D. P. Parker (2013). Transaction costs and environmental markets: The role of entrepreneurs. *Review of Environmental Economics and Policy 7*, 259–275.

Andreoni, J. (1990). Impure altruism and donations to public goods: A theory of warm-glow giving. *The Economic Journal 100*(401), 464–477.

Asheim, G. B., T. Fæhn, K. Nyborg, M. Greaker, C. Hagem, B. Harstad, M. O. Hoel, D. Lund, and K. E. Rosendahl (2019). The Case for a Supply-Side Climate Treaty. *Science 365*(6451), 325–327.

Athey, S., J. Levin, and E. Seira (2011). Comparing open and sealed bid auctions: Evidence from timber auctions. *Quarterly Journal of Economics 126*(1), 207–257.

Ausubel, L. M., P. Cramton, M. Pycia, M. Rostek, and M. Weretka (2014). Demand reduction and inefficiency in multi-unit auctions. *Review of Economic Studies 81*(4), 1366–1400.

Banzhaf, H. S., T. Fitzgerald, and K. Schnier (2013). Nonregulatory approaches to the environment: Coasean and pigouvian perspectives. *Review of Environmental Economics and Policy 7*(2), 238–258.

Basche, A., K. Tully, N. L. Álvarez Berríos, J. Reyes, L. Lengnick, T. Brown, J. M. Moore, R. E. Schattman, L. K. Johnson, and G. Roesch-McNally (2020). Evaluating the untapped potential of u.s. conservation investments to improve soil and environmental health. *Frontiers in Sustainable Food Systems 4*.

Bastani, S. (2024). The marginal value of public funds: a brief guide and application to tax policy. *International Tax and Public Finance*.

Bergstrom, T., L. Blume, and H. Varian (1986). On the private provision of public goods. *Journal of Public Economics 29*(1), 25–49.

Brown, T. C., J. C. Bergstrom, and J. B. Loomis (2007). Defining, valuing, and providing ecosystem goods and services. *Natural Resources Journal 47*(2), 329–376.

Browning, E. K. (1976). The marginal cost of public funds. *Journal of Political Economy 84*, 283–298.

Bureau of Land Management (2024). Conservation and landscape health. 89 Fed. Reg. 40308. Codified at 43 C.F.R. pt. 1600 & 6100.

Chan, N. W. (2024). Pigouvian policies under behavioral motivations. *Journal of the Association of Environmental and Resource Economists*.

Chan, N. W. and M. J. Kotchen (2014). A generalized impure public good and linear characteristics model of green consumption. *Resource and Energy Economics 37*, 1–16.

Chan, N. W. and M. J. Kotchen (2022). Funding public goods through dedicated taxes on private goods. *Land Economics 98*(3), 428–439.

Coase, R. H. (1960). The problem of social cost. *Journal of Law and Economics 3*(1), 2.

Costello, C., S. Gaines, and L. R. Gerber (2012). A market approach to saving the whales. *Nature 481*(7380), 139–140.

Costello, C. and M. Kotchen (2022). Policy instrument choice with coasean provision of public goods. *Journal of the Association of Environmental and Resource Economists 9*(5), 947–980.

Cramton, P., D. Hellerstein, N. Higgins, R. Iovanna, K. López-Vargas, and S. Wallander (2021). Improving the cost-effectiveness of the conservation reserve program: A laboratory study. *Journal of Environmental Economics and Management 108*, 102439.

Feld, A., T. S. Sims, and J. Nielsen (2022). Green, or greed? a fresh perspective on the valuation of conservation easements. *SSRN Electronic Journal*.

Harstad, B. (2012). Buy Coal! A Case for Supply-Side Environmental Policy. *Journal of Political Economy 120*(1), 77–115.

Henderson, L. (2025, Jun). What are american public lands for? *The Regulatory Review*.

Hendren, N. (2016). The policy elasticity. *Tax Policy and the Economy 30*, 51–89.

Huang, B., J. K. Abbott, E. P. Fenichel, R. Muneepeerakul, C. Perrings, and L. R. Gerber (2017). Testing the feasibility of a hypothetical whaling-conservation permit market in norway. *Conservation biology 31*(4), 809–817.

Hudiburg, T. W., B. E. Law, W. R. Moomaw, M. E. Harmon, and J. E. Stenzel (2019). Meeting GHG reduction targets requires accounting for all forest sector emissions. *Environmental Research Letters 14*(9), 095005.

Jacobs, B. (2018). The marginal cost of public funds is one at the optimal tax system. *International Tax and Public Finance 25*, 883–912.

Kauffman, J. B., R. L. Beschta, P. M. Lacy, and M. Liverman (2022). Livestock use on public lands in the Western USA exacerbates climate change: Implications for climate change mitigation and adaptation. *Environmental Management 69*(6), 1137–1152.

Kauffman, J. B., R. L. Beschta, P. M. Lacy, and M. Liverman (2023). Forum: Climate, ecological, and social costs of livestock grazing on Western public lands. *Environmental Management 72*(4), 699–704.

Kotchen, M. J. (2006). Green markets and private provision of public goods. *Journal of Political Economy 114*(4), 816–834.

Krieger, D. J. (2001). Economic value of forest ecosystem services: A review. Technical report, The Wilderness Society, Washington, DC.

Krutilla, J. V. (1967). Conservation reconsidered. *The American Economic Review 57*(4), 777–786.

Leonard, B., C. Costello, and G. D. Libecap (2020). Expanding water markets in the western united states: barriers and lessons from other natural resource markets. *Review of Environmental Economics and Policy*.

Leonard, B. and S. Regan (2019). Legal and institutional barriers to establishing non-use rights to natural resources. *Natural Resources Journal 59*(1), 135–180.

Leonard, B., S. Regan, C. Costello, S. Kerr, D. P. Parker, A. J. Plantinga, J. Salzman, V. K. Smith, and T. Stoellinger (2021). Allow "nonuse rights" to conserve natural resources. *Science 373*(6558), 958–961.

Leshy, J. D., R. L. Fischman, and S. A. Krakoff (2021). *Coggins & Wilkinson's Federal Public Land and Resources Law* (8th ed.). St. Paul, MN: Foundation Press.

Parker, D. P. (2004). Land trusts and the choice to conserve land with full ownership or conservation easements. *Natural Resources Journal 44*(2), 483–518.

Parker, D. P. and W. N. Thurman (2018). Tax incentives and the price of conservation. *Journal of the Association of Environmental and Resource Economists 5*(2), 331–369.

Pigou, A. C. (1932). The effect of reparations on the ratio of international interchange. *The Economic Journal 42*(168), 532–543.

Polasky, S., E. Nelson, J. Camm, B. Csuti, P. Fackler, E. Lonsdorf, C. Montgomery, D. White, J. Arthur, B. Garber-Yonts, R. Haight, J. Kagan, A. Starfield, and C. Tobalske (2008). Where to put things? Spatial land management to sustain biodiversity and economic returns. *Biological Conservation 141*(6), 1505–1524.

Public Lands Council (2024). Public Lands Council et al. v. United States Department of the Interior. Complaint, U.S. District Court for the District of Wyoming.

Ruple, J. C., J. Pleune, and E. Schlenker-Goodrich (2023). Blm's conservation rule and conservation as a "use". *Environmental Law Reporter 53*, 10825.

Salzman, J., G. Bennett, N. Carroll, A. Goldstein, and M. Jenkins (2018). The global status and trends of payments for ecosystem services. *Nature Sustainability 1*(3), 136–144.

State of Utah (2024). Utah v. United States Department of the Interior. Complaint, U.S. District Court for the District of Utah.

State of Wyoming (2024). Wyoming v. United States Department of the Interior. Complaint, U.S. District Court for the District of Wyoming.

Stavins, R. N. (1995). Transaction costs and tradeable permits. *Journal of Environmental Economics and Management 29*(2), 133–148.

Stavins, R. N. (2003). Experience with market-based environmental policy instruments. *Handbook of Environmental Economics 1*, 355–435.

Stevenson, I. M. (2026, Apr). White house completes review of blm public lands rule. *E&E News PM*.

Talberth, J. and E. Carlson (2024). Forest carbon tax and reward: Regulating greenhouse gas emissions from industrial logging and deforestation in the US. *Environment, Development and Sustainability*.

U.S. Congress (2024). Joint resolution disapproving the bureau of land management conservation and landscape health rule. 118th Congress, Congressional Review Act resolution.

U.S. Environmental Protection Agency (2023). Report on the social cost of greenhouse gases: Estimates incorporating recent scientific advances. Technical report, U.S. Environmental Protection Agency.

USDA National Agricultural Statistics Service (2024). Grazing fees: Animal unit fee. USDA-NASS Quick Stats, 17-state average.

Vincent, C. H. (2019). Grazing fees: Overview and issues. Congressional Research Service Report RS21232.

Weitzman, M. L. (1974). Prices vs. quantities. *The review of economic studies 41*(4), 477–491.

Appendix A Proofs

The appendix contains formal proofs of all propositions and corollaries in the main text, organized in four parts: **A.** equilibrium results (1, 1.1); **B.** distributional incidence (2(a)–(c)); **C.** aggregate welfare (3, 3.1, 3.2); and **D.** extensions (4, 5).

Notation and standing assumptions. Throughout, $MB : [0, \infty) \to \mathbb{R}$ is strictly decreasing ($MB' < 0$) and $MD : [0, \infty) \to \mathbb{R}$ is strictly increasing ($MD' > 0$), both continuous. The cap $\bar{Q}$, the extraction fee $f \geq 0$, and the conservation fee $k \in [0, f]$ are exogenous policy parameters. The social optimum Q^* solves $MB(Q^*) = MD(Q^*)$. With buyouts allowed, the equilibrium quantity $\hat{Q}$ solves (1): $MB(\hat{Q}) - f = MD(\hat{Q}) - k$. Without buyouts, the cap binds and extraction equals $\bar{Q}$. Welfare changes ΔC, ΔU, ΔG, ΔW are differences (with-buyouts) − (without-buyouts).

A.1 Equilibrium

Proof of Proposition 1. Define $\Phi(Q) := MB(Q) - MD(Q)$. Since $MB' < 0 < MD'$, Φ is strictly decreasing on $[0, \bar{Q}]$.

Step 1 (existence and uniqueness). The equilibrium condition (1) can be written $\Phi(\hat{Q}) = f - k$. Under the hypothesis $\Phi(\bar{Q}) = MB(\bar{Q}) - MD(\bar{Q}) < f - k$, strict monotonicity of Φ gives a unique $\hat{Q} < \bar{Q}$ satisfying $\Phi(\hat{Q}) = f - k$.

Step 2 (comparative statics). By the implicit function theorem applied to $\Phi(\hat{Q}) = f - k$,

$$\Phi'(\hat{Q})\,\frac{\partial \hat{Q}}{\partial f} = 1, \qquad \Phi'(\hat{Q})\,\frac{\partial \hat{Q}}{\partial k} = -1.$$

Since $\Phi'(\hat{Q}) = MB'(\hat{Q}) - MD'(\hat{Q}) < 0$, the partials have the signs claimed. The cap $\bar{Q}$ does not appear in Φ, so $\partial \hat{Q}/\partial \bar{Q} = 0$ on the interior.

Step 3 (corner case). If $\Phi(\bar{Q}) \geq f - k$, then for any $Q < \bar{Q}$, $\Phi(Q) > \Phi(\bar{Q}) \geq f - k$, so $\Phi(Q) = f - k$ has no interior solution; $\hat{Q} = \bar{Q}$ binds and no buyouts occur. □

Proof of Corollary 1.1. The hypothesis $f - k \leq MB(\bar{Q}) - MD(\bar{Q}) = \Phi(\bar{Q})$ is the corner condition in Step 3 of the previous proof, so $\hat{Q} = \bar{Q}$. With $\hat{Q} = \bar{Q}$, every welfare integral in Proposition 2 reduces to an integral over an empty interval, hence $\Delta C = \Delta U = \Delta G = 0$ and consequently $\Delta W = 0$. □

A.2 Distributional Incidence

The proofs in this section use one preliminary fact, which follows directly from the equilibrium condition (1):

> **Lemma B.1.** *In equilibrium, the per-unit cost C pays for each conserved unit equals $MD(\hat{Q})$, and the per-unit revenue U receives equals $MB(\hat{Q}) - f$.*

Proof of Lemma B.1. C pays the equilibrium per-unit market price p to U *plus* the conservation fee k to G, for total per-unit cost $p+k$. U accepts the lowest p such that $p \geq MB(\hat{Q}) - f$ (its outside option from extracting the unit). In equilibrium, $p = MB(\hat{Q}) - f$. By (1), $MB(\hat{Q}) - f = MD(\hat{Q}) - k$, so $p + k = MD(\hat{Q}) - k + k = MD(\hat{Q})$. □

Proof of Proposition 2(a). Setup. C's payoff is $-$ (damage borne) $-$ (conservation payments).

Step 1 (without buyouts). C bears damage on all extracted units:

$$\Pi_C^{\text{no}} \; = \; -\int_0^{\bar{Q}} MD(q)\, dq.$$

Step 2 (with buyouts). C bears damage on $[0, \hat{Q}]$ and pays per-unit cost $MD(\hat{Q})$ on each of the $(\bar{Q} - \hat{Q})$ conserved units (Lemma B.1):

$$\Pi_C^{\text{buy}} \; = \; -\int_0^{\hat{Q}} MD(q)\, dq \; - \; (\bar{Q} - \hat{Q}) MD(\hat{Q}).$$

Step 3 (difference).

$$\begin{aligned}
\Delta C &= \Pi_C^{\text{buy}} - \Pi_C^{\text{no}} \\
&= \int_0^{\bar{Q}} MD(q)\, dq - \int_0^{\hat{Q}} MD(q)\, dq - (\bar{Q} - \hat{Q}) MD(\hat{Q}) \\
&= \int_{\hat{Q}}^{\bar{Q}} \big(MD(q) - MD(\hat{Q})\big)\, dq.
\end{aligned}$$

Step 4 (sign). For $q \in (\hat{Q}, \bar{Q}]$, $MD(q) > MD(\hat{Q})$ since $MD' > 0$. Hence $\Delta C > 0$.

Step 5 (allocation invariance). No allocation parameter appears anywhere in Steps 1–4; ΔC is identical under free allocation and under auction. □

Proof of Proposition 2(b), free allocation. Setup. Under free allocation, U receives $\bar{Q}$ rights at zero cost, pays the per-unit fee f on extracted units, and sells unused rights to C at the equilibrium price $MB(\hat{Q}) - f$ (Lemma B.1).

Step 1 (without buyouts). U extracts $\bar{Q}$:

$$\Pi_U^{\text{no}} \; = \; \int_0^{\bar{Q}} \big(MB(q) - f\big)\, dq.$$

Step 2 (with buyouts). U extracts $\hat{Q}$ and sells $(\bar{Q} - \hat{Q})$ at price $MB(\hat{Q}) - f$:

$$\Pi_U^{\text{buy,free}} \; = \; \int_0^{\hat{Q}} \big(MB(q) - f\big)\, dq \; + \; (\bar{Q} - \hat{Q})\big(MB(\hat{Q}) - f\big).$$

Step 3 (difference).

$$\begin{aligned}\Delta U^{\text{free}} &= \Pi_U^{\text{buy,free}} - \Pi_U^{\text{no}} \\ &= (\bar{Q} - \hat{Q})\big(MB(\hat{Q}) - f\big) - \int_{\hat{Q}}^{\bar{Q}} \big(MB(q) - f\big)\, dq \\ &= \int_{\hat{Q}}^{\bar{Q}} \big(MB(\hat{Q}) - MB(q)\big)\, dq.\end{aligned}$$

Step 4 (sign). For $q \in (\hat{Q}, \bar{Q}]$, $MB(q) < MB(\hat{Q})$ since $MB' < 0$. Hence $\Delta U^{\text{free}} > 0$. □

Proof of Proposition 2(b), auction. Setup. Under auction, U bids for rights at the auction-clearing price. Without buyouts, the marginal bidder is at $\bar{Q}$, so the price is $MB(\bar{Q}) - f$. With buyouts, C's entry pushes the marginal bidder to $\hat{Q}$, so the price rises to $MB(\hat{Q}) - f$.

Step 1 (without buyouts). U wins $\bar{Q}$ rights at price $MB(\bar{Q}) - f$, then pays per-unit fee f on extracted units:

$$\Pi_U^{\text{no,auct}} = \int_0^{\bar{Q}} MB(q)\, dq - \bar{Q}\big(MB(\bar{Q}) - f\big) - f\bar{Q} = \int_0^{\bar{Q}} \big(MB(q) - MB(\bar{Q})\big)\, dq.$$

Step 2 (with buyouts). U wins $\hat{Q}$ rights at price $MB(\hat{Q}) - f$, then pays per-unit fee f:

$$\Pi_U^{\text{buy,auct}} = \int_0^{\hat{Q}} MB(q)\, dq - \hat{Q}\big(MB(\hat{Q}) - f\big) - f\hat{Q} = \int_0^{\hat{Q}} \big(MB(q) - MB(\hat{Q})\big)\, dq.$$

Step 3 (difference).

$$\Delta U^{\text{auct}} = \int_0^{\hat{Q}} \big(MB(q) - MB(\hat{Q})\big)\, dq - \int_0^{\bar{Q}} \big(MB(q) - MB(\bar{Q})\big)\, dq.$$

Step 4 (rearrangement). Split the second integral at $\hat{Q}$ and combine with the first:

$$\begin{aligned}\Delta U^{\text{auct}} &= \int_0^{\hat{Q}} \big[(MB(q) - MB(\hat{Q})) - (MB(q) - MB(\bar{Q}))\big]\, dq - \int_{\hat{Q}}^{\bar{Q}} \big(MB(q) - MB(\bar{Q})\big)\, dq \\ &= \int_0^{\hat{Q}} \big(MB(\bar{Q}) - MB(\hat{Q})\big)\, dq - \int_{\hat{Q}}^{\bar{Q}} \big(MB(q) - MB(\bar{Q})\big)\, dq \\ &= -\hat{Q}\big(MB(\hat{Q}) - MB(\bar{Q})\big) - \int_{\hat{Q}}^{\bar{Q}} \big(MB(q) - MB(\bar{Q})\big)\, dq.\end{aligned}$$

Step 5 (sign). Since $MB' < 0$ and $\hat{Q} < \bar{Q}$, $MB(\hat{Q}) > MB(\bar{Q})$, so the first term is strictly negative. For $q \in (\hat{Q}, \bar{Q})$, $MB(q) > MB(\bar{Q})$, so the integrand of the second term is positive and the term enters with a negative sign. Both terms are non-positive (strictly negative whenever $\hat{Q} < \bar{Q}$). Hence $\Delta U^{\text{auct}} < 0$. □

Proof of Proposition 2(c), free allocation. Under free allocation, G collects only fee revenue: f per extracted unit and k per conserved unit (when buyouts are allowed).

Step 1 (without buyouts). $\Pi_G^{\text{no,free}} = f\bar{Q}$.

Step 2 (with buyouts). $\Pi_G^{\text{buy,free}} = f\hat{Q} + k(\bar{Q} - \hat{Q})$.

Step 3 (difference). $\Delta G^{\text{free}} = f\hat{Q} + k(\bar{Q} - \hat{Q}) - f\bar{Q} = (k - f)(\bar{Q} - \hat{Q})$.

Step 4 (sign). Since $k \le f$ and $\bar{Q} \ge \hat{Q}$, $\Delta G^{\text{free}} \le 0$, with equality iff $k = f$ or $\hat{Q} = \bar{Q}$. □

Proof of Proposition 2(c), auction. Under auction, G collects auction revenue (the per-unit clearing price times $\bar{Q}$) plus fee revenue.

Step 1 (without buyouts). Auction price $MB(\bar{Q}) - f$ on $\bar{Q}$ units, plus f per extracted unit:

$$\Pi_G^{\text{no,auct}} \;=\; \bar{Q}\big(MB(\bar{Q}) - f\big) + f\bar{Q} \;=\; \bar{Q}\,MB(\bar{Q}).$$

Step 2 (with buyouts). Auction price $MB(\hat{Q}) - f$ on $\bar{Q}$ units, plus f on $\hat{Q}$ extracted units, plus k on $(\bar{Q} - \hat{Q})$ conserved units:

$$\Pi_G^{\text{buy,auct}} \;=\; \bar{Q}\big(MB(\hat{Q}) - f\big) + f\hat{Q} + k(\bar{Q} - \hat{Q}).$$

Step 3 (difference).

$$\begin{aligned}\Delta G^{\text{auct}} &= \bar{Q}\big(MB(\hat{Q}) - f\big) + f\hat{Q} + k(\bar{Q} - \hat{Q}) - \bar{Q}\,MB(\bar{Q}) \\ &= \bar{Q}\big(MB(\hat{Q}) - MB(\bar{Q})\big) - (\bar{Q} - \hat{Q})(f - k).\end{aligned}$$

Step 4 (sign). The first term is strictly positive ($MB(\hat{Q}) > MB(\bar{Q})$). The second is non-negative (and enters with a minus sign). The net sign is therefore indeterminate without additional restrictions on parameters. Two limiting cases:

- $k = f$: the second term vanishes and $\Delta G^{\text{auct}} = \bar{Q}(MB(\hat{Q}) - MB(\bar{Q})) > 0$.
- $k = 0$: $\Delta G^{\text{auct}} = \bar{Q}(MB(\hat{Q}) - MB(\bar{Q})) - f(\bar{Q} - \hat{Q})$, sign indeterminate; depends on relative magnitudes of the auction-revenue rebound and the fee-revenue loss.

□

A.3 Aggregate welfare

Proof of Proposition 3. Step 1 (welfare identity). By definition $\Delta W = \Delta U + \Delta C + \Delta G$. We verify by direct substitution that this sum reduces to the integral form regardless of allocation.

Step 2 (free allocation algebra). Substituting the closed forms from Propositions 2(a)–(c) under free allocation:

$$\Delta W^{\text{free}} = \int_{\hat{Q}}^{\bar{Q}} \big(MD(q) - MD(\hat{Q})\big)dq + \int_{\hat{Q}}^{\bar{Q}} \big(MB(\hat{Q}) - MB(q)\big)dq + (k-f)(\bar{Q} - \hat{Q})$$
$$= \int_{\hat{Q}}^{\bar{Q}} \big(MD(q) - MB(q)\big)dq \;+\; (\bar{Q} - \hat{Q})\big[MB(\hat{Q}) - MD(\hat{Q}) + k - f\big].$$

By the equilibrium condition (1), $MB(\hat{Q}) - MD(\hat{Q}) = f - k$, so the bracketed term vanishes:

$$\Delta W^{\text{free}} \;=\; \int_{\hat{Q}}^{\bar{Q}} \big(MD(q) - MB(q)\big)\, dq.$$

Step 3 (auction algebra). Substituting the auction expressions from Proposition 2(b)–(c):

$$\Delta W^{\text{auct}} = \int_{\hat{Q}}^{\bar{Q}} \big(MD(q) - MD(\hat{Q})\big)dq$$
$$+ \Big[-\hat{Q}(MB(\hat{Q}) - MB(\bar{Q})) - \int_{\hat{Q}}^{\bar{Q}} (MB(q) - MB(\bar{Q}))\, dq\Big]$$
$$+ \bar{Q}(MB(\hat{Q}) - MB(\bar{Q})) - (\bar{Q} - \hat{Q})(f-k).$$

Combining the $MB(\bar{Q})$ terms:

$$-\hat{Q}(MB(\hat{Q}) - MB(\bar{Q})) + \bar{Q}(MB(\hat{Q}) - MB(\bar{Q})) = (\bar{Q} - \hat{Q})(MB(\hat{Q}) - MB(\bar{Q})),$$

and noting that $\int_{\hat{Q}}^{\bar{Q}}(MB(q) - MB(\bar{Q}))\, dq = \int_{\hat{Q}}^{\bar{Q}} MB(q)\, dq - (\bar{Q} - \hat{Q})MB(\bar{Q})$, the auction expression simplifies to

$$\Delta W^{\text{auct}} = \int_{\hat{Q}}^{\bar{Q}} \big(MD(q) - MB(q)\big)\, dq + (\bar{Q} - \hat{Q})\big[MB(\hat{Q}) - MD(\hat{Q}) - (f-k)\big],$$

and again the bracket vanishes by (1), giving the same expression as in Step 2.

Step 4 (sign analysis). Recall Q^* solves $MB(Q^*) = MD(Q^*)$. By $MB' < 0 < MD'$, $MD(q) - MB(q)$ is strictly increasing in q and changes sign at Q^*. Two cases:

- If $\hat{Q} \geq Q^*$ (improvement or irrelevance regime): the integrand $MD(q) - MB(q) \geq 0$ for all $q \in [\hat{Q}, \bar{Q}]$, so $\Delta W \geq 0$.
- If $\hat{Q} < Q^*$ (overshoot regime): the integrand is negative on $[\hat{Q}, Q^*)$ and positive on $(Q^*, \bar{Q}]$. The total ΔW is positive iff the gain on the second sub-interval exceeds the loss on the first.

Step 5 (sufficient condition). If $f - k \leq MB(Q^*) - MD(Q^*) = 0$, then $\hat{Q} \geq Q^*$ (improvement or irrelevance regime) by Proposition 1, so by Step 4 case (i), $\Delta W \geq 0$. Combined with $f - k > MB(\bar{Q}) - MD(\bar{Q})$ to rule out the irrelevance regime (Corollary 1.1), we obtain strict $\Delta W > 0$. □

Proof of Corollary 3.1. By Steps 2–3 of the proof of Proposition 3, $\Delta W^{\text{free}} = \Delta W^{\text{auct}} = \int_{\hat{Q}}^{\bar{Q}}(MD(q) -$

$MB(q))\,dq$. The integrand contains no allocation argument, and $\hat{Q}$ is determined by (1), which also contains no allocation argument. Hence ΔW is allocation-invariant. □

Proof of Corollary 3.2. Suppose the overshoot regime holds, i.e., $\Delta W < 0$.

Step 1 (welfare identity). By (2), $\Delta W = \Delta U + \Delta C + \Delta G$, hence $\Delta U + \Delta G = \Delta W - \Delta C$.

Step 2 (lower bound). By Proposition 2(a), $\Delta C > 0$ (strict, since $\hat{Q} < \bar{Q}$ in the overshoot regime). Combined with $\Delta W < 0$,

$$\Delta U + \Delta G \;=\; \Delta W - \Delta C \;<\; -\Delta C \;<\; 0.$$

Step 3 (free allocation case). By Proposition 2(b), $\Delta U^{\text{free}} \geq 0$. Combined with Step 2:

$$\Delta G^{\text{free}} \;=\; (\Delta U^{\text{free}} + \Delta G^{\text{free}}) - \Delta U^{\text{free}} \;\leq\; \Delta W - \Delta C - 0 \;<\; 0.$$

Hence G is the unique net loser; the magnitude of G's loss is at least $|\Delta W| + \Delta C$, which equals the welfare loss plus the transfer to U.

Step 4 (auction case). By Proposition 2(b), $\Delta U^{\text{auct}} \leq 0$. The loss $\Delta U^{\text{auct}} + \Delta G^{\text{auct}} < 0$ from Step 2 is split between the two parties; nothing in Steps 1–2 pins down the sign of ΔG^{auct}, which by Proposition 2(c) depends on whether the auction-revenue rebound dominates the fee-revenue loss. □

Table A1 reports the linearization closed forms for each of the four (allocation × fee) configurations summarized qualitatively in main-text Table 1. Two quantities are allocation-invariant under linearization $MB(Q) = a - bQ$, $MD(Q) = c + dQ$ and $\hat{Q} = (a - c + k - f)/(b + d)$:

$$\Delta C \;=\; \tfrac{d}{2}(\bar{Q} - \hat{Q})^2, \qquad \Delta W \;=\; (\bar{Q} - \hat{Q})\Big[\tfrac{1}{2}(b + d)(\bar{Q} - \hat{Q}) - (f - k)\Big].$$

The remaining two quantities, ΔU and ΔG, vary across cells:

Table A1. Linear closed forms for ΔU and ΔG across the four configurations

	Free allocation	**Auction**
$k = 0$	$\Delta U^{\text{free}} = \frac{b}{2}(\bar{Q} - \hat{Q})^2$	$\Delta U^{\text{auct}} = -b\hat{Q}(\bar{Q} - \hat{Q}) - \frac{b}{2}(\bar{Q} - \hat{Q})^2$
	$\Delta G^{\text{free}} = -f(\bar{Q} - \hat{Q})$	$\Delta G^{\text{auct}} = (\bar{Q} - \hat{Q})\big[b\bar{Q} - f\big]$
$k = f$	$\Delta U^{\text{free}} = \frac{b}{2}(\bar{Q} - \hat{Q})^2$	$\Delta U^{\text{auct}} = -b\hat{Q}(\bar{Q} - \hat{Q}) - \frac{b}{2}(\bar{Q} - \hat{Q})^2$
	$\Delta G^{\text{free}} = 0$	$\Delta G^{\text{auct}} = b\bar{Q}(\bar{Q} - \hat{Q}) > 0$

Notes: Substituting $MB(Q) = a - bQ$, $MD(Q) = c + dQ$, and $\hat{Q} = (a - c + k - f)/(b + d)$ into the integrals of Proposition 2. At $k = f$, $\hat{Q} = Q^* = (a - c)/(b + d)$ so $(\bar{Q} - \hat{Q})$ collapses to $(\bar{Q} - Q^*)$. Auction ΔG at $k = 0$ is signed by $b\bar{Q} \gtrless f$: at $k = f$ the fee-revenue loss vanishes and $\Delta G^{\text{auct}} > 0$.

A.4 Extensions

Proof of Proposition 4. We work directly with general MB and MD_S satisfying the monotonicity assumptions; the linear closed form follows as Corollary 4.1.

Step 1 (existence and uniqueness of reference quantities). Define $\Phi(Q) = MB(Q) - \beta\, MD_S(Q)$. Strict monotonicity of MB (decreasing) and MD_S (increasing) makes Φ strictly decreasing in Q for any $\beta > 0$. Provided $\Phi(0) > 0$ and $\Phi(\bar{Q}) < 0$ (the standard interior assumption), $\tilde{Q}(\beta)$ exists and is unique; the same argument with $\beta = 1$ gives Q_S^*.

Step 2 (over-bargaining when $\beta < 1$). At Q_S^*, $MB(Q_S^*) = MD_S(Q_S^*)$. For $\beta < 1$,

$$\Phi(Q_S^*) \;=\; MB(Q_S^*) - \beta\, MD_S(Q_S^*) \;=\; (1-\beta)\, MD_S(Q_S^*) \;>\; 0,$$

so strict monotonicity of Φ implies $\tilde{Q}(\beta) > Q_S^*$: the private equilibrium overshoots the social optimum.

Step 3 (modified equilibrium target). The cap-and-fee equilibrium condition is $MB(\hat{Q}) - f = \beta\, MD_S(\hat{Q}) - k$, equivalently $\Phi(\hat{Q}) = f - k$. We seek the wedge $f - k$ that yields $\hat{Q} = Q_S^*$.

Step 4 (solve for the wedge). Substituting:

$$(f-k)^{\text{opt}}(\beta) \;=\; \Phi(Q_S^*) \;=\; MB(Q_S^*) - \beta\, MD_S(Q_S^*) \;=\; (1-\beta)\, MD_S(Q_S^*),$$

where the last equality uses $MB(Q_S^*) = MD_S(Q_S^*)$. The wedge is strictly positive whenever $\beta < 1$ and $MD_S(Q_S^*) > 0$, and equals zero when $\beta = 1$, recovering the textbook Coase result. □

Proof of Corollary 4.1. Under linearization, $MD_S(Q_S^*) = c + d\, Q_S^*$ with $Q_S^* = (a-c)/(b+d)$, so substituting into Proposition 4 gives

$$(f-k)^{\text{opt}}(\beta) \;=\; (1-\beta)\,(c + d\, Q_S^*) \;=\; (1-\beta)\,\frac{ad+bc}{b+d}.$$

The equivalent slope-distance form follows from $\tilde{Q}(\beta) = (a-\beta c)/(b+\beta d)$. Direct expansion yields the algebraic identity $(a-\beta c)(b+d) - (a-c)(b+\beta d) = (1-\beta)(ad+bc)$, so

$$\tilde{Q}(\beta) - Q_S^* \;=\; \frac{(1-\beta)(ad+bc)}{(b+\beta d)(b+d)}.$$

Multiplying by $(b+\beta d)$ recovers $(b+\beta d)\big(\tilde{Q}(\beta) - Q_S^*\big) = (1-\beta)(ad+bc)/(b+d) = (1-\beta)\,(c+dQ_S^*)$. Both equalities equal $(1-\beta)\, MD_S(Q_S^*)$, agreeing with Proposition 4. □

Proof of Proposition 5. Adopt linearization. By Proposition 2(a) under linear MD,

$$\Delta C(\hat{Q},\bar{Q}) \;=\; \int_{\hat{Q}}^{\bar{Q}} \big(MD(q) - MD(\hat{Q})\big)\, dq \;=\; \int_{\hat{Q}}^{\bar{Q}} d(q-\hat{Q})\, dq \;=\; \tfrac{d}{2}(\bar{Q}-\hat{Q})^2.$$

Step 1 (participation condition). C enters iff $\Delta C \geq T$:

$$\tfrac{d}{2}(\bar{Q} - \hat{Q})^2 \;\geq\; T \quad\Longleftrightarrow\quad \bar{Q} - \hat{Q} \;\geq\; \sqrt{2T/d}.$$

Step 2 (translate to wedge). Substitute $\hat{Q} = (a - c + k - f)/(b + d)$ from Proposition 1 (linear case, $k \in [0, f]$):

$$\bar{Q} - \frac{a - c + k - f}{b + d} \;\geq\; \sqrt{2T/d}.$$

Multiplying through by $(b + d)$ and rearranging:

$$f - k \;\geq\; (a - c) - (b + d)\bar{Q} + (b + d)\sqrt{2T/d}.$$

Step 3 (geometry). The irrelevance frontier from Corollary 1.1 is $f - k = (a - c) - (b + d)\bar{Q}$. The feasibility frontier in Step 2 has the same slope $-(b + d)$ in $\bar{Q}$, shifted upward by the constant $(b + d)\sqrt{2T/d}$.

Step 4 (welfare-symmetric blocking). At the feasibility boundary, $|\bar{Q} - \hat{Q}| = \sqrt{2T/d}$, regardless of whether $\hat{Q}$ exceeds or falls short of Q^*. The aggregate welfare $|\Delta W|$ at the boundary is bounded above by a function of T alone (specifically, $|\Delta W| \leq \frac{1}{2}(b+d) \cdot 2T/d = (b+d)T/d$ in the linear case). Trades with welfare impact below this threshold are blocked, regardless of sign. □

Appendix B Robustness of Calibration Exercises

This appendix presents three robustness exhibits that the calibration discussion in Section 6 summarizes in prose. Together they show that the headline policy claim—that $k = f$ free allocation is the Pareto-improving regime within the model's surplus framework—is robust to plausible perturbations of the calibration primitives, the marginal cost of public funds, and the inferential parameters themselves.

B.1 Local sensitivity of the break-even threshold

Table B1 reports the partial derivatives of the break-even threshold $md^*_{\max}$ with respect to each calibration primitive, at the calibration point for grazing and timber. The closed form $md^*_{\max} = a + f - k - b\bar{Q}$, combined with $b = (a - p_{\bar{Q}})/\bar{Q}$, simplifies to $md^*_{\max} = p_{\bar{Q}} + f - k$: the threshold depends only on the private lease rate $p_{\bar{Q}}$ and the fee setting (f, k), with the reservation value a and the cap $\bar{Q}$ both dropping out. $\partial md^*_{\max}/\partial a = 0$ and $\partial md^*_{\max}/\partial \bar{Q} = 0$ in both calibrations, with the elasticity of the threshold to $p_{\bar{Q}}$ approaching unity.

Table B1. Local sensitivity of the break-even threshold $md^*_{\max}$ to calibration primitives

	Grazing ($k = 0$)			Timber ($k = 0$)		
Parameter θ	Value	$\partial md^*_{\max}/\partial\theta$	Elasticity	Value	$\partial md^*_{\max}/\partial\theta$	Elasticity
a (MB intercept)	30	0	0	100	0	0
$p_{\bar{Q}}$ (MB at cap)	23.40	1	0.945	70	1	0.946
$\bar{Q}$ (cap)	12.3	0	0	3	0	0
f (extraction fee)	1.35	1	0.0545	4	1	0.0541
k (conservation fee)	0	-1	0	0	-1	0
$md^*_{\max}$ at calibration		24.75			74.00	

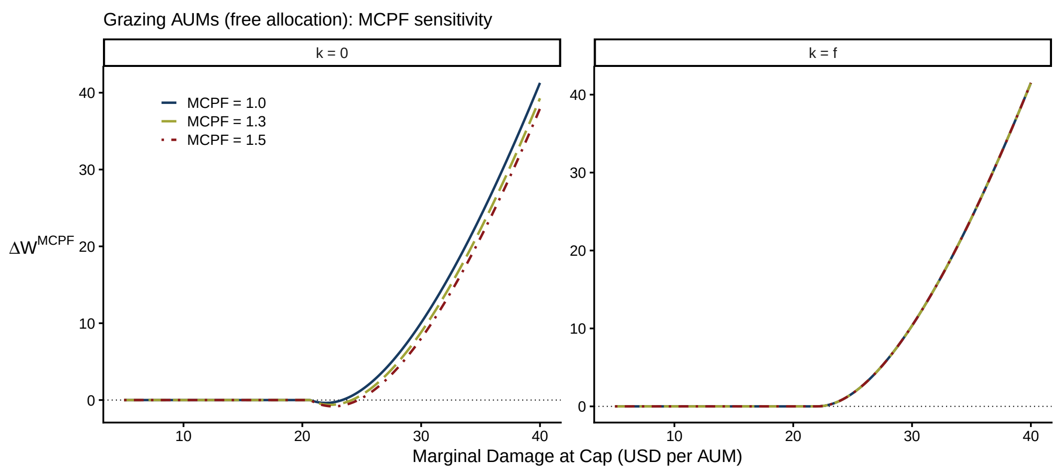
Notes: Closed-form derivatives evaluated at the grazing and timber calibration points (k=0). Elasticities are unit-free $\partial \ln md^*_{\max}/\partial \ln \theta$. The threshold is invariant to a and $\bar{Q}$ because they cancel through $b = (a - p_{\bar{Q}})/\bar{Q}$.

B.2 Marginal cost of public funds

Figure B1 shows the MCPF-weighted welfare $\Delta W^{\text{MCPF}} = \Delta U + \Delta C + \text{MCPF} \cdot \Delta G$ as a function of $md_{\max}$ for grazing under MCPF $\in \{1.0, 1.3, 1.5\}$, a standard range from the literature (Browning, 1976; Hendren, 2016; Jacobs, 2018). The status-quo regime ($k = 0$) deepens the welfare-reducing zone as MCPF rises—the break-even threshold shifts from $\$23.4$/AUM at MCPF=1.0 to $\$24.9$/AUM at MCPF=1.5—because G bears the entire fee-revenue loss and that loss is amplified by the public-funds shadow price. The Pareto regime ($k = f$) is insensitive: $\Delta G = 0$ by construction, so the MCPF weight is inert. Figure B2 shows the same exercise for timber. Under auction the conclusion strengthens: the auction-revenue rebound makes $\Delta G > 0$ in the active range, so

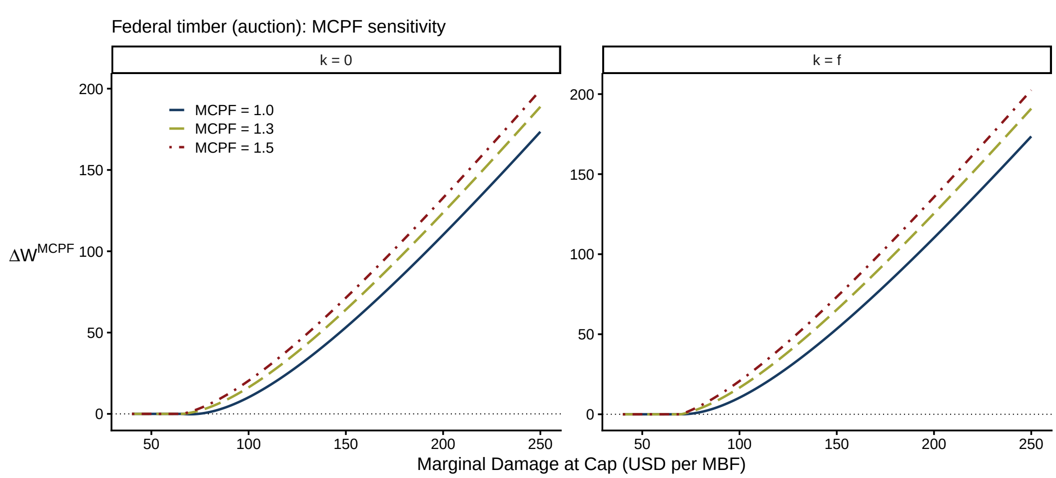
MCPF > 1 amplifies a positive transfer rather than a negative one and aggregate welfare improves uniformly with MCPF.

Figure B1. MCPF sensitivity: grazing AUMs (free allocation)



Notes: ΔW^{MCPF} vs $md_{\max}$ under MCPF $\in \{1.0, 1.3, 1.5\}$. Left panel: status-quo $k = 0$, where G bears the fee-revenue loss and MCPF widens the welfare-reducing zone. Right panel: Pareto $k = f$, where $\Delta G = 0$ and MCPF is inert.

Figure B2. MCPF sensitivity: federal timber (auction)

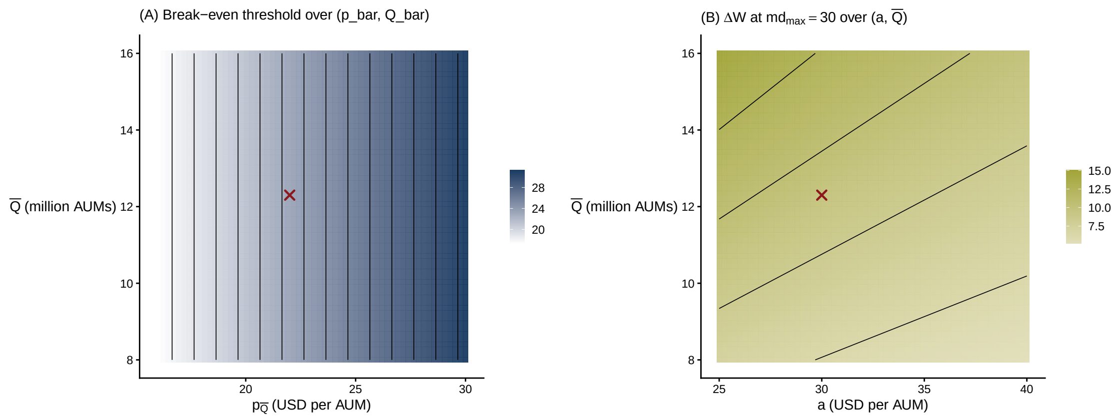


Notes: ΔW^{MCPF} vs $md_{\max}$ under MCPF $\in \{1.0, 1.3, 1.5\}$. Under auction, the auction-revenue rebound makes $\Delta G > 0$, so MCPF amplifies a positive transfer and aggregate welfare improves uniformly with MCPF in the active range.

B.3 Two-dimensional robustness in $(p_{\bar{Q}}, \bar{Q})$ and $(a, \bar{Q})$

Figure B3 varies the grazing calibration along two two-dimensional planes. Panel A traces the break-even threshold $md^*_{\max}$ over $(p_{\bar{Q}}, \bar{Q})$, holding a fixed: contour lines are vertical, confirming the closed-form result that the threshold depends on $p_{\bar{Q}}$ and not on $\bar{Q}$. Panel B traces aggregate welfare ΔW at $md_{\max} = \$30/\text{AUM}$ (a plausible above-threshold damage value) over $(a, \bar{Q})$, holding $p_{\bar{Q}}$ fixed at the calibration point. Welfare remains positive across the full sweep—100% of the $(a, \bar{Q})$ neighborhood delivers $\Delta W > 0$—with the magnitude varying between roughly $5M and $15M depending on the slope and cap parameters. The welfare conclusion does not flip in any plausible neighborhood of the calibration.

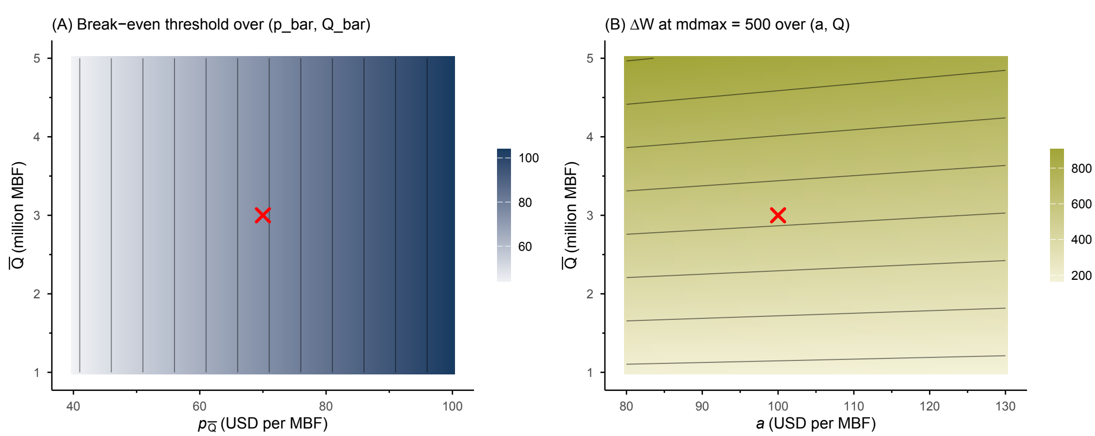
Figure B3. Two-dimensional robustness for grazing



Notes: Red × marks the calibration point. Panel A: $md^*_{\max}$ over $(p_{\bar{Q}}, \bar{Q})$, holding a fixed at $30/AUM; vertical contours confirm threshold invariance in $\bar{Q}$. Panel B: ΔW at $md_{\max} = \$30$/AUM over $(a, \bar{Q})$, holding $p_{\bar{Q}}$ fixed at $23.40/AUM; dashed red line traces $\Delta W = 0$ contour, which lies entirely outside the swept neighborhood.

The same exercise for federal timber (Figure B4). Panel A traces the break-even threshold $md^*_{\max}$ over $(p_{\bar{Q}}, \bar{Q})$, holding a fixed at $100/MBF; contour lines are vertical, confirming threshold invariance in $\bar{Q}$. Panel B traces ΔW at $md_{\max} = \$500$/MBF (a plausible above-threshold damage value, well within the full-accounting carbon range from Section 6.3) over $(a, \bar{Q})$, holding $p_{\bar{Q}}$ fixed at the calibration point. Welfare remains positive across the full range, with the welfare-zero contour lying entirely outside the relevant neighborhood. As with grazing, the welfare conclusion does not flip in any plausible neighborhood of the timber calibration.

Figure B4. Two-dimensional robustness for timber



Notes: Red × marks the calibration point. Panel A: $md^*_{\max}$ over $(p_{\bar{Q}}, \bar{Q})$, holding a fixed at $100/MBF; vertical contours confirm threshold invariance in $\bar{Q}$. Panel B: ΔW at $md_{\max} = \$500$/MBF over $(a, \bar{Q})$, holding $p_{\bar{Q}}$ fixed at $70/MBF; dashed red line traces $\Delta W = 0$ contour, which lies entirely outside the swept neighborhood.