A Welfare Analysis of Conservation Easement Tax Credits

February, 2018

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Abstract

The use of conservation easements to protect vulnerable land is growing rapidly but there is growing public concern about the social cost of easement tax credit programs which promote the use of easements. Landowners who agree to an easement sell or donate their development rights to a conservation agency and receive a tax credit on the "gifted" amount. The tax credit is intended to reduce under-investment in land preservation by conservation agencies that operate with tight budgets. Using a model that combines asymmetric information and real options this papers shows that the tax credit program is least effective for land with the highest environment value because the value of the easement gift is lowest in these situations. Moreover, if the land's environmental value is sufficiently large such that the easement gift falls below a threshold value then the marginal tax credit serves to decrease rather than increase the probability of an easement outcome. The combination of adverse selection and a failure of the conservation agency to internalize the land's development value can result in the agency agreeing to accept a welfare-worsening donated easement.

Keywords: Conservation Easement, Tax Credit, Environmental Externality, Crowding Out, Real Option.

JEL classification: Q24, R14, H23, L14.

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1 Introduction

Conservation easements are a popular market based instrument for preserving U.S. farmland, forest land and land that is rich in biodiversity. A conservation easement allows a land trust or conservation agency to purchase or accept a donation of a landowner's development rights rather than purchasing and managing the actual land in order to permanently prevent development activities [Anderson and King, 2004]. Landowners who agree to an easement receive sizeable federal tax deductions and state tax credits that extend over multiple years and in some cases are transferable (see Parker and Thurman [2017] and Suter, Dissanayake, and Lewis [2014] for detailed examples)[1] Largely because of these tax benefits easement uptake by landowners and the creation of new land trusts has experienced strong growth in recent years. Indeed, as of September, 2015 an estimated 23,349,840 acres of U.S. land was protected with 114,216 easements [Updike and Mick, 2016] and as of 2010 there were over 1700 local, state and national land trusts operating in the U.S. [Chang, 2010]. The taxpayer cost of this rapid expansion has been sizeable. Updike and Mick [2016] (note 3) indicate that approximately $11 billion of conservation easement tax credits were granted to U.S. landowners between 2003 and 2009. Colorado alone granted $965 million in easement tax credits over a recent 15 year period [Migoya, 2016].

There are two opposing views of the social value of conservation easements and their associated tax credits. One view is that easements have the potential to efficiently preserve public goods as compared to zoning and other forms of land use regulation [McLaughlin, 2004, Parker and Thurman, 2013]. The other view is that because land trusts and conservation agencies are likely to have objectives beyond maximizing public welfare, and the tests for an easement's environmental preservation value are often inadequate, easement tax credits generally result in small public benefits relative to the taxpayers' cost [Parker, 2005, Swift, 2010, Migoya, 2016].[2]

[1] To simplify the language the combined federal tax deduction and state tax credit will be referred to generically as a tax credit. The distinction between a deduction and a credit and the importance of the various parameters of these programs are emphasized later in the paper.

[2] Easements have also been criticized because they result in higher property tax rates and fewer locally-provided public goods[Raymond and Fairfax, 2002, Anderson and King, 2004, Merenlender, Huntsinger, Guthey, and Fairfax, 2004, Fishburn, Kareiva, Gaston, and Armsworth, 2009].

The dividing line between these two views is generally blurred because of significant asymmetric information. Specifically, easement tax credits that are designed to induce owners of environmentally vulnerable land to switch from development to protection will also draw in high tax-bracket owners of environmentally benign land who have no interest in land development [Parker and Thurman, 2013]. The high taxpayer cost that results from the asymmetric information may be incorrectly attributed to misaligned incentives and lack of oversight of conservation agencies.

In light of these stylized facts about conservation easement markets, the purpose of this paper is to analyze the social value of easement tax credits within a framework that combines elements of pricing with imperfect competition, asymmetric information and decision making with uncertainty and irreversibility (i.e., real option). This analysis builds on the literature that examines the efficiency of tax credits as a policy instrument. For example, Parker and Thurman [2017] identify three distinct channels through which tax policy affects conservation incentives, Suter et al. [2014] examine how tax policy affects conservation quality (rather than quantity) and Parker [2005] describes the implications of tax credit programs that require perpetuity agreements. The empirical side of this literature measure tax policy impacts on conservation in various settings [Sundberg and Dye, 2006, Sunberg, 2008, Suter et al., 2014, Soppelsa, 2016, Parker and Thurman, 2017]. The main conclusion of this empirical work is that tax policies are generally effective at inducing landowners to conserve land.

Inefficient outcomes that result from "rouge" conservation agencies, which operate primarily to facilitate tax credit claims are rather obvious and so this undesirable feature of easement markets is not included in this analysis. Similar to [Parker, 2005] it is assumed instead that the conservation agency makes easement decisions in a way that maximizes environmental surplus. Focusing on environmental surplus rather than overall surplus represents only a partial misalignment of incentives for the agency relative to society as a whole. The misalignment is small when the easement has a positive price because the easement price that the agency would offer in the absence of a budget constraint would largely internalize the land's development value. As will be shown below the misalignment is much more severe for the more common case of donated easements.

To set the stage for the analysis it is useful to highlight the role of the agency's budget constraint as driving the need for an easement tax credit. Prior to development the land generates a stream of profits (π) and non-market amenities such as a rural lifestyle (s) for the landowner, and a stream of external environment benefits (ω) for the general public. If a now-or-never decision regarding land development was required and there is no uncertainty then the owner of the land would agree to development if the value of the land in development (V) exceeds the present value of the $\pi + s$ stream. In contrast, society would like the land to be developed only if V exceeds the present value of the $\pi + s + \omega$ stream. Suppose the general public was willing to provide donations to the agency in an amount equal to the present value of the ω stream. Further suppose that the agency offered this amount to the landowner in the form of a payment for agreeing to a conservation easement (P). In this case the landowner will agree to development only if V exceeds P plus the $\pi + s$ stream. Because P is equal to the present value of the ω stream by assumption, the landowner's development decision is now in the best interest of society.

The obvious problem with the above scenario is that due to the well-known free rider problem in the voluntary provision of public goods agencies are generally not able to solicit donations that equal the present value of ω. If P is less than the present value of the ω stream due to insufficient donations from the general public (i.e., the agency is budget constrained) then land that society would like to see protected will sometimes be developed. The easement tax credit aims to bridge this gap by "forcing" taxpayers to finance part of the environmental public good. A second obvious problem with the above scenario is the assumption of symmetric information. In the context of a finite horizon conservation contract Ferraro [2008] shows how asymmetric information in the payment for ecosystem services allow landowners to extract information rents. Moreover, asymmtric information draws in landowners who would have chosen conservation in the absence of a payment (i.e., lack of additionality) and who supply land that has a comparatively low net conservation benefit for society. The situation is similar in this current analysis except the implications are stronger due to the perpetual nature of the easement contract.

Two important results emerge from this analysis. First, easement tax credits will induce certain types of landowners to donate easements on land that should not be protected because of insufficient environmental value, and conservation agencies may agree to hold these socially undesirable easements. This result may appear obvious because the problem is similar to the the "bad" side of easements that was discussed above. However, keep in mind that this result emerges despite the fact that the agency's objective is to maximize environmental surplus, which is well aligned with overall surplus when the easement price is positive. Consequently, the problem of socially undesirable donated easements that are linked to easement tax credits is not expected to disappear if the "rogue" agencies that are described by are eliminated. Indeed, even if all agencies are incentivized to make decisions that maximize the environmental interests of society the problem of socially undesirable donated easement will likely remain. Parker [2005] made a similar claim but did so using descriptive analysis rather than formal economic analysis.

The second important result of this paper is that the effectiveness of an easement tax credit as an instrument for reducing market failure (i.e., the "good" side of the equation) is lower for more environmentally sensitive land. In fact, for sufficiently high levels of the land's environmental value the standard comparative static result reverses and the easement tax credit decreases rather than increases the probability of an easement outcome. This result is important because the "bad" side of easement tax credits are more tolerable if it is known these credits are highly effective at protecting environmentally sensitive land. The argument in favour of easement tax credits loses much of its punch if in fact tax credits have relatively low effectiveness for the most environmentally vulnerable land.

To understand this argument concerning tax credit effectiveness it is necessary to understand the determinants of the easement gift. The easement gift is formally defined as the difference between the market value of the land without and with an easement minus any compensation the landowner receives for agreeing to the easement. The tax credit received by the landowner is equal to the easement gift multiplied by the tax credit rate and as such the size of the easement gift is a key variable with respect to landowner decision making. The second result of this paper emerges because the equilibrium size of the easement gift is smaller and possibly negative for land that has higher environmental value. This means that the influence of the tax credit program on landowner decision making is smaller and possibly with opposite the intended effect for land that has relatively high environmental value.

The value of the landowner's real option when deciding whether or not to accept the easement is also an important determinant of the size of the easement gift. The higher the degree of development value uncertainty the higher the landowner's opportunity cost of signing the easement (i.e., real option value) and thus the higher the price that must be offered by the agency to achieve an easement outcome. However, a more valuable real option results in a longer delay of the landowner's development decision in the event of easement rejection. This longer delay lengthens the temporary flow of environmental benefits, which in turn decreases the agency's valuation of permanent protection via an easement and lowers the easement price that the agency is prepared to offer. The combined offsetting real option impact is complicated but nevertheless is an important determinant of the value of the easement gift and thus the effectiveness of the easement tax credit program.

The formal analysis in the next section has been simplified (implications discussed below) by assuming the tax credit is the same for all landowners, is not subject to any maximums and is fully refundable in the year the gift was made. In reality, the donation or sale of an easement allows for a multi-year capped income tax deduction at the federal level and a capped multi-year tax credit that may or may not be transferable at the state level. The federal tax deduction depends on the landowner's marginal tax rate whereas this is not the case for the state tax credit. The efficiency properties of a transferable state tax credit are discussed later in the paper.[3]

The next section lays out the assumptions of the model and derives the equilibrium conditions for the easement market. Formal results concerning socially undesirable donated easements and socially desirable paid easements are presented in Section 3. In Section 4 descriptive analysis and the presentation of simulated examples are used to analyze the implications of relaxing several key assumptions. Section 5 contains a discussion about the limitations of the analysis and implications of the results. Concluding remarks are presented in Section 6.

[3]As of 2015 Colorado landowners can claim a state tax credit of 75 percent of the value of the easement gift on the first $100,000 and 50 percent on the remaining balance, up to a maximum of $1.5 million. Landowners are allowed to sell unused tax credits in a secondary market at a rate of $0.83 per dollar of credit.

2 Assumptions and Market Equilibrium

2.1 Basic Assumptions

A local conservation agency allocates its budget B between land preservation and an external environmental project (e.g., wetland restoration) in order to maximize environmental surplus for the general public.[4] Land preservation implies using a conservation easement to purchase the development rights for a parcel of land from a local landowner at price $P \geq 0$. The agency's valuation of the external project is equal to λ per dollar of allocation.[5] Thus, if the landowner agrees to the easement proposal then the external project generates environmental surplus $\lambda(B - P - F)$ for the agency where F is the fixed administrative cost of setting up the easement. The agency views λ as a fixed parameter when constructing its easement offer but due to the project's diminishing marginal value an agency with a tighter budget (smaller B) is associated with a higher-return external project (larger λ) and vice versa. This association is useful because now budget restrictiveness can be described with both the B and λ parameters.

While the land is undeveloped, external environmental benefits for the general public are assumed to flow at rate ω as of date 0 and grow at a constant rate $\gamma \geq 0$ over time. These external benefits include wildlife habitat, preserved biodiversity, green space and a carbon sink for greenhouse gas emissions.[6] With an easement in place the agency's date 0 valuation of the perpetual environmental benefit flow is equal to $\Omega = \omega/(\rho - \gamma)$ where ρ is the agency's rate of discount. As will be explained in greater detail below, if the easement is rejected by the landowner then environmental benefits will flow at a fixed fraction of ω between date 0 and development date T, and then remain at zero for all time beyond T.[7]

[4]Appendix A provides a summary of all the notation used in the formal analysis.

[5]If the external project requires a direct expense such as planting buffer strips near creeks that run through agricultural land then the λ parameter is a measure of the project's net valuation.

[6]Estimates of ω and γ by an independent assessor are assumed to be accurate and fully observable by all interested parties free of charge.

[7]A more general version of the model would allow for both positive pre-development environmental flows and negative post-development environmental flows. Assuming zero post-development flow is unlikely to be important

While the land is undeveloped, the owner receives a constant instantaneous profit flow, π, and a constant instantaneous "lifestyle" amenity flow, $s \in (s^{min}, \infty)$, which is private information. With discount rate ρ (same as the agency) the landowner's valuation of her land with an easement in place can be expressed as $(\pi + s)/\rho$. The s variable includes the landowner's valuation of open space, quiet surroundings and possibly some capacity to produce food. From the agency's perspective, s is drawn from a probability density function, $g(s; \Omega)$, with corresponding cumulative density function, $G(s; \Omega)$.[8] It is reasonable to assume that a larger value for Ω shifts $g(s; \Omega)$ to the right (i.e., state-wise dominance), which implies a positive relationship between the agency's expected value of the "lifestyle" amenity variable, s, and the flow of external environmental benefits, ω. The agency's offer is based on expected s rather than actual s and so easement acceptance by the landowner is probabilistic rather than deterministic.

The game unfolds as follows. At date -2 the landowner's type (s) is randomly drawn by nature and privately revealed to the landowner. If the land's environmental value (Ω) is sufficiently large, then at date -1 the risk neutral agency provides the landowner with a take-it-or-leave-it offer to purchase the land's development rights. The offer price (P) will either be a positive value (i.e., a "purchased" easement) or a zero value (i.e., a "donated" easement). At date 0 the agency's offer is either accepted or rejected by the risk neutral landowner. If the offer is accepted then the landowner receives price P from the agency, a tax credit from the taxing authority and the $\pi + s$ flow from the undeveloped land into perpetuity. If the offer is rejected then the landowner waits until the optimal time to sell her land to a local developer. When the sale eventually occurs at stochastic date T the landowner receives a one time payment from the developer and forfeits the $\pi + s$ flow. To avoid confusion regarding the discounting of the various flows, assume the amount of time between date -1 and date 0 is arbitrarily small.

The developer payment to a landowner who previously rejected the easement offer and has at date T agreed to the developer's offer is denoted $V(T)$ because this payment is the date T

for the results, especially if it is assumed that the agency cares only about the differential in the environmental flow before and after development.

[8]The results are expected to be the same if the model was constructed with multiple heterogeneous landowners and one landowner randomly selected to interact with the agency.

value of the developer's perpetual standing offer $V(t)$, which evolves stochastically over time. A high degree of competition amongst developers implies that $V(t)$ is the full value of the land's contribution toward the development project and as such is independent of the landowner's willingness to accept. The developer's offer price is assumed to evolve stochastically over time over time as geometric Brownian motion with drift parameter $\alpha \in (0, \rho)$ and volatility parameter σ. This assumption, which implies that $dV = \alpha V dt + \sigma V dz$ where $dz = \epsilon_t \sqrt{dt}$ is the increment of a Wiener process, is intended to reflect ongoing random supply and demand shocks in the developed land market.[9]

Let $C(\Omega)$ denote the landowner's date T legal cost of completing the land sale. The net selling price received by the landowner at date T is therefore $V(T) - C(\Omega)$. To simplify the analysis this legal cost is fixed over time and is also independent of the value of the land sale. Of course $C(\Omega)$ must be discounted from date T back to date 0 because it is the date 0 value of the date T legal cost that the landowner uses when assessing the attractiveness of the agency's easement offer. Legal costs are assumed to be higher for more environmentally valuable land, which implies $C'(\Omega) > 0$. This assumption reflects the fact that environmental groups are more likely to use legal means to block the land sale the higher the environmental value of the land.[10]

Recall that if the agency's easement offer is rejected at date 0 then there will exist a temporary flow of environmental benefits until the time of land development at date T. By assumption this temporary environmental flow is a fixed fraction, ϕ, of the permanent environmental flow that results with an easement in place. This restriction, which is imposed for technical reasons (details below), is reasonable because an easement is likely to magnify external environmental benefits such as less restricted access for hunters and enhanced biodiversity due to stronger incentives for long-term environmental management initiatives. Because T is stochastic, the present value of the temporary environmental flow, denoted W, is also stochastic. Let $W(V, s) = \int_0^{\Omega} W f(W; V, s) dW$ denote the expected present value of the temporary environ-

[9]Standard models of real estate development such as Capozza and Sick [1994] make similar assumptions about real estate price uncertainty.

[10]If the land has very high environmental value then the high value of $C(\Omega)$ may eliminate the development option. In this case the landowner will always accept the easement and the easement tax credit only serves to transfer resources from taxpayers to the landowner (i.e., there are no efficiency implications).

mental flow assuming a type s landowner is choosing when to developer her land. Details about $f(W; V, s)$, which is the probability density function for W, are provided below.

2.2 Landowner's Demand for the Easement

The easement tax credit is an important component of the landowner's decision. The one-time (date 0) tax credit at rate τ compensates the landowner for "gifting" a portion of the current market value of the land to the agency.[11] The date 0 easement gift, $H(V, P) = V - \pi/\rho - P$, is the difference between the date 0 development value of the land, $V(0) \equiv V$, and the status quo use value of the land, π/ρ, minus the easement payment, P. Note that a negative easement gift, $H(V, P) < 0$, corresponds to a relatively large easement price, a portion of which is deemed taxable income. Accounting for the easement tax credit, a measure of well-being for a landowner with "lifestyle" amenity value s who chooses to accept the easement can be expressed as

$$Z(V, s, P) = \frac{\pi + s}{\rho} + P + \tau(V - \pi/\rho - P) \tag{1}$$

The agency's offer price, P, depends on the landowner's valuation of the easement, $Z(V, s, P)$, and also on $L(V, s)$, which is the landowner's date 0 opportunity cost of giving up the option to eventually sell the land to the developer. The value of the option to wait and develop the land at an optimal time in the future as measured by $L(V, s)$ is derived using a standard real options framework. Specifically, following Dixit and Pindyck [1994], it is shown in Appendix B that for a type s landowner

$$L(V, s) = \left[1 - \left(\frac{V}{V^D(s)}\right)^\beta\right] \frac{\pi + s}{\rho} + \left(\frac{V}{V^D(s)}\right)^\beta \left[V^D(s) - C(\Omega)\right] \tag{2}$$

[11] As noted in the Introduction, the analysis is simplified by assuming the tax benefit is a fully refundable tax credit with no upper limit. Consequently, the full value of the credit is realized when the landowner agrees to the easement. The implications of this strong assumption for the results are discussed later in the analysis.

Within equation (2) the variable $V^D(s)$ is the development trigger (i.e., the landowner should develop only if $V(t)$ rises to $V^D(s)$) and β is the markup variable (see Appendix B for the full expression).[12] The former depends on the latter according to:

$$V^D(s) = \frac{\beta}{\beta - 1}\left[\frac{\pi + s}{\rho} + C(\Omega)\right] \tag{3}$$

At this point it is useful to comment on the rather strong assumption that the agency has all of the bargaining power when interacting with the landowner. It is reasonable to assume that the agency has more bargaining power than the landowner because agencies with budgets for land preservation are relatively scarce. Nevertheless, assuming 100 percent bargaining for the agency is rather extreme. In the absence of asymmetric information assuming Nash bargaining rather than a now-or-never offer would be straight forward. However, in this current analysis with asymmetric information it is not possible to obtain a closed form solution with the assumption of two-sided bargaining. To strike a balance between realism and simplicity, the analysis proceeds by assuming the landowner exerts limited bargaining power by credibly committing to reject all easement offers that do not provide her with positive easement surplus at level $\theta(\Omega)$ or higher. It is reasonable to assume that $\theta'(\Omega) > 0$ because owners of land with comparatively high environmental value are expected to be in a better position to bargain with the agency.

In the case of a positive price/interior solution, for a given easement price, P, there exists a landowner with "lifestyle" amenity flow $\hat{s}$ who is indifferent between accepting and rejecting the agency's date 0 easement offer. This indifferent landowner is implied by $Z(V, \hat{s}, P) = L(V, \hat{s}) + \theta(\Omega)$. In this analysis it is more convenient to treat $\hat{s}$ rather than P as the agency's choice variable. If $Z(V, \hat{s}, P) = (\pi + \hat{s})/\rho + P + \tau H(V, P)$ is solved for P the resulting equation can be written as

$$P(\hat{s}) = \frac{L(V, \hat{s}) + \theta(\Omega) - \tau V - (1 - \tau)(\pi/\rho) - \hat{s}/\rho}{1 - \tau} \tag{4}$$

[12]Note that the stochastic discount factor, $(V/V^D(s))^\beta$, discounts money received at the expected time of development back to date 0 and $1 - (V/V^D(s))^\beta$ is a measure of the present value of a one dollar annuity between date 0 and the expected time of land development. These expressions are analogous to the no uncertainty case where the present value of one dollar received at time T is $e^{-\rho T}$ and the present value of a one dollar continuously compounded annuity is $(1 - e^{-\rho T})/\rho$.

Equation (4) shows the easement price the agency must offer if it chooses $\hat{s}$ to maximize environmental surplus.

An important property of equation (4) is that it is a decreasing function:

$$\frac{dP(\hat{s})}{d\hat{s}} = -\frac{1}{\rho(1-\tau)}\left(\frac{V}{V^D(\hat{s})}\right)^{\beta} \tag{5}$$

The inverse relationship between $\hat{s}$ and P that is implied by equation (5) ensures that the landowner will only agree to the easement if her randomly selected type, s, is greater than or equal to $\hat{s}$. Thus, if the agency chooses $\hat{s}$ and offers easement price $P(\hat{s})$ according to equation (4), the probability that the easement will be accepted is given by $1 - G(\hat{s})$ where, as noted above, $G(\hat{s})$ is the probability distribution function for s.

2.3 Optimal Pricing by the Agency

The agency's objective is to choose $\hat{s}$ to maximize $\Gamma(\hat{s})$, which is the expected present value of the environmental surplus that flows from the undeveloped land and the external project:

$$\Gamma(\hat{s}) = (1 - G(\hat{s}))\left[\Omega + \lambda(B - F - P(\hat{s}))\right] + G(\hat{s})\lambda B + \int_{s^{min}}^{\hat{s}} W(V,s)ds \tag{6}$$

The first part of equation (6) indicates that with probability $1-G(\hat{s})$ the easement will be signed, in which case the agency earns environment surplus Ω from the land and $\lambda(B-F-P(\hat{s}))$ from the external project. With probability $G(\hat{s})$ the easement will not be signed in which case the agency earns environmental surplus λB from the external project. If the easement is not signed then the agency also earns environmental surplus that is associated with the temporary flow of environmental benefits from the land (i.e., between date 0 and when the land is developed). The expected value of this surplus, which is measured by $W(V,s)$ in equation (6), must be integrated over all landowner types who choose to reject the easement. The notation in equation (6) has been simplified by suppressing the Ω parameter in the $g(s;\Omega)$ and $G(s;\Omega)$ functions.

Using equation (5), the first-order condition for the agency's optimal choice of $\hat{s}$ can be rearranged and written as

$$P(\hat{s})) = \frac{1}{\lambda}\left(\Omega - W(V,\hat{s})\right) - F - \frac{\mu(\hat{s})}{\rho(1-\tau)}\left(\frac{V}{V^D(\hat{s})}\right)^{\beta} \tag{7}$$

Within equation (7) the variable $\mu(\hat{s})$ is shorthand notation for the inverse hazard rate function $[1 - G(\hat{s})]/g(\hat{s})$. Similarly, the $P(\hat{s})$ variable on the left side of equation (7) is a placeholder for equation (4). If equation (4) was substituted for $P(\hat{s}))$ in equation (7) then it would be clear that the agency's first-order condition implies a unique equilibrium value $\hat{s}$. This unique value, $\hat{s}^*$, together with equation (4) gives the equilibrium easement price, $P(\hat{s}^*)$, and together with $1 - G(\hat{s})$ gives the equilibrium probability of an easement outcome, $1 - G(\hat{s}^*)$.

The $\Omega - W(V, \hat{s})$ term on the right side of equation (7) is the expected net increase in the environmental value of the land after accounting for the temporary flow of environmental benefits that would result in the presence of an easement. This net benefit is adjusted by λ to reflect the fact that an agency with a tighter budget and thus higher λ will offer a lower price for the easement because funding the easement rather than the external environmental project has a higher opportunity cost. The last term on the right side of equation (7) is a measure of the price shading that results from monopsony pricing by the agency (i.e., $\hat{s}$ ensures marginal outlay is equal to marginal benefit). Equation (7) shows that through the inverse hazard rate ($\mu(\hat{s})$) variable the price discount is larger the less elastic is the landowner's demand for the easement.[13]

3 Analysis of an Easement Tax Credit

The purpose of this section is to formally examine how the easement tax credit impacts the easement market outcome and the welfare of market participants. To keep the results focused a number of simplifying assumptions are incorporated into the base model. These assumptions are relaxed in the following section in order to determine if the base case results continue to hold in a more general setting. Specifically, assume there is no development value uncertainty ($\sigma = 0$), there is zero growth in the land's environmental value ($\gamma = 0$), the distribution for s is

[13]To establish this result let $Q = 1 - G(\hat{s})$ denote the fraction of landowner types who accept the easement. Divide $dQ = -g(\hat{s})d\hat{s}$ by $dP = -\frac{1}{\rho(1-\tau)}\left(\frac{V}{V^D}\right)^{\beta} d\hat{s}$ from Equation (5), multiply the resulting expression by P/Q and substitute in $\mu(\hat{s})^{-1} \equiv g(\hat{s})/(1 - G(\hat{s}))$ to obtain an expression for the extensive margin demand elasticity: $\frac{dQ}{dP}\frac{P}{Q} = \mu(\hat{s})^{-1}\rho(1-\tau)\left(\frac{V}{V^D}\right)^{-\beta} P$. Notice that a smaller elasticity implies a larger value for $\mu(\hat{s})$.

independent of the land's environmental value (i.e., $G(s,\Omega)$ does not depend on Ω), the agency is assumed to capture all of the bargaining surplus ($\theta(\Omega) = 0$) and the landowner incurs zero legal cost when selling her land to the developer ($C(\Omega) = 0$).

Setting $\sigma = 0$ in order to eliminate development value uncertainty requires constructing an expression for the temporary environmental flow variable, W, as an explicit function of time. With $\sigma = \gamma = 0$, let $W_0(V,s)$ denote the discounted expected environmental flow from the land between when the easement is rejected at date 0 and the optimal time for land development at date T. In Appendix C it is shown that

$$W_0(V,s) = \left[1 - \left(\frac{V}{V^D(s)}\right)^{\beta}\right]\phi\Omega \tag{8}$$

Equation (8) shows that delaying development after rejecting the easement offer is generally still optimal for the landowner provided there is positive growth in V.

In addition to the above simplifying assumptions it is useful to impose various parameter restrictions to ensure that the easement pricing problem is well behaved. First, it is shown in Appendix D that $\phi\omega < \lambda\pi/\beta$ is sufficient to ensure that the second-order condition for the agency's maximization problem holds.[14] Second, it is useful to assume that for all landowner types, some development delay is optimal if the agency's easement offer is rejected. Using equation (3), delay is optimal for all landowner types if $V < \frac{\beta}{\beta-1}\frac{\pi+s^{min}}{\rho}$. Finally, assume that the date 0 development value of the land exceeds its status quo use value (i.e., $V > \pi/\rho$). After dividing $\phi\omega < \lambda\pi/\beta$ through by ρ/β, the three restrictions can be written as

Assumption 1. *(a)* $\beta\Omega < (\lambda\pi)/(\phi\rho)$*; and (b)* $\frac{\pi}{\rho} < V < \frac{\beta}{\beta-1}\frac{\pi+s^{min}}{\rho}$

To formally examine the easement tax credit it is useful to first discuss the market failure that the tax credit is intended to address. The first of the two market failures is that social welfare is highest when the land is permanently protected with an easement but due to the agency's budget constraint and exercise of market power its investment in the easement is inefficiently low. The

[14]The second order condition may fail to hold if ϕ is close to 1 because in this case the marginal cost of raising $\hat{s}$, as measured by the reduced probability of a successful easement outcome, may consistently remain below the marginal benefit of raising $\hat{s}$, which is a longer period of post-rejection temporary environmental flow.

second type of market failure is that social welfare is highest when land development is allowed to occur at the socially optimal time but the land is nevertheless permanently protected by an easement. This inefficient protection occurs because the easement tax credit induces landowners to donate easements and these donations are accepted by the agency because it fails to fully internalize the value of the land in development.

To formalize these two notions of market failure it is useful to have a measure of the difference in date 0 social welfare with and without the easement for a type s landowner. The expression of interest is

$$\Delta(s,\Omega) = \Omega - W_0(V,s) - F - [L(V,s) - (\pi+s)/\rho]. \tag{9}$$

The $\Omega - W_0(V,s) - F$ expression on the right side of equation (9) is the net environment benefit of protecting the land with an easement, and $L(V,s) - (\pi+s)/\rho$ is the net value of the option to eventually develop the land if an easement is rejected. After substituting in equations (2) and (8) and simplifying a revised expression for $\Delta(s,\Omega)$ can be written as

$$\Delta(s,\Omega) = (1-\phi)\Omega - F - \left[\frac{1}{\beta-1}\frac{\pi+s}{\rho} - \phi\Omega\right]\left(\frac{V}{V^D}\right)^{\beta} \tag{10}$$

Equation (10) shows that for a sufficiently high (low) environmental value of the land as measured by Ω the easement outcome results in an increase (decrease) in social welfare. A positive value for $\Delta(s,\Omega)$ is a necessary condition for the first type of market failure (a socially desirable easement is not adopted) and a negative value is necessary for the second type of market failure (a socially undesirable easement is adopted).

The mechanics of the first type of market failure are worked out in Appendix E and the mechanics of the second type are worked out in the next section. In Appendix E the problem of easement pricing is solved from the perspective of a social planner who wishes to maximize overall market surplus rather than focusing exclusively on environmental surplus. The only other difference between the planner and the agency is that the planner has a lower opportunity cost of allocating funds to the easement.[15]

[15]This assumption is reasonable because the ability of the agency to raise funds is limited due to free riding by members of the public. There is no equivalent free riding with a social planner because it's tax-funded budget is government sanctioned and thus its λ is a measure of the marginal deadweight loss of taxation.

The results in Appendix E show that there are two distinct reasons why the probability of an easement outcome is lower with the agency than with the planner. First, as compared to the planner the agency operates with a more restricted budget and therefore has a higher opportunity cost of investing the last dollar in the easement project. Second, similar to a standard monopsonist, the agency maximizes environmental surplus by paying less and thus lowering the probability of an easement outcome because the funds that are transferred from the easement to the external project generates positive net environmental surplus. In real world markets where conservation agencies typically operate with highly restricted budgets the under-investment in the easement that is attributable to the difference in budget constraints (i.e., $\lambda > \lambda^g$) is likely far larger in magnitude than the under-investment in the easement that is attributable to the exercising of market power by the agency.

3.1 Zero-Price Easements

The formal analysis of an easement tax credit begins with the most commonly observed type of easement – those for which there is zero payment from the agency to the landowner. A zero-price outcome can occur if the agency has a positive demand for the easement but operates without a budget or if the agency has zero demand for the easement (with or without a budget) but agrees to accept an easement that is donated by the landowner. In real world markets it would be difficult to empirically distinguish between these two types of zero-price easements. To keep the analysis in this section focused, the assumptions from the previous section are maintained.

Of particular importance from a public policy perspective is the second case where acceptance of a donated easement by the agency reduces social welfare. A necessary condition for this outcome is an environmental value of the land (Ω) that is equal or below a critical value Ω^c, and a "lifestyle" amenity value of the landowner that is equal or above a critical value $\hat{s}^c$, where Ω^c and $\hat{s}^c$ are such that the agency's first-order condition that is given by equation (7) is satisfied and the equilibrium easement price that is given by equation (4) is equal to zero. The resulting pair of expressions can be rewritten as follows:

$$\hat{s}^c/\rho = \left(\frac{1}{(\beta-1)\tau(V-\pi/\rho)}\right)^{\frac{1}{\beta-1}} \left(\frac{\beta-1}{\beta}V\right)^{\frac{\beta}{\beta-1}} - \pi/\rho \tag{11}$$

and

$$\Omega^c = \mu(\hat{s}^c)\frac{\lambda}{\rho(1-\tau)}\left(\frac{V}{V^D(\hat{s}^c)}\right)^\beta + W_0(V, \hat{s}^c) + \lambda F \tag{12}$$

Whether or not the agency will accept a donated easement depends on the specific value of Ω. The agency will certainly accept the easement if $\Omega = \Omega^c$ because by construction Ω^c satisfies the agency's condition for optimization. At the opposite extreme, the agency would not accept a donated easement if $\Omega = 0$ because doing so would result in negative environmental surplus, assuming that the fixed cost of holding the easement (F) is positive. This means there must exist a value for the land's environment value, call it Ω^*, such that for $\Omega < \Omega^*$ the agency will refuse to hold a donated easement and for $\Omega^* \leq \Omega < \Omega^c$ the agency will not pay a positive amount for a donated easement but will nevertheless agree to hold it.

Of interest is how social welfare is impacted by a donated easement that the agency agrees to hold. The following result establishes that there exists a range of values for Ω and s that simultaneously satisfy the pair of donated easement conditions, $s \geq \hat{s}^c$ and $\Omega^* \leq \Omega \leq \Omega^c$, and the negative social welfare condition, $\Delta(s, \Omega) < 0$ (see Appendix F for the proof of this result and all other formal results).

Result 1. *For a landowner with a sufficiently high "lifestyle" amenity value (s) and land that has an intermediate range of environmental value, $\Omega \in [\Omega^*, \Omega^c]$, the easement will be donated rather than purchased by the agency. There exists a second range of values, $\Omega \in [\Omega^*, \Omega^{**}]$, with Ω^{**} either smaller or larger than Ω^c, for which the donation results in a decrease in social welfare.*

Result 1 highlights the market failure that results from the agency failing to internalize the land's development value other than through the price of the easement. Market failure of this type generally requires a low environmental value of the land because in this case the valuation of the easement by the agency and by society is also low. The market is most likely to fail when the landowner has a comparatively high "lifestyle" valuation of their land (i.e., a high s) because in this situation the easement gift is particular large (this raises the attractiveness of the donation by the landowner) and the temporary flow of environmental benefits as measured by $W_0(V, \hat{s}^c)$ is particularly long (this diminishes the relative value of the easement). It should be noted that this combination of low Ω and high s will be relatively rare if s and Ω are strongly positively correlated (more details below).

The next result shows that a more generous tax credit program as measured by the tax credit rate (τ) significantly expands the range of values for Ω and s for which market failure occurs.

Result 2. *A market failure of the type that is described in Result 1 cannot occur in the absence of an easement tax credit. The higher the tax credit rate (τ) the larger the combination of parameters that give rise to a Result 1 market failure.*

Result 2 is expected because the donation would not occur in the absence of a tax credit and a more generous tax credit increases the attractiveness of a socially undesirable donation of an easement. Result 2 corresponds to the stylized fact that generous tax credit programs are drawing in socially undesirable donated easements which are being accepted by conservation agencies.

The next result highlights the crowding out implications of a donated easement.

Result 3. *If the easement price was fixed by statute then raising the rate of the easement tax credit, τ, would have a relatively large impact on the probability of an easement outcome. A similar result emerges for the case of a donated easement since P is fixed at zero.*

In the absence of a constant-price statute the easement tax credit policy is characterized by crowding out. Specifically, the agency decreases its easement payment if the easement tax credit is increased and this response by the agency implies a less effective policy instrument. Result 3 highlights the fact that if there is a zero-price corner solution in the easement market then there is no crowding out at the margin and thus the effectiveness of the easement tax credit will be relatively high. This outcome is particularly important when the easement outcome is socially desirable but due to a binding budget constraint the agency is not able to offer a positive price for the easement. The lack of crowding out allows the tax credit to fully pass through to the landowner rather than being partially captured by the agency.

3.2 Positively-Priced Easements

The purpose of this section is to examine tax credit effectiveness for the case of a positively-priced easement, assuming for the reasons discussed above that there is under-investment in the easement by the agency. Similar to other types of market subsidies it is expected that a marginal increase in the tax credit rate (τ) will increase the probability of an easement outcome, and the size of the response will depend on various explicit and implicit response elasticities. The analysis below reveals some unexpected reversals of these standard results.

Figure 1 is a graph of the two expressions which make up the agency's first order condition that is given by equation (7). The schedules with the solid line assume no tax credit ($\tau = 0$) and the schedules with the dashed lines assume a positive tax credit ($\tau > 0$). Smaller values of $\hat{s}$ correspond to easement entry by additional landowner types and for this reason it is useful to interpret the graph moving from right to left rather than the traditional left to right. With this interpretation the two upward sloping schedules can be interpreted as the agency's downward sloping demand for the easement, and the two downward sloping schedules can be interpreted as the agency's upward sloping net marginal outlay schedules. Figure 1 shows that a positive tax credit shifts the demand for easements out and this results in a smaller equilibrium value for $\hat{s}$ (i.e., "more" easements), which is the standard result when a monopsonist receives an input subsidy. It is straight forward to verify the slopes and shifts of the schedules in Figure 1 using Assumption 1 and the properties of the various functions.

The result that an easement tax credit draws in more landowner types and thus raises the probability of an easement outcome is expected. What is not expected is the offsetting effect that can be attributed to the net marginal outlay schedule shifting up and to the right when a tax credit is put in place. Figure 1 shows that this shift results in a diminished impact of the easement tax credit on the probability of an easement outcome. This offsetting occurs for several reasons including the agency's market power and the landowner's real option. For example, unlike a standard input subsidy, the easement tax credit makes the landowner's demand for the easement less elastic and this is equivalent to a shifting out of the agency's net marginal outlay schedule. An important feature of Figure 1 is that it is possible that the offsetting exceeds 100 percent,

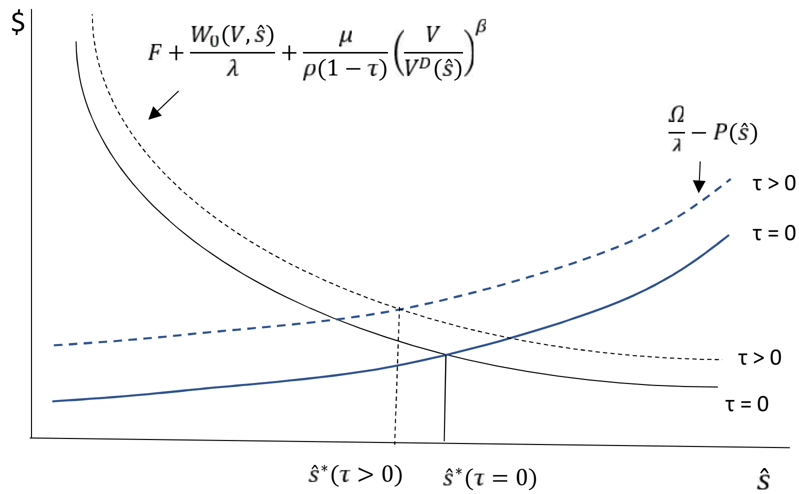

Figure 1: Impact of easement tax credit on market equilibrium

in which case an increase in τ will decrease rather than increase the probability of an easement outcome. Full details about this reversal are provided below.

Key to understanding this unexpected outcome is the easement gift. Indeed, the size of the gift largely determines how the pair of schedules in Figure 1 shift in response to a change in τ. First note that if there was no tax credit and the agency knew the landowner was type $s = 0$ with certainty then the agency would offer $P = L(V, s) - \pi/\rho$ because this would ensure the landowner is indifferent between accepting and rejecting the offer. In this particular case the easement gift would take on a negative value because $H(V, P(s)) = V - \pi/\rho - [L(V, s) - \pi/\rho] = -[L(V, s) - V] < 0$. In contrast, if the agency knew that $s > 0$ and V is such that development would be immediate if the easement is rejected, then $L(V, s) = V$ and the agency would offer $P = V - (\pi + s)/\rho$. In this case the easement gift would take on a positive value because $H(V, P(s)) = V - \pi/\rho - [V - (\pi + s)/\rho] = s/\rho > 0$. In the general case with incomplete information, there are two offsetting forces that determine the size of the easement gift. A larger value for $\hat{s}^*$ implies a larger easement gift because the payment from the agency to the landowner is reduced with a higher value for $\hat{s}^*$ but this reduction is not recognized by the taxing authority when determining the size of the easement gift. In contrast, a larger real option as measured by $L(V, \hat{s}^*) - V$ implies a smaller and possibly negative easement gift because the payment from the agency to the landowner is increased but this increases is also not recognized by the taxing authority.

The ambiguous sign of the easement gift can be established for the more general case by substituting the expression for the valuation of the easement gift, $H(V, P(\hat{s})) = V - \pi/\rho - P(\hat{s})$, into the agency's first-order condition that is given by equation (7) and into the $\Delta(\hat{s})$ net welfare function that is given by equation (9):

$$\begin{aligned} H(V, P(\hat{s})) =& \frac{\hat{s}}{\rho} - [L(V, \hat{s}) - V] - \Delta(\hat{s}) + F + \frac{\mu(\hat{s})}{\rho(1-\tau)} \left(\frac{V}{V^D}\right)^{\beta} \\ &+ \left(\frac{\lambda - 1}{\lambda}\right) (\Omega - W(V, \hat{s})) \end{aligned} \tag{13}$$

The first two terms on the right side of equation (13) reveal that the non-market amenity valuation, $\hat{s}$, and the real option, $L(V, \hat{s}) - V$, are important determinants of the sign and size of the easement gift.

The following numerical example provides additional context. As discussed in Appendix G, the parameter values for this numerical example were chosen to be "realistic" and to also satisfy the Assumption 1 restrictions. Assume s is drawn from an exponential distribution to ensure a fixed inverse hazard rate, μ. This assumption necessarily implies $s^{min} = 0$ and $1 - G(\hat{s}) = e^{-\frac{1}{\mu}\hat{s}}$. Also assume $\alpha = 0.0333$ ($\beta = 3$), $\pi = 1$, $\rho = 0.1$, $V = 11$, $\lambda = 1.5$, $\tau = 0$, $\mu = 2$, $\phi = 0.2$ and $F = 4$. Initially assume $\Omega = 8.5$, which corresponds to a comparatively low environmental value for the land. In this case the easement price is $P = 0.232$, the probability of an easement outcome is $1 - G(\hat{s}^*) = 0.385$, and the easement gift, $H(V, P(s)) = 0.768$, takes on a positive value. However, if the environmental value of the land is raised to $\Omega = 15$ then the agency raises its price to $P = 1.087$, the probability of an easement outcome increases to $1 - G(\hat{s}^*) = 0.841$ and the easement gift, $H(V, P(s)) = -0.087$, takes on a negative value.

The above example shows that the easement gift is smaller and possibly negative for land that has a higher environmental value. This important result, which is central to the paper, can be established more formally. It turns out that the land's environmental value affects the size of the easement gift entirely through the $\hat{s}$ variable. Specifically, totally differentiate the agency's first-order condition that is given by equation (7) with respect to $\hat{s}$ and Ω and then solve for $d\hat{s}/d\Omega$ evaluated at $\hat{s} = \hat{s}^*$:

$$\frac{d\hat{s}}{d\Omega} = -\frac{1}{\lambda} \frac{1 - \phi \left[1 - \left(\frac{V}{V^D(\hat{s}^*} \right)^{\frac{\beta(\rho - g)}{\rho}} \right]}{-SOC} \tag{14}$$

Equation (14) takes on a negative value because the variable SOC represents the second-order condition for the agency's maximization problem, which is necessarily negative (see Appendix D). Because the easement price, $P(\hat{s})$, is a decreasing function of $\hat{s}$ it follows from the negative sign of equation (14) that $P(\hat{s})$ is an increasing function of Ω. With this result in hand it follows immediately from the easement gift function, $H(V, P(\hat{s})) = V - \pi/\rho - P(\hat{s})$, that the size of the easement gift is smaller for land that has a higher environmental value (i.e., $dH/d\Omega < 0$).

The effectiveness of the easement tax credit as an instrument for reducing failure in the easement market can now be formally examined. The results to follow implicitly assume that with the existing value of the easement tax credit (τ) the probability of an easement outcome is inefficiently low. Consequently, a negative sign for $\frac{d\hat{s}^*}{d\tau}$ implies an efficient policy instrument and a positive sign implies an inefficient policy instrument. The following result summarizes this marginal impact of τ.

Result 4. *A marginal increase in the easement tax credit rate, τ, efficiently raises the probability of an easement outcome as measured by $1 - G(\hat{s}^*)$ if and only if the equilibrium easement gift, $H(V, P(\hat{s}^*))$, is sufficiently positive. The impact of higher τ on $1 - G(\hat{s}^*)$ is small and possibly negative if the environmental value of the land as measured by Ω is sufficiently high.*

The first part of Result 4 is expected because as noted above a tax credit has the properties of an implicit easement subsidy. The second part is more important because it shows that tax credit effectiveness is lowest for the most environmentally sensitive land. Moreover, it is possible that raising the tax credit may worsen rather than improve social welfare if the land's environmental value is sufficiently high. The fact that tax credit effectiveness is low when the value of the easement gift is low is not surprising because the size of the tax credit payment is directly related to the size of the easement gift.

To illustrate Result 4 by way of an example, assume a scenario with the same parameter values as presented above but now allow τ to increase from 0 to 0.2. When $\Omega = 8.5$ (low environmental value) the increase in τ raises the probability of an easement outcome from 0.385 to 0.419. In contrast, when $\Omega = 15$ the increase in τ lowers the probability of an easement outcome from 0.841 to 0.804. This result is expected because with $\tau = 0$ the easement gift is positive when $\Omega = 8.5$ and negative when $\Omega = 15$.

Result 4 can also be related to tax credit crowding out. Specifically, the unexpected positive sign for $d\hat{s}/d\tau$ that is featured in Result 4 is a direct result of crowding out in excess of 100 percent. To establish this result let $N(\hat{s}^*, \tau) = P(\hat{s}^*) + \tau(V - \pi/\rho - P(\hat{s}^*))$ denote combined landowner receipts from the agency and the taxing authority. Of interest is the comparative static result, $dN/d\tau$, since the sign of this expression identifies if crowding out is less than or greater than 100 percent. Specifically, $dN/d\tau > 0$ implies less than 100 percent crowding out because in this case the increase in taxpayer expenditures more than offsets the decrease in the easement price offered by the agency. The opposite is true for $dN/d\tau < 0$.

Result 5. *The probability of an easement outcome increases (decreases) with marginally higher τ if there is less (more) than 100 percent crowding out. Formally, $d\hat{s}^*/d\tau < 0 \Leftrightarrow dN/\tau > 0$ and $d\hat{s}^*/d\tau > 0 \Leftrightarrow dN/\tau < 0$.*

Results 4 and 5 together imply that tax credit effectiveness may be limited both because the associated easement gift is small and the crowding out of the agency payment is high. Unfortunately for policy makers both of these effects are most prominent for land that has the highest environmental value.

4 Relaxing the Parameter Restrictions

Result 4, which is that tax credit effectiveness is lower and possibly opposite in sign for land with high environmental value, is obviously important. The purpose of this section is to advance arguments (theoretical and numerical examples) which support the continuation of this result as the various key assumptions from Section 3 are relaxed.

4.1 Correlated Valuations

The first assumption to be relaxed is that of zero correlation between the landowner's "lifestyle" amenity value (s) and the land's environmental value (Ω). Of interest is the extent that a positive correlation weakens Result 4 which establishes that tax credit effectiveness is lower and possibly negative for land that has higher environmental value. Formally, how does positively correlated valuations affect the relationship between Ω and $\hat{s}^*$?[16] The comparative static analysis is too complicated to establish a formal result but the general intuition is fairly straight forward. If the landowner's "lifestyle" amenity value tends to be high when the land's environmental value is high then the agency will account for this correlation and offer a relatively lower easement price. This lower easement price implies a relatively larger easement gift for the landowner, which in turn implies a relatively higher impact of the easement tax credit. This line of logic ignores secondary effects that may offset or reinforce the linkage that was described above. In any event it appears likely that the decline in the tax credit impact for land that has higher environmental value will be smaller the stronger the correlation between s and Ω (i.e., Result 4 is weakened).

Table 1 shows simulation results that continue with the example that was presented above. The top set of values in Table 1 correspond to the base case, the second set of values correspond to the current case of correlated valuations and the rest of the table corresponds to other scenarios to be discussed below. The first column shows that Ω increases in value from 8.5 to 9.0. The values in the last column are the most important because they show the marginal impact of higher τ on $\hat{s}^*$, which is negatively related to the probability of an easement outcome as measured by $1 - G(\hat{s}^*)$. Consistent with Result 4, the declining absolute values in the last column of the base case reflect declining marginal effectiveness of the easement tax credit for land with higher environmental value.

To examine the case of correlated valuations assume $\mu = k_0 + k_1\Omega$ where $k_0 = -32$ and $k_1 = 4$. These values imply a very strong correlation between s and Ω because the mean value

[16] The goal is to examine the extent that higher Ω weakens the tax credit impact as measured by $\frac{d[1-G(\hat{s}^*)]}{d\tau}$. In Appendix H it is shown that it is sufficient to examine how Ω affects $\frac{d\hat{s}^*}{d\tau}$ because if higher Ω weakens $\frac{d\hat{s}^*}{d\tau}$ then it will necessarily also weaken $\frac{d[1-G(\hat{s}^*)]}{d\tau}$.

of the s distribution changes from a low of 2 when $\Omega = 8.5$ to a higher of 4 when $\Omega = 9$. The second column of Table 1 shows that the increase in $\hat{s}$ that results from the strong positive correlation between s and Ω more than offsets the decrease in $\hat{s}$ that results from the higher easement price. The net increase in $\hat{s}$ with an increasing value of Ω is quite small and so the decrease in the easement price and increase in size of the easement gift is also quite small. Despite the fact that the easement gift is increasing rather than decreasing with higher Ω the effectiveness of the tax credit as measured by $\frac{d\hat{s}^*}{d\tau}$ steadily declines as Ω increases in value, and so the basic properties of Result 4 remain intact. A comparison of the results in the last column for the base case (top) and correlated valuation case (second) reveals that the tax credit impacts are quite insensitive to the strong correlation between s and Ω

4.2 Landowner Bargaining Power

A strong assumption in the base case analysis is that the agency has all of the bargaining power by virtue of making a now-or-never offer to the landowner. A more realistic scenario is that the surplus earned by the landowner is an increasing function of the land's environmental value.[17] Recall that $\theta(\Omega)$ denotes the surplus earned by the type $\hat{s}^*$ landowner as a function of the land's environmental value. In the base case it was assumed that $\theta(\Omega) = 0$ and in this section it is assumed that $\theta(\Omega)$ is an increasing function of Ω. In the base case a higher value for Ω raises $P(\hat{s}^*)$ and reduces $\hat{s}^*$. In this current scenario the higher value for Ω also raises the minimum surplus for the landowner, and this results in additional upward pressure on $P(\hat{s}^*)$ and additional downward pressure on the easement gift, $H(V, P(\hat{s}^*))$. The rate of decline in $\hat{s}^*$ in response to the higher easement price will be slower as compared to the base case because of the landowner's growing surplus requirement. These results suggest that even with the landowner earning a positive surplus the effectiveness of the easement tax credit will continue to decline with higher Ω. However, the rate of decline is ambiguous because the faster increase in the

[17] A counter argument is that a conservation agency is likely to have better information than the landowner about the land's environmental value, and this asymmetric information raises the agency's bargaining power.

Ω	$\hat{s}^*$	$1 - G(\hat{s}^*)$	$P(\hat{s}^*)$	$H(V, P(\hat{s}^*))$	$d\hat{s}^*/d\tau$
		Base Case			
8.5	1.909	0.385	0.232	0.768	-0.953
8.6	1.803	0.406	0.250	0.750	-0.728
8.7	1.710	0.425	0.268	0.732	-0.552
8.8	1.627	0.443	0.285	0.715	-0.411
8.9	1.552	0.461	0.302	0.698	-0.296
9.0	1.485	0.476	0.318	0.682	-0.202
		Correlated s and Ω Valuations ($k_0 = -32$, $k_1 = 4$)			
8.5	1.909	0.385	0.232	0.768	-0.953
8.6	1.929	0.448	0.229	0.771	-0.755
8.7	1.944	0.499	0.226	0.774	-0.594
8.8	1.957	0.542	0.224	0.776	-0.460
8.9	1.968	0.579	0.223	0.777	-0.346
9.0	1.977	0.610	0.222	0.778	-0.249
		Landowner Bargaining Power ($a_0 = -4.25$, $a_1 = 0.5$)			
8.5	1.909	0.385	0.232	0.768	-0.953
8.6	1.902	0.386	0.283	0.717	-0.831
8.7	1.894	0.388	0.334	0.666	-0.712
8.8	1.887	0.389	0.386	0.614	-0.594
8.9	1.880	0.391	0.437	0.563	-0.479
9.0	1.872	0.392	0.488	0.512	-0.366
		Development Value Uncertainty ($\sigma = 0.1$)			
8.5	3.001	0.223	0.316	0.684	-1.821
8.6	2.803	0.246	0.340	0.660	-1.373
8.7	2.631	0.268	0.364	0.636	-1.029
8.8	2.480	0.289	0.387	0.613	-0.759
8.9	2.347	0.309	0.410	0.590	-0.545
9.0	2.228	0.328	0.432	0.568	-0.371

Table 1: Simulation Results for the Analysis of Key Assumptions

easement price will work to speed up the decline but the slower reduction in $\hat{s}^*$ will slow down the decline.

To numerically examine the case of correlated valuations assume $\theta = a_0 + a_1\Omega$ where $a_0 = -4.25$ and $a_1 = 0.5$. These values imply that landowner rents rise modestly with higher Ω, ranging from a low of 0 when $\Omega = 8.5$ to a high of 0.25 when $\Omega = 9$. Despite this low sensitivity of landowner rents to the land's environmental value, the results change significantly, as can be seen in the middle section of Table 1. As compared to the base case the second column shows a relatively slow decrease in $\hat{s}^*$, the fourth column shows a relatively fast increase in $P(\hat{s})$ and the fifth column shows a relatively fast decrease in the value of the easement gift. In this particular case the offsetting impacts of the changes in $\hat{s}^*$ and the easement gift results in a relatively slower decline in the effectiveness of the easement tax credit (see last column). Result 4 is therefore likely to continue to hold in the presence of positive landowner bargaining surplus but the overall impacts are likely to be weaker.

4.3 Landowner Legal Costs

It is reasonable to assume that owners of land with high environmental value are likely to experience higher transaction and legal costs when attempting to sell their land to a developer. In the previous section the date T legal cost function, $C(\Omega)$, was restricted to zero. In this section it is assumed that C is an increasing function of Ω. An obvious result is that a positive value for $C(\Omega)$ will increase the landowner's demand for the easement and this will raise the probability of an easement outcome. Less obvious is the result that the effectiveness of the easement tax credit does not depend on this legal cost assumption. This independence result emerges because of the additive and ex post nature of the cost function (see Appendix H for details).

4.4 Development Value Uncertainty

The previous analysis was simplified by assuming no development value uncertainty. This assumption is relaxed in this section with the goal of identifying how development value uncertainty impacts the effectiveness of the easement tax credit. Higher uncertainty as measured by σ

affects the real option value of the landowner's irreversible development decision, which in turn affects the landowner's demand for the easement, the easement price, the size of the easement gift and ultimately the effectiveness of the tax credit program.

To place more structure on these arguments equation (3) and the expression for β in Appendix B can be used to show that a higher value for σ raises the value of the development threshold $V^D(\hat{s}^*)$ relative to V. This change necessarily implies a longer expected time to development should the easement be rejected by the landowner. Similarly, it is straight forward to show that for a fixed value of s the stochastic discount factor, $\left(\frac{V}{V^D(\hat{s})}\right)^\beta$, is a decreasing function of σ. In the expression for $L(V, \hat{s})$ that is given by equation (2), notice that a smaller stochastic discount factor implies more weight on the pre-development flow, $\frac{\pi+\hat{s}^*}{\rho}$, and less weight on the post-development stock value, V^D. The combination of less weight on V^D and a higher value for V^D implies that the effect of more uncertainty on $L(V, \hat{s})$ is theoretically ambiguous. Nevertheless, under a wide range of feasible parameters the latter effect dominates and thus $L(V, \hat{s})$ increases with higher values for σ.

There are two pathways that a longer expected time to development and a higher value for $L(V, \hat{s})$ impacts the easement price. A longer time to development implies a longer flow of temporary environment benefits as measured by $W(V, \hat{s})$. A higher value for $L(V, \hat{s})$ implies a higher opportunity cost for the landowner who contemplates signing the easement. The $W(V, \hat{s})$ pathway puts downward pressure on $P(\hat{s}^*)$ and the $L(V, \hat{s})$ pathway puts upward pressure on $P(\hat{s}^*)$. The parameter restrictions implied by Assumption 1 ensure the latter effect dominates the former and thus higher σ results in a higher value for $P(\hat{s}^*)$. As discussed above, a higher value for $P(\hat{s}^*)$ reduces the size of the easement gift, $H(V, P(\hat{s}^*))$, which in turn potentially reduces tax credit effectiveness. However, similar to previous results, there is an offsetting effect that works through the $V^D(\hat{s}^*)$ term.

To generate simulation results with $\sigma > 0$ it is necessary to utilize the stochastic version of $W(V, s) = \int_0^\Omega W f(W; V, s) dW$. The expression for $f(W; V, s)$ is derived in Appendix C. Numerical integration of $f(W; V, s)$ is used to generate the simulation results that appear in Table 1. A comparison of the top and bottom set of rows in Table 1 show how the base case results change when development value uncertainty is added to the model. Consistent with the theoretical predictions, the uncertainty raises the values for $\hat{s}^*$ and $P(\hat{s}^*)$), and lowers the probability of an easement outcome as measured by $1 - G(\hat{s}^*)$. The higher price in turn lowers the value of the easement gift, $H(V, P(\hat{s}^*))$, relative to the base case. Under normal conditions the effectiveness of the easement program will be lower because of the lower value of the easement gift but as can be seen in the last column that tax credit effectiveness is actually higher than in the base case. Presumably the relative large values for $\hat{s}^*$ give rise to a relatively large reduction in the participation elasticity and this serves to increase the effectiveness of the tax credit relative to the base case. The percent rate of decline in the $\frac{d\hat{s}^*}{d\tau}$ values for higher values of Ω are similar in the base case and the uncertainty case.

5 Discussion

The results of this analysis are conditioned on a number of fairly strong assumptions, some of which were explicitly relaxed in the previous section. An assumption which was not relaxed is that there is only one parcel of land with exogenous environmental value that is being considered for the easement. A more realistic scenario is that there are multiple land units with varying levels of environmental benefits, and the agency must choose which land units to target. Moreover, a land unit's environmental value is expected to be endogenous and to change over time because it depends on the sequence of development and protection in neighboring plots of land.[18] With multiple plots of land the agency is expected to divert funds to a new easement project if its initial easement offer is reject by the landowner. Incorporating this realistic assumption would significantly complicate the analysis because in this case the agency's opportunity cost when making an easement offer is the shadow value of the next best easement opportunity. An immediate implication of this change in opportunity cost is that agency crowding out by the

[18]The conservation literature emphasizes the dynamic and stochastic nature of choosing which land to protect when the decision maker has a fixed conservation budget. In some parts of this literature the shadow values of neighboring land plots that emerge from stochastic dynamic programming can be used to guide land conservation decisions [Costello and Polasky, 2004, Newburn, Berck, and Merenlender, 2006].

tax credit is much less problematic because the crowded-out payment will eventually contribute to a different easement project rather than the external project.

With multiple land units and a fixed budget the agency must decide whether to hold a smaller number of acres of land that has higher environmental value versus a larger number of acres of land that has lower environmental value. A similar issue was investigated at an empirical level by Suter et al. [2014]. If the goal of the agency is to maximize environmental surplus then the usual elasticity argument will emerge to reveal the optimal quality – quantity tradeoff. However, if the agency is motivated to maximize protected acres rather than maximizing environmental surplus then pricing and outcomes in the easement market will be distorted. Unfortunately the easement tax credit worsens the distortion because more landowners are willing to agree to the easement and at a lower price. Both of these conditions imply that the agency will have a greater choice of lower-quality acres to choose from and more lower-quality acres overall will be selected because of the lower purchase price and/or availability of donated easements.

There are a number of reasons why agencies may choose to maximize acreage rather than environmental surplus. First, agencies who are competing against each other for charitable contribution will recognize that members of the general public who do not directly observe the environmental value of land may use the number of acres held by the agency as a quality signal. Second, landowners who care about the long term preservation of their land may prefer to deal with a high-acreage agency because of a perceived relationship between the size of the organization and the ability to enforce the terms of the easement in both the short and long term. Finally, agency managers may take the perspective that the more land that can be protected the better because "all" land is worthy of protection. Actively soliciting donations of "any" undeveloped land is unlikely to be in the best interests of society.

Another implicit assumption of the model is that the terms of the easement are enforced into perpetuity. This is a strong assumption because as was discussed in the Introduction there is often ineffective monitoring of small-scale land trusts. This lack of oversight is particularly problematic if conservation agencies are indeed being created solely for the purpose of allowing landowners to donate easements in exchange for generous tax credits. If landowners both obtain tax credits for agreeing to an easement and subsequently violate the terms of the easement then the outcome is particularly bad for society. The extent that the easement tax credit program is contributing towards an increasing fraction of easements that have ineffective monitoring is an important consideration when assessing the overall costs and benefits of this program.

As was noted in the Introduction, the current analysis assumes a refundable easement tax credit with no cap. This is a strong assumption because it implies that the landowner's marginal tax rate and/or the amount of tax owing is not important for a landowner's easement decision, and the full tax benefit is realized immediately upon agreeing to the easement. In reality most of the tax benefit from the gift portion of an easement is a federal income tax deduction, which allows the landowner to use the easement gift to shelter either 50 percent (non-farmer) or 100 percent (farmer) of annual income for a maximum of 15 years. If land has high environmental value but the landowner has low taxable income (e.g., an "equity rich" but "cash flow poor" farmer) then the tax benefits of an easement gift will be small and the effectiveness of the federal program will be relatively low. In contrast, if the land's environmental value is high and the landowner happens to be in a high tax bracket then the effectiveness of the federal program will be high.

Tax credits have the advantage that the easement gift is used to reduce taxes owning and therefore are not dependent on the landowner's marginal tax rate. Currently there are only 15 U.S. states which offer a tax credit for gifted easements, and in all cases the tax credits are non-refundable but can be used over multiple years.[19] The specific parameters vary widely across states with the most common allowing the landowner to claim a credit equal to 50 percent of the gift with a maximum claim in the range \$50,000 to \$375,000 and a carry over period in the range 5 to 20 years. Another important property of a state tax credit is that authorization of the credit typically requires a sufficiently high score on an environmental benefits assessment. The various restrictions on tax credit programs slow the supply of socially undesirable donated easements (a "good" outcome) but also require the conservation agency to offer a higher price for a socially desirable easement and to face a lower probability of reaching an easement agreement (a "bad" outcome).

[19]See `http://www.conservationeasementadvisors.com/overview/state.php` for full details.

Transferable tax credits (e.g., Colorado) are particularly attractive to landowners because they can be sold in a secondary market consisting of bidders with comparatively high valuations of tax write-offs. On the "good" side of the equation the higher demand for easements results in a lower average easement price and overall more effective land protection for each dollar spent by taxpayers. Transferability allows agencies to target land that has high environmental value and with owners who have low valuation of a tax write-off. The transferability feature of the tax credit program raises the demand for the easement to an approximately equal level for all landowners, and this equalization will improve the efficiency of easement market outcomes. Unfortunately transferability of the tax credit also increases the potential for abuse of the tax credit program because of the higher supply of socially undesirable donated easements. The recent controversy over abuse of the tax credit program in Colorado is a case in point.[20]

It is important to ask if the results from this analysis can be empirically tested if the data is available. Many regional governments (e.g., City of Ann Arbor) have developed *purchase of development rights* (PDF) programs. PDF programs are generally small in scale, have strong environmental eligibility standards and tend to focus on purchased rather than donated easements. These programs are likely to have data on the externally-assessed value of the land with and without the easement as well as the amount that was paid to the landowner in the form of an easement payment. These three data series allow the size of the easement gift to be calculated. Because of the rigorous eligibility requirements it is also likely that some measure of the land's environmental value is also available. With this data in hand, the main hypothesis of this paper can be tested. Specifically, do easement gifts tend to be smaller on land that has higher environmental value? This test can be conducted without knowing the marginal tax rate of the landowner. It would also be useful to estimate the degree of crowding out for different assumptions about the landowner's marginal tax rate. This can be done using a tax benefit calculator similar to that used by Parker and Thurman [2017]. For easements that are donated it is necessary to have data on the budgets of the participating conservation agencies in order to

[20] An auditor in Colorado questioned whether nearly $1 billion in tax breaks for landowners were justified since in each case there was no or very little determination of environmental gain [Migoya, 2016].

determine if the reason for the donation is due to a binding budget constrain or zero valuation of the easement by the agency.

6 Conclusions

A conservation easement tax credit has considerable appeal as an instrument for preserving farmland, forest land and other land that is rich in biodiversity. Budget-constrained conservation agencies are only partially effective at protecting land and so it is natural to consider subsidies in the form of tax credits. Over the past two decades, major U.S. conservation agencies such as the Nature Conservancy have been successful at convincing the federal and various state governments to expand tax credit coverage. Landowner response has been rapid, and it is only recently that policy makers have begun questioning in a meaningful way whether this rapid response belongs in the "intended" or "unintended" category. The literature on conservation easements and their associated tax credits is mostly found in law journals and as such lacks economic rigour. This paper appears to be the first to model in a comprehensive economics framework an easement tax credit program and the conditions which lead to socially desirable and undesirable outcomes.

Two important results emerge from this analysis. First, the size of the easement gift is smallest and thus the effectiveness of the tax credit program is lowest for land that has the highest environmental value. This relationship is unfortunate because policy makers would undoubtedly prefer a positive correlation between program effectiveness and the land's environmental value. Second, socially undesirable land may by drawn into the easement market via a donation because the conservation agency fails to internalize the land's development value. This scenario is most likely to be relevant when a landowner has high private valuation of the land's non-market amenities because in this case she values the tax credit high relative to the developer's offer. Other studies have describe the market failure that results because of conservation agencies agreeing to hold easements but in these studies the incentives of the agency and society are generally strongly misaligned.

The impact of the landowner's real option for land development gives rise to a set of interesting secondary results. Perhaps most importantly, easements are more expensive to purchase and thus the likelihood of an easement outcome is lower when there is higher development value uncertainty. This occurs because uncertainty raises the opportunity cost of the landowner signing the easement. Higher development value uncertainty also results in a longer expected time to development, and this extra delay works in the agency's favour because the environmental benefits that temporarily flow between the date the easement is rejected and the date when the land is developed is lengthened. These real option results are considered secondary rather than primary because they depend on a two rather strong assumptions which underlie the model. The first assumption is that the timing of the agency's easement offer is fixed exogenously at date 0 rather than emerging endogenously at a time that maximizes joint surplus for the agency and the landowner. The second assumption is that there is no uncertainty in the land's future environmental value. If these two assumptions are relaxed then the landowner would face a stochastic easement offer price from the agency as well as a stochastic offer price from the developer. While this scenario is both realistic and important, modeling this type of scenario would be complex and quite likely require extensive numerical analysis because the landowner would face a two-dimensional, inter-related real option problem.

The realism of the assumption that the easement decision is fully irreversible is open to debate. From a legal perspective, an easement contract is perpetual and not designed to be reversed. Moreover, there is little evidence that reversals are actually taking place. Nevertheless, it is reasonable to assume that in a priority situation a reversal of the easement will occur. It is easy to imagine a scenario where a piece of land that is protected by an easement becomes very valuable in a development context. Promising to obtain the development rights from neighboring land in exchange for eliminating the easement requirements for the land in question, and further promising to repay the original easement tax credit, is a scenario that might be agreeable to the various parties and will potentially raise overall market welfare when implemented. The problem is that if a precedent for this type of activity became established then the expectations of a perpetual agreement will be distorted and the effectiveness of the tax credit program will be weakened. This topic should be considered in future research.

In summary, critics of easements tax credits are well justified in worrying about how social benefits compare with social costs. The tax credit program has strong potential to reduce the premature development externality but there are a number of complexities and unintended consequences that must be considered when assessing the overall desirability of this program. Improved landowner targeting and requiring eased land to have a minimum level of environmental value would go a long way toward improving program effectiveness. It is important to note that this analysis focused exclusively on direct financial costs. The fact that there is no or little coordination regarding which land is protected by an easement results in a patchwork of developed land, and this will necessarily raise the cost of development. The cost of utilizing second best development options when first best options are not available is likely to be sizeable and will continue to grow in importance as more and more easements are enacted. Certainly this topic is in need of both additional theoretical analysis and rigorous empirical analysis.

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Appendix

A Notation

See Appendix Table 1

B Real Option Equations

In this section expressions for the landowner's development decision rule and option-inclusive value of the land are derived. Following Dixit and Pindyck [1994], begin by constructing a Bellman equation for the following dynamic programming problem:

$$L(V,s) = \max\left\{V - C, \pi + s + (1+\rho dt)^{-1} E\left[L(V+dV,s)|V\right]\right\}$$

Notice that the value function is the maximum of the land's immediate net development value, $V - C$, and expected deferred development value, which includes the instantaneous profit and non-market amenity flow that accrues to the landowner. The solution to the corresponding differential equation has the general form $L(V,s) = AV^{\beta} + (\pi + s)/\rho$ for $V < V^D(s)$ where the expression for β is given by

$$\beta = \frac{1}{2} - \frac{\alpha}{\sigma^2} + \sqrt{\left(\frac{1}{2} - \frac{\alpha}{\sigma^2}\right)^2 + 2\frac{\rho}{\sigma^2}}$$

Simultaneously solving the value matching condition, $AV^{\beta} + (\pi + s)/\rho = V - C$, and the smooth pasting condition, $d(AV^{\beta})/dV = 1$, for A and V, gives $A^D(s)$ and $V^D(s)$, respectively. The expression for $V^D(s)$ is reported as equation (3) and $A^D = \left[V^D - \left(\frac{\pi+s}{\rho} + I\right)\right]\left(\frac{1}{V^D}\right)^{\beta}$. Substituting this expression for A^D into $L(V,s) = AV^{\beta} + (\pi+s)/\rho$ gives equation (2).

C Temporary Environmental Flow

This section is used to derive an expression for $W(V,s)$, which is a measure of the expected present value of the environmental flow from the date of easement rejection until the date of land

Symbol	Description	Symbol	Description
α	Average rate of growth in V	Ω	Capitalized environmental value (ω/ρ)
β	Exponent in real option expression, $(V/V^D)^\beta$	P	Easement price
B	Agency's budget	ρ	Discount rate
$C(\Omega)$	Date T land development legal cost	σ	Standard deviation of V
ϕ	Scaling factor for temporary environmental flow	s	Landowner's non-market amenity flow
$f(W; V, s)$	Density for for temporary environmental flow	s^{min}	Minimum value for s
F	Agency's fixed cost of managing the easement	$\hat{s}$	Marginal landowner type who chooses the easement
γ	Rate of growth in ω	τ	Tax credit rate
$\Gamma(\hat{s})$	Agency's objective function (environmental surplus)	$\Delta(s)$	Net welfare gain if land is protected
$g(s; \Omega)$	Density function for s	$\theta(\Omega)$	Surplus demanded by landowner
$G(s; \Omega)$	Distribution function for s	T	Date of land development
$H(V, P)$	Easement gift	$V(t)$	Development value of land at time t
λ	Marginal value of external project	V	Development value of land at time 0
$L(V, s)$	Land's option-inclusive development value	$V^D(s)$	Value of V that triggers development
$\mu(\hat{s})$	Inverse of hazard rate for s	$W(V, s)$	PV of temporary flow of environment benfits
π	Profit flow from undeveloped land	$W_0(V, s)$	Expression for $W(V, s)$ when $\sigma = 0$
ω	Environmental flow from undeveloped land	$Z(V, s, P)$	Landowner's valuation of easement opportunity

Appendix Table 1: Description of Parameters and Variables development. The analysis begins with zero development value uncertainty, in which case $\sigma = 0$ and the function of interest is $W_0(V,s)$. According to Dixit and Pindyck [1994], β is the solution to the following second order differential equation: $0.5\sigma^2 F"(V)V^2 + \alpha F'(V)V - \rho F(V) = 0$ where $F(V) = AV^{\beta}$. With $\sigma = 0$ it follows from this equation that $\beta = \rho/\alpha$, which in turn implies from equation (3) that $V^D(s) = (\pi+\hat{s})/(\rho-\alpha)$. The optimal time to development, T^*, is therefore the solution to $Ve^{\alpha T} = \frac{\pi+\hat{s}}{\rho-\alpha}$. Rearrange this expression to obtain $e^{-\rho T^*} = \left[\frac{(\rho-\alpha)V}{\pi+\hat{s}}\right]^{\rho/\alpha}$, which further reduces to $e^{-\rho T^*} = \left(\frac{V}{V^D}\right)^{\beta}$. This expression can be solved for T^* and substituted into $\tilde{W}(\tilde{t}) = \phi\Omega[1 - e^{-(\rho-g)\tilde{t}}]$, which is a measure of the present value of the environmental flow from date 0 to an arbitrary date $\tilde{t}$. The resulting expression can be interpreted as $W_0(V,s)$, which appears as equation (8) in the text.

Now consider the more general case of stochastic V that results when $\sigma > 0$. In this case the environmental flow begins at rate $\phi\omega$ at date 0 and grows continuously at rate g until the time of land development, which itself is stochastic. If the land is never expected to be developed then $W(V,s) = \phi\Omega$ where $\Omega = \omega/(\rho - g)$. Let $\tilde{W}(\tilde{t}) = \phi\int_0^{\tilde{t}} \omega e^{-(\rho-g)t}dt = \phi\Omega[1 - e^{-(\rho-g)\tilde{t}}]$ denote the present value of the environmental flow for a particular development time outcome, $\tilde{t}$. As well, let $f(\tilde{W};V,s)$ denote the probability density that governs $\tilde{W}$, acknowledging that $\tilde{t} = \inf(t : V = V^D)$ is defined as the first time that $\tilde{V}$ rises up to level $V^D(s)$. It follows that $W(V,s) = \int_0^{\phi\Omega} \tilde{W} f(\tilde{W};V,s)d\tilde{W}$. To derive the expression for $f(\tilde{W};V,s)$ invert $\tilde{W}(\tilde{t}) = \phi\Omega[1 - e^{-(\rho-g)\tilde{t}}]$ and use the resulting expression to show the probability that $W \leq \tilde{W}$ is equal to the probability that $\tilde{t} \leq -\frac{1}{\rho-g} ln\left(1 - \frac{\tilde{W}}{\phi\Omega}\right)$. Thus, $F(W;V,s) = \Psi(-\frac{1}{\rho-g}ln(1 - \frac{W}{\phi\Omega}); V, V^D)$ where $\Psi(\tilde{t};V,V^D)$ is the cumulative probability function for $\tilde{t}$. Using equation (15) from Grenadier [1996], an expression for $\Psi(\tilde{t};V,V^D)$ can be written as

$$\Psi(\tilde{t};V,V^D) = \Phi\left(\frac{ln(V/V^D) + (\alpha - 0.5\sigma^2)t}{\sigma t^{0.5}}\right) + \left(\frac{V}{V^D}\right)^{\frac{-2(\alpha-0.5\sigma^2)}{\sigma^2}} \Phi\left(\frac{ln(V/V^D) - (\alpha - 0.5\sigma^2)t}{\sigma t^{0.5}}\right)$$

Within this expression, $\Phi()$ is the cumulative probability function for a normal random variable. The desired expression for $f(W;V,s)$, accounting for the fact that all of the probability mass is centered on $W=0$ when $V \geq V^D(s)$, can now be expressed as

$$f(W;V,s) = \begin{cases} 0 & if \quad V \geq V^D(s) \\ dF(W;V,s)/dW & if \quad V < V^D(s) \end{cases}$$

D Second-Order Condition

To derive the second-order condition for the agency's maximization problem it is useful to first substitute the expression for $\frac{dP}{d\hat{s}}$ that is given by equation (5) into the agency's first-order condition, which is given by equation (7). The second order condition (SOC) can now be written as

$$SOC \equiv \frac{dP(\hat{s})}{d\hat{s}} + \frac{1}{\lambda}\frac{dW(V,\hat{s})}{d\hat{s}} - \mu(\hat{s})\frac{d^2P(\hat{s})}{d\hat{s}^2} - \frac{dP(\hat{s})}{d\hat{s}}\frac{d\mu(\hat{s})}{d\hat{s}} < 0 \qquad \text{(D.1)}$$

Knowing from equation (5) that $\frac{dP(\hat{s})}{d\hat{s}}$ takes on a negative value and $\frac{d^2P(\hat{s})}{d\hat{s}^2}$ takes on a positive value, it follows from equation (D.1) that the second-order condition holds if $\frac{dP(\hat{s})}{d\hat{s}} + \frac{1}{\lambda}\frac{dW(V,\hat{s})}{d\hat{s}} < 0$. Equation (8) shows that $\frac{1}{\lambda}\frac{dW(V,\hat{s})}{d\hat{s}}$ is positive and a decreasing function of the g growth parameter. It is therefore sufficient to construct a restriction for the second-order condition for the special case of $g=0$.

The first step for signing $\frac{dP(\hat{s})}{d\hat{s}} + \frac{1}{\lambda}\frac{dW(V,\hat{s})}{d\hat{s}}$ is to make more explicit the expression for $\frac{dP(\hat{s})}{d\hat{s}}$ within equation (D.1), assuming $\tau = 0$. Substitute the expression for $L(V,s)$ that is given by equation (2) and the expression for $V^D(\hat{s})$ that is given by equation (3) into the expression for $P(\hat{s})$ that is given by equation (4) and then simplify. The resulting expression is $P(\hat{s})_{\tau=0} = \frac{V}{\beta}\left(\frac{V}{V^D}\right)^{\beta-1}$. The next step is to note that $\frac{d}{d\hat{s}}\left(\frac{V}{V^D}\right)^{\beta} = -\beta\left(\frac{V}{V^D}\right)^{\beta}\frac{1}{\pi+\hat{s}}$. This expression can be used together with equation (8) to show that $\frac{dP(\hat{s})}{d\hat{s}} + \frac{1}{\lambda}\frac{dW(V,\hat{s})}{d\hat{s}} < 0$ is equivalent to $\frac{1}{\pi+\hat{s}}\left(\frac{V}{V^D}\right)^{\beta}\left(\beta\phi\frac{\Omega}{\lambda} - \frac{\pi+\hat{s}}{\rho}\right) < 0$. It follows directly that a sufficient condition for this inequality to hold is $\beta\phi < \lambda\pi/\omega$ where $\omega = \rho\Omega$. Because $\frac{dP(\hat{s})}{d\hat{s}} + \frac{1}{\lambda}\frac{dW(V,\hat{s})}{d\hat{s}} < 0$ is sufficient for the second-order condition to hold it follows that $\beta\phi < \lambda\pi/\omega$ is also sufficient for the second-order condition to hold.

E Social Planner Pricing

This section begins by deriving the first-order condition for the planner when choosing $\hat{s}$ to maximize social surplus (i.e., welfare of all market participants) and then comparing the market outcome with the planner versus the agency.[21] The planner uses taxpayer funds to finance the easement and the marginal social opportunity cost of these funds are fixed at level λ^G. Assume $\lambda^G < \lambda$, which implies that in comparison to the agency, the planner has a lower social opportunity cost of financing the easement. The planner does not use a tax credit and so the date 0 welfare of the landowner is equal to $\frac{\pi+s}{\rho} + P$ if the easement is accepted and $L(V, s)$ if the easement is rejected. Ignoring the external project since it is not relevant for easement pricing, the objective function for the planner can be expressed as

$$\Gamma^g(\hat{s}) = (1 - G(\hat{s}))\left[\Omega + \pi/\rho - (\lambda^g - 1)P(\hat{s}) - \lambda^g F\right] + \int_{\hat{s}}^{\infty} \frac{s}{\rho} g(s)ds \qquad \text{(E.1)}$$
$$+ \int_0^{\hat{s}} \left[W(V, s) + L(V, s)\right] g(s)ds$$

Similar to the case of the agency, the first-order condition for the planner's optimal choice of $\hat{s}$ can be rearranged and written as

$$P(\hat{s})) = \frac{1}{\lambda^g}\left(\Omega - W(V, \hat{s})\right) - F - \left(\frac{\lambda^g - 1}{\lambda^g}\right)\frac{\mu(\hat{s})}{\rho}\left(\frac{V}{V^D(\hat{s})}\right)^{\beta} \qquad \text{(E.2)}$$

A comparison of equations (7) and (E.2) reveal that apart from the assumed differences in the values for λ and λ^g, and no tax credit for the agency, the only structural difference between the first-order conditions for the planner and the agency is that the last term is multiplied by $(\lambda^g - 1)/\lambda^g$ for the planner whereas there is no analogous adjustment for the agency. This difference is expected given the theory of Ramsey−Boiteux pricing in the public finance literature [Laffont and Tirole, 2000].[22]

[21] The welfare of the land developer is zero due to competitive bidding and can thus be ignored when calculating social welfare.

[22] In the planner's problem the λ^g parameter can also be interpreted as the shadow value of the planner's budget constraint. In this context, the problem considered is equivalent to optimal pricing for a regulated natural monopoly. It is well known that the optimal price for a regulated natural monopoly is the same as that for a regular monopoly except it is multiplied by a scaling factor.

Assume the easement outcome is socially desirable (i.e., $\Delta(s^{min} > 0)$ and the parameters are such that equilibrium payment to the landowner is positive (i.e., no corner solution). It can now be established that the probability of an easement outcome with an agency decision maker is inefficiently low. Formally, $\hat{s}^* > \hat{s}^{**}$, which implies $1 - G(\hat{s}^*) < 1 - G(\hat{s}^{**})$. To prove this outcome rearrange the agency's first-order condition that is given by equation (7) with $\tau = 0$:

$$\frac{1}{\lambda}\left(\Omega - W(V,\hat{s})\right) - F - P(\hat{s})) = \mu(\hat{s})\frac{1}{\rho}\left(\frac{V}{V^D(\hat{s})}\right)^{\beta} \tag{E.3}$$

Similarly, the first-order condition for the planner, which is given by equation (E.2), can be rewritten as

$$\frac{1}{\lambda^g}\left(\Omega - W(V,\hat{s})\right) - F - P(\hat{s})) = \frac{1-\lambda^g}{\lambda^g}\mu(\hat{s})\frac{1}{\rho}\left(\frac{V}{V^D(\hat{s})}\right)^{\beta} \tag{E.4}$$

Using the results from section D of this Appendix it follows that the left sides of equations (E.3) and (E.4) are both increasing functions of $\hat{s}$ given assumption 1(a). Similarly, maintaining the previous assumption that $\mu(\hat{s})$ is a decreasing function of $\hat{s}$ it follows that the right sides of equations (E.3) and (E.4) are both decreasing functions of $\hat{s}$. For a given value of $\hat{s}$ the left side of equation (E.4) takes on a larger value than the left side of equation (E.3) because $\lambda > \lambda^g$ by assumption. Similarly, for a given value of $\hat{s}$ the right side of equation (E.4) takes on a smaller value than the right side of equation (E.3) because the former expression is multiplied by $(\lambda^g - 1)/\lambda^g$, which has a value less than one. These two differences combined with the slope properties of equations (E.3) and (E.4) imply that $\hat{s}^* > \hat{s}^{**}$ and $1 - G(\hat{s}^*)) < 1 - G(\hat{s}^{**}))$.

F Proofs of Formal Results

Result 1

The definitions of Ω^* and Ω^c are such that for $s > \hat{s}^c$ and $\Omega \in [\Omega^*, \Omega^c]$ the easement is donated rather than purchased by the agency. Equation (10) shows that the gain in social welfare with the easement as measure by $\Delta(s, \Omega)$ is positive for a sufficiently large value of Ω. Consequently, if it can be shown that $\Delta(s, \Omega^*) < 0$ for $s > \hat{s}^c$ then it must be the case that there exists a critical value of Ω, call it Ω^{**}, such that $\Delta(s,\Omega) < 0$ for $\Omega \in [\Omega^*, \Omega^{**}]$. This is the outcome that is claimed in 1.

To obtain a specific expression for Ω^* note that the agency "breaks even" on the donated easement if $\Omega - E_s\{W_0(V,s)\} = F$ where F is the agency's fixed cost of holding the easement, $W_0(V,s)$ is given by equation (8) and $E\{W_0(V,s)\} = \int_{s^c}^{\infty} W_0(V,s)g(s)ds$ is the expected value of the temporary environmental flow that will result if the donation is not accepted. Consequently, the desired expression is $\Omega^* = E_s\{W_0(V,s)\} + F$. A comparison of this expression to the expression for Ω^c in equation (12) reveals that $\Omega^c > \Omega^*$. To show that $\Delta(s,\Omega^*) < 0$ for a sufficiently large value of s in excess of $\hat{s}^c$ use equation (9) to write the desired expression as

$$\Delta(s,\Omega^*) = \int_{s^c}^{\infty} W_0(V,s)g(s)ds - W_0(V,s)g(s)ds - \left[L(V,s) - \frac{\pi+s}{\rho}\right] \quad \text{(F.1)}$$

Noting that $L(V,s) > \frac{\pi+s}{\rho}$, this expression takes on a negative value for a sufficiently large value of s.

Result 2

To establish the first part of Result 2 note that equation (11) shows that $s^c \to \infty$ as $\tau \to 0$. The probability of an easement outcome as measured by $1 - G(s^c)$ therefore vanishes as $s^c \to \infty$. This means that a donated easement is not feasible as τ approaches zero. To establish the second part of Result 2 note from equation (12) that $\Omega^c \to \infty$ as $\tau \to 1$. This increase in the value of Ω^c allows a larger range of values of Ω to simultaneously satisfy the two conditions that are required for Result 2: (i) $\Omega^* \leq \Omega \leq \Omega^c$ and $\Omega < \Omega^{**}$.

Result 3

Given optimal pricing by the agency the marginal landowner is defined by $\frac{\pi+\hat{s}^*}{\rho} + P(\hat{s}^*) + \tau(V - \frac{\pi}{\rho} - P(\hat{s}^*)) = L(V,\hat{s}^*)$. Using equation (2) this expression can be rewritten as $P(\hat{s}^*) + \tau(V - \frac{\pi}{\rho} - P(\hat{s}^*)) = \frac{1}{\beta-1}\left(\frac{\pi+\hat{s}^*}{\rho}\right)^{-(\beta-1)} V^{\beta}$. The right hand side of this expression is a decreasing function of $\hat{s}$, which means that the equilibrium value of $\hat{s}$ necessarily decreases if the left hand side of the expression increases. An expression which shows how the left hand side of the equation increases given a marginal increase in τ and a fixed value of $\hat{s}$ is $(V - \frac{\pi}{\rho} - P(\hat{s}^*))d\tau + (1 - \tau)\frac{dP^*}{d\tau}$. The first part of this expression takes on a positive value (assuming a positive value for the easement gift) and the second part takes on a negative value, which can be established by differentiating equation (4) and then signing the resulting expression. If the easement price set by the agency is fixed and τ is increased marginally then $\frac{dP(\hat{s}^*)}{d\tau} = 0$. Using the results from above it follows that the increase in the left hand side of $P(\hat{s}^*) + \tau(V - \frac{\pi}{\rho} - P(\hat{s}^*)) = \frac{1}{\beta-1}\left(\frac{\pi+\hat{s}^*}{\rho}\right)^{-(\beta-1)} V^{\beta}$ will be larger and the decrease in $\hat{s}$ will be also be larger than in the case where $P(\hat{s})$ can be freely adjusted. Consequently, for a given increase in τ the probability of an easement outcome as measured by $1 - G(\hat{s})$ increases by a greater amount if $P(\hat{s}^*)$ is fixed rather than free to adjust.

Result 4

With the assumption that s is exponentially differentiated and thus $\mu(\hat{s})$ takes on a fixed value, it is sufficient to examine how marginally higher τ impacts $\hat{s}^*$ rather than $1 - G(\hat{s}^*)$ because lower $\hat{s}$ necessarily implies higher $1 - G(\hat{s}^*)$ and vice versa. To assess $\frac{d\hat{s}^*}{d\tau}$ totally differentiate equation (7) with respect to $\hat{s}$ and τ and then solve for $\frac{d\hat{s}}{d\tau}$ evaluated at $\hat{s} = \hat{s}^*$. After substituting in equation (5) and the expression for the easement gift, $H(V, P(\hat{s})) = V - \pi/\rho - P(\hat{s})$, the differential can be written as

$$\frac{d\hat{s}}{d\tau} = \frac{-H(V, P(\hat{s}^*)) + \frac{\mu(\hat{s}^*)}{\rho(1-\tau)}\left(\frac{V}{V^D(\hat{s}^*)}\right)^{\beta}}{-(1-\tau)SOC} \tag{F.2}$$

To establish the first part of Result 4 note from equation (F.2) that a sufficiently large and positive value for $H(V, P(\hat{s}))$ is required for $\frac{d\hat{s}^*}{d\tau} < 0$. To establish the second part of Result 4 it is sufficient to show that $H(V, P(\hat{s}))$ takes on a lower (and possibly negative) value for a higher value of Ω. This negative relationship between $H(V, P(\hat{s}))$ and Ω was previously established. Numerical examples of negative values of $H(V, P(\hat{s}))$ with high values of Ω were also previously presented.

Result 5

Use $N(\hat{s}^*,\tau) = P(\hat{s}^*) + \tau(V - \pi/\rho - P(\hat{s}^*))$ to show that $\frac{dN}{d\tau} = V - \pi/\rho - P(\hat{s}^*) + (1-\tau)\frac{dP}{d\tau}$ where $\frac{dP}{d\tau} = \frac{dP}{d\tau}|_{\hat{s}fixed} + \frac{dP}{d\hat{s}^*}\frac{d\hat{s}^*}{d\tau}$. Use equation (4) to show that $\frac{dP}{d\tau}|_{\hat{s}fixed} = -\frac{H(V,\hat{s})}{1-\tau}$ and $\frac{dP}{d\hat{s}} = [(1-\tau)\rho]^{-1}$. Making the required substitutions gives $\frac{dN}{d\tau} = -\frac{1}{\rho}\frac{d\hat{s}^*}{d\tau}$. The inverse relationship between $\frac{dN}{d\tau}$ and $\frac{d\hat{s}^*}{d\tau}$ is now obvious.

G Selection of Parameter Values for Simulations

The simulations use a common set of base-case parameter values. The land's pre-development profit flow is normalized to $\pi = 1$. A 10 percent rate of discount ($\rho = 0.1$) is a commonly assumed value in the economic modeling literature. The present value of an infinite stream of $\pi = 1$ profits implies that the pre-development use value of the land is 1/0.1 = 10. Setting the date 0 development value of the land equal to $V = 11$ is therefore reasonable. Assuming a 3.33 percent continuously compounded growth ($\alpha = 0.033$) in the development value of the land is also reasonable (at this rate of growth the development value will double approximately every 20 years). Assuming $\lambda = 1.5$ implies the conservation agency has a moderate budget constraint because an additional dollar added to its budget would generate $1.5 dollars in external project environmental benefits. Assuming $\mu = 2$ implies that the cumulative distribution function for the s variable is given by $G(\hat{s}) = 1 - e^{-0.5\hat{s}}$, which has a typical shape for an exponential distribution. Assuming a comparatively low value for the ϕ parameter (in particular, $\phi = 0.2$) implies that the conservation agency discounts by 80 percent the environmental flow from land that will eventually be developed as compared to land that is protected by an easement. This comparatively low value was chosen because with higher and likely more realistic values the equilibrium is rather unstable (recall that a sufficiently low value for ϕ is required to ensure that the agency's second-order condition holds). The environmental value of the land as measured by Ω was allowed to vary between 8.5 and 15. In comparison to the use value of the land which is 1/0.1 = 10, assuming this range of environmental values for the land is reasonable because it implies that the land's environmental value is approximately equal to the land's use value.

H Section 4 Comment

This first part of this Appendix establishes that it is sufficient to examine the impact of Ω on $\frac{d\hat{s}^*}{d\tau}$ rather than $\frac{d[1-G(\hat{s}^*)]}{d\tau}$. The assumption is that s follows an exponential distribution with mean $\mu(\Omega)$ where $\mu(\Omega)$ is an increasing function to reflect the positive association between the landowner's "lifestyle" valuation and the land's environmental value. With this assumption the impact of marginally higher τ on the probability of an easement outcome can be expressed

$$\frac{d[1-G(\hat{s};\Omega)]}{d\tau} = \frac{1}{\mu(\Omega)} e^{\frac{-1}{\mu(\Omega)}\hat{s}^*} \left(-\frac{d\hat{s}^*}{d\tau}\right) \tag{H.1}$$

It follows from the structure of equation (H.1) that the positive relationship between μ and Ω magnifies the negative impact of higher Ω on $\frac{d[1-G(\hat{s};\Omega)]}{d\tau}$. For this reason it is sufficient to focus on how $\frac{d\hat{s}^*}{d\tau}$ changes with Ω. Specifically, if it can be shown that $\frac{d\hat{s}^*}{d\tau}$ weakens with higher Ω then it must be the case that $\frac{d[1-G(\hat{s};\Omega)]}{d\tau}$ also weakens with higher Ω.

This second part of this Appendix shows that the relationship between Ω and $\frac{d[1-G(\hat{s}^*)]}{d\tau}$ is independent of the landowner's date T legal costs. Begin by noting from equation (3) that an increase in $C(\Omega)$ can be fully offset by a decrease in $\hat{s}$, which implies there is no change in $V^D(\hat{s}^*)$ when $C(\Omega)$ increases. Equation (2) shows that the increase in $\hat{s}$ that is consistent with no change in $V^D(\hat{s}^*)$ results in $L(V,\hat{s}^*)$ decreasing by an amount equal to the increase in $C(\Omega)$. Moreover, equation (4) shows that if $L(V,\hat{s}^*)$ and $\hat{s}$ both decrease by the amount described above then there is no change in $P(\hat{s}^*)$. Because ex post legal cost has no effect on $P(\hat{s}^*)$, $V^D(\hat{s}^*)$ and $H(V,P(\hat{s}^*))$ it follows from equation (F.2) that tax credit effectiveness does not depend on ex post legal costs.