

A Welfare Analysis of Conservation Easement Tax Credits*

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James Vercammen[†]

Sauder School of Business & Food and Resource Economics

University of British Columbia

Abstract

The use of conservation easements to protect farmland, wetlands and forests has grown rapidly in recently years, especially in North America. This paper uses a dynamic real option framework to theoretically examine the market efficiency of a conservation easement when a participating landowner is compensated for forfeiting the development rights of his or her land with a combination of a cash payment from a land trust and an income tax credit. If the land trust sets a competitive easement price then a positive real option for delaying the development decision is shown to result in an inefficiently high probability of a successful easement outcome. In the more realistic case where the land trust has market power the probability of a successful easement outcome may be inefficiently low (if the market power effect dominates) or inefficiently high (if the real option effect dominates). The marginal effectiveness of the tax credit depends on the degree of pricing pass-through, ranging from high effectiveness in the case of a budget constrained or zero-price land trust, to low effectiveness in the case of high environmental value and thus inelastic easement demand by the landowner

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[†]Contact information: (Postal) 2053 Main Mall, Vancouver, British Columbia, Canada, V6T 1Z2; (Telephone) 16048273844; (e-mail) james.vercammen@ubc.ca

1 Introduction

Public concern over land development continues to grow due to a shrinking supply of land for food production, wildlife habitat, biodiversity and green space. In North America private land trusts have formed to conserve land through a combination of outright purchases and conservation easements. A conservation easement is a perpetual legal contract that allows land to remain in private hands, but which requires current and future owners of the land to preserve specific land attributes and to forego certain types of activities [Anderson and King, 2004]. Easements vary from simple restrictions on land modification such as water drainage to major restrictions that prohibit any type of non-natural activity. The amount of land that is protected by conservation easements and the number of private land trusts who administer these easements has grown rapidly over the past two decades. Between 2000 and 2010 the number of local, state and national land trusts operating in the U.S. grew 36 percent to 1,723, and the total acres conserved by these trusts approximately doubled from 23.8 to 47.0 million acres [Alderich and Wyerman, 2005, Chang, 2010]. The Nature Conservancy in the U.S., which is the world's largest land trust, had protected 17.2 million acres by 2008 at an up-front cost of USD\$7.5 billion [Fishburn, Kareiva, Gaston, and Armsworth, 2009].

In most cases a landowner donates the conservation easement to a land trust, and in exchange is provided with one or more tax credits relating to property, income and estate.¹ The value of the donation is typically calculated as the difference in the appraised value of the land without the easement versus with the easement. Subject to various restrictions, the value of the donated easement is treated as a charitable donation (e.g., a U.S. landowner in a 30 percent tax bracket who donates a \$10,000 easement would earn a \$3000 tax credit that can be carried over for up to five years). In high priority scenarios, the land trust will provide a cash payment to the landowner, in which case the tax credit is applicable to the residual easement gift (this is called "split receipting" in Canada and "bargain selling" in the U.S.).² A land trust may also use a

¹See the U.S. Nature Conservancy website for details about the tax credits that are available to U.S. land owners: <http://www.nature.org/about-us/private-lands-conservation/conservation-easements/all-about-conservation-easements.xml>

²See pp. 39-40 of Hillyer and Atkins [2006] for the details about "split receipting" in Canada.

purchase-of-development rights (PDRs) program to ensure the protection of high priority land. In this paper no distinction is made between a land owner receiving a cash payment for signing a conservation easement and participating in a PDRs program because the two mechanisms are essential equivalent.³

Of interest in this paper is the efficiency of a conservation easement market outcome when a cash payment is used by a land trust to ensure the protection of high priority land. This is a relevant issue to examine because there appears to be growing concern by economists and public administrators about whether the rapid growth in the use of easements is in society's best interest. For example, Raymond and Fairfax [2002], Merenlender, Huntsinger, Guthey, and Fairfax [2004] and Fishburn et al. [2009] are concerned about the potential for easements to eliminate socially desirable development opportunities, spotty monitoring and easement enforcement by small-scale land trusts, higher property tax rates and fewer public goods for the community in order to offset the reduced flow of taxes from the land protected by the easements [Anderson and King, 2004]. McLaughlin [2004] shows how tax incentives favour high income landowners, which goes against the principle of helping cash poor landowners resist the temptation to sell their land for development for purely financial considerations.⁴

To examine market efficiency a model is constructed where a landowner has a now-or-never option to accept a cash payment easement offer made by a land trust who values the land for its environmental attributes, knowing that if the offer is rejected then he or she will eventually sell the land for development. Acceptance or rejection of the offer is probabilistic because the landowner values non-market attributes of the land (e.g., living outside of the city), and the land trust is uncertain about this valuation when the easement offer is made. The timing of land

³If the parcel of protected land is small with minimal opportunity for development then the landowner who agrees to a conservation easement may receive an upfront cash payment and no explicit tax credits. This is the standard procedure for Ducks Unlimited, who use easements to protect small pockets of wetland that are distributed throughout grain producing regions of Canada and the U.S. [Lawley and Towe, 2014].

⁴King and Anderson [2004] and Anderson and Weinhold [2008] argue that the tax-based social cost of the easement may be overstated in the literature because easements generally increase the market value of non-easement properties. Sundberg and Dye [2006] find that the tax advantages of an easement usually more than compensates the landowner for the reduced market value of the land.

development in the event of easement rejection is endogenous within the model because it is the solution to an embedded real option problem facing the landowner. The value of the option to delay the development decision is a key feature of the analysis and gives rise to many of the important results.

The first set of results are derived assuming competitive pricing by the land trust. This assumption is not realistic in most real-world situations, but it is nevertheless useful to have a competitive benchmark in place before examining the more realistic case of a land trust with some degree of market power. The first formal result is that competitive behaviour by the land trust does not ensure an efficient market outcome. Specifically, an efficient market outcome emerges only if the landowner finds it optimal to immediately sell his or her land for development should the land trust's easement offer be rejected. If instead the option to delay the development decision has positive value, then the competitive market outcome is characterized by an inefficiently high probability that the easement is signed (i.e., there is too little development of the land relative to the first best outcome). This result is unexpected because in the absence of the easement the environmental externality implies too much land development relative to the first best outcome.

The second set of results are derived by comparing the market outcome with a monopsony land trust to the first best market outcome. In this case if immediate land sale in the event of easement rejection is optimal for the landowner, then the market power of the land trust translates into an inefficiently low probability that the easement is signed and thus there is too much land development relative to the first best outcome. If instead the option to delay the development decision has positive value then the efficiency of the market outcome is ambiguous. On the one hand, the market power of the land trust drives the probability of a successful easement outcome to an inefficiently low level. On the other hand, the real option, which results in overuse of the easement in the competitive market case, drives the probability of a successful easement outcome to an inefficiently high level. The extent to which the market outcome is characterized by under or over use of the easement depends on the value of the real option to delay the development decision relative to the effectiveness of the market power of the monopsony land trust.

The third set of results focus on the efficiency of the tax credit as a mechanism for shifting the private land trust market equilibrium toward the first best outcome. In a competitive market where easement usage is either at the first-best level or excessively high (depending on whether the value of the option to delay the development decision is zero or positive), a positive tax credit is never optimal, unless the land trust is budget constrained. With a monopsony land trust, a positive tax credit is optimal if the land trust is budget constrained or if there is an inefficiently low probability of easement adoption due to relatively high market power for the land trust. This latter case is of particular interest due to the existence of tax credit pass-through, which is defined as a reduction in the land trust's easement offer price in response to a more generous tax credit. The analysis shows that pass-through is the largest and thus the tax credit is least effective when the environmental value of the land is relatively high. In other words, the tax instrument is the least effective in situations when the need for this instrument to correct the environmental market failure is highest. Interestingly, if the tax credit is relatively low and the land trust is budget constrained then a marginal increase in the tax credit is shown to be highly effective at stimulating easement usage due to zero pass-through. However, if the tax credit becomes sufficiently generous such that the budget constraint no longer binds then a marginal increase in the tax credit is only partially effective at stimulating easement usage by landowners because of a relatively high degree of tax credit pass-through.

The real option framework that is central to this analysis straddles two separate strands of literature. The first literature, which includes a key paper by Capozza and Sick [1994] and which builds on earlier work by McDonald and Seigel [1986] and Dixit and Pindyck [1994], focuses on privately optimal land development and the associated pricing of land. The second literature focuses on the socially optimal timing of natural resource exploitation when the decision to exploit is irreversible and when the future environmental benefits from the resource are uncertain [Arrow and Fisher, 1974, Reed, 1993, Conrad, 2000, Pindyck, 2002, Leroux, Martin, and Goesch, 2009]. It should be noted that Tenge, Wiebe, and Kuhn [1999] analyze the minimum level of compensation that is required to induce a landowner to voluntarily sign an easement when development value is uncertain. Their approach to value undeveloped land is similar to the approach used in this paper. Anderson and King [2004] use a simple game theoretic framework

and laboratory experiments to describe how a private market easement decision is expected to result in non-optimal levels of community welfare because of a property tax externality.

In the next section the basis assumptions are laid out, the option value of the land is derived and the pricing problem facing the land trust is set up and solved. Section 3 is used to examine the efficiency of the market outcome assuming zero option value from delaying the land development decision in the event the easement offer is rejected. The alternative case of a positive option value for delaying the development decision is considered in Section 4. The special case of a zero payment corner solution is briefly examined in Section 5. Concluding comments are provided in Section 6.

2 Easement Market Equilibrium

2.1 Basic Assumptions

Central to this analysis is a risk neutral landowner with an infinitely long time horizon and a fixed rate of discount, $\rho \in (0, 1)$. This landowner earns a fixed and continuous flow of after-tax profits, π , from the undeveloped land where profit is defined as revenue minus all expenses other than the cost of land ownership.⁵The land also provides the landowner with a fixed and continuous flow of non-market amenities, which includes open space, quiet surroundings and control over food production. The landowner's instantaneous valuation of these amenities is a constant and private value s . It follows that the minimum price the landowner would accept if the land was to be sold is $(\pi + s)/\rho$, and this minimum price is private information for the landowner.

The landowner has an on-going option to sell the land to a developer at price, $V(t)$. Assume this offer price evolves stochastically over time according to the supply and demand fundamentals in the developed land market. Specifically, $V(t)$ evolves continuously over time as geometric Brownian motion with drift parameter $\alpha \in (0, \rho)$ and volatility parameter σ . This

⁵This profit parameter is positive for the case of agricultural land (e.g., cropland and grazing land) and is equal to zero for the case of wetland and other land that is not involved in commercial activities (e.g., non-harvested forests).

assumption implies that $dV = \alpha V dt + \sigma V dz$ where $dz = \epsilon_t \sqrt{dt}$ is the increment of a Wiener process.⁶ Of particular importance in this analysis is $V(0)$, or simply V , which is the land's development value as of date 0. Assume $V > \pi/\rho$, which implies that the development value of the land exceeds the monetary use value of the land.

The landowner also has the option to negotiate a conservation easement with a local agency. Agreeing to a conservation easement is equivalent to the landowner selling the land's development rights to the agency. The agency is either "private" or "public", the former referring to an organization whose objective is to maximize environmental surplus and the latter referring to an organization whose objective is to maximize social surplus, which includes the development and environmental value of the land plus the profits of the landowner minus all costs to taxpayers and those who contribute directly to the operation of the agency. If the landowner accepts the agency's easement offer then environmental surplus is equal to the difference between the environmental value of the land minus the agency's cost of purchasing the land's development rights. If instead the easement offer is rejected then environmental surplus is equal to a fraction of the environmental value of the land from the time of rejection to the time of land development (details below)⁷To formally define the environmental value of the land, let ω denote the agency's instantaneous valuation of the undeveloped land's continuous flow of environmental services, which include wildlife habitat, preserved biodiversity, green space and a carbon sink for greenhouse gas emissions. Assuming the agency's discount rate is also equal to ρ , let $\Omega = \omega/\rho$ denote the present value of the flow environmental services into perpetuity, which is a relevant measure if the agency is successful in purchasing the land's development rights at date 0.

In exchange for agreeing to the conservation easement the landowner receives a tax credit (details below) and a one time easement payment, P , from the agency. To keep the analysis simple, assume the agency can access funds at a constant marginal cost of 1 up until level M . The

⁶Standard models of real estate development such as Capozza and Sick [1994] make a similar set of assumptions about real estate price uncertainty.

⁷The analysis could be made more general by assuming the agency is also interested in preventing the flow of undesirable environmental outcomes that are associated with land development. This assumption is not incorporated into the analysis because doing so is unlikely to change the major findings of this paper.

cost of acquiring funds in excess of M is assumed to be infinitely large, and thus M plays the role of an absolute budget constraint, which may or may not be binding. Rather than complicating the analysis by assuming that P is the outcome of a bargaining game, assume instead that in the absence of a budget constraint the agency has all of the bargaining power. Specifically, the agency selects the value of P that maximizes its surplus and then makes a now-or-never offer of this particular payment to the landowner.⁸ In addition to having full bargaining power, assume the agency cannot revise its offer if it does not meet the landowner's participation constraint and is thus rejected. This assumption circumvents the complications associated with renegotiation proof contracting and the well-known Coase Conjecture about dynamic pricing by a durable goods monopoly [Coase, 1972]. High bargaining transaction costs or the availability of a mechanism to "tie ones hands" [Schelling, 1956] are two possible justifications for this assumption.

Signing the easement agreement implies the landowner continues to earn the profit and non-market amenity flow, $\pi + s$, for the full span of his or her infinite time horizon. In addition to receiving payment P for selling the development rights the landowner is provided a one-time tax refund at rate t on the gift portion of the easement.⁹ The easement gift, $G(V) = V - \pi/\rho - P$, is the difference between the date 0 development value of the land, V , and the date 0 non-development use value of the land, π/ρ , as deemed by the taxation authorities, minus the easement payment, P . If the easement payment, P , is relatively large then $G(V) = V - \pi/\rho - P$ may take on a negative value. A negative value for $G(V)$ is appropriate because the taxing authority will treat as taxable income any payment in excess of what is required to compensate the landowner for signing the easement rather than immediately selling the land to a developer.

To determine the optimal value of P it is necessary for the agency to obtain an expression for $L(V, s)$, which is the landowner's date 0 opportunity cost of giving up the option to either immediately or eventually sell the land to the developer. If immediate development is optimal, then $L(V, s) = V$, and if delay is optimal then $L(V, s) = L(V, s)^{wait}$ where V is the

⁸The assumption that the agency has all of the bargaining power is not unreasonable because it is common for a region to have a large number of landowners demanding easements but just one conservation agency.

⁹In reality an easement gift tax refund will typically be spread out over time (e.g., 5 years) but this feature is not important for the current analysis and so is ignored.

land's current (date 0) development value. In the latter case $L(V, s)^{wait} > V$ and the difference, $L(V, s)^{wait} - V$, is the value of the option to wait and develop the land only if doing so becomes sufficiently profitable. The landowner's opportunity cost calculation must be made using a real options framework because selling the land to the developer is fully irreversible and, as noted above, the development value evolves stochastically over time as geometric Brownian motion.

In Appendix A a standard real options solution procedure (e.g., Dixit and Pindyck [1994]) is used to show that the landowner maximizes her expected surplus by selling the land to the developer only if the land's development value is at level $V^D(s)$ or higher where

$$V^D(s) = \frac{\beta}{\beta - 1} \frac{\pi + s}{\rho} \quad (1)$$

Moreover,

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

Within equations (1) and (2) the variable β is a decreasing function of both the expected rate of growth and the standard deviation of the land's stochastic development value (see Appendix A for details). Moreover, the term $(V/V^D(s))^\beta$, which is sometimes referred to as the stochastic discounted factor (e.g., Wong [2007]), discounts money received at the time of development back to date 0 while accounting for development trigger, V^D , and the uncertain time path of the land's development value. Similarly, the term $1 - (V/V^D(s))^\beta$ is a measure of the present value of a one dollar annuity from date 0 to the expected time of land development.¹⁰

2.2 Agency's Problem

The agency observes π and V , and also understands the calculations used by landowner to obtain expressions for $V^D(s)$ and $L(V, s)$. However, the agency cannot observe the specific value of s for the landowner since this is private information. Assume s is uniformly distributed over the interval $[0, s^u]$ where s^u is a fixed parameter. The agency is aware of this distribution

¹⁰The standard finance formula that is used to discount one dollar received at time T back to date 0 is $e^{-\rho T}$ and the formula used to calculate the present value of a one dollar continuously compounded annuity between date 0 and date T is $(1 - e^{-\rho T})/\rho$. The expressions in equation (2) are the same with $\left(\frac{V}{V^D(s)} \right)^\beta$ playing the role of $e^{-\rho T}$.

and also knows that the landowner will accept the agency's easement offer at date 0 if and only if $Z(s) \geq L(V, s)$ where $Z(s) = P + \tau G(V) + (\pi + s)/\rho$ is the total value of the easement outcome to the landowner. In other words, the easement payment, P , plus the tax credit, $\tau G(V)$, plus the present value of the perpetual profit and non-market amenity value flow, $(\pi + s)/\rho$, must be greater than or equal to $L(V, s)$, which is the value of the land with the option to develop.

It is straight forward to show that $P + \tau G(V) + (\pi + s)/\rho - L(V, s)$ is a strictly increasing function of s and P . Thus, the agency knows that the landowner will accept its offer if s is greater than or equal to $s(P)$ where $s(P)$ is a strictly decreasing function that is defined implicitly by $P + \tau G(V) + (\pi + s)/\rho - L(V, s) = 0$. Let $\hat{s} \equiv s(P)$ to simplify the notation. At various points in the analysis it is more convenient to work with the inverse easement selection rule for the landowner: accept if and only if $P \geq P(\hat{s}) = s^{-1}(\hat{s})$ where

$$P(\hat{s}) = \frac{L(V, s) - \tau V - (1 - \tau)(\pi/\rho) - s/\rho}{1 - \tau} \quad (3)$$

Equation (3) was derived by substituting $V - \pi/\rho - P$ for $G(V)$ in the landowner's break-even expression, $P + \tau G(V) + (\pi + s)/\rho - L(V, s) = 0$, and then solving for P . Later in the analysis an expression is needed for $dP/d\hat{s}$. Using equations (2) and (3), and noting that $L(V, s) = L(V, s)^{wait}$ if $V < V^D(s)$ and $L(V, s) = V$ if $V \geq V^D(s)$, it is straight forward to show that

$$\frac{dP}{d\hat{s}} = \begin{cases} -[\rho(1 - \tau)]^{-1} & \text{if } V \geq V^D(s) \\ -[\rho(1 - \tau)]^{-1} \left(\frac{V}{V^D(\hat{s})}\right)^{-\beta} & \text{if } V < V^D(s) \end{cases} \quad (4)$$

The break-even function, $\hat{s} \equiv s(P)$, together with the assumption that s is uniformly distributed on $[0, s^u]$, can now be used to construct a measure of the probability of easement acceptance, which is denoted $\Gamma(\hat{s})$. Acceptance requires a landowner for which $s \geq \hat{s}$, which implies

$$\Gamma(\hat{s}) = 1 - \frac{1}{s^u} \int_0^{\hat{s}} ds = \frac{1}{s^u} (s^u - \hat{s}) \quad (5)$$

To construct the agency's objective function it is important to ask how the agency values the flow of environmental services from between date 0 and the time the land is developed should the easement offer be rejected by the landowner. If the agency is public (i.e., a central planner) then this external flow is not discounted because it is a legitimate component of system-wide

welfare. If the agency is private then it is reasonable to assume that this external flow will be discounted because land in the portfolio can be used to leverage future growth of the agency whereas land that resides outside of the agency's portfolio due a failed easement offer cannot be used for this purpose.¹¹ Let $\gamma \in [0, 1]$ denote weight the private agency attaches to the land's temporary environmental flow if the easement is rejected (i.e., until the land is developed), and let $1 - \gamma$ be the corresponding percent discount.

Subject to a possible binding budget constraint, the agency chooses the easement payment, P , to maximize its surplus. However, the same solution can be obtained by allowing the agency to choose \hat{s} to maximize its surplus. This latter approach is used because the notation is less complicated. To account for a budget constraint that binds at level M for the private agency, let the agency's cost of funds be given by $C(P) = P + (P/M)^a$ where $a \rightarrow \infty$.¹² With a binding budget constraint the market outcome features the private agency offering M and the landowner accepting this offer with probability $\Gamma(s^0)$ where s^0 is the implicit solution to $M = P(s^0)$.

Using equation (5) the agency's objective function (multiplied by s^u) can now be stated as

$$W(\hat{s})s^u = [\Omega - (1 - \lambda)C(P(\hat{s}))](s^u - \hat{s}) + \int_0^{\hat{s}} [\lambda L(V, s) + \Psi(s)\Omega] ds + \lambda \int_{\hat{s}}^{s^u} \frac{\pi + s}{\rho} ds \quad (6)$$

Within equation (6) $\lambda = 0$ implies the agency is private and $\lambda = 1$ implies the agency is public. As well, the notation has been simplified by introducing a new variable $\Psi(s)$ where

$$\Psi(s) = \begin{cases} 0 & \text{if } V \geq V^D(s) \\ [\lambda + (1 - \lambda)\gamma] \left[1 - \left(\frac{V}{V^D(s)} \right)^{-\beta} \right] & \text{if } V < V^D(s) \end{cases} \quad (7)$$

Equation (6) shows that for the case of a private agency ($\lambda = 0$) with a non-binding budget constraint the objective function reduces to the agency's environmental surplus, $\Omega - P$, multiplied by the probability of easement acceptance plus the scaled temporary expected environmental surplus in the event the easement offer is rejected by the landowner.¹³ For the public agency

¹¹This discounting assumption is consistent with the Niskanen [1968] theory of bureaucracy where growth of the organization carries implicit weight in an agency's objective function.

¹²The discontinuity at $P = M$ is ignored because it is not important for the analysis.

¹³The second half of the second line in equation (7) is a measure of the expected value of a one dollar annuity that starts at date 0 and ends when the land is sold because V has risen to the development trigger. This is the

($\lambda = 1$), the payment function, $P(\hat{s})$, vanishes because it has no impact on system-wide welfare. As well, the objective function includes landowner welfare, and $\gamma = 1$ because post-rejection environmental surplus is not discounted.

It is straight forward to show that the properties of $P(\hat{s})$ and $L(V, s)$ are such that the agency's objective function is concave with a unique maximum value. Consequently, assuming M is very large so that the private agency is not budget constrained, the first-order condition for choosing \hat{s} to maximize equation (6), with equation (3) substituting for $P(\hat{s})$, can be expressed as

$$-(1-\tau)[1-\Psi(s)]\Omega - (1-\lambda)\tau \left(V - \frac{\pi}{\rho} \right) + (1-\lambda\tau) \left(L(V, \hat{s}) - \frac{\pi + \hat{s}}{\rho} \right) + \frac{1-\lambda}{\rho}(s^u - \hat{s}) = 0 \quad (8)$$

3 Development Triggered at Date 0

This section begins by deriving and characterizing the equilibrium conditions assuming $V \geq V^D(s^u)$, which implies that for all $s \in [0, s^u]$ the landowner will immediately sell the land for development if the easement offer is rejected.

3.1 Equilibrium Outcome

As was discussed above, the $V \geq V^D(s^u)$ assumption implies $L(V, s) = V$. This simplification allows equations (3) and (8) to be respectively rewritten as

$$P(\hat{s}) = V - \frac{\pi}{\rho} - \frac{1}{1+\tau} \frac{\hat{s}}{\rho} \quad (9)$$

and

$$(1-\lambda\tau) \left[V - \frac{\pi + \hat{s}}{\rho} \right] + \frac{1-\lambda}{\rho}(s^u - \hat{s}) - (1-\tau)\Omega - (1-\lambda)\tau \left(V - \frac{\pi}{\rho} \right) = 0 \quad (10)$$

Let P^* and \hat{s}^* denote the solution values to this pair of equations for the $\lambda = 0$ non-constrained private agency case, and let P^{**} and \hat{s}^{**} denote the analogous values for the $\lambda = 1$ public correct expression to account for the temporary flow of environment services because this same expression is used in equation (2) to calculate the expected present value of the temporary $\pi + s$ annuity flow.

agency case. The variable interest is the probability of easement acceptance, $\Gamma(\hat{s})$, but because this variable is a linear negative function of \hat{s} via equation (5), the graphical analysis below will be presented in terms of \hat{s} rather than $\Gamma(\hat{s})$. The public agency achieves maximum welfare when the outcome is not distorted with a positive easement tax credit. Consequently, it follows that the private agency outcome is characterized by an inefficiently low probability of a successful easement outcome when $s^* > s_{\tau=0}^{**}$, and an inefficiently high probability when $s^* < s_{\tau=0}^{**}$.

To compare s^* and s^{**} note that for the case of a non-constrained private agency with $\lambda = 0$ equation (10) reduces to

$$\Omega = V - \frac{\pi}{\rho} + \frac{s^u}{\rho(1-\tau)} - \frac{2}{\rho(1-\tau)}\hat{s}^* \quad (11)$$

This condition for the agency's optimal choice of \hat{s} is the standard marginal benefit (left side of equation) equal to marginal outlay (right side of equation) optimal pricing formula for a monopsonist. The marginal outlay schedule slopes down rather than up when graphed with \hat{s} on the horizontal axis because the "quantity" variable, which is the probability of a successful easement outcome, is $s^u - \hat{s}$ rather than \hat{s} . For the case of a public agency with $\lambda = 1$ and $\tau = 0$, equation (10) reduces to

$$\Omega = V - \pi/\rho - \hat{s}_{\tau=0}^{**} \quad (12)$$

If this equation is rearranged it shows that the easement outcome is efficient only if the full social value of the easement for the landowner and the agency, $(\pi + s)/\rho + \Omega$, is equal to or higher than the land's development value, V .

Before formally comparing s^* and $s_{\tau=0}^{**}$ it is useful to restrict the parameters such that both of these variables lie strictly within the $[0, s^u]$ interval, particularly when the easement tax credit, τ , optimizes welfare in the private agency case. At this point in the analysis the parameter restrictions are stated without showing how they prevent a corner solution. This feature of the parameter restrictions will become clear in the analysis below.

Assumption 1. (a) $\Omega < V - \pi/\rho$

(b) $V - \frac{\pi}{\rho} - \Omega < \frac{s^u}{\rho(1-\tau)} > 2 \left(V - \frac{\pi}{\rho} - \Omega \right)$

Assumption 1 ensures that the net value of the undeveloped land excluding non-market amenities for the landowner, $\Omega + \pi/\rho$, minus the value of the land in development, V , is neither excessively small nor excessively large.

The first formal result can now be stated as follows:

Result 1. *If the land's development value, V , equals or exceeds the development trigger, $V^D(s)$, then given Assumption 1 the probability of a successful easement outcome is lower with a non-constrained private agency versus a public agency. Specifically, $s^* > s_{\tau=0}^{**}$ and $\Gamma^* < \Gamma_{\tau=0}^{**}$.*

Proof. See Appendix B for the proof of this result and all remaining formal results. □

Result 1 is expected because although the private agency fully internalizes the environmental value of the land (i.e., there is no environmental externality), it does not internalize the profits of the landowner, which includes the option to sell the land to a developer. For the case of $\tau = 0$, it can be shown using equations (9), (11) and (12) that the public agency sets $P = \Omega$, which is the standard Pigouvian subsidy. In contrast, the private agency exploits its market power by pricing at level $P = \Omega - (s^u - \hat{s})(-1)(dP/d\hat{s})$, which is below Ω . The lower the absolute response in \hat{s} to a change in P the lower the price offered by the private agency, which is consistent with the well-known inverse elasticity pricing rule.

The right hand side (RHS) of equations (11) and (12) are illustrated in Figure 1 for the case of $\tau = 0$ as the upper and lower downward sloping schedules, respectively. The intersection of these two schedules with Ω defines the two equilibrium values, s^* and s^{**} . The area of optimized surplus for the private agency, scaled by the parameter s^u , is also identified in Figure 1. The width of this rectangle is $s^u - s^*$, which is the probability of easement acceptance multiplied by s^u . The height of this rectangle is the surplus earned by the private agency if its easement offer is accepted, $\Omega - P^*$. Figure 1 shows that if the private agency has a budget of size M then this budget will constrain the previous outcome such that \hat{s} is equal to s^0 rather than s^* .

The next result focuses on a key determinant of the $s^* - s_{\tau=0}^{**}$ and $\Gamma_{\tau=0}^{**} - \Gamma^* <$ gaps that are highlighted in Result 1.

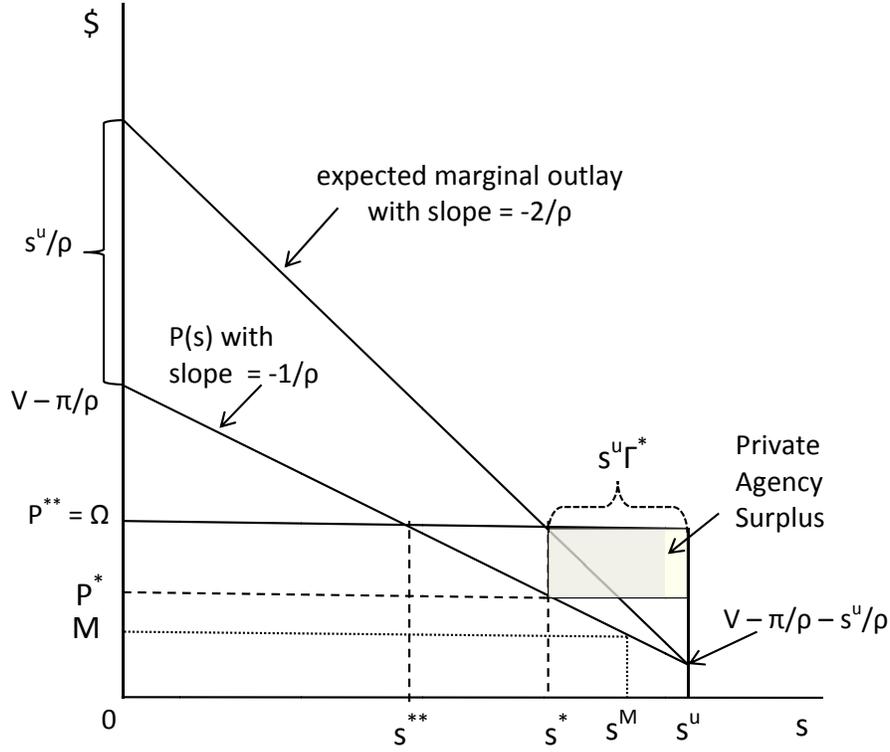


Figure 1: Private and Public Agency Easement Outcome

Result 2. *If $V \geq V^D(s)$ and if the private agency's budget constraint is not binding, then the $s^* - s_{\tau=0}^{**}$ and $\Gamma_{\tau=0}^{**} - \Gamma^*$ gaps are larger with higher values for the two non-market variables, Ω and s^u .*

Figure 1 shows for the case of a non-binding budget constraint and $\tau = 0$ that an increase in the environmental value of the land as measured by Ω results in lower values for both \hat{s}^* and \hat{s}^{**} . However, the latter decreases faster than the former and so the $s^* - s^{**}$ gap is larger with a higher value for Ω . An increase in the $s^* - s^{**}$ gap implies a larger gap between the socially efficient probability of easement acceptance, Γ^{**} , and the private market probability of easement acceptance, Γ^* .¹⁴ A particularly interesting feature of this result is that the $\Gamma^{**} - \Gamma^*$ gap is largest when the probability of a successful easement outcome, as measured by Γ^* , is largest.

¹⁴ Although not formally included in this analysis, it is straight forward to show that an increase in Ω or s^u results in higher deadweight loss for the market as a whole.

This result concerning the relationship between Ω and the $s^* - s^{**}$ gap can be best explained in the context of the easement demand elasticity. The landowner's demand for the easement is more elastic when s^* takes on a relatively small value and Γ^* takes on a relatively large value. This relationship is intuitive because Γ^* is equivalent to quantity in standard monopsony pricing theory. When demand is highly elastic the monopsonist has an incentive to lower the price on offer by a relatively large amount in order to lower the demand elasticity until its absolute value is inelastic (the optimal point is where marginal outlay is equal to marginal benefit). Consequently, the easement market outcome is most distorted relative to first best when s^* takes on a relatively small value. Although not explicitly shown, it should be obvious from Figure 1 that a higher value for Ω reduces the value of \hat{s}^* and thus results in a more distorted market outcome.

Figure 2 shows that an increase s^u , which is the average landowner valuation of the land's non-market amenities, results in a higher value for \hat{s}^* and no change in \hat{s}^{**} . Consequently, the $s^* - s_{\tau=0}^{**}$ gap is larger with a higher value for s^u . Similar to Ω , a larger value of s^u raises the landowner's elasticity of demand for the easement, and this reduction magnifies the monopsony pricing outcome. To see the connection between s^u and the easement demand elasticity notice in Figure 1 for the $\tau = 0$ case that a higher value for s^u increases the width of the private agency's surplus rectangle, which is equivalent to making the landowner's easement demand more elastic.¹⁵

3.2 Easement Tax Credit Effectiveness

This section of the paper examines the effectiveness of the easement tax credit as a mechanism for improving the efficiency of the easement outcome. In this analysis the tax credit is similar to a standard subsidy in a monopolized market, which serves to shift the private market outcome toward the first-best outcome. It is important to note that if the private agency is not budget

¹⁵This result can also be viewed in the context of marginal benefit and marginal outlay for the private agency. Maximizing $W(\hat{s}) = (\Omega - P)(s^u - \hat{s})/s^u$ requires setting marginal benefit, Ω , equal to marginal outlay, $P - (s^u - \hat{s})(dP/d\hat{s})$. A larger value for s^u raises marginal outlay and thus requires an increase in \hat{s} because a larger value of \hat{s} both lowers the probability of a successful easement outcome and the size of the payment to the landowner.

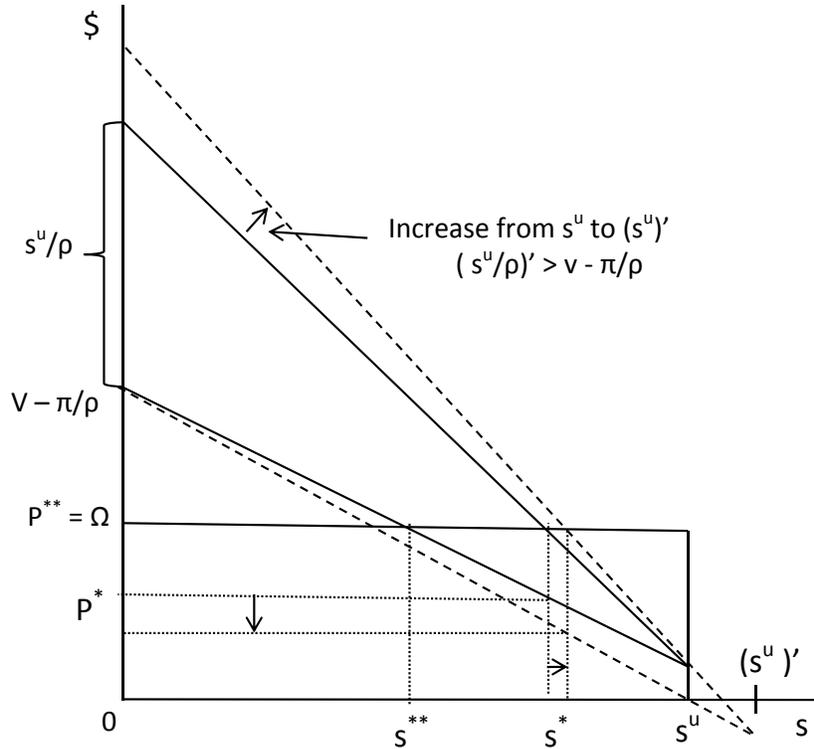


Figure 2: Private and Public Agency Easement Outcome

constrained and chooses to set a $P = \Omega$ competitive easement price rather than a monopsonistic easement price, then the outcome in the absence of a tax credit is efficient because it is identical to the public agency $\hat{s}_{\tau=0}^{**}$ outcome (see Figure 1). In this current analysis it is the possibility of either a budget constraint or monopsony pricing by the private agency that justifies the use of the easement tax credit.

Equation (11) reveals that a positive easement tax credit (i.e., $\tau > 0$) causes both the intercept and absolute slope of the private agency's marginal outlay schedule to increase in value. The thick schedules in Figure 3 are the marginal outlay and pricing schedules for the private agency with a positive value for τ . Notice that relative to the zero tax credit case the positive value for τ reduces \hat{s}^* from \hat{s}^* to \hat{s}^τ (assuming a non-binding budget constraint for the agency), which is the desired effect of the tax credit. The tax credit also induces the agency to reduce the easement price from P^* to P^τ , which is the undesired effect of the tax credit. This type of

pricing "pass-through" has been studied in a more general monopoly market setting by Fabinger and Weyl [2013].

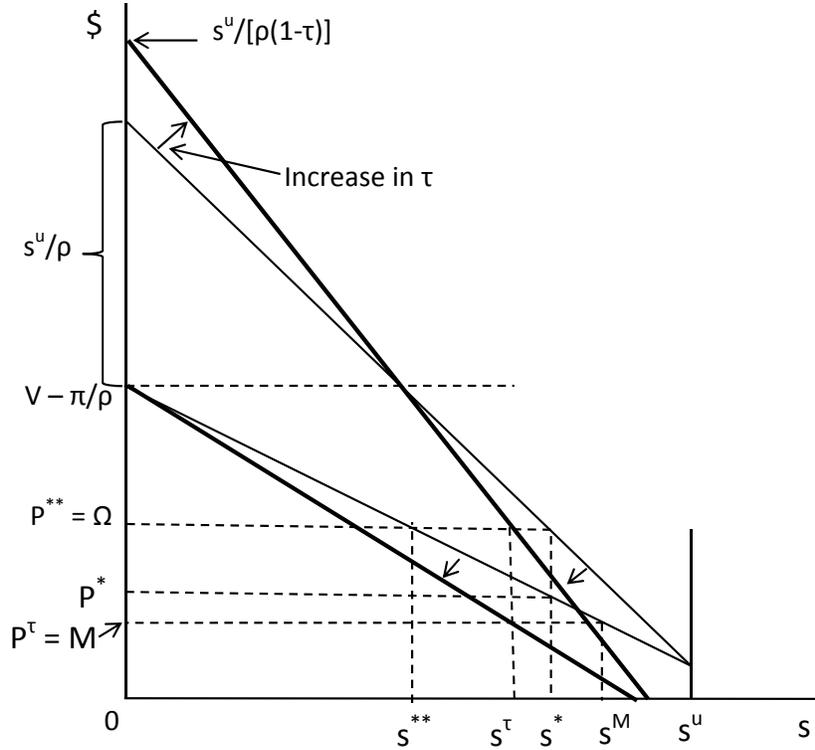


Figure 3: Impact of Easement Tax Credit on Easement Outcome

To formally examine the agency's price adjustment in response to a change in the tax credit define μ as the marginal pass-through variable for this current case where the land's development value, V , equals or exceeds the development trigger, $V^D(\hat{s})$. Specifically, noting that $Z(\hat{s}) = (\pi + \hat{s})/\rho + P + \tau(V - \pi/\rho - P)$ is the value of the easement to the landowner, the desired expression for μ is:

$$\mu = 1 - \frac{(\partial Z/\partial \tau)^{P=P^*} + (\partial Z/\partial P)(\partial P/\partial \tau)}{(dZ/d\tau)^{P=P^*}} \quad (13)$$

Equation (3) can be used to show that within this expression $\partial P/\partial \tau$ takes on a negative value. Consequently, $\mu = 0$ takes on its smallest value when $\partial P/\partial \tau = 0$ due to a binding budget constraint for the private agency. Conversely, μ takes on its largest value when the absolute

value of $\partial P/\partial \tau = 0$ is largest in absolute value (i.e., a maximum price response). A more explicit expression for equation (13) is derived in the Appendix and is written here as

$$\mu = \begin{cases} 0 & \text{if } P \leq M \text{ binding} \\ \frac{(1-\tau)^{-1}s^u/\rho}{V-\pi/\rho-\Omega+(1-\tau)^{-1}s^u/\rho} & \text{if } P \leq M \text{ not binding} \end{cases} \quad (14)$$

Before analyzing equation (14) it is useful to establish a link between marginal pass-through and the marginal effectiveness of the easement tax credit. To quantify this latter variable, let marginal effectiveness, $E \in [0, 1]$, be defined as the increase in the probability of easement acceptance for the last dollar the government spends on financing the easement tax credit, normalized by s^u/ρ . Specifically, $E = (d\Gamma^*/d\tau)/(d[\tau G(V)]/d\tau)s^u/\rho$. In the Appendix it is shown that E and μ are related as follows:

$$E = \frac{1}{1 + \frac{1}{1-\tau} \frac{\mu}{1-\mu}} \quad (15)$$

Equations (13) and (14) can be used to establish the following result.

Result 3. *If $V \geq V^D(s)$, then*

- (a) $\mu = 0$ and $E = 1$ ($\mu > 0$ and $E < 1$) if the private agency's budget constraint is binding (is not binding)
- (b) E and μ are negatively related.
- (c) μ is lower with higher values of $V - \pi/\rho - \Omega$ and s^u .

Part (a) of Result 3 is nicely illustrated in Figure 3. As discussed above, in the absence of a binding budget constraint for the private agency the easement tax credit results in a decrease in P from P^* to P^τ and a decrease in \hat{s} from \hat{s}^* to \hat{s}^τ . With a binding budget constraint of size M the tax credit reduces \hat{s} from \hat{s}^M to \hat{s}^τ . In this case the easement payment remains equal to M because the agency's budget constraint continues to bind with the increase in τ . The same tax credit results in a much larger reduction in \hat{s} when the budget constraint is binding due to the lack of adjustment in the easement price. Specifically, there is non pass-through and 100 percent tax credit effectiveness with the binding constraint, and there is positive pass-through and less than 100 percent effectiveness without the binding constraint.

Part (b) of Result 3 identifies pass-through as the primary determinant of tax credit effectiveness. Using the three restrictions in Assumption 1 it can be shown that in the absence of a binding budget constraint μ ranges in value from a low of $1/3$ to a high of $1/2$ for all feasible parameter combinations. If these results are inserted into equation (15) it follows that for τ near zero E will tend to be in the $[1/2, 2/3]$ range. Of course, these specific findings are not general, but they nevertheless nicely illustrate the substantial impact that pass-through can have on the effectiveness of the easement tax credit program.

Part (c) of Result 3 is a corollary of Result 3, where it was shown that a higher value for either of the two non-market valuation variables, Ω and s^u , results in larger degree of market distortion. Part (c) of Result 3 follows up this result by showing that the higher value for Ω or s^u also increases pass-through and reduces the effectiveness of the easement tax credit.

4 Delay in Development

Now suppose $V^D(\hat{s}) > V$, which implies that immediate development of the land is not optimal if the agency's easement offer is rejected by the landowner at date 0. Throughout this section assume the private agency is not budget constrained. In order to compare this situation to the previous $V^D(\hat{s}) \leq V$ results it is useful to assume the same value for V and a higher value of $V^D(\hat{s})$ due to higher development value uncertainty. Equation (1) shows that $V^D(\hat{s})$ is a decreasing function of β , and in the derivation of equation (1) in the Appendix it can be seen that β is a decreasing function of the development value uncertainty parameter, σ . Consequently, V can be chosen such that a sufficiently small value for σ implies $V^D(\hat{s}) \leq V$ and a sufficiently large value of σ implies $V^D(\hat{s}) > V$.

The analysis proceeds by re-examining the agency's first-order condition for maximizing surplus, which is given by equation (8). Note that $L(V, \hat{s})$ is now given by equation (2) rather than by V , and Ψ is now given by $(\lambda + (1 - \lambda)\gamma)[1 - (V/V^D)^\beta]$ rather than 0. The $\gamma \in [0, 1]$ parameter is important for this analysis because it is the weight that the private agency attaches to the stream of environmental services from non-portfolio land, starting from when the easement was rejected and ending when the land is developed.

With a public agency, $\lambda = 1$ and $\Psi = 1 - (V/V^D(\hat{s}))^\beta$. Consequently, equation (8) reduces to $\Omega = V^D(\hat{s}) - (\pi + \hat{s})/\rho$. This expression is same as the case examined in the previous section except $V^D(\hat{s})$ replaces V . The Appendix is used to establish that $V^D(\hat{s}) - (\pi + \hat{s})/\rho$ is a decreasing convex function. For the private agency, $\lambda = 0$ and $\Psi = \gamma[1 - (V/V^D(\hat{s}))^\beta]$, and so equation (8) can be rewritten as

$$\Omega = \frac{(1 - \tau)(V - \pi/\rho) + L(V, \hat{s}) - V + s^u/\rho - 2\hat{s}/\rho}{(1 - \tau)[1 - \gamma(1 - (V/V^D)^\beta)]} \quad (16)$$

Comparing this expression to equation (11) reveals that for the special case of $\gamma = 0$ this marginal outlay expression is the same as the $V^D(s) \leq V$ case except for the additional term $[L(V, \hat{s}) - V]/(1 - \tau)$. The Appendix is used to show that this additional term shifts up the private agency's marginal outlay function, and also makes it steeper and convex to the origin. The Appendix also shows that a sufficiently large value of γ results in an upward sloping marginal outlay function. The specific restriction on γ that ensures a downward sloping marginal outlay function is complicated and of little interest in the analysis. Instead, it is sufficient to assume that γ is sufficiently close to zero to ensure a downward sloping marginal outlay function.

Using the revised first-order conditions for the public and private agencies as described above, the following result can be established.

Result 4. *For a given value of V , assume sufficiently high development value uncertainty, as measured by σ , such that $V^D(\hat{s}) > V$ instead of $V^D(\hat{s}) \leq V$. All else equal, this assumption raises the equilibrium values of both \hat{s}^{**} and \hat{s}^* , which implies a lower probability of the landowner accepting the easement.*

Result 4 reflects the option value associated with the land development decision. A positive option value emerges because land development uncertainty combined with an irreversible development decision means that delaying the development decision and waiting for a sufficiently high offer price from the developer is valuable from the landowner's perspective. The expected delay in the development decision implies that the flow of environmental services will remain intact during the time interval between when the easement is rejected and when the land is developed. This additional flow of environmental services means that the public agency values

the easement somewhat less, and this reduction in value translates into a lower probability of a successful easement outcome.

For the private agency with a fixed value of V , higher development value uncertainty that triggers $V^D(s) \leq V$ induces the private agency to decrease the easement payment, which in turn decreases the probability of a successful easement outcome. If $\gamma > 0$ then, similar to the public agency, the private agency will reduce its valuation of the easement because the flow of environmental benefits will temporarily continue should the easement be rejected. Even if $\gamma = 0$ the positive option value for land development reduces the landowner's demand for the easement, and this inward shift in demand induces the private agency to raise \hat{s} and thus reduce the probability of easement adoption.¹⁶ The general message of Result 4 is that the easement is less valuable to both the private and public agency when higher development value uncertainty triggers $V^D(s) \leq V$.

The next result focuses on a new type of $\hat{s}^* - \hat{s}^{**}$ market efficiency gap that emerges for the $V^D(\hat{s}) > V$ case if the private agency places less than 100 percent weight on the flow of environmental services from non-portfolio land (i.e., $\gamma < 1$). In order to simplify the analysis only the extreme case of $\gamma = 0$ is considered. Assuming $0 < \gamma < 1$ subject to a maximum value for γ as discussed above is expected to give rise to a similar result but it does not appear that the desired result can be established analytically.

Result 5. *With $\gamma = 0$ and σ sufficiently large, the probability of a successful easement outcome is higher for the private agency than for the public agency, despite a zero easement tax credit. Formally, $\hat{s}^*(\gamma = \tau = 0) < \hat{s}^{**}(\tau = 0)$.*

Result 5 emerges for the reasons associated with Result 4. Specifically, with a high level of development value uncertainty the public agency anticipates that in the event the easement offer is rejected, the landowner will wait a relatively long time before the land is sold to a developer. During this time between easement rejection and land development environmental services will

¹⁶A similar result emerges with standard monopsony theory. Specifically, an inward shift in the upstream firm's demand for the services supplied by the monopsonist results in a lower equilibrium quantity after the monopsonist adjusts its price optimally.

continue to flow, and so the public agency discounts the value of the easement. Because the private agency's valuation of this post-rejection easement flow is less than the public agency's valuation, it follows that the private agency discounts the value of the easement less than that of the public agency. Hence, for a sufficiently high level value for σ it is possible for $\hat{s}_0^{**} > \hat{s}_0^*$, which implies that the probability of a successful easement outcome is higher rather than lower when the private agency rather than the public agency is in charge of the easement decision.

Result 5 was derived assuming no easement tax credit. A positive tax credit will result in an even larger private agency over-shooting of the probability of a successful easement outcome relative to the first best (zero tax credit) easement outcome. For more moderate levels of development value uncertainty the private agency's discounting of the flow of environmental services from non-portfolio land results in a narrowing of the $\hat{s}^* - \hat{s}^{**}$ gap but not a reversal. In this situation the market distortion that is associated with monopsony pricing by the private agency more than offsets the market distortion that is associated with the private agency not fully internalizing the flow of environmental services from non-portfolio land. In this situation an easement tax credit is still needed to reduce the $\hat{s}^* - \hat{s}^{**}$ gap to zero, but the size of the tax credit will be relatively smaller, and decreasing with the level of development value uncertainty.

Result 5 is illustrated in Figure 4. The linear pricing and marginal outlay schedules correspond to the previous case of $V^D(s) \leq V$, and the convex pricing and marginal outlay schedules correspond to the current case of $V^D(s) > V$. With the $\gamma = \tau = 0$ assumption the shift and curvature is relatively large for the pricing schedule and relatively small for the marginal outlay schedule. Figure 4 illustrates the extreme case where the differences in the shifts of the pair of schedules is large enough for the gap between \hat{s}^* and \hat{s}^{**} to reverse. As discussed earlier, a discounting of the flow of environmental services from non-portfolio land will result in the $\hat{s}^* - \hat{s}^{**}$ gap narrowing but not necessarily reversing.

5 Zero Payment Corner Solution

This last section examines a scenario where the private agency chooses to offer a zero easement payment (i.e., a corner solution, since a negative easement payment is not feasible). As dis-

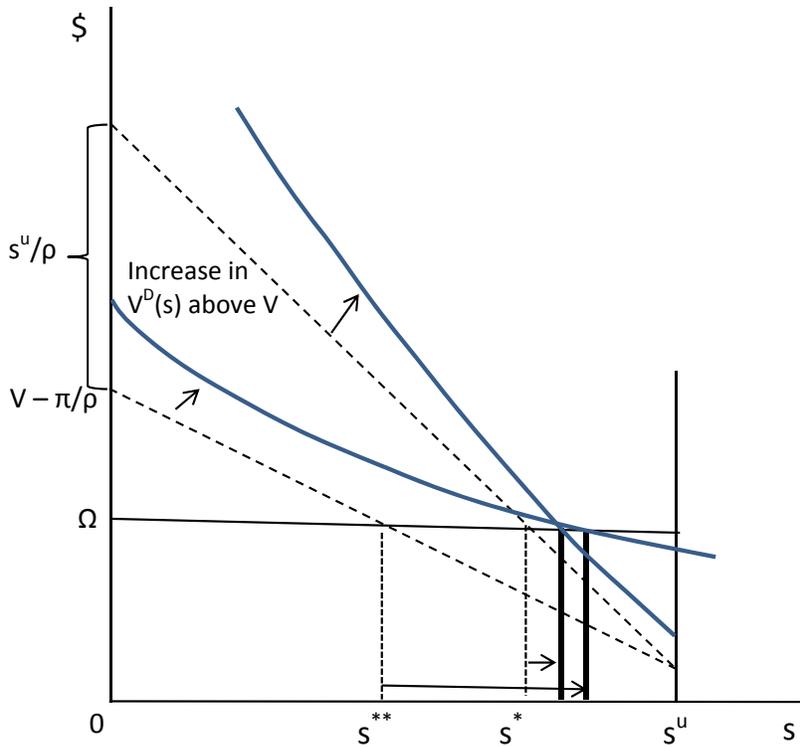


Figure 4: Impact of Uncertainty on the $s^* - s^{**}$ gap

cussed in the Introduction, this outcome is commonly observed in real-world easement markets. One explanation for this outcome is that the easement tax credit is excessively generous relative to the environmental value of the land, and thus a zero easement payment is sufficient compensation for the landowner to accept the private agency's zero payment offer. In this section a second explanation is provided for this private agency outcome. Specifically, a comparatively high value of the flow of environmental services or non-market amenities for the landowner results in a high enough level of tax credit pass-through to drive the agency's easement offer price to zero. What is formally shown in this section is that this outcome can emerge even when the probability of a successful easement outcome remains inefficiently low.

The analysis in this section is kept as simple as possible by assuming $V^D(s) \leq V$, which, as shown above, ensures linear payment and marginal outlay schedules. A key component of the formal result is an expression for the socially efficient easement tax credit; i.e., the level of τ

which ensures $\hat{s}^* = \hat{s}_{\tau=0}^{**}$. To derive this expression for τ^* , set the expressions on the right sides of equations (11) and (12) equal to each other and then solve for τ :

$$\tau^* = \frac{s^u/\rho}{V - \pi/\rho - \Omega} \quad (17)$$

Result 6. Suppose $V^D(s) \leq V$ and the value of Ω and s^u are such that $(V - \pi/\rho - \Omega) \left(1 + \frac{\Omega}{V - \pi/\rho}\right) < s^u/\rho < (V - \pi/\rho - \Omega)$. Then,

(a) Assumption 1 is satisfied, $P^* = 0$ and $\tau < \tau^*$.

(b) A marginal increase in τ is one hundred percent effective (i.e., $E = 1$).

To help illustrate the corner solution outcome that is implied by Result 6 first consider Figure 5, which shows the equilibrium outcome with the socially efficient easement tax credit and a positive value for P^* . The light shaded schedules correspond to $\tau = 0$. The heavy shaded schedules correspond to $\tau = \tau^*$ because with these schedules $s^* = s_{\tau=0}^{**}$. In Figure 5 the level of easement price pass-through is only moderately large because the selected values of both Ω and s^U are only moderately large. Consequently, despite the comparatively large value for τ the private agency's easement offer price is positive and the first-best easement market outcome has been achieved.

Now consider Figure 6, which shows the case where s^u takes on a comparatively large value. In this scenario the landowner's demand for the easement is highly inelastic, and as a result the level of easement tax credit pass-through is comparatively large. The chosen value for τ in Figure 6 is such that the $P^* \geq 0$ restriction just begins to bind. In the resulting equilibrium, $s^* < s_{\tau=0}^{**}$, which implies an inefficiently low probability of a successful easement outcome. Although it is not shown in Figure 6 it should be easy to see that if τ is increased further by pivoting the dark shaded schedules further toward the origin, then s^* will decrease without an accompanying decrease in P . It is in this sense that further increases in the tax credit are 100 percent efficient, as stated in part (b) of Result 6.

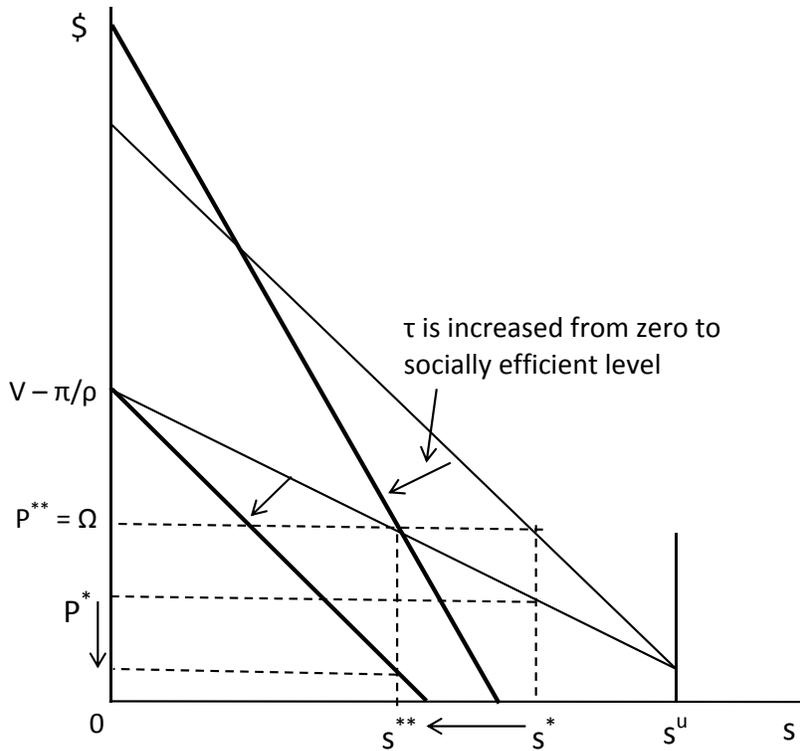


Figure 5: Positive Easement Price with Socially Efficient Easement Tax Credit

6 Conclusions

This paper examined the efficiency properties of a conservation easement market outcome. The analysis focused on a scenario where the easement is supplied by a private agency whose goal is to maximize environmental surplus. The land in question is assumed to have relatively high environmental value, and thus a landowner who agrees to the easement demands to be compensated with both a tax credit and an easement payment from the agency. A key feature of the model is the land's development value uncertainty. This uncertainty, combined with an irreversible land development decision, implies that the opportunity cost of a landowner who faces a now-or-never easement decision must be calculated as a real option. Higher uncertainty raises the value of delaying the land development decision and thus extends the expected time until the land is developed. This delay is important for the analysis because the public agency, whose goal is to maximize system wide welfare, fully accounts for it, whereas the private agency, whose goal is to maximize environmental surplus, only partial accounts for it. This "delay ex-

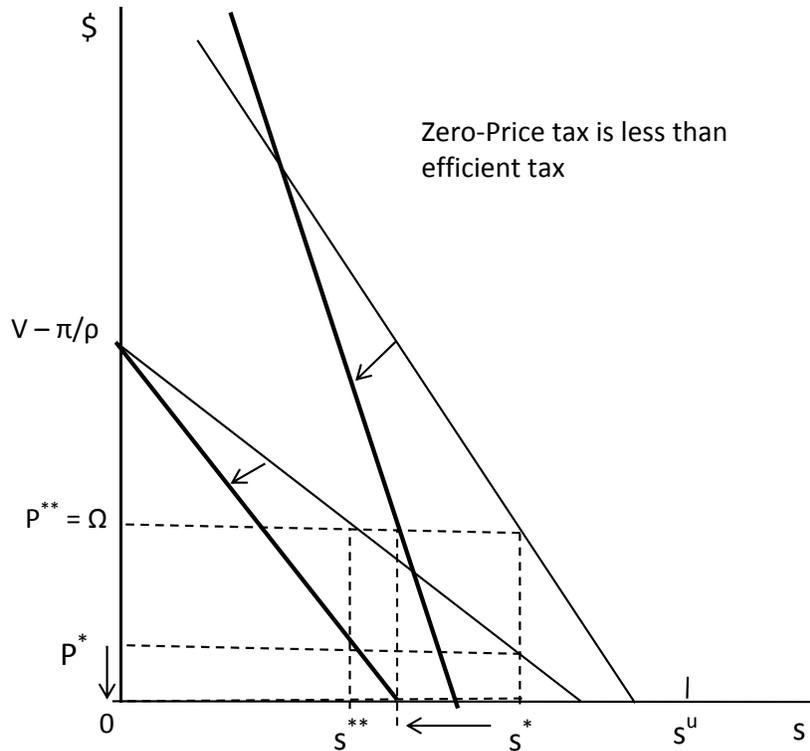


Figure 6: Zero Easement Price and Inefficiently Small Easement Tax Credit

ternality" gives rise to the unexpected result that even with competitive pricing by the private agency the probability of a successful easement outcome is inefficiently high, unless the value of the option to delay development is zero. With non-competitive pricing the pricing distortion associated with the private agency is ambiguous because on the one hand the delay externality results in an inefficiently high offer price to the landowner, while on the other hand the market power enjoyed by the agency results in an inefficiently low offer price. The second part of the paper focuses on the efficiency of the easement tax credit. The main result in this section is that a higher environmental value lowers the landowner's easement demand elasticity, which in turn raises the level of tax credit pass through and lowers the marginal effectiveness of the tax credit. With low levels of the tax credit the agency is more likely to face a binding budget constraint, in which case marginal effectiveness of the tax credit is 100 percent.

There are two ways to make this analysis more general. First, a stochastic and upward trending environmental value of the land would make the analysis more realistic. Incorporating this

assumption into the present analysis would not be too difficult because due to the now-or-never offer assumption, only the net-present value of the flow of environmental services would enter into the agency's objective function. If the non-constant environmental value assumption was combined with the additional assumption that the agency provides the landowner with a standing offer rather than a now-or-never offer, then the problem would have a second real option dimension. This is bound to generate a set of new and interesting results, but such a problem would be complicated, and almost certainly numerical methods would be required to solve the problem. The second way to make this analysis more general is to model how the private agency sources the funds it needs to finance the easement payment. The current assumption of either a constant cost or an infinitely large cost of capital is quite restrictive. Modeling the contribution decision of the beneficiaries of the land's environmental value would be an interesting extension of this work, but once again much more complex analysis would be required.

References

- Alderich, R. and J. Wyerman (2005). National Land Trust Census Report - Land Trust Alliance (www.lta.org).
- Anderson, C. M. and J. R. King (2004). Equilibrium behavior in the conservation easement game. *Land Economics* 80(3), 355–374.
- Anderson, K. and D. Weinhold (2008). Agricultural land values and the value of rights to future development. *Ecological Economics* 68, 437–466.
- Arrow, K. J. and A. Fisher (1974). Environmental preservation, uncertainty and irreversibility. *Quarterly Journal of Economics* 88(2), 312–319.
- Capozza, D. R. and G. A. Sick (1994). The risk structure of land markets. *Journal of Urban Economics* 35(4), 297–319.
- Chang, K. (2010). National Land Trust Census Report - Land Trust Alliance (www.lta.org).
- Coase, R. (1972). Durability and monopoly. *Journal of Law and Economics*, 143–49.
- Conrad, J. (2000). Wilderness: Options to preserve, extract or develop. *Resource and Energy Economics* 22, 205–219.
- Dixit, A. K. and R. S. Pindyck (1994). *Investment Under Uncertainty*. Princeton, NJ: Princeton University Press.
- Fabinger, M. and E. G. Weyl (2013). Pass-Through and Demand Forms. Available at SSRN: <http://ssrn.com/abstract=2194855> or <http://dx.doi.org/10.2139/ssrn.2194855>; last update January 13, 2013.
- Fishburn, I., P. Kareiva, K. Gaston, and P. Armsworth (2009, March). The growth of easements as a conservation tool. *PLoS ONE* 4(3), 1–6.

- Hillyer, A. and J. Atkins (2006). Appraising Easements, Covenants and Servitudes. Available at <http://cpiciv.org/pdf/12-Appraising20Easements202007-06-04.pdf>; downloaded October 8, 2014.
- King, J. R. and C. M. Anderson (2004). Marginal tax effects of conservation easements: A Vermont case study. *American Journal of Agricultural Economics* 86(4), 919–932.
- Lawley, C. and C. Towe (2014). Capitalized costs of habitat conservation easements. *American Journal of Agricultural Economics*.
- Leroux, A. D., V. L. Martin, and T. Goesch (2009). Optimal conservation, extinction debt, and the augmented quasi-option value. *Journal of Environmental Economics and Management* 58, 43–57.
- McDonald, R. and D. Seigel (1986). The value of waiting to invest. *The Quarterly Journal of Economics* 101, 707–728.
- McLaughlin, N. A. (2004). Increasing the tax incentives for conservation easement donations. *Ecology Law Quarterly* 31, 1–113.
- Merenlender, A., L. Huntsinger, G. Guthey, and S. Fairfax (2004). Land trusts and conservation easements: Who is conserving what for whom? *Conservation Biology* 18, 65–75.
- Niskanen, W. A. (1968). The peculiar economics of bureaucracy. *The American Economic Review*, 293–305.
- Pindyck, R. S. (2002). Optimal timing problems in environmental economics. *Journal of Economics, Dynamics and Control* 26(9-10), 1677–1697.
- Raymond, L. and S. K. Fairfax (2002). The shift to privatization in land conservation: A cautionary essay. *Natural Resources Journal* 42, 599–639.
- Reed, W. J. (1993). The shift to privatization in land conservation: A cautionary essay. *Ecological Economics* 8, 45–69.

Schelling, T. C. (1956). An essay on bargaining. *The American Economic Review*, 281–306.

Sundberg, J. O. and R. F. Dye (2006). Tax and property value effects of conservation easements. Working paper, Lincoln Institute of Land Policy.

Tenge, A., K. Wiebe, and B. Kuhn (1999). Irreversible investment under uncertainty: Conservation easements and the option to develop agricultural land. *Journal of Agricultural Economics* 50(2), 203–219.

Wong, K. P. (2007). The effect of uncertainty on investment timing in a real options model. *Journal of Economic Dynamics and Control* 31(7), 2152 – 2167.

Appendix

A Derivation of Real Option Expressions

Begin by constructing a Bellman equation for the following dynamic programming problem:

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

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

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

Now simultaneously solve the value matching condition, $AV^\beta + (\pi + s)/\rho = V$, and the smooth pasting condition, $d(AV^\beta)/dV = 1$, for A and V , and refer to the solution values as $A^D(s)$ and $V^D(s)$, respectively. The expression for $V^D(s)$ is reported as equation (1). Substituting the solution value for A into $L^D(V, s)^{wait} = AV^\beta + (\pi + s)/\rho$ gives equation (2).

B Proofs of Formal Results

Result 1

Equations (11) and (12) can be solved and used to show that a necessary and sufficient condition for $s^* > s^{**}$ is $s^u/\rho > V - \pi/\rho - \Omega$. Assumption 1 ensures that this condition holds.

Result 2

To show that $s^* - s_{\tau=0}^{**}$ is increasing in s^u note from equations (11) and (12), respectively, that s^* is an increasing function of s^u , and $s_{\tau=0}^{**}$ is not dependent on s^u . This outcome, together with equation (5), implies that $\Gamma_{\tau=0}^{**} - \Gamma^*$ is also an increasing function of s^u .

Result 3

Part (a) follows directly from Assumption 1b, equation (14) and equation (15). Part (b) follows directly from equation (15), and part (c) follows directly from equation (14).

Result 4

Equation (1) shows that $V^D(\hat{s})$ is a decreasing function of β , and the expression for β in Appendix A shows that β is a decreasing function of σ . Consequently, V can be chosen such that a sufficiently small value for σ implies $V^D(\hat{s}) \leq V$ and a sufficiently large value of σ implies $V^D(\hat{s}) > V$. The public agency's first-order condition for choosing \hat{s} is $\Omega = V - (\pi + \hat{s})/\rho$ with $V^D(\hat{s}) \leq V$ and $\Omega = V^D(\hat{s}) - (\pi + \hat{s})/\rho$ with $V^D(\hat{s}) > V$. The solution value, s^{**} , is larger when $V^D(\hat{s}) > V$ versus $V^D(\hat{s}) \leq V$ because $V^D(\hat{s}) > V$ according to equation (1). Similarly, a comparison of equations (11) and (16) imply that \hat{s}^* is larger when $V^D(\hat{s}) > V$ versus $V^D(\hat{s}) \leq V$ because $\gamma \in [0, 1]$ and $L(V, \hat{s}) > V$ according to equation (2).

Result 5

Assume σ is sufficiently large such that $V^D(\hat{s}) > V$. Let \hat{s}_0^{**} denote the solution to equation (16) with $\lambda = 1$ and $\tau = 0$ (i.e., the zero tax credit public agency case). Similarly, let \hat{s}_0^* denote the solution to equation (16) with $\lambda = 0$, $\gamma = 0$ and $\tau = 0$ (i.e., the zero tax credit private agency case with $\gamma = 0$). Eliminating Ω from this pair of expressions gives

$$V^D(\hat{s}_0^{**}) - \hat{s}_0^{**}/\rho = L(V, \hat{s}_0^*) + s^u/\rho - 2\hat{s}_0^*/\rho$$

Rearrange this expression to give

$$\frac{2\hat{s}_0^* - \hat{s}_0^{**} - s^u}{\rho} = L(V, \hat{s}_0^*) - V^D(\hat{s}_0^{**})$$

Using equations (1) and (2) this expression can be written more explicitly as

$$\frac{-(\hat{s}_0^{**} - \hat{s}_0^*) - (s^u - \hat{s}_0^*)}{\rho} = \left[1 - \left(\frac{V}{V^D(\hat{s}_0^*)} \right)^\beta \right] \left[\frac{\pi + \hat{s}_0^*}{\rho} - V^D(\hat{s}_0^*) \right] + V^D(\hat{s}_0^*) - V^D(\hat{s}_0^{**})$$

The right side of this expression takes on a negative value assuming $\hat{s}_0^{**} > \hat{s}_0^*$, which is the result to be established. A negative value for the left side of the previous expression implies $\hat{s}_0^{**} > \hat{s}_0^*$ for \hat{s}_0^* sufficiently close to s^u . A higher value for σ (development value uncertainty) makes the right side more negative and also reduces the $s^u - \hat{s}^*$ gap. Consequently, a sufficiently large value for σ ensures $s_0^{**} > \hat{s}_0^*$.

Result 6

Let τ^0 denote the highest value of τ that is consistent with a positive value for P^* . Showing that $\tau^0 < \tau^*$ is sufficient to establish part (a) of Result 6 because P^* is a decreasing function of τ according to equation (3). Solving equation (9) for τ with $P = 0$ results in $\tau^0 = (V - \pi/\rho + \Omega - s^u/\rho)/(V - \pi/\rho + \Omega)$. After subtracting this expression for τ^0 from the expression for τ^* that is given by equation (17), it can be seen that the second inequality displayed in Result 6 is sufficient to ensure $\tau^0 < \tau^*$. The left side of the inequality in Result 6 takes on a smaller value than the right side because $\Omega < V - \pi/\rho$ according to Assumption 1. Thus, Result 6 necessarily exists for a range of values for Ω and s^u . To establish part (b) of Result 6 note that that P^* remains fixed at zero with a marginal increase in τ because P^* is a decreasing function of τ . This situation is equivalent to the payment being fixed at level M with a marginal increase in τ due a binding budget constraint for the private agency. Thus, for the current situation easement payment pass-through, μ , is zero from equation (14), and easement payment effectiveness, E , is equal to one from equation (15).

C Miscellaneous Derivations

Derivation of Equation (14)

To derive the expression for μ in equation (14) it is necessary to substitute into equation (13) explicit expressions for the pair of $dZ/d\tau$ differentials. Recall that $Z(s) = (\pi + s)/\rho + P + \tau(V - \pi/\rho - P)$ is the value of the easement to the landowner. Differentiating implies that $dZ/d\tau = (1 - \tau)(dP/d\tau) + V - \pi/\rho - P$. If equations (9) and (11) are combined and totally differentiated

with respect to P and τ , then the resulting expression, $dP/d\tau = -0.5(1 - \tau)^{-2}s^u/\rho$, can be substituted into the previous expression for $dZ/d\tau$ to obtain a more explicit expression for the differential of interest: $(dZ/d\tau)^{\text{free } P} = 0.5(1 - \tau)^{-1}$. Similarly, differentiating $Z(s) = (\pi + s)/\rho + P + \tau(V - \pi/\rho - P)$ with respect to τ while treating P as a fixed parameter gives $(dZ/d\tau)^{\text{fixed } P} = V - \pi/\rho - P$. Now substitute the two previously-derived differentials into equation (13) to obtain the explicit expression for μ that is shown in equation (14). It follows directly that this expression is an increasing function of both Ω and s^u .

Derivation of Equation (15)

Using $\Gamma^* = (s^u - \hat{s}^*)/s^u$ and equation (11) it can be shown that $d\Gamma^*/d\tau = 0.5(V - \pi/\rho - \Omega)\rho/s^u$. Similarly, using $G(V) = V - \pi/\rho - P$ and $dP/d\tau = -0.5(1 - \tau)^{-2}s^u/\rho$, it can be shown that $d[\tau G(V)]/d\tau = 0.5(V - \pi/\rho - \Omega) + 0.5(1 - \tau)^{-2}s^u/\rho$. Combining these results gives rise to an explicit expression for tax credit effectiveness:

$$E = \frac{V - \pi/\rho - \Omega}{V - \pi/\rho - \Omega + (1 - \tau)^{-2}s^u/\rho} \quad (\text{C.1})$$

The last step is to solve equation (14) for s^u and then substitute the resulting expression in equation (C.1) to obtain equation (15).

Derivation of Convexity Results for Section 4

The first result to be established is that the public agency's pricing function, $P(\hat{s}) = V^D(\hat{s}) - (\pi + \hat{s})/\rho$ is a decreasing convex function. To simplify the notation, let $M(\hat{s}) \equiv V^D(\hat{s})$. Using equation (1) it can be shown that $M'(\hat{s}) = -\beta M(\hat{s})/(\pi + \hat{s})$. It now follows directly that $P(\hat{s})$ is a decreasing function. To show that $P(\hat{s})$ is convex it is sufficient to show that $M''(\hat{s}) > 0$. Using the previous expression for $M'(\hat{s})$ it can be shown that $M''(\hat{s}) = \beta(\beta - 1)M(\hat{s})/(\pi + \hat{s})^2$, which takes on a positive value.

Next, consider the right hand side of equation (16) for the special case of $\gamma = 0$. A comparison to the right hand side of equation (11) reveals that the vertical intercept of the marginal outlay function is higher for the case of $V^D(\hat{s}) > V$. The slope of the right hand side of equation (16) with $\gamma = 0$ is given by $MO'(\hat{s}) = [dL(V, \hat{s})/d\hat{s} - 2/\rho](1 - \tau)^{-1}$. Using equation

(2) and the $M'(\hat{s}) = -\beta M(\hat{s})/(\pi + \hat{s})$ result from the previous paragraph, it can be shown that $dL(V, \hat{s})/d\hat{s} = [1 - M(\hat{s})]/\rho$. Thus, $MO'(\hat{s}) = -[1 + M(\hat{s})]/\rho$, which necessarily takes on a negative value. To show that $MO(\hat{s})$ is a convex function for the special case of $\gamma = 0$ it is sufficient to show that $d^2L(V, \hat{s})/d\hat{s}^2 > 0$. This outcome emerges because, using the previous expression for $dL(V, \hat{s})/d\hat{s}$, it can be shown that $d^2L(V, \hat{s})/d\hat{s}^2 = M(\hat{s})/\rho$.

The last property of equation (16) to be established is that the right side of this expression is an increasing function of \hat{s} for a sufficiently large value of γ . This outcome necessarily follows if the denominator of equation (16) is a decreasing function of \hat{s} when $\gamma > 0$. This outcome necessarily follows because it was previously established that $M'(\hat{s}) = -\beta M(\hat{s})/(\pi + \hat{s})$.