Land development restrictions and preemptive action

-- On the benefits of differentiated regulation

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1 Introduction

Public goals often on land use are often in conflict with private interests of some members of society. In particular, policies that interfere with standing property rights mostly face strong opposition. One example are regulatory takings legalized by the federal Endangered Species Act (ESA)[1] The ESA, which was passed in 1973, gives federal agencies the power to limit or prohibit any activities, including land development, that possibly destruct habitat for endangered and threatened species.

An extensive literature has developed that discusses compensation or taxation schemes in order to deal with individual landowners' non-optimal incentives to develop land or make costly investments under the threat of takings. The rationale for regulation is the divergence of the private from the public value of land and the induced externalities from private land development. Starting with Blume et al. (1984), many authors have addressed the issue of compensation for takings in order to reflect the above notion of property rights. These studies thereby apply to much of current legislation that often relies on compensation of landowners.[2] Innes et al. (1998), Innes (1997, 2000), Shapiro (2003), and others show that compensation can be problematic as it might distort investment decisions. Miceli and Segerson (1994) suggest a compensation scheme which conditions payments on the optimal land use decision in an earlier period. Most of these papers thereby include uncertainty about future public use value of the land (or an uncertain level of the negative externality from developing land), but leave the landowners private value nonstochastic and abstract from problems of asymmetric information. We address both of these problems in this paper. We show that landowners with different land values should be regulated in a

[1] According to Hendrickson (2005), the ESA received the second highest number of references in the year among all the major federal environmental statutes, second only to the Clean Air Act – based on coverage in Chicago Tribune, Los Angeles Times, the New York Times, and the Washington Post from September 2002 to September 2003.

[2] For example, the Fifth Amendment to the U.S. Constitution states that "nor shall private property be taken for public use, without just compensation".

differentiated way. Even if the regulator cannot identify the landowners' types, i.e. faces asymmetric information, we show that such differentiated regulation is still feasible and can be beneficial.

Our paper is motivated and guided by ESA regulation that – differently from situations studied by the papers mentioned above – does not generally grant compensation when limiting property rights.[3] Without appropriate regulation, the risk of being deprived of development rights therefore gives private landowners incentives to remove the features of their land that are suitable for a listed species.[4] For example, landowners may alter or destroy habitat or potential habitat, kill or remove species on their land before they are listed as endangered or threatened. Similarly, land developers may rush to acquire building or construction permits before the listing of endangered species or critical habitat takes effect. By doing so, landowners avoid future regulation (listing) that limits the market potential of their land. Indeed, Lueck and Michael (2003) find that the listing of Red-cockaded woodpecker (RCW) in North Carolina caused significant habitat destruction. List et al. (2005) provide further evidence of preemptive behavior in Arizona. Such preemptive behavior contradicts the goals of ESA and imposes negative impacts on society.

To encourage private landowners to engage in endangered specie conservation, Congress amended the ESA by adding section 10(a) in 1983. Under the section 10(a), a landowner or a group of landowners can obtain an Incidental Take Permit (ITP) from Fish and Wild life Service (FWS) to incidentally "take" a listed species or a species that is not yet listed but can be listed in the future. The ITP authorizes the taking of a protected species if the taking is not for the purpose of, but will be only incidental to, carrying out of an otherwise

[3] Smith and Shogren (1998) propose a scheme to compensate agricultural landowners financially for limiting their production activities to protect Endangered Species. However, in reality, landowners generally are not compensated for the restrictions on land use imposed by ESA except under special situation where Fish and Wildlife Service(FWS) buy conservation easement for National Wildlife Refuges. While compensation is one of the mechanisms that FWS might be able to adopt to motivate private landowners to conserve endangered species in the future, we focus on a reduced taxation scheme in this study.

[4] The listing process of an endangered species usually takes about two years and even longer. The FWS currently has long backlog of more than 250 candidate species to be considered for listing. The FWS is trying to work out a plan with the District Court for the District of Columbia to review and address this long backlog in the next six years. This plan, if approved, will reduce the workload and cost from frequent court orders and allow that FWS to focus its money and time on reviewing the Candidate species (Department of Interior, 2011). Despite this effort, it will take a while before the candidate species are protected by the ESA.

lawful activity. In exchange for an ITP, landowners have to prepare a Habitat Conservation Plan (HCP) that aims at minimizing or mitigating the negative impact of permitted land development and provide adequate funds to implement the HCP. In 1994, a "no surprise" policy was introduced. The "no surprise" implies that landowners do not need to alter their HCPs for any unforeseen circumstances and exempts them from paying costs caused by events that were unforeseen ex ante.[5] That is, by bearing the costs of creating a HCP, landowners can keep their right to develop land or alleviate future development costs.[6] This essentially creates differentiated regulation levels, depending on the existence and the provisions of the HCP.

Anticipating that developing a (costly) HCP reduces their future development costs or allows them to keep development rights, landowners might be willing to acquire ITPs rather than take preemptive actions to reduce or avoid the future risk from regulation. This reduced future development cost, meanwhile, reduces landowners' incentives to preserve land in the future. Regulators, thus, face a trade-off: to allow more future controlled land development, or to induce more preemptive development. In this paper, we demonstrate how the two effects can be balanced to optimize welfare.

Our paper adds to a vibrant literature on regulation on land development. Existing studies, however, focus either on HCP's deviation from optimal regulatory stringency level or on landowners' ex post effort to conserve species. Some studies criticize that "no surprise" policy and HCP plans favor development over endangered species, may be prone to political influence by interest groups, or ignore scientific uncertainty associated with complex ecosystem (Rahn, Doremus, and Diffendorfer, 2006; Mcclure and Stiffler, 2005; Wilhere,

[5]This process also could include cost-sharing agreements between the public and the private landowners. Ferraro et al. (2007) study the impact of ESA on the recovery of endangered species using matching methods. They find that only listing with substantial government funds improve the recovery the listed species. The listing with no or little fund is detrimental to the recovery of the listed species.

[6]For example, the Coachella Valley Fring-Toed Lizard HCP includes several preserves and a fee area. In the fee area, developers could transfer habitat by paying a per-acre mitigation fee of $600 to a city or county to buy conservation easement in the preserved areas. The Yolo County HCP in CA covers 29 species, and of which 12 are listed species. The developers are required to pay $2640 per acre mitigation fee which is enough to buy one fourth acres of agricultural land and represent 1 to 2% of the profits made in developing the acre. The Snowshoe Mountain Resort HCP covers 125 acres of forest land as habitat for Northern Flying Squirrels. The mitigation measures include rerouting road, developing 39 acres of the forest land and preserving the rest 86 acres of habitat in perpetuity for the listed species.

2002). Another group of studies argue that HCP policy, as an incentive scheme, works better than strict regulation in motivating landowners to conserve listed species. Using the theoretical framework in Segerson and Miceli (1998), Langpap and Wu (2004) show that HCPs, as one of voluntary conservation agreements with assurance (VCA), can induce higher levels of conservation effort and higher net social benefits than no assurance. Langpap (2006) examines various incentive-based conservation programs on forest landowners' conservation effort using survey data. He finds that HCP is as least as effective as compensation scheme in motivating landowners to conserve endangered species. His study also indicates that a combination of compensation and assurance works better than compensation or assurance alone. None of the above studies address the interaction between HCP policy and landowners' incentive to alter or destruct habitat (preemption) *before* a species is listed as endangered or threatened.

We use a two-period model similar to Miceli and Segerson (1996) and assume irreversibility of development decisions. Different from the existing studies, we assume that the future value of developed land is subject to ex ante uncertainty. Landowners are heterogeneous in their propensity to develop land and have different regulation thresholds for preempting. We derive the condition under which regulator should compromise and to what extent to compromise on future regulation levels in order to reduce preemption. Using a mechanism design approach with two different types of players, we demonstrate that even when the regulator does not know the landowners' private incentive to preempt, i.e. the individual compromise level needed to avoid preemption, a differentiated treatment can be welfare-improving: we propose that regulator should offer a less stringent future regulation level against an ex ante payment. Applied to our motivating example of ESA, this means that a costly development of HCPs that reduce the future development costs, can actually serve as a welfare-enhancing screening devices for landowners to deter preemptive behavior.

The remainder of the paper is organized as follows. Section 2.1 gives the basic setup of the theoretical model. We study the case of first-best regulation and explore the effects of taxation in section 2.2. The second-best regulation under perfect information is discussed in section 2.3. We distinguish the case where the regulator can differentiate policies across landowners and the case where he is restricted to an one-fits-all regulation and thereby provide the basis for studying the case of asymmetric information in section 2.4. We conclude in section 3.

2 Theoretical model

2.1 Basic setup

The model is built upon a two-period framework and is similar to Miceli and Segerson (1996). We model a community with N landowners who each owns one unit of undeveloped land. A landowner can choose to develop his land in period 1, period 2 or never to develop his land.[7] The value of one unit of developed land to landowners is identical for every landowner and is denoted in period 1 by V_D^1. The value in period 2, v_D^2, is uncertain in period 1 and follows a distribution $G(v_D^2)$ (density $g(v_D^2) > 0$ on the support $[\underline{v}^2, \bar{v}^2]$) and is revealed before the start of the second period. Landowners differ with respect to the value of their land if left undeveloped, denoted by V_i^1 and V_i^2 in the two periods, respectively. V_i^1 and V_i^2 are the benefits that landowners earn from agriculture or forest production. The value of undeveloped land is known to the landowner but not necessarily to the regulator. We consider both the case of perfect information and asymmetric information in which a regulator is not perfectly informed of the specific undeveloped land values.

Land development generates negative externalities to the community. For example, land development leads to habitat or potential habitat alteration or destruction. The net present value of negative externality is E^1 per unit of land if it is developed in period 1 and E^2 if in period 2. Landowners are assumed to care only about the value of their land and not about externalities.

To address these externalities, regulators charge a tax τ^t for development in period t.[8] In

[7]Landowners do not have to put buildings on their land in period one. They can alter the features of their land or not to do so. The alteration of habitat in period one preserves the opportunity to develop land later and generates higher benefits than doing so in period two. We, hence, refer it as preemptive land development in this paper.

[8]Regulator could subsidies landowners for not developing their land and preserve habitat. This, however, is not the focus of our paper as FWS does not buy conservation easement. Furthermore, budget constraints make it highly unrealistic to pay all landowners that do not develop their land.

reality, the price comprises, for example, mitigation payments to conservation easement, the costs of leaving some portion of land undeveloped, or altering construction plan. The mitigation measures may therefore reduce the negative externality from developing land. For simplicity, we concentrate on a development tax and ignore any reduction on negative externality or possible net conservation benefits in this paper.

The timeline of the events is: (1) the regulator proposes regulation in period 1 which takes effect in period 2. Period 1 refers to the time period before a species is listed as endangered or threatened. (2) landowners make individual decisions whether they develop land in period 1. The list of an endangered species takes effect. (3) the value of land in period 2, v_D^2 is revealed, (4) landowners decide on development in period 2.

2.2 Private vs. socially optimal development decisions

Given regulation (τ^1, τ^2), we first consider the private decisions of the respective landowners starting with the decision in period 2. If the landowner does not develop the land in period 1, he can condition his period 2 development decision on the realization of land value v_D^2. Landowner i develops land only if the value of developed land v_D^2 net of the development tax exceeds the value of leaving the land undeveloped:

$$v_D^2 - \tau^2 > V_i^2 \tag{1}$$

Otherwise the land stays undeveloped. This possibility of conditioning period 2 development on v_D^2 creates an option value of land that is left undeveloped in the first period:

$$O(V_i^2, \tau^2) = \int_{V_i^2+\tau^2}^{\bar{v}^2} [v_D^2 - \tau^2] dG(v_D^2) + V_i^2 G(V_i^2 + \tau^2) \tag{2}$$

Consequently, landowner i develops the land in the first period if and only if the benefits from this development exceed the sum of its undeveloped value and the option value:

$$V_D^1 - \tau^1 > V_i^1 + O(V_i^2, \tau^2). \tag{3}$$

It is obvious, that the socially optimal land development potentially deviates from the private incentives. In period 2, it is socially optimal to develop land if

$$v_D^2 - E^2 > V_i^2 \tag{4}$$

and therefore, land i should be developed in period 1 only if

$$V_D^1 - E^1 > V_i^1 + O(V_i^2, E^2) \tag{5}$$

Comparing condition (3) with (5) and (1) with (4), we obtain the well-known condition of first-best Pigouvian taxation: $\tau^1 = E^1$ and $\tau^2 = E^2$. To achieve first-best, the regulator necessarily needs to apply taxes in both periods. In this paper, however, we focus on a situation where regulation only applies in the future (i.e. in period 2) and therefore $\tau^1 = 0$.[9] We therefore study situations where the regulator is bound to regulate via choosing the tax level τ^2.

Equation (3) implies that the private option value, specifically τ^2 and the value of land if left undeveloped in period 2, determines the decision to preemptively develop land in period 1. To see how land development depends on τ^2 and on undeveloped land value, we partially differentiate (2):

$$\frac{\partial O}{\partial V_i^2}(V_i^2, \tau^2) = G(V_i^2 + \tau^2) \geq 0 \tag{6}$$

$$\frac{\partial O}{\partial \tau^2}(V_i^2, \tau^2) = -(1 - G(V_i^2 + \tau^2)) \leq 0 \tag{7}$$

$$\frac{\partial^2 O}{\partial V_i^2 \partial \tau^2}(V_i^2, \tau^2) = g(V_i^2 + \tau^2) > 0 \tag{8}$$

From equation (1), (3), and (6)-(8), we immediately obtain the following results for the landowners' reactions to changes in the tax system:

Lemma 1 *(i) The option value $O(V_i^2, \tau^2)$ is decreasing in period two tax τ^2 but increasing in the value of undeveloped land in period two V_i^2. Landowners with a larger V_i^2*

[9] Equivalent to taxing development in the first period would be to pay landowners a subsidy of E^1 for not developing land in period 1. However, as stated above, such an option does appear feasible due to budget constraints as all landowners would need to be offered this payment.

benefit less from a reduction in τ^2.

(ii) A larger period two tax τ^2 *reduces a landowner's incentive to develop land in the second period, given that land stayed undeveloped in the first period. However, a larger* τ^2 *generates more incentive for a landowner to develop land in the first period.*

(iii) An increase in period one tax τ^1 *leaves the conditional second period decision unaffected but decreases development in the first period.*

Lemma 1 (iii) shows that missing regulation in period 1 ($\tau^1 = 0$) can drive landowners into preemption compared with the socially optimal level ($\tau^1 = E^1$). Since the option value of postponing the development decision is decreasing in τ^2 (Lemma 1 (i),(ii)), a way to reduce preemption is to compromise by charging a reduced tax in period 2, i.e. by choosing $\tau^2 < E^2$ instead of $\tau^2 = E^2$. This way of compromise, however, distorts land development decision in period 2 as can be seen from Lemma 1 (ii).

To further analyze the development decisions of specific landowners, we derive the tax level τ^2 where a landowner of type i is indifferent between developing land in the first period and not developing given that $\tau^1 = 0$. This threshold value is denoted by $\bar{\tau}_i^2$ and is implicitly defined by:

$$V_D^1 = V_i^1 + O(V_i^2, \bar{\tau}_i^2)$$

if a finite solution exists and $\bar{\tau}_i^2 = \infty$ if $V_D^1 < V_i^1 + O(V_i^2, \tau^2)$ for all finite τ^2.

The threshold value, $\bar{\tau}_i^2$, depends on the specific values of undeveloped land (V_i^1, V_i^2). Intuitively, the opportunity costs of land development increase with the value of undeveloped land. Landowners with high (V_i^1, V_i^2), hence, would prefer keeping land undeveloped to preemptively developing their land. The threshold level $\bar{\tau}_i^2$ above which landowner i would preempt would increase with the value of undeveloped land. Given $\tau^1 = 0$, the landowner i develops land in period 1 if and only if $\tau^2 > \bar{\tau}_i^2$. When τ_i^2 is chosen below the threshold value, $\bar{\tau}_i^2$, landowners of type i will leave land undeveloped in period 1.[10]

[10] Note that this threshold value can take positive or negative values. It takes negative value for the landowners who would develop land in first period even if there is no regulation. That is, in the extreme case the "tax" would have to turn into a subsidy in order to induce a landowner to preserve rather than develop land in the first period.

In order to formally discuss the effect of regulation on social welfare and thereby the optimal level of taxation τ^2, we introduce the notion of social option value. It differs from the private option value by the expected value of the externality minus the expected tax, given that the tax payments are assumed as a transfer among households:[11]

$$\begin{aligned} OS(V_i^2, \tau_2) &= \int_{V_i^2+\tau^2}^{\bar{v}^2} [v_D^2 - E^2] dG(v_D^2) + V_i^2 G(V_i^2 + \tau^2) \\ &= O(V_i^2, \tau_2) - (E^2 - \tau^2)(1 - G(V_i^2 + \tau^2)) \end{aligned} \tag{9}$$

Assuming that there are no shadow costs of social funds, and that taxes are redistributed lump sum to households, expected social welfare is then formally given by:

$$W(\tau^2) = \sum_{i:\tau^2 > \bar{\tau}_i^2} [V_D^1 - E^1] + \sum_{i:\tau^2 \leq \bar{\tau}_i^2} [V_i^1 + OS(V_i^2, \tau^2)] \tag{10}$$

Knowing that the optimal regulation involves $\tau^1 = E^1$ and $\tau^2 = E^2$, we address how the regulator's decision on τ^2 should reflect the lack of regulation in the first period ($\tau^1 = 0$) in this section. We start by exploring how social welfare changes with marginal changes in the regulation level τ^2 and discuss the optimal differentiated and undifferentiated taxation in the next section.

Studying conditions (7) and (9) immediately reveals the marginal effect of taxation on the social option value:

$$\frac{\partial OS}{\partial \tau^2}(V_i^2, \tau^2) = (E^2 - \tau^2) g(V_i^2 + \tau^2). \tag{11}$$

At a level where $\tau^2 \neq \bar{\tau}_i^2$ for all i, any small change of τ^2 does not induce any landowner to change his development decision and the marginal effect on welfare is hence given by:

$$\frac{\partial W}{\partial \tau^2}(\tau^2) = \sum_{i:\tau^2 \leq \bar{\tau}_i^2} (E^2 - \tau^2) g(V_i^2 + \tau^2). \tag{12}$$

Social welfare increases with τ^2 as long as $\tau^2 < E^2$ since second period decisions move towards the optimum for the landowners who wait to develop land.

[11] Compare with Innes (2000) who describes this value as "public use value are in private hands".

The impact of a marginal change of τ_2 is different at tax level $\tau^2 = \bar{\tau}_i^2$ (and $\bar{\tau}_i^2 < \infty$) at which landowner i is indifferent between developing land in period 1 or waiting: here, a small change in τ^2 would induces landowner i to change his development decision in the first period. The social welfare function, at $\bar{\tau}_i^2$, is no longer continuous. The change in social welfare induced by the change in τ^2 at $\tau^2 = \bar{\tau}_i^2$ is:

$$\lim_{\tau^2 \uparrow \bar{\tau}_i^2} W(\tau^2) - \lim_{\tau^2 \downarrow \bar{\tau}_i^2} W(\tau^2) = k_i[E^1 - (E^2 - \bar{\tau}_i^2)(1 - G(V_i^2 + \bar{\tau}_i^2))] \tag{13}$$

where $k_i = \#\{j : \bar{\tau}_j^2 = \bar{\tau}_i^2\}$ is the number of landowners with this specific threshold value for their first period development. Here, $\lim_{\tau^2 \uparrow \bar{\tau}_i^2} W(\tau^2)$ denotes the social welfare when τ^2 converges to $\bar{\tau}_i^2$ from below, i.e. such that the landowners of type i comply with the regulation and do not preempt. Differently, $\lim_{\tau^2 \downarrow \bar{\tau}_i^2} W(\tau^2)$ is the resulting welfare limit when when τ^2 is converges to this level from above such that landowners of type i preemptively develop land. It should be noted that the behavior of all landowners that are not of type i is identical in these two settings. Therefore, the change in social welfare is proportional to the number of players of type i. Depending on the sign of equation (13), social welfare increases or decreases as landowners with $\tau^2 = \bar{\tau}_i^2$ change their decision from not developing land in the first period to preemptively developing land.

These effects of τ^2 on development decision and social welfare are illustrated in Figures 1 and 2 with two types of landowners i and j ($V_i^2 < V_j^2$ and $\bar{\tau}_i^2 < \bar{\tau}_j^2 < E^2$). Figure 1 demonstrates private and Figure 2 social value functions for each of the two types. This optional value depend on the probability that a landowner will develop land at τ^2 and the value of land if left undeveloped. At a given tax level, landowner j have less incentive to develop land as he earns a high benefit from undeveloped land. Thus landowner i's private option value function is steeper than landowner j's according equation (6). In another word, landowner i benefits more from lowering regulatory stringency level than does landowner j. When τ^2 takes values in the ranges of $(-\infty, \bar{\tau}_i^2)$, $(\bar{\tau}_i^2, \bar{\tau}_j^2)$, or $(\bar{\tau}_j^2, E_2)$, no landowner's first period development decision changes with a marginal change in τ^2. For example, if $\tau^2 \in (\bar{\tau}_i^2, \bar{\tau}_j^2)$, type i landowner preemptively develops land and type j complies the regulation. The social welfare function is differentiable and social welfare increases with τ^2 in the range. However, at $\tau^2 = \bar{\tau}_i^2$ or $\tau^2 = \bar{\tau}_j^2$, a marginal increase in τ^2 induces landowner i or j to change their development decision in the first period. Correspondingly, the social value function is no longer differentiable at $\bar{\tau}_i^2$ and $\bar{\tau}_j^2$. Social value jumps from $V_i^1 + OS(V_i^2, \tau^2)$ or $V_j^1 + OS(V_j^2, \tau^2)$ to $\left(V_D^1 - E^1\right)$ at $\bar{\tau}_i^2$ or $\bar{\tau}_j^2$.

From (12) and (13), we obtain the following lemma:

Lemma 2 *When the regulatory instrument is missing in period 1 ($\tau^1 = 0$),*

(i) second-best welfare $W(\tau^2)$ is increasing in period two tax τ^2 for $\tau^2 < E^2$ as long as a marginal decrease in τ^2 does not change the decision of any landowner in the first period and at least one landowner does not develop land in the first period.

(ii) a marginal decrease of period two tax τ^2 increases welfare if and only if $E^1 > (E^2 - \tau^2)(1-G(V_i^2+\tau^2))$ at a finite level $\tau^2 = \bar{\tau}^2$ where a landowner i is indifferent between developing the land in period 1 or waiting.

Lemma 2 reveals the trade-off for the regulator when trying to maximize social welfare by choosing the second period regulation level τ^2 on welfare: (i) a reduction of τ^2 below E^2 distorts the second period development decision (leads to more development) and thereby generally reduces welfare (equation 12). (ii) If, however, by a marginal decrease in τ^2, at least one landowner shifts from preemption to preserving land in period 1, welfare can increase (equation 13). The decision about a further reduction of the tax rate – i.e. on further compromising – must therefore take into account the trade-off of the welfare loss from the landowners who do not develop land in the first period (effect (i)) and the welfare gain from changing the first period development decision of other landowners (effect (ii)).

In particular, note that no distortions occur if $\bar{\tau}_i^2 \geq E^2$ for all i, i.e. if the impossibility to regulate in the first period (i.e. $\tau^1 = 0$) while keeping the second period tax at $\tau^2 = E^2$ does not induce any landowners to change their first period decision. From Lemma 2 (i) it follows that the optimal tax level is still $\tau^2 = E^2$. However, the case where the lack of regulation in the first period leads (some) landowners into preemption is clearly the more interesting case and the focus of the following analysis.

We distinguish different versions of the model: we first consider the case where the regulator is perfectly informed on the types (i.e. on V_i^t and therefore on $\bar{\tau}_i^2$) and (i) can, (ii) can not use differentiated policies for different landowners. In a second step, we consider a regulator who is not informed on the types of specific landowners but bases the policy on beliefs over a distribution of types.

2.3 Perfect information

In the perfect information scenario, regulators know each landowner's value of undeveloped land and therefore landowner's private incentive to preempt. He can set specific tax levels for each individual landowners or to all landowners as a group to achieve maximum social welfare. Depending on the distribution of landowners' private incentive level $\bar{\tau}_i^2$ and available regulatory instruments, regulator may have to compromise to certain extent to prevent some landowners from preempting and to allow some landowners to preempt.

We first study the case of a perfectly informed regulator who can differentiate policies across landowners. Here, Lemma 2 immediately implies that the optimal tax level for the landowners of type i is given by $\tau_i^{2*} = E^2$ if $\bar{\tau}_i^2 \geq E^2$. If $\bar{\tau}_i^2 < E^2$ and

$$E^1 > (E^2 - \bar{\tau}_i^2)(1 - G(V_i^2 + \bar{\tau}_i^2)), \tag{14}$$

it is beneficial to compromise to bring landowner i out of preemption. The conditions also imply that if at $\bar{\tau}_i^2 < \infty$ and $E^1 < (E^2 - \bar{\tau}_i^2)(1 - G(V_i^2 + \bar{\tau}_i^2))$ hold, the landowner should be left in the preemption mode. In this case, regulator should set the tax level at $\tau_i^{2*} = E^2$. The intuition behind this result is that bringing one player out of preemption reduces the externality by E^1 but also imposes welfare losses in the second period as the landowner is more likely to develop land due to the reduced τ^2. If the potential distortions in the second period, $(E^2 - \bar{\tau}_i^2)(1 - G(V_i^2 + \bar{\tau}_i^2))$, are severe compared to those in the first period, the landowner should rather be left to preempt.

Proposition 1 *A perfectly informed regulator who can differentiate policies across landowners, should either regulate a landowner using a period two tax at level $\tau^2 = E^2$ or – if*

$\bar{\tau}_i^2 < E^2$ *and* $E^1 > (E^2 - \bar{\tau}_i^2)(1 - G(V_i^2 + \bar{\tau}_i^2))$ *– compromise with the individual landowner in a way which just makes him slightly better off from not developing in the first period.*

Proposition 1 shows that it is not necessarily optimal for a regulator to compromise in a way to prevent preemptive behavior. Compromising itself could be more costly to society than letting the landowner develop the land in the first period. However, when the social damage from preemptively developing land is sufficiently high, it is always beneficial to compromise to each individual landowner so to prevent them from preemption.

Applying this setting to the case of HCP and "no surprise" policy, the regulator would have to know the private benefits from undeveloped land relative to development for all landowners. To enforce differentiated regulations, regulator would also have to be able to choose the mitigation measures for each landowner or landowners group. In reality, however, it may be problematic for the regulator to differentiate policies across landowners. If he cannot differentiate τ^2 across landowners, it again follows from Lemma 2 that regulation can only be optimal at levels $\tau^2 \in \{E^2, \bar{\tau}_1^2, \ldots, \bar{\tau}_n^2\}$. A reduction in τ^2 leads to welfare losses from those landowners whose second period decisions are distorted by the reduction in the tax rate, i.e. the landowners who do not develop in period 1 and are less likely (or do not) development in period two. These losses would have to be traded off with welfare gains from reducing the number of preempting landowners.

This immediately shows that for the determination of the optimal regulation level, the distribution of types is decisive. In particular, the regulator does not need to know the type of an individual landowner, but rather only the fraction of each type of players.

Proposition 2 *A regulator who cannot differentiate policies across landowners, chooses* $\tau^2 \in \{E^2, \bar{\tau}_1^2, \ldots, \bar{\tau}_n^2\}$*. The optimal decision crucially depends on the distribution of types* $(\bar{\tau}_1^2, \ldots, \bar{\tau}_n^2)$*. The undifferentiated regulation maintains a lower social welfare level than differentiated policies as long as at least one landowner preemptively develops land and preemptive land development causes sufficiently large negative externality, i.e.,* $\bar{\tau}_i^2 < E^2$ *and* $E^1 > (E^2 - \bar{\tau}_i^2)(1 - G(V_i^2 + \bar{\tau}_i^2))$ *hold.*

To illustrate how the optimal regulation level depends on the distribution of types, we focus the case where landowners can only be of two types L and H ($\bar{\tau}_L^2 < \bar{\tau}_H^2$); the number of the respective types is denoted by n_L and n_H. We will later use this example to explore optimal regulation for the case of asymmetric information. For simplicity, we assume that $E^1 > (E^2 - \bar{\tau}_i^2)(1 - G(V_i^2 + \bar{\tau}_i^2))$, i.e. it is always beneficial to reduce the tax rate marginally if this induces additional landowners to refrain from preemption. Furthermore, we assume $\bar{\tau}_L^2 < E^2$ such that (at least) landowners of low type preempt at $\tau^2 = E^2$ and we define $\tau_H^2 = \min[\bar{\tau}_H^2, E^2]$.

Since the regulators' objective is to achieve maximum social welfare, we compare the welfare at $\tau^2 \in \{\bar{\tau}_L^2, \tau_H^2\}$. From conditions (9) and (10), we obtain:

$$
\begin{aligned}
& \lim_{\tau^2 \uparrow \tau_H^2} W(\tau^2) < \lim_{\tau^2 \uparrow \bar{\tau}_L^2} W(\tau^2) \\
\Leftrightarrow\quad & n_H[\underbrace{OS(V_H^2, \tau_H^2) - OS(V_H^2, \bar{\tau}_L^2)}_{>0}] < n_L[\underbrace{E^1 - (E^2 - \bar{\tau}_L^2)(1 - G(V_L^2 + \bar{\tau}_L^2))}_{\geq 0}] \\
\Leftrightarrow\quad & f_H[\underbrace{OS(V_H^2, \tau_H^2) - OS(V_H^2, \bar{\tau}_L^2)}_{>0}] < f_L[\underbrace{E^1 - (E^2 - \bar{\tau}_L^2)(1 - G(V_L^2 + \bar{\tau}_L^2))}_{\geq 0}] \qquad (15)
\end{aligned}
$$

where $f_i = n_i/(n_H + n_L)$ is the fraction of landowner types $i \in \{L, H\}$. Equation (15) shows that it is welfare-maximizing to set regulation at low type of landowners threshold level, $\tau^2 = \bar{\tau}_L^2$, if and only if the fraction of low type players ($f_L = n_L/(n_H + n_L)$) is sufficiently large. In other words, the ratio of low types must be sufficiently large such that the benefits from preventing them from preemption is larger than the welfare losses from distorted the second-period decisions of high type landowners.[12]

When the negative externality from preemptive land development is sufficiently high, it is always socially beneficial to bring all landowners out of preemption. However, in order to bring low type landowners out of preemption, the regulator further distorts the development decision of landowners of high type. In cases where these distortions are relatively high, the regulator would allow low types to preempt. The optimal regulation therefore crucially depends on the distribution of landowners' private incentive to preempt, $\bar{\tau}_i^2$.

[12]This threshold value of $f_L = n_L/(n_H + n_L)$ that determines the optimal regulation at either $\tau^2 = \bar{\tau}_L^2$ or $\tau^2 = \tau_H^2$ is also non-monotonic in V_H^2. We skip this analysis for the sake of space as it is not a crucial part of our analysis. The point is that second best regulation level depends on the distribution of landowners' incentive to preemptively develop land.

These disadvantages from undifferentiated regulation make it worthwhile to explore option of differentiated regulation. Obviously, a perfect differentiation generates a higher welfare level. However, it requires the regulator to know the landowners' private information and to have the power to assign specific regulation levels to individual landowners. Such a perfect information and enforcement power does generally not apply in reality. Rather, landowners are mostly better informed than regulators about their own value of the land.

In the following section we show that even if regulator faces a problem of asymmetric information regarding landowner types, he may improve upon the undifferentiated regulation. We consider a mechanism that allows landowners to choose between different regulation levels. In practice, the voluntary nature of HCPs combined with the "no surprise" policy and the flexibility in choosing mitigation measures may provide such instrument that allows the regulator to discriminate between landowners.

2.4 Asymmetric information

For studying the regulatory decision under asymmetric information, we again concentrate on two potential player types of L and H with values V_i^t in periods $t = 1, 2$, and induced threshold value $\bar{\tau}_i^2$. The regulator is not informed about the type of any individual landowner, but knows the distribution of types, i.e. the fraction of landowner types $i \in \{L, H\}$ which is denoted by f_i. Define $d^1(v_i, \tau^2)$ as a dummy variable of development decision with $d^1(v_i, \tau^2) = 1$ if landowner i develops his land in first period. Expected welfare (per landowner) when choosing an undifferentiated level τ^2 is given by

$$\sum_{i \in \{L,H\}} f_i \left[d^1(i, \tau^2)(V_D^1 - E_1) + (1 - d^1(i, \tau^2))(V_i^1 + OS(V_i^2, \tau_2)) \right]$$

In this section, we assume that preemption causes a sufficiently high negative externality to make compromise worthwhile, i.e., $E^1 > (E^2 - \bar{\tau}_i^2)(1 - G(V_i^2 + \bar{\tau}_i^2))$ holds.

We explore conditions under which differentiated regulation improves welfare relative to an undifferentiated regulation level. Given our discussion in the previous section, maximizing expected welfare based on undifferentiated regulation will either imply $\tau^2 = \bar{\tau}_L^2$ or $\tau^2 = \tau_H^2 = \min[\bar{\tau}_H^2, E^2]$, with the decision governed by condition (15).

This solution corresponds to the situation where regulator requires landowner to adopt the mitigation measures with the same cost or even the same mitigation measure, e.g., to leave a proportion of land undeveloped. We now demonstrate how the regulator can improve upon the welfare generated from such an undifferentiated regulation level by offering different regulation options to *all* landowners such that they can self-select into one of the options. Under ESA, landowners may choose to bear the costs of developing high quality HCPs and to apply for an ITP or rather they may decide to preempt.

We assume that the regulator offers regulation menus (p_i, τ_i) $(i \in \{L, H\})$. A menu thereby consists of a costs p_i that the landowner has to pay for a second period regulation $\tau^2 = \tau_i$. p_i is the cost that the landowner has to bear, e.g. for developing a HCP. The second period development chances depend on this price.

Obviously, these menus must satisfy the individual incentive compatibility constraint (IC).[13] That is, the expected profit for type i landowner must be larger under (p_i, τ_i) than under the alternative regulation schedule:

$$\text{(IC)} \;\; \max[V_D^1, V_i^1 + O(V_i^2, \tau_i)] - p_i \geq \max[V_D^1, V_i^1 + O(V_i^2, \tau_j)] - p_j \qquad (16)$$

for $i \in \{L, H\}$ and $j \neq i$. The following lemma characterizes such incentive compatible mechanisms:

Lemma 3 *Any non-trivial incentive compatible mechanisms* $(p_i, \tau_i)_i$ *must satisfy either (i)* $\tau_i < \bar{\tau}_i^2$ *and,* $\tau_L < \tau_H$*,* $p_L > p_H$*, and*

$$\begin{aligned} & V_L^1 + O(V_L^2, \tau_L) - \max[V_D^1, V_L^1 + O(V_L^2, \tau_H)] \\ \geq \;\; & p_L - p_H \geq O(V_H^2, \tau_L) - O(V_H^2, \tau_H) \geq 0 \end{aligned} \qquad (17)$$

or

[13] Our model contains implicitly an individually rationality constraint which implies that landowners can achieve non-negative expected profits as compared to that if they preempt. This is guaranteed by normalizing one $p_i = 0$ which is feasible since the IC only involves the difference $p_i - p_j$ $(i \neq j)$.

(ii) $\tau_L \geq \bar{\tau}_L^2$ *and,* $\tau_L > \tau_H$, $p_L < p_H$, *and*

$$\begin{aligned} & \max[V_D^1, V_H^1 + O(V_H^2, \tau_H)] - \max[V_D^1, V_H^1 + O(V_H^2, \tau_L)] \\ \geq \;& p_H - p_L \geq \max[V_D^1, V_L^1 + O(V_L^2, \tau_H)] - V_D^1 \end{aligned}$$

Proof: See Appendix.

Lemma 3 characterizes the set of incentive compatible mechanisms from which the regulator can choose.[14] With the objective of maximizing welfare, we can immediately rule out the mechanisms which are characterized in Lemma 3 (ii) as they would be dominated by a regulation at $\tau^2 = \max[\bar{\tau}_H^2, E^2]$ (see Lemma 2). It remains to study mechanisms given by Lemma 3 (i) and condition (17). Here, it is obvious that any mechanism with $\tau_H \leq \bar{\tau}_L^2$ is dominated in welfare terms by a uniform regulation of $\tau^2 = \bar{\tau}_L^2$ (again Lemma 2).

We therefore have to compare the trivial mechanisms $\tau_H = \tau_L = \bar{\tau}_i^2$ for $i \in \{L, H\}$ with those given in Lemma 3 (i): $\tau_L < \bar{\tau}_L^2$, and $\bar{\tau}_L^2 < \tau_H < \bar{\tau}_H^2$. We first establish existence:

Lemma 4 *For any given* $\tau_L < \bar{\tau}_L^2$*, there exists incentive compatible mechanisms* $(\tau_i, p_i)_i$*. They are characterized by:*

$$V_L^1 + O(V_L^2, \tau_L) - V_D^1 \geq p_L - p_H \geq O(V_H^2, \tau_L) - O(V_H^2, \tau_H) \tag{18}$$

with $\bar{\tau}_L^2 < \tau_H \leq \hat{\tau}_H^2(\tau_L)$ *where* $\hat{\tau}_H^2 = \hat{\tau}_H^2(\tau_L)$ *is implicitly defined by*

$$V_L^1 + O(V_L^2, \tau_L) - V_D^1 = O(V_H^2, \tau_L) - O(V_H^2, \hat{\tau}_H^2)$$

Proof: See Appendix.

The basic idea of our optimal mechanism is to demand a high price/payment, p_L, for a low regulation τ_L in period 2. The mechanism makes it unprofitable for the high type of landowner to mimic low type of landowner and it prevents low type of landowner from preemption. Figure 3 demonstrates the incentive compatible mechanisms proposed by Lemma

[14] We allow for positive and negative values of τ_i as we explained early in the paper. That is, in the extreme case the "tax" would turn into a subsidy.

4. As a high tax level harms landowner's private benefit, high type of landowner always has incentive to mimic low type and low type of landowner would always want to reveal his true type. The figure depicts the private utility gains relative to the welfare associated with a tax level that leads to preemption ($\tau^2 > \bar{\tau}_i^2$) as a function of τ^2. Landowners' private utility for a specific value of τ_L are given by AB for a low type landowner and by AC for the high type. Clearly both types are better off with τ_L than with $\bar{\tau}_H^2$.

The regulator's problem is to prevent high type landowners from claiming to be low type. The combination of high and low tax rates therefore has to be chosen such that the willingness to pay for a lower tax rate is larger for low than for high type of landowners. In particular, when the regulator asks a price $p_L = AB$ for the tax level τ_L, low-type landowner's net benefit from claiming to be the low type is zero. However, high-type landowner would gain a net benefit of BC by pretending to be the low type and paying p_L if the high tax rate is $\bar{\tau}_H^2$. In order to provide incentives for high-type landowner to reveal his true type, the regulator has to set tax τ_H at such level that net benefit for high-type landowner from revealing his true type is no smaller than that from claiming himself to be the low type. This is satisfied for any tax level that falls in the range of $(\bar{\tau}_L^2, \hat{\tau}_H^2(\tau_L)]$. The tax level $\hat{\tau}_H^2(\tau_L)$ with a price $p_H = 0$ therefore makes the high type indifferent between revealing his true type or pretending to be a low type.

With the combination of payment and regulation, high type landowners earn a net benefit EF that equals to BC from telling his true type. For any tax level that is smaller than $\hat{\tau}_H^2(\tau_L)$ but larger than $\bar{\tau}_L^2$, a positive price exists that provides high type of landowner a net benefit that is no smaller than BC or EF. With this tax level and benefit gain, high type landowner would be willing to reveal his type. Rather than letting low type to earn a zero benefit, the regulator can set the price of $p_L < AB$ such that low type of landowner gains a strictly positive net benefit from revealing his true type, which is part of the mechanism proposed by Lemma 4. In case that the landowner is type H, welfare is increasing in τ^2 for $\tau^2 < \bar{\tau}_H^2$. For a given $\tau_L < \bar{\tau}_L^2$, Lemma 4 implies that the welfare optimum among mechanism with (τ_L, τ_H) is given by $(\tau_L, \hat{\tau}_H^2(\tau_L))$ with appropriate prices satisfying $p_L - p_H = V_L^1 + O(V_L^2, \tau_L) - V_D^1$.

The mechanism is a way to differentiate regulation for individual landowners. We now explore conditions under which such a mechanism that reduces incentives to preempt and reveals landowners private information, is socially beneficial. For this, we explore when a marginal change from undifferentiated regulation, i.e. a trivial mechanism, of $\tau^2 = \bar{\tau}_i^2$ for $i = L$ or $i = H$, increases welfare.

Expected welfare (per landowner) under a differentiated regulation (τ_L, τ_H) with $\tau_H = \hat{\tau}_H^2(\tau_L)$ is given as follows:

$$EW(\tau_L) = \sum_{i \in \{L,H\}} f_i \left[V_i^1 + O(V_i^2, \tau_2) - (E^2 - \tau_i)(1 - G(V_i^2 + \tau_i)) \right] \tag{19}$$

In order to compare the welfare with regulating at $\tau^2 = \bar{\tau}_L^2$, it proves helpful to consider the derivative of expected welfare with respect to τ_L. Here we obtain with condition (7):

$$EW'(\tau_L) = \sum_{i \in \{L,H\}} f_i (E^2 - \tau_i) g(V_i^2 + \tau_i)) \frac{\partial \tau_i}{\partial \tau_L} \tag{20}$$

where with the definition of $\tau_H = \hat{\tau}_H^2(\tau_L)$ in Lemma 4 we have

$$\frac{\partial \tau_H}{\partial \tau_L} = \frac{G(V_L^2 + \tau_L) - G(V_H^2 + \tau_L)}{1 - G(V_H^2 + \tau_H)}$$

With these preliminaries, we can show the following result:

Proposition 3 *By offering a mechanism which gives landowners the chance to receive a lower tax rate when paying a fee ex ante or can be anticipated ex ante, the regulator can increase expected welfare if* $f_L \in (\widetilde{f_L}, \widehat{f_L})$, *where* $\widetilde{f_L} = \frac{1}{\alpha+1}$, $\widehat{f_L} = \frac{1}{\frac{\beta}{\gamma-1}+1}$. $\alpha = \frac{E^1 - (E^2 - \bar{\tau}_L^2)(1 - G(V_L^2 + \bar{\tau}_L^2)}{OS(V_H^2, \tau_H^2) - OS(V_H^2, \bar{\tau}_L^2)}$, $\beta = \frac{\frac{\partial OS}{\partial \tau^2}(V_L^2, \bar{\tau}_L^2)}{\frac{\partial OS}{\partial \tau^2}(V_H^2, \bar{\tau}_L^2)}$ *and* $\gamma = \frac{\frac{\partial O}{\partial \tau^2}(V_L^2, \bar{\tau}_L^2)}{\frac{\partial O}{\partial \tau^2}(V_H^2, \bar{\tau}_L^2)}$. α *is the ratio of marginal welfare between landowners of low type and of high type around* $\bar{\tau}_L^2$, β *is the ratio of marginal social option value between landowners of low type and high type at* $\bar{\tau}_L^2$, *and* γ *is the ratio of marginal private option value between landowners of low type and high type.*

Proof: See Appendix.

The proof of Proposition 3 demonstrates that when $\widehat{f_L}$ is sufficiently large or $\widetilde{f_L}$ is sufficiently small, mechanisms that offer differentiated treatments based on different payments increase welfare compared to a undifferentiated tax treatment at $\tau^2 = \bar{\tau}_L^2$ or $\tau^2 = \bar{\tau}_H^2$. A sufficiently high $\widehat{f_L}$ requires that the ratio of marginal social option value between landowners of low type and landowners of high type, β, is sufficiently small, or the ratio of marginal private value, γ, around $\bar{\tau}_L^2$ is sufficiently large. A small β requires that marginal social option value is sufficiently large for high type landowners but small for low type landowners. Intuitively, this implies that the reduction in social option value for high type from lowering regulation level at $\bar{\tau}_L^2$ is sufficiently large relative to that for low type. In another word, the reduction in τ^2 would cause large welfare loss by distorting the development decision of high type landowners compared to the welfare loss from distorting low type landowners' decision. It, therefore, is socially beneficial to prevent high type from getting the regulation, $\tau_L < \bar{\tau}_L^2$, designed for low type of landowners. A sufficiently large ratio of marginal private value, γ, around $\bar{\tau}_L^2$ requires that the marginal private option value for low type is sufficiently large compared to that for high type. Intuitively, the reduction in period two regulation τ^2 at $\bar{\tau}_L^2$ benefits low type of landowners more than to high type of landowners. It, therefore, is not profitable for high type of landowners to mimic low type of landowners. In terms of private value of land if left undeveloped, or landowners' type, a sufficiently small β and/or a sufficiently large γ can be achieved if the disparity in V_i^2s between high and low type is sufficiently large.

A sufficiently small $\widetilde{f_L}$ requires that the marginal welfare gain from reducing τ_L is sufficiently large compared to the marginal welfare loss, which can be the case if the negative externality E^1 is sufficiently large. The welfare gain is the avoided negative externality from preventing low type of landowners from preemption, or the reduction in first period distortion. The welfare loss is the reduced expected social welfare from encouraging high type of landowners to develop land in period two, or the increment in second period distortion.

Figure 4 demonstrates a scenario where our mechanism can improve welfare. We fix $E^1 = E^2 = 50$, $V_D^1 = 55$ and let second period land values v^2 be uniformly distributed in $[0, 100]$. Furthermore, we choose $V_L = 5$ and allow V_H to take values $V_H \in [V_L, 100]$. The threshold value of V_H above which regulation at $\bar{\tau}_H^2$ is optimal depends on the distribution of types, i.e. on the probability of facing a low type, $f_L = 1 - f_H$ and is non-monotonic in V_H. The threshold value $\hat{f}$ defines the maximal f_L for which the mechanism approach increases expected welfare compared to regulation at $\bar{\tau}_L^2$. $\hat{f}$ is increasing in V_H. If V_H is sufficiently large such that $\tilde{f} < \hat{f}$, there is a range of intermediate probabilities f_L in which our proposed mechanism improves welfare compared with both a regulation at $\bar{\tau}_H^2$ and $\bar{\tau}_L^2$. The range for which our mechanism improves welfare is even larger if the externality E^1 is larger that E^2, that is, if preemption leads to significantly larger social costs. This is illustrated in Figure 5 where we choose $E^1 = 2E^2 = 100$. Then, our mechanism dominates undifferentiated regulation for any $V_H > 20$.

Proposition 3 therefore shows that in the case of asymmetric information, the regulator should not necessarily treat landowners in an undifferentiated way. Instead, he can offer landowners reduced development costs on prices that are paid ex ante or ex post. By this, the landowners voluntarily sort into different tax treatments. Those who are more likely to preempt, pay money in order to receive a reduced tax for development in period 2. Our results indicate that the HCP policy, which offers reduced and differentiated regulation to different landowners, can improve social welfare with the presence of preemptive land development.

Note that we assumed that the payments are welfare neutral, i.e. are not associated with additional social costs. We can therefore reinterpret our result as a version of socially beneficial lobbying. Instead of announcing an undifferentiated regulation for the second period which might lead some landowners into preemption, the regulator should be open to compromise with those landowners who take on effort and expenses to credibly demonstrate that a strict regulation would lead them into preemption.

3 Conclusions

Motivated by the example of the Endangered Species Act that may create incentives for preemptive habitat destruction, we studied the potential benefits from compromising, i.e. from reducing the regulatory stringency. We derived a condition under which regulator should compromise in order to reduce preemption and improve social welfare. This condition requires that regulator knows perfectly the landowners' propensity to preemptively develop land. We proposed a mechanism that enables the regulator to use landowners' private information by providing differentiated regulation to different types of landowners. This mechanism allows landowners to obtain less stringent future regulation levels against a payment. It can potentially improve social welfare over undifferentiated regulation.

Applied to our motivating example of HCP regulation, landowners who are willing to take efforts to develop an HCP that meets the basic criteria of HCP should be awarded with a reduced cost, i.e., mitigation measures that landowners can afford and the exemption from future unforeseen circumstances. To prevent high type of landowners from mimicking to be the low type, FWS should set criteria for satisfactory HCPs to be sufficiently strict such that it is not profitable for high type of landowners to acquire an ITP. The criteria, however, should be soft enough such that low type of landowner can afford the price and do not preemptively develop land. In a more complex scenario, landowners who spent extra effort to interact with scientists and environmentalist groups and collect better/detailed information on the species on their land should be awarded with more assurance or even be allowed to choose the mitigation measures that cost less on landowners.

Our mechanism provides a new rationale for the designation of HCP. Instead of prohibiting any land development after regulation takes effect, the ESA should make it less costly for the landowners who otherwise would preemptively develop land to exert effort (time, money) to develop a HCP for a lower future land development cost. Furthermore, regulator should provide certainty to landowners by further clarifying the rule for HCP such that landowners can foreseen the they can afford a good HCP. The HCP should, of course, provide flexibility to landowners in choosing mitigation measure that fits both the need of listed species and private landowners' land use plan. This type of compromise through differentiated treatment of regulation can increase social welfare above the level attainable by undifferentiated regulation.

Our mechanism abstracts from many real-world features: we simplified the problem by assuming that there are only two time periods and regulatory status jumps from no regulation at all in the first period to regulating at a specific level in the second period. In a more continuous time framework, the regulator could potentially take advantage of the timing of private land development for each individual landowners: low type of landowners develop land earlier than the high types. The regulator can set a regulatory stringency level at a time point to the threshold level for the type for whom it is optimal to develop land. By doing so, the regulator could potentially avoid preemptive development of high types of landowners due to an unnecessarily high regulatory stringency level at that time point. We therefore foresee that gradually increasing regulatory stringency level that is compatible to landowners' threshold levels over time would be effective in preventing preemption.

The basic findings of this paper are thereby not restricted to the case of Endangered Species Act. Any anticipated change in regulation can induce individuals to rush into certain actions to reduce expected future costs. The mechanism that we developed in this paper could therefore be applied to other situations in which preemptive behavior generates a negative externality to the society and is irreversible.

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Proof of Lemma 3:
(a) Assume that $\tau_H \geq \bar{\tau}_H^2$. Then both types would preempt when choosing regulation (p_H, τ_H). Therefore, (IC) would imply

$$\max[V_D^1, V_L^1 + O(V_L^2, \tau_L)] - p_L \geq V_D^1 - p_H \geq \max[V_D^1, V_H^1 + O(V_H^2, \tau_L)] - p_L$$

which contradicts Lemma 1 as $O(v^2, \tau_L)$ is increasing in v^2 and $V_H^t \geq V_L^t$ for $t = 1, 2$.

(b) Assume that $\tau_L \geq \bar{\tau}_L^2$. If $\tau_H > \tau_L$, low type would preempt under both regulation levels such that incentive compatibility requires $p_L < p_H$. This, however, would violate the (IC) for the high type since the lower tax ($\tau_L < \tau_H$) could be achieved with a lower payment ($p_L < p_H$). If, however, $\tau_L > \tau_H$, incentive compatibility for low types would require

$$V_D^1 - p_L \geq \max[V_D^1, V_L^1 + O(V_L^2, \tau_H)] - p_H$$

and for high types we would have

$$\max[V_D^1, V_H^1 + O(V_H^2, \tau_H)] - p_H \geq \max[V_D^1, V_H^1 + O(V_H^2, \tau_L)] - p_L$$

This immediately leads to the claimed relationship (ii).

(c) In the remaining case of $\tau_i \leq \bar{\tau}_i^2$ for $i \in \{L, H\}$, the (IC) immediately gives condition (17). With Lemma 1, the option value is increasing in v^2 but decreasing in τ^2 with a positive cross derivative. We therefore obtain $\tau_L < \tau_H$ and $p_L > p_H$.□

Proof of Lemma 4:
We choose p_i such that $p_L - p_H = V_L^1 + O(V_L^2, \tau_L) - V_D^1$. Note that this difference is larger than zero for all $\tau_L < \bar{\tau}_L^2$. Now, with Lemma 1, $V_L^1 + O(V_L^2, \tau^2) - V_D^1 - [O(V_H^2, \tau^2) - O(V_H^2, \bar{\tau}_L^2)]$ is decreasing in τ^2 for $\tau^2 < \bar{\tau}_L^2$ and takes a value of zero at $\tau^2 = \bar{\tau}_L^2$. Therefore, $p_L - p_H = V_L^1 + O(V_L^2, \tau_L) - V_D^1 > O(V_H^2, \tau_L) - O(V_H^2, \bar{\tau}_L^2)$. As the option value is decreasing in τ^2, any such mechanism with $\bar{\tau}_L^2 < \tau_H \leq \hat{\tau}_H^2(\tau_L)$ is incentive-compatible. □

Proof of Proposition 3:
In order to prove this result, it is sufficient to come up with examples where welfare can be improved. Consider a situation where a uniform regulation at $\tau^2 = \bar{\tau}_L^2$ leads to larger expected welfare than $\tau^2 = \bar{\tau}_H^2$ (see condition (15)). Note that, independent of the value distribution, this would be the case if E^1 is sufficiently large. The condition (15) implies that the regulator chooses to regulate at $\tau^2 = \bar{\tau}_L^2$ if the regulator's prior belief that landowner is low type is sufficient high:

$$f_L > \frac{OS(V_H^2, \tau_H^2) - OS(V_H^2, \bar{\tau}_L^2)}{[E^1 - (E^2 - \bar{\tau}_L^2)(1 - G(V_L^2 + \bar{\tau}_L^2)] + [OS(V_H^2, \tau_H^2) - OS(V_H^2, \bar{\tau}_L^2)]}$$

We define the critical f_L above which $\tau^2 = \bar{\tau}_L^2$ dominates $\tau^2 = \bar{\tau}_H^2$ as $\widetilde{f_L}$.

$$\widetilde{f_L} = \frac{1}{\alpha + 1}$$

where $\alpha = \frac{E^1 - (E^2 - \bar{\tau}_L^2)(1 - G(V_L^2 + \bar{\tau}_L^2)}{OS(V_H^2, \tau_H^2) - OS(V_H^2, \bar{\tau}_L^2)}$.

A sufficient condition under which a deviation from $\tau^2 = \bar{\tau}_L^2$ via our mechanisms is beneficial, is given by $EW'(\bar{\tau}_L^2) < 0$ as defined in (20):

$$\begin{aligned} EW'(\bar{\tau}_L^2)\frac{1 - G(V_H^2 + \bar{\tau}_L^2)}{E^2 - \bar{\tau}_L^2} &= f_L g(V_L^2 + \bar{\tau}_L^2)(1 - G(V_H^2 + \bar{\tau}_L^2)) \\ &\quad - f_H g(V_H^2 + \bar{\tau}_L^2)(G(V_H^2 + \bar{\tau}_L^2) - G(V_L^2 + \bar{\tau}_L^2)) \end{aligned}$$

Our mechanism therefore improves social welfare if

$$\begin{aligned} & EW'(\bar{\tau}_L^2) < 0 \\ \Leftrightarrow\ & f_L g(V_L^2 + \bar{\tau}_L^2)(1 - G(V_H^2 + \bar{\tau}_L^2)) < f_H g(V_H^2 + \bar{\tau}_L^2)(G(V_H^2 + \bar{\tau}_L^2) - G(V_L^2 + \bar{\tau}_L^2)) \\ \Leftrightarrow\ & f_L < \frac{g(V_H^2 + \bar{\tau}_L^2)(G(V_H^2 + \bar{\tau}_L^2) - G(V_L^2 + \bar{\tau}_L^2))}{g(V_L^2 + \bar{\tau}_L^2)(1 - G(V_H^2 + \bar{\tau}_L^2)) + g(V_H^2 + \bar{\tau}_L^2)(G(V_H^2 + \bar{\tau}_L^2) - G(V_L^2 + \bar{\tau}_L^2))} \\ \Leftrightarrow\ & \frac{1}{\frac{g(V_L^2 + \bar{\tau}_L^2)}{g(V_H^2 + \bar{\tau}_L^2)}\frac{(1 - G(V_H^2 + \bar{\tau}_L^2))}{(G(V_H^2 + \bar{\tau}_L^2) - G(V_L^2 + \bar{\tau}_L^2))} + 1} \end{aligned}$$

This shows that as long as the probability of the landowner being of low type (f_L) is sufficiently small, one can improve welfare upon a undifferentiated tax regulation at $\tau^2 = \bar{\tau}_L^2$.

We define the critical value f_L below which the incentive compatible mechanisms dominate regulating at $\tau^2 = \bar{\tau}_L^2$ as $\widehat{f_L}$,

$$\widehat{f_L} = \frac{1}{\frac{\beta}{\gamma - 1} + 1}$$

where $\beta = \frac{\frac{\partial OS}{\partial \tau^2}(V_L^2, \bar{\tau}_L^2)}{\frac{\partial OS}{\partial \tau^2}(V_H^2, \bar{\tau}_L^2)}$ and $\gamma = \frac{\frac{\partial O}{\partial \tau^2}(V_L^2, \bar{\tau}_L^2)}{\frac{\partial O}{\partial \tau^2}(V_H^2, \bar{\tau}_L^2)}$. Note that $\frac{\partial OS}{\partial \tau^2}(V_i^2, \tau^2) = (E^2 - \tau^2)g(V_i^2 + \tau^2)$ and $\frac{\partial O}{\partial \tau^2}(V_i^2, \tau^2) = -(1 - G(V_i^2 + \tau^2))$.

Combining $\widehat{f_L}$ and $\widetilde{f_L}$, it is clear that our incentive compatible mechanisms improve social welfare if $\widetilde{f_L} < f_L < \widehat{f_L}$.

□

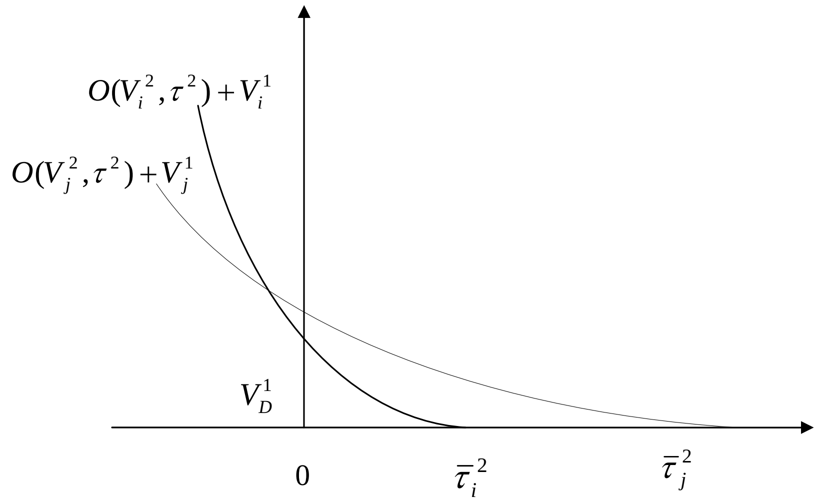

Figure 1: *Illustration of private option values as a function of* τ^2*.*

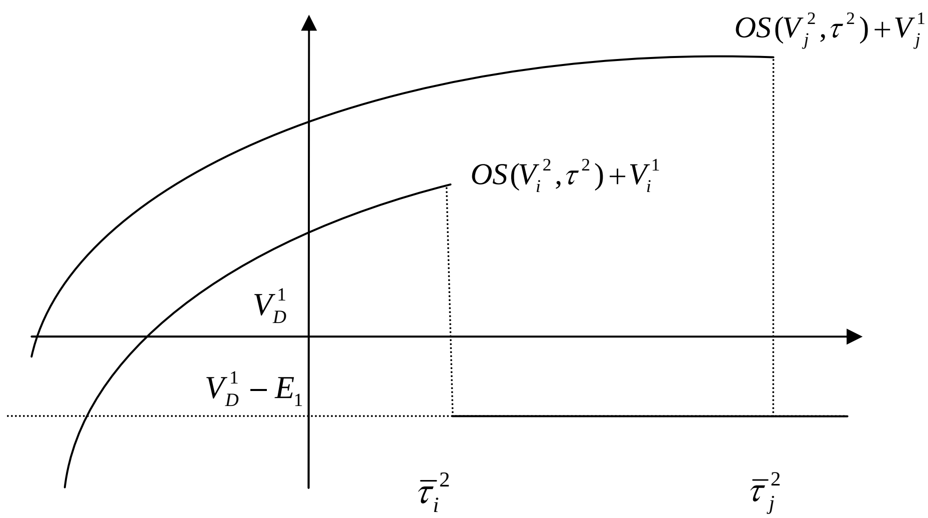

Figure 2: *Illustration of social option values as a function of* τ^2*.*

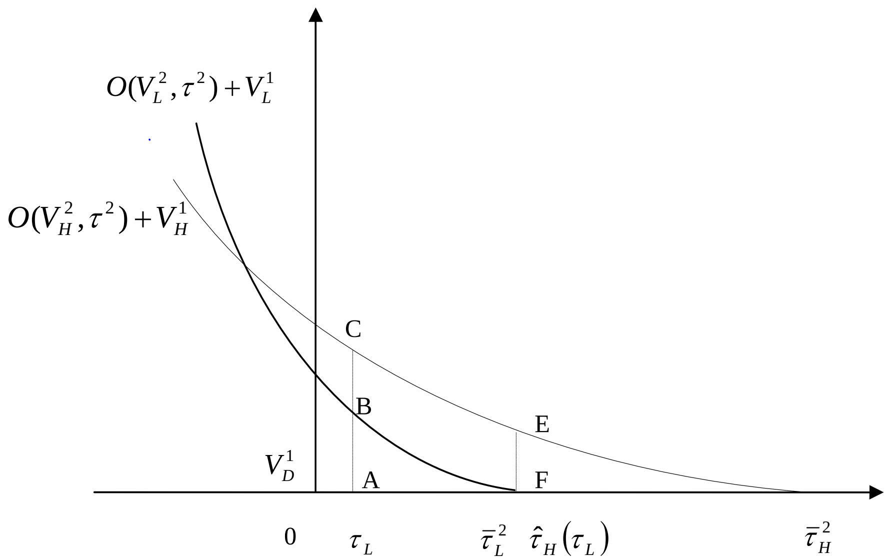

Figure 3: *Illustration of incentive compatible mechanism.*

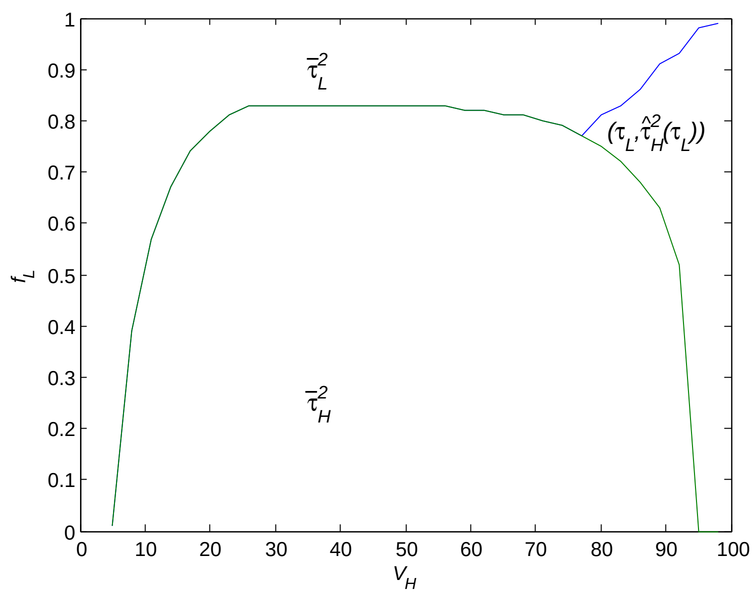

Figure 4: *Optimal regulation (uniform at* $\bar{\tau}_L^2$, $\bar{\tau}_H^2$ *or mechanism* $(\tau_L, \hat{\tau}_H^2(\tau_L))$ *as a function of* V_H *and* $f_L = 1 - f_H$ $(V_L = 5,\ E_1 = E_2 = 50)$*.*

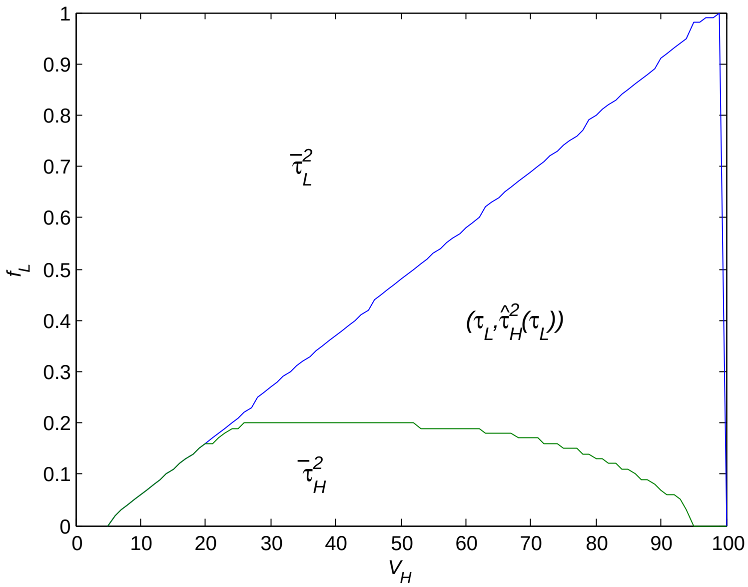

Figure 5: *Optimal regulation (uniform at* $\bar{\tau}_L^2$, $\bar{\tau}_H^2$ *or mechanism* $(\tau_L, \hat{\tau}_H^2(\tau_L))$ *as a function of* V_H *and* $f_L = 1 - f_H$ *(*$V_L = 5$, $E_1 = 2E_2 = 100$*).*