Economic science viewpoints

Biodiversity conservation on private lands: information problems and regulatory choices

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1 Introduction

The single greatest threat to biodiversity in the U.S. and around the globe is the loss of natural habitat to development and agriculture. Changing patterns of land use have reduced the carrying capacity of the environment in terms of the numbers of species that it can sustain. As Oldfield (1984, 1991) puts it,"Developments are proposed, the development alternatives are evaluated, the social costs of habitat losses or extinction are ignored or casually considered, and the decision to develop is given the go-ahead, actually on the basis of incomplete economic information. It is by this gradual process of land conversion that entire ecosystems and wildlife species have disappeared." Agriculture is following a trend in that more productive systems tend to have fewer species (Pimm and Gittleman, 1992). Both agriculture practice and urban sprawl are converting species' natural habitats with an alarming speed - for example a net loss of approximate 65 million hectares of forests is estimated in developing countries between 1990 and 1995, representing 3.7% of the total remaining forests in these countries (UNEP, 2000, p. 38).

Current economic systems have often led to over-exploitation of biological resources for reasons common to other public goods' over-exploitation: weak ownership, missing markets, severe free ridings and large externalities etc. (see Clark, 1973a; Dasgupta, 1982; Fisher, 1981b; Norgaard, 1984 and Pearce, 1976 for more detailed discussions). Frequently, externalities exist in cases where it is not possible to identify the particular individuals who are negatively affected by the actions of others but where public goods which accrue to society at large are affected. This holds particularly in the case of biodiversity. If a given ecosystem disappears, the negative impact on each individual might be too small to warrant individual action, but nevertheless the total impact, due to the large number of individuals affected, might be considerable and require policy intervention. Governments therefore are called upon to implement incentive measures to achieve a sustainable use of land in those cases in which private utility-maximization causes imperfect outcomes, as individuals do not take into account the impacts of their activities on the well-being of other individuals or the public at large.

Most instruments developed by environmental economists and regulators to correct for externality problems have been studied in the context of environmental pollution. Examples include the imposition of artificial shadow prices in the form of environmental taxes or charges which reflect the damage to public goods, the better definition of property rights with the enabling markets, and the payment for / subsidization of behaviors more sympathetic to public interests etc.

The situation concerning the conservation or the sustainable use of biodiversity is comparable but not identical. This is mainly due to greater information insufficiencies that prevent the regulatory measures being effective for biodiversity conservation. Compared to other environmental degradation, biodiversity losses is more difficult to measure in extent and value - oftentimes the value of biodiversity resides in its pure existence, or possibly in its – as yet still unknown – future uses. The presumption for effective government invention in correcting/internalizing externalities relies in that government has superior information and vastly reduced transaction costs in ensuring that public health and amenity considerations are adequately reflected in the actions of individual producers. This is oftentimes not true in case of biodiversity conservation. Individual landowners oftentimes either have better information on the species habituated in their lands (and the costs associated to preserve them) or are in a better position to discover this information because of legal boundaries that prevent government investigation of the lands.

This paper examines various information insufficiencies in biodiversity conservation and their impact of regulatory choices. The structure of the paper is the following: In the next section, we shortly review various types of information insufficiencies in biodiversity conservation efforts. In section 3, we examine major regulatory tools for biodiversity and their bearings on information constraints. Section 4 concludes.

2 Information insufficiencies in biodiversity conservation

Information insufficiency presents one of the greatest challenges to biodiversity conservation (OECD, 1999). Information insufficiency arises from many aspects for the regulator to take effective conservation measures. The efficiency of many regulatory tools (e.g. standards and limits, charges and taxes, contracts etc.) that are used to internalize the environmental externalities critically depends on the amount of information regulator has on the marginal benefits and costs of abatement / conservation. Besides serving as a prerequisite for effective regulation, information per se can well be a goal of regulation in dynamic settings. In this section we review various informational constraints faced by regulators and identify four types of information failures in making conservation decisions: biological uncertainty, natural variability, hidden individual information, and monitoring problem[1]. All these four types of informational failures result in insufficient information on the marginal benefit and cost curves of conservation that are essential for regulatory tools to effectively internalize the externalities.

First type of information insufficiency comes from biological uncertainty. Even though recent years ecological research has greatly furthered our knowledge of the complex aspects of biodiversity, such as ecosystem changes, habitat patchiness, and the role of natural and human-induced disturbances on biota (e.g. Reid and Miller, 1989), we still only have very limited knowledge for biology process (e.g. threshold values), which results in the uncertain forms of relationships in the system. Many fundamental questions about several aspects regarding the specific levels and their linkage at which biodiversity may be considered remain unanswered. We do not know, for example, how many species the world holds, even to an order of magnitude, much less the range and habitat each species inhabits. The impacts of habitat loss / fragmentation on genetic diversity and how biodiversity influences the ability of ecosystems to withstand stress are poorly known; so are the impacts of landscape fragmentation on the functioning of ecosystems, population viability and the functions and activities of many individual species (Myers, 1995; Ehrlich and Daily, 1993; Myers and Simon, 1993; Perrings et al. 1992; Solbrig, 1991). The impact of changing pattern of land use upon biodiversity is highly complicated and research has just begun. We poorly understand in quantity, if not in quality, how the encroachment of agricultural production system (especially in an uncoordinated manner) cause habitat loss and fragmentation, how air and /or water pollution, excessive sedimentation of water course and excessive hunting and logging lead to species loss even when natural habitat remain intact; how adoption of new farming practices contributes to decline of biodiversity of crop species on farm; and certain agrochemicals leads to decline in biodiversity within species (Srivastava, et al. 1996).

Biological uncertainty inherent probably is the greatest obstacle for proper evaluation of biodiversity enhancing activities, but there are possibilities for improving information over time. Learning aspect of this process provides interesting research prospects. According to Tomas et. al., learning may be passive or active. Passive learning has not been addressed in any substantive fashion in the biodiversity literature, although there exist more general economics analyses upon which such analyses could be based. For example, the exact locations of the thresholds are unknown until the biodiversity loss process passes the threshold, and information jumps. Some work on dynamic resource problems with uncertain technology might offer some insights to this problem (e.g. Dasgupta and Stiglitz, 1981), but little research has been conducted in the biodiversity context. Active learning refers tosocial experiments whose main purpose is to generate information. These would involve deliberately manipulating the system in what may appear to be a sub-optimal way in order to improve our understanding of the relevant relationships. While such experiments may be politically unpopular, they might improve efficiency in the long run.

Second type of information insufficiency is natural variability. Natural variability in biodiversity conservation context is associated mainly with stochastic shocks from uncontrollable factors such as climate change and invasion of some alien species to local ecosystem. The distinction between natural variability and biological uncertainty arises from the ability to learn over time regarding the latter, while natural variability is mainly uncontrollable and stochastic. Unlike crop markets, there are not even partial risk and insurance markets to hedge/control the randomness in environmental effect. Therefore any state-contingency must be built into the conservation policies under consideration. This physical uncertainty feature implies that there will be a range of possible biodiversity outcomes observed by regulator with any conservation effort. The disappearance of certain birds in one area for example might well be a result of weather change rather than the actual logging activities taken in that area. Researchers are increasingly aware of the stochastic influence resulted from physical uncertainty (e.g. Segerson, 1988). In the model Segerson presented in 1988 in the context of non-point source pollution, for example, the ambient level is represented by a probability function that is conditional on the abatement practice. This type of models also corresponds to the situation where the environmental impact is deterministic, but the regulator can only observe the impact level imprecisely and inaccurately with a probability distribution.

Third type of information insufficiency, hidden individual information, stems from asymmetric information between the regulator and landowners. Landowners to be regulated are diverse and heterogenetic in land development potentials, production technology, conservation awareness, habitat and specie situation, conservation skills, and attitude toward risks (Smith 1995, Smith and Tomasi 1995, Horowitz and Hueth 1995, Wu and Babcock 1995), for which oftentimes landowners either have better information or are in a better position to collect the information (Goeschl and Lin, 2003). When serious information asymmetry exists between a regulator and landowners, the design of efficient environmental policy is hampered.

There are two types of information asymmetries studied by literature, one related to information stock (status information asymmetry) and the other related to information flow (ability information asymmetry) (Goeschl and Lin, 2003). Status information asymmetry comes from landowner's superior information about her own (e.g. production technology) and the land (e.g. habitat and specie situation), while ability information asymmetry states the ability differences between the regulator and landowners in collecting these information. Conventional arguments for status information asymmetry root in specialization but recent literatures emphasize the role of self-conscious investment in information discovery (Cremer et al. 1998a and b). It is the ability asymmetry that gives rise to these investment decisions in collecting information. There are many plausible reasons that both types of information asymmetries (status and ability) exist, with legal barrier being an important one in biodiversity conservation context. In United States of America, for example, according to Natural Heritage Data Center Network's estimate, 70% of species listed under the Endangered Species Act depend on nonfederal land for the majority of their habitat (Polasky and Doremus 1998). Without land owners' consent, legal barriers exist for the regulator to enter the private land and collect biodiversity-related information on these lands, which implies the cost / ability asymmetry in collecting information between the regulator and the landowners.

Status information asymmetry, and the efficiency loss associated with it, is well studied in economics literature built on the seminal work on mechanism design theory under asymmetric information by Hurwicz (1972), Groves (1973), Mirrlees (1971), Baron and Myerson (1982) and others. Not until recent years did economists start studying ability information asymmetry (Cremer et al. 1992, 1998a, 1998b, Sobel 1993, Lewis and Sappington 1997). These studies, all starting with the assumption that there is only information acquisition cost (ability) difference between the regulator and agent, try to endogenize the information structure and evaluate the regulated agent's incentives to acquire information. Goeschl and Lin (2003) studied dual information asymmetry situation where both types of asymmetry exist in the context of biodiversity conservation. There are also some literatures on the incentives of agents to acquire information about the value of an object before participating the auction (Lee, 1982; Matthews, 1984; Milgrom, 1981; etc.).

Last type of information insufficiency arises with monitoring problems closely associated with regulator's inability to observe directly individual's conservation efforts and impact on the biodiversity or to infer them from observable inputs (i.e. land development) or the total biodiversity loss.

There are a number of contributing factors to regulator's inability to monitor input (effort level) and output (impact) of conservation measures, as Xeppapadeas observed in the context of pollution, "such as equipment and personnel limitations, or inability to enter the polluter's premises. On the other hand, while it is relatively easy to determine whether the polluter has installed adequate equipment for pollution abatement, it is difficult to make sure that this equipment is being operated at the desired level. As a result, the development of efficient measurement methods could be very costly" (Xepapadeas, 1991). Therefore, the government faces a situation where it could be prohibitively costly to measure with sufficient precision the individual's production of / contribution to conservation. In environmental economics literature, this is addressed by standard moral hazard models in which conservation efforts are privately observable (see Laffont and Tirole 1993 among others).

Monitoring problem sharpens when the number of landowners increases. When there is only one landowner in a setting – either where one farm accommodates all the species under consideration, or where many landowners are sufficiently independent one another to allow them to be regulated individually – there is no question of "responsibility" for observed biodiversity loss (Dosi and Moretto, 1994, 1997). However, it is more likely that many landowners' (diffuse) activities combine to determine a single measure of biodiversity loss at a given location. This is similar to non-point source water pollution question in the literature and moral hazard models and adverse selection with multiple firms are discussed by, respectively, Segerson (1988) and Xepapadeas (1991, 1992) and Shortle and Dunn (1988). The existence of multiple landowners raises a number of difficult regulatory issues, most of which relate to information and monitoring. It is no longer possible to attribute the biodiversity loss to the activities of any one landowner since "damages" are not separable across landowners. Thus, it is necessary to infer each landowner's potential contribution in case of violation. The larger the number of landowners, the more difficult is the monitoring, and the more difficult is the information problem for both regulator (obtaining information about landowners) and the landowners themselves (obtaining information about each other). The existence of more landowners implies a greater potential free-rider problem, if each landowner perceives its own damage to biodiversity to be small relative to the group, and decreases the likelihood of cooperation among landowners to reduce biodiversity loss. Moreover, this observability problem is particularly severe in biodiversity conservation as many species (e.g. migrating birds and animals) roam across a vast territory. The regulator in general is in a difficult position to detect biodiversity loss /specie endanger in a certain location, not to mention to attribute this loss to individual landowners. Researchers and regulators duly discuss in this context regulatory options like team reward/punishment (e.g. Groves, 1973) and random reward/punishment (e.g. Xepapadeas, 1991), which we will discuss later.

Even though information is one of the greatest constraints in effective conservation regulation, the effort of collecting information is no less controversial. Property owners and regulators have sharply divergent view of the desirability of increased information about species status and distribution. In North America, for example, the Endangered Species Act has been the center of a fierce debate. On one side, groups representing various economic interests have called for radical reform of the law in order to reduce economic impacts and to protect private property rights. On the other side, environmental groups vehemently oppose any weakening of the current law, contending that it must be maintained or strengthen to ensure the long-term survival of endangered species. Conservation proponents favor greater efforts to collect information about the status of species, including location and health of population and habit (e.g. Wilson, 1992). By contrast, property rights advocates vociferously attack any move to expand government information collection efforts, such as the short-lived National Biological Survey.

3 Regulatory instruments for biodiversity under information constraints

Environmental economist and regulators have been developing and practicing a wide array of regulatory tools to preserve the biodiversity around the world, each of which subjects to different information constraints. We discuss in this section three major types of regulatory tools, namely land takings, environmental taxes, and contracts, and the informational constraints they face. Summarized in Table 1, these three measures portrait a wide spectrum of regulatory choices, under which many other regulatory tools, land access restrictions for example, fall into. In practice, a combination of different regulatory measures oftentimes is a more desirable choice to tackle the pressures that lead to biodiversity loss (OECD, 1999; Smith, 1995).

3.1 Land takings and land access restrictions

The traditional instruments of biodiversity conservation in Europe and North America have been the acquisition of land (takings) by the state with or without compensation and the imposition of restrictions on the use privilege of private property. Examples include establishment of national parks and reserve zones worldwide. The advantages of these approaches are that they are conceptually easy to understand and that pre-formulated

Table 1. Three regulatory choices for biodiversity conservation.

Regulatory choices	Land takings and land access restriction	Environmental taxes/ Changes and removal of adverse Incentives/Subsidies	Contracts
Producer of public goods	Public	Private	Private
Financial costs to the regulator	High	Low	Medium
Landowners' cooperation	Often times mandatory	Mandatory	Voluntary

goals can be achieved with high probability, as long as adequate monitoring and enforcement can be assured. (OECD, 1999)

These approaches however have several problems and limitations besides imposing high financial costs to the regulator. The problems have been discussed widely in the literature and many have to do with insufficient information (see Shogren and Tschirhart 2001 for a review). As a consequence of insufficient information on land's conservation values (because of any type of aforementioned informational failures), regulator's land acquisition decisions are prone to efficiency losses. Without sufficient conservation value information it is imaginably difficult for the regulator to make trade-offs among conservation projects given a limited governmental budget. When it comes to a specific land parcel, an acquisition decision has to be made upon the comparison between conservation value and market value, which is problematic without sufficient information on the former (Polasky and Doremus 1998). In the case of acquisition, the government not only asserts ownership of the land, but usually also takes on a management role. Similar to other settings, generating a public good, in this case conservation, through public production is prone to suffer from efficiency losses implicit in public production such as lower productivity and excessive opportunity and management costs of the conservation activity (Innes 2001). Apart from the problem of the government as an inefficient producer, compensation is fraught with various difficulties. If compensation is absent or too low, governments may be tempted to oversupply conservation. Also problematic incentives may be created for landowners (such as 'shoot, shovel, and shut up', see Brown and Shogren 1998), and little cooperation can be expected from landowners in prospecting for biodiversity (Polasky and Doremus 1998). If on the other hand a compensation scheme is implemented, basing compensation on opportunity costs (market value of the land mainly) may be problematic since it will encourage early development of land in order to raise the payment (Blume et al. 1984). Basing compensation on benefits (paying for number of birds increased for example) on the other hand will be problematic since, with only a few exceptions that the results can be monitored through satellite (Pagiola et al. 2003), it generally requires the cooperation of the landowner and cannot be relied on to produce a reliable result (Polasky and Doremus 1998). Imposition of land use restrictions is less drastic than land takings, but to the extent that they are imposed, their impact is fundamentally identical to that of land takings in direction, if not in volume (Innes 2001).

Both land takings and land use restrictions are quantity-base instruments. Compared to price-base instruments such as taxes discussed in the next section, quantity-base instruments were traditionally regarded less affected by environmental benefit (damage) uncertainties (due to aforementioned biological uncertainties and natural variability) (Weitzman 1974 and others). Environmental economists acknowledged that benefit uncertainty on its own has no effect on the identity of the optimal efficient control instrument, but that cost uncertainty can have significant effects, depending upon the relative slopes of the marginal benefit damage and marginal cost functions. Adar and Griffin (1976, p. 180) stated ". . . the introduction of uncertainty in the damage function has nothing to say about the choice of policy instruments" and similar views were hold other environmental economists (Fishelson 1976; Baumol and Oates 1988). Starvins (1996) observedin the real world, we rarely encounter situations in which there is exclusively either benefit uncertainty or cost uncertainty and in the presence of simultaneous uncertainty in both marginal benefits and marginal costs and some statistical dependence between them, benefit uncertainty expressed through the covariance term can make a difference for identifying the efficient policy instrument. A positive correlation tends to favor the quantity instrument, and a negative correlation favors the price instrument. Research along this direction however has been slighted since.

Apart from the theoretical shortcomings of the traditional approach of providing conservation, over the last twenty years this model of biodiversity conservation has encountered several practical and political limitations. First, conservation opportunities on public land are naturally limited when significant amounts of target species exist on private land (see for example Innes, Polasky and Tschirhart 1998). At the same time, this model of conservation cannot reach forms of biodiversity, such as agro-biodiversity, where conservation is inherently tied up with continuing private production activities. In the managed landscapes of Europe that have been in productive agri- or silvicultural use for many centuries, a significant proportion of biodiversity falls into this category. The involvement of the landowner as the manager of the essential production input land is critical in these circumstances. A second limitation has been the increasing political cost of limiting the property rights of landowners and practical experiences with the adverse conservation incentives contained in some of these measures. The third limitation has been the questioning of the logic of public production of public goods and a shift in economic policy in many European countries, leading to a retreat of the state from production activities. This had two effects: On the one hand, for new projects there has been an interest in alternatives to the conventional model, such as contracts, through which the private production of public goods would be carried out. On the other hand, for existing conservation projects the retreat of the state has created a necessity to develop alternative instruments as a result of management of significant land assets having been transferred to newly privatised entities. To manage these fundamentally new relationships between public bodies and private corporations, new instruments have to be developed.

3.2 Environmental taxes/fees and removal of adverse incentives

One important change in biodiversity regulation over the past twenty years has been the move towards new instruments for the private production of public goods through price mechanisms – imposing environmental fees /taxes, removing adverse incentives / subsidies, or both. We include in environmental taxes the wide range of non-compliance fees, nature taxes, and conservation levies being applied around the world to discourage biodiversity damaging activities. Removal of the adverse subsidies, which are usually the results of government support programmes to agriculture, is fundamentally equivalent to imposition of environmental taxes (See OECD 1999 for a review of countries' practices).

These price-based incentives measures which aim to internalize the externalities are easily understandable but only applicable in situations where impacts are easily measurable (e.g. hunting) and sources of impacts can be easily monitored. Informational insufficiencies can greater jeopardize the efficiency of these measures. For the discussion below, we focus on two types of these taxes – the Pigouvian type and the Ambient Tax type. Most taxes we find in biodiversity conservation are Pigouvian type and ambient tax, originated in water and air pollution regulation, is often applied in biodiversity conservation projects where collective/team reward/ punishment is implemented.

There are considerable amount of literature on how a system of Pigouvian taxes can generate efficient outcomes by internalizing the negative externalities and therefore inducing individual agents to produce the public goods (biodiversity) at the socially desirable levels (e.g. Baulmol and Oats, 1988). However, this is critically dependent on the condition that marginal benefit and cost curves are observable with sufficient accuracy and at a sufficiently lost cost. Weitzman (1974) and others show how uncertainties of marginal benefit and cost curves can result in inefficiency of such taxes.

However, when an individual's damage to biodiversity cannot be observed with sufficient accuracy at a reasonable cost because of unknown biological process (biological uncertainty), stochastic influences (natural variability) and / or because of the inability to measure individual contribution to the environmental problem (monitoring problem), Pigouvian taxes will be not appropriate. An ambient tax system has been proposed by some economists such as Segerson (1988) and Xepapadeas (1991, 1992) in context of environmental pollution.

"[Ambient] taxes are essentially a charge per unit deviation between a desired and a measured ambient concentration level, and are imposed on every potential polluter once measured ambient pollutant levels exceed some desired cutoff level" (Xepapadeas, 1995a).

The approach proposed by Segerson is composed of two parts. The first is tax/subsidy payment that depends upon the extent to which the total ambient level (observable) exceed the cutoff level, the suspected polluter pays a tax proportional to the excess, while ambient levels below the cutoff result in a subsidy. The second part is fixed penalty imposed whenever ambient levels exceed the cutoff. This scheme is similar to on described by Holmstrom as a solution to free riding in the context of organizational structure. By eliminating the need for firm level monitoring of emissions or abatement effort, the mechanism can lower a regulator's administration costs. In addition, Segerson' approach solves free rider problem by imposing a penalty equivalent to the full marginal benefit of reduced ambient pollutant levels, rather than just paying a share of it, on each firm[2]. However, Sergeson'spenalize all mechanism does not have government's budget balancing condition, which would require the regulator to dip further into a general revenues (in case of subsidies) than would the random penalty scheme proposed by Xepapadeas (1991).

Xepapdeas (1991) advocates a combination of subsidies and random penalties when only aggregated ambient level can be observed. This random penalty approach was much criticized because of its limits (Kritikos, 1993; Herriges et al. 1994). First, contrary to the original claim in Xepapadeas, random penalties cannot be used to achieve compliance if firms are risk natural. Budget balancing still requires that each firm pay, on average, only a fraction of the damages associated with pollution emissions. Second, the random penalty mechanism may face problems in both political and legal arenas, due to the random assignment of the penalty in the event of shirking. Firms that consistently comply with their assigned abatement objective can still be penalized. Finally, the random penalty mechanism relies on the assumption that each firm treats the other firms as being in compliance otherwise multiple equilibria problem remains to be solved.

Mix of Pigouvian tax and ambient tax is further proposed by Xepapadeas (1995b). The paper argues that severe monitoring problems make Pigouvian taxes preferable to ambient taxes as the latter does not require individual level of observibility. However, when the information insufficiencies increase along the dimension of natural variability or biological uncertainty, increase in observability of individual emissions through, for example, investment in pollution monitoring equipment might be desirable for both the regulator and the agents – given agents are risk averse. Increase in observability of individual emissions will lead to a reduction or even abolition of ambient taxes and increase of Pigouvian tax. Therefore, Xepapadeas (1995) shows that under uncertainty the efficient regulatory scheme is a mix of Pigouvian and ambient taxes. The Pigouvian fees are imposed on emissions / environmental damages revealed by the polluting firms in exchange for a lower ambient tax.

3.3 Contracts

Another important phenomenon of the move towards new instruments for the private production of public goods has been the rise of contracts between the relevant public entity (such as conservation agencies) and private landowners. Contract mechanisms are receiving increasing attention in recent years worldwide to encourage biodiversity-friendly agricultural practices. One example is the Regional Integrated Silvopastoral Ecosystem Management Project implemented by the World Bank in Colombia, Costa Rica, and Nicaragua (Pagiola et al., 2003). Under these types of contracts, locals are paid to generate biodiversity conservation.

A key concern for both researchers and policy makers in the development of such contracts has been to ensure that the conservation contracts are drawn up as efficiently as possible. Contract design is therefore a major consideration and has increasingly attracted the attention of environmental economists.

Initially, the literature identified as the source of such efficiency losses the asymmetry of contract-relevant information (hidden information) between the conservation agency (the regulator) and the conservation provider (the landowner) with respect to the cost of conservation (Smith 1995, Smith and Tomasi 1995, Horowitz and Hueth 1995, Wu and Babcock 1995). This perspective leads to casting the problem in terms of a standard principal-agent problem with two types (typically low- and high-efficiency) or a continuum of types (Hurwicz 1972, Groves 1973, Mirrlees 1971, Baron and Myerson 1982 and others).

It has been noted subsequently that one serious shortcoming in that literature is the underlying assumption that the costs and/or benefits of preservation are actually known to the agent. This assumption has been attacked as unrealistic on a number of grounds: Often, there are no existing markets for the outputs of conservation activities, so both agent and principal will find it hard to assign a proper cost and/or benefit estimate to a particular conservation activity. Also, collecting information about the cost structure of complying with obligations regarding inputs and/or outputs is costly so that landowners will not enter negotiations fully informed about their own costs while the regulating agency cannot collect this information without considerable cost, consent, and often support of the landowner (Polasky and Doremus 1998). A second generation has therefore started to explore the issue of information collection in the context of biodiversity conservation in order to provide answers to situations where the both principal and agent are imperfectly informed, but differ in their ability to collect information either for technical (capital) or legal (property rights) reasons (Polasky 2001).

Goeschl and Lin (2003) studies a mixture of asymmetries between the conservation agency and the contracting landowner, one relating to asymmetric status regarding information about the type of landowner (low- or high efficiency) involved in the contract and the other relating to asymmetric ability to collect contract-relevant information that is unknown to both parties at the outset of the contract negotiations. As a typical example, think of a conservation contract that requires the contracting farmer to provide adequate habitat for some species. Informational asymmetry will arise on the one hand because the farmer will have information about the opportunity cost of giving up agricultural land based on his intimate knowledge of his land assets. This information will not be available to the conservation agency. On the other hand, prior to a careful inspection under the consideration of habitat provision neither the agency nor the farmer will know whether additional resources will be required to provide adequate habitat on the land under consideration. Examples would be measures to ensure higher soil moisture or different cultivation patterns. On one farm, the land may be adequate as it is, on another, certain measures will be required to ensure adequacy. Since there will commonly not have been a need to collect this information at some previous point in time, both the farmer and the conservation agency will not know the additional cost to the farmer of providing adequate habitat. What makes this information deficiency relevant to consider in the contract, however, is that the farmer will have much greater scope to ascertain the adequacy of his land for the activities to be contracted over than the agency for both legal and technical reasons. In situations that involve such a combination of informational asymmetries between the conservation agency and the landowner, the agency needs to consider not only the static information asymmetry, but also the differential ability of the parties to become informed about contract-relevant parameters. If conservation agencies take these aspects into consideration, we show that we would expect to observe very different contract negotiation strategies than those optimal under either pure status or pure ability asymmetry.

4 Concluding remarks

Informational constraint represents one of greatest challenges to both environmental economists and policy makers in regulatory choices. The nature, type, and extent of informational insufficiencies have profound impacts on regulatory measure choices, research of which is of both intellectual vitality and real-world relevance. This review suggests an integrated framework that explicitly consider efficiency trade-offs of different regulatory measures under various informational structures will be a key step in enhancing our understanding of this area further.

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Footnotes

[1] We refer to Dosi, C and M. Moretto's work on non-point source pollution in defining various information insufficiencies.

[2] For example, if marginal damages are valued at $100, the regulatory agency will collect $100 from each pollutant for the marginal unit of ambient pollution, for a total collection of $ (100n) (Segerson, 1988).