Public: Private Benefits Framework version 3†

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ABSTRACT. *The choice of policy mechanisms for encouraging environmentally beneficial land-use change should depend on the relative levels of private (or internal) net benefits, and public (or external) net benefits. A map of recommended policy mechanisms is developed, depending on the relative levels of these variables. Positive incentives, negative incentives and extension need to be targeted carefully to appropriate projects – where private net benefits are closer to zero, and/or public net benefits are more extremely positive or negative. Technology development is suggested where private net benefits are negative, but not too negative, and public net benefits are positive. No action is recommended for many potential projects.* (JEL Q28, Q58)

I. INTRODUCTION

Many problems of environmental conservation or natural resource management require changes in land management on privately owned lands. A number of government programs have been created to attempt to encourage such changes, including the Conservation Reserve Program, the Environmental Quality Incentive Reserve Program, and the Conservation Security Program in the United States of America; the Rural Development Regulation in the European Union; the National Farm Stewardship Program in Canada; and the Natural Heritage Trust in Australia.

These programs use a range of mechanisms to encourage change, including education, awareness raising, technology transfer, research and development, regulation, subsidies and other economic instruments. In practice, the choice among these possible policy mechanisms is often not very sophisticated. Programs tend to rely primarily on a small number of mechanisms, sometimes as few as one.

In this paper I develop a simple framework for selecting among broad groups of policy mechanisms. I show that the choice of mechanism should particularly depend on the relative levels of (a) private (or internal) net benefits, and (b) public (or external) net benefits.

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† Citation: This paper is an update of the Public: Private Benefits Framework, and is the latest version, as of March 2016. Version 1 was originally presented in Pannell Discussions (www.pannelldiscussion.net, numbers 73-80). Version 2 was the journal article published in *Land Economics* in May 2008 (Pannell, D.J. (2008). Public benefits, private benefits, and policy intervention for land-use change for environmental benefits, *Land Economics* 84(2): 225-240). It corrected several minor errors and omissions from version 1. This version of the paper corrects an error in Figure 10 (technology development was omitted in the journal version) and also modifies the treatment of technology development in response to a better understanding of that issue which was developed in a subsequent paper (Pannell, D.J. (2009). Technology change as a policy response to promote changes in land management for environmental benefits, *Agricultural Economics* 40(1), 95-102).

For more information about the framework, examples of its use, and related PowerPoint and Excel files, see http://dpannell.science.uwa.edu.au/ppf.htm

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'Private net benefits' refer to benefits minus costs accruing to the private land manager as a result of the proposed changes in land management. They exclude transfers which are part of the policy intervention, so that we can compare landholder behaviour with and without the intervention. In principle, private benefits are broader than financial benefits, and include the broad range of factors that influence the relative advantage of the new land use options (as perceived by the landholders) such as riskiness, complexity, social considerations, personal attitude to the environment, and farming-systems impacts of the land-use practice (Kabii and Horwitz, 2006; Knowler and Bradshaw, 2006; Pannell et al., 2006).

'Public net benefits' means benefits minus costs accruing to everyone other than the private land manager. They exclude any costs borne by the environmental manager in the process of intervening to encourage the change in land management. This will allow us to compare the benefits of an intervention with its costs.

Underlying the framework is a proposed set of rules or principles for choosing whether a particular policy mechanism is appropriate, as described in Section II. There have been many studies in which analysts have compared choices between broadly similar policy instruments, such as between emission standards, tradeable permits and emission taxes (e.g., Aidt and Dutta, 2004; Bruneau, 2004; Jensen and Vestergaard, 2003; Weitzman, 2002). However, there has been a lack of analysis of the choice between disparate types of policy mechanisms, such as between mechanisms that only provide information (e.g. extension) and those that change incentives (e.g. subsidies or taxes). For example, Gjertsen and Barrett (2004) note that

> 'Some researchers question the utility of the search for a single, universally "best" institutional design for conservation, and ask whether different arrangements are perhaps appropriate for different setting (Barrett et al. 2004; Ostrom et al. 1999; Hobley 1996). To date, however, there has been little analytical work that explores how key variables interact and determine when one arrangement will be more effective than another.' (Gjertsen and Barrett 2004, p.322).

Gjertsen and Barrett (2004) themselves develop an analysis to select between community management, government management or co-management of a resource, depending on government management efficiency and community fundraising efficiency. Skonhoft and Solstad (1998) consider the choice between different tools for reducing poaching activity, although, again, the policy tools are from the same broad group (size of penalty, changes in probability of detection, size of penalty, prices, property rights).

The framework presented here similarly seeks to identify context-specific policy regimes. It assists in choosing between broad groups of policy tools, to achieve efficient resource conservation on private lands. It is intended to be a guide for environmental managers who wish to know which types of policy mechanisms are likely to be most efficient in particular circumstances.

II. CATEGORIES OF POLICY MECHANISMS

Policy mechanisms are selected from five broad categories, as shown in Table 1. The first two categories consist of financial or regulatory instruments, including polluter-pays mechanisms (command and control, pollution tax, offsets), beneficiary-pays mechanisms (subsidies, conservation auctions and tenders) and mechanisms that can work in either way depending on how they are implemented (define and enforce property rights, such as through tradable permits). Any of these approaches can be used to create either positive incentives (to encourage change) or negative incentives (to discourage change). For example, to create an incentive for land-use change, we could offer landholders a payment out of public funds (beneficiary-pays in the sense that the public benefits from the environmental improvements), or we could charge them a tax for the pollution that they generate as a result of not changing land use (polluter-pays). The choice depends on who is considered to have the property rights, which is essentially political (Pannell, 2004), and the politics can work in either direction. In this paper, I do not address the choice between polluter-pays and beneficiary-pays mechanisms, but instead consider them jointly to constitute one of the broad groups of mechanisms.

Table 1. Alternative policy mechanisms for seeking changes in management of private lands

Category	Specific policy mechanisms included
Positive incentives	Financial or regulatory instruments[A] to encourage change
Negative incentives	Financial or regulatory instruments[A] to inhibit change.
Extension	Technology transfer, education, communication, demonstrations, support for community network
Technology development	Development of improved land management options, such as through strategic R&D, participatory R&D with landholders, provision of infrastructure to support a new management option.
No action	Informed inaction

[A]Financial or regulatory instruments include polluter-pays mechanisms (command and control, pollution tax, offsets) beneficiary-pays mechanisms (subsidies, conservation auctions and tenders), and mechanisms that can work in either way depending on how they are implemented (define and enforce property rights, such as through tradable permits).

Existing environmental programs include examples of both beneficiary pays mechanisms and polluter pays mechanisms. In practice, if often seems to be the case that beneficiary pays is used to encourage landholders to change their current land management in environmentally beneficial ways (e.g. the Conservation Reserve Program in the US; Environmental Stewardship in the UK; the National Farm Stewardship Program in Canada; and the Natural Heritage Trust in Australia). On the other hand, polluter pays is often used to discourage landholders from changing their current land management away from the status quo to new practices that are believed to be more environmentally damaging (e.g. regulations prohibiting establishment of new intensive farming operations in urban areas, prohibitions on production of genetically modified organisms in a number of countries (Center for Food Safety, 2006), legal limits on clearing of native vegetation in Australia (Productivity Commission, 2004)).

III. POSSIBLE COMBINATIONS OF PUBLIC AND PRIVATE BENEFITS

The starting point for the analysis is the recognition that environmental managers can invest in a range of projects involving changes in land management or land use on private land, and that the available options vary widely in the levels of public and private net benefits they generate, including, potentially, negative net benefits. (The estimation of public and private net benefits is discussed later, in Section VI.)

Figure 1 shows the sample space for possible projects with various levels of public and private net benefits; any project would correspond to one point on this graph. It illustrates that a project may have any combination of positive or negative public or private net benefits. The set of potential projects that would generate positive net benefits overall consists of those projects that fall in areas A, B, and C.

In area A, public net benefits outweigh private net costs. For example, it may be that establishment of a riparian buffer strip in a particular location would be costly to a landholder, but these costs would be exceeded by the public benefits due to improved water quality. In area C, private net benefits outweigh public net costs. For example, conversion of grazing land to a forestry plantation may be highly profitable to a landholder, but result in reduced flows of surface water into a waterway, with off-site costs to downstream water users that are not sufficient to outweigh the on-site benefits. In area B, there are positive net benefits for both landholders and the public. For example, cropping with reduced tillage may be beneficial to a landholder as well as beneficial to the environment. The six labelled areas in Figure 1 are relevant to the choice of policy mechanism, because a different mix of policy mechanisms can be identified as being most appropriate in each case.

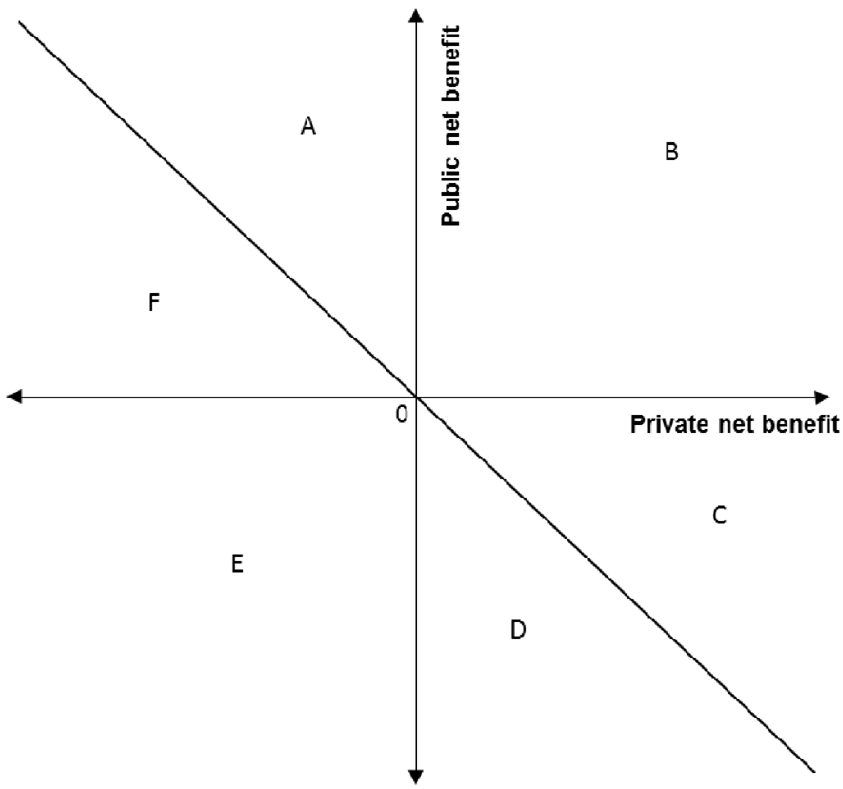

Figure 1. The sample space for potential projects, involving specific changes in land management in specific locations, depending on private and public net benefits.

The question addressed here is, for any project, given its location on Figure 1, what policy mechanism, if any, should the environmental manager choose in order to maximize the net benefits of intervening?

IV. RULES FOR CHOOSING POLICY MECHANISMS

The aim is to allocate the categories of mechanisms in Table 1 to the six areas in Figure 1. It is assumed that landholders will adopt all land-management practices with positive private net benefits (projects in areas B, C, D), provided that they are able to learn about those practices. Initially, zero learning costs for landholders are assumed. Given this assumption, the following rules for selecting policy mechanisms are proposed.

1. *Do not use positive incentives for land-use change unless public net benefits of change are positive: no positive incentives for C, D, E.*
2. *Do not use positive incentives if landholders would adopt land-use changes without those incentives: no positive incentives for B.*
3. *Do not use positive incentives if private net costs outweigh public net benefits: no positive incentives for F.*

These rules narrow the use of positive incentives down to area A. Now consider rules for the use of extension. These rules are based on the use of extension to improve decision making, rather than to improve skills. They relate to the use of extension as the main policy tool, rather than as a support to other policy mechanisms.

4. *Do not use extension unless the change being advocated would generate positive private net benefits. In other words, the practice should be sufficiently attractive to landholders for it to be 'adoptable' once the extension program ceases.*
5. *Do not use extension where a change would generate negative net public benefits*

These rules narrow extension down to area B.

6. *If private net benefits are negative and public net benefits are positive (areas F and A), consider technology development to create improved (environmentally beneficial) land management options that can be made adoptable (with or without positive incentives). The merits of technology depend on the public and private benefits of the best available projects, and how much these can be improved through technology change.*
7. *If private net benefits outweigh public net costs (area C), the land-use changes should be accepted if they occur, implying no action. Alternatively, if it is not known whether private net benefits are sufficient to outweigh public net costs, a relatively flexible negative incentive instrument may be used to communicate the public net costs to land managers (e.g. a pollution tax), leaving the ultimate decision to the land managers. Inflexible negative incentives, such as command and control, should not be used in this case.*
8. *If public net costs outweigh private net benefits (area D), use negative incentives to discourage uptake of the land use.*
9. *If public net benefits and private net benefits from a set of land-use changes are both negative (area E), and landholders accurately perceive this, then no action is necessary. Adverse practices are unlikely to be adopted. If there is concern that landholders have misperceptions about the relevant land uses, adoption of environmentally adverse practices could be discouraged by extension, or more strongly by negative incentives.*
10. *In all cases, the suggested action needs to be weighed up against a strategy of no action.*

These rules lead to Figure 2. In the sections that follow, further details about each of the policy mechanisms are provided.

V. DETAILS AND ELABORATION

Positive Incentives

Consider a project i that falls in area A, so that the private net benefit (π_i) is negative. Because the public net benefit of this project is greater than the private net cost, policy intervention to create a positive incentive (σ) to change land use is potentially justified. There remains the question of how large the incentive should be. The proposed rule is that the incentive should be just large enough to prompt adoption. For example, if a beneficiary-pays instrument is used, and price discrimination is possible (e.g. via a conservation tender), payments under the scheme should equal the minimum necessary payment to achieve adoption ($-\pi_i$). Larger payments than this would include a component that is effectively a transfer payment – a redistribution with no net benefit to society, resulting in lower capacity of the program to achieve environmental outcomes (assuming a fixed program budget).

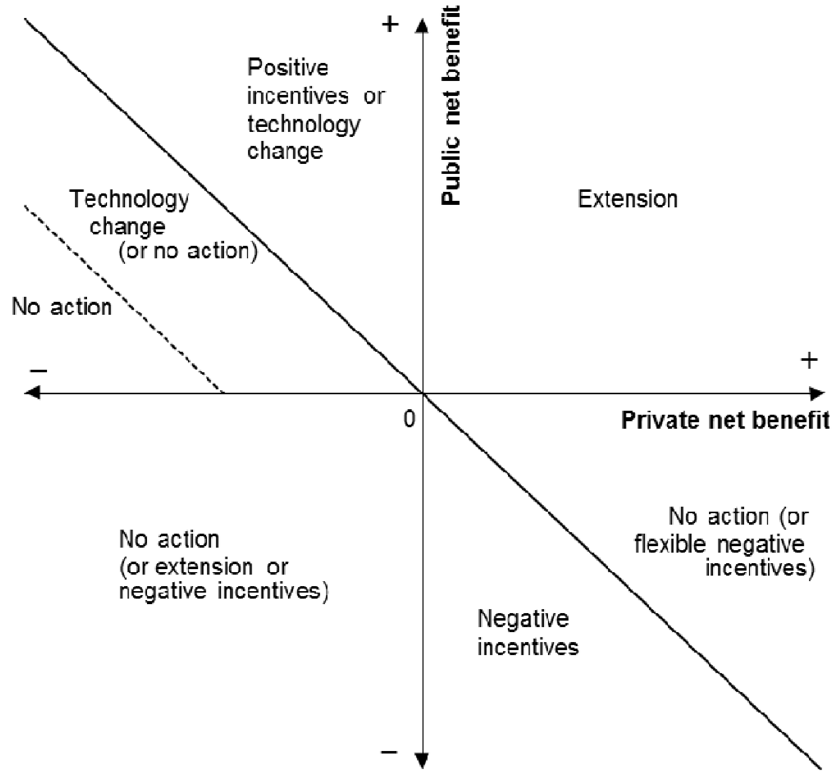

Figure 2. Suggested classes of policy tools for different levels of public and private benefits

Given this assumption about the level of incentive provided, Figure 3 shows how the priority of investment varies within area A. For a given level of public benefit, as the private net benefit increases (becomes less negative) within area A, the required incentive falls, so the public benefit generated per unit cost increases. The cost is either (a) for beneficiary-pays style incentives, the level of expenditure of public funds, or (b) for polluter-pays mechanisms, the private net cost from adopting the new land use. Within A, the benefit:cost ratio (BCR) of public investment is maximised as the private net benefits approach zero (i.e. as the required incentive approaches zero). Note that although the BCR = 1 line marks the boundary of area A, project opportunities close to that line are of relatively low priority, since the benefits they generate are only slightly greater than the costs.

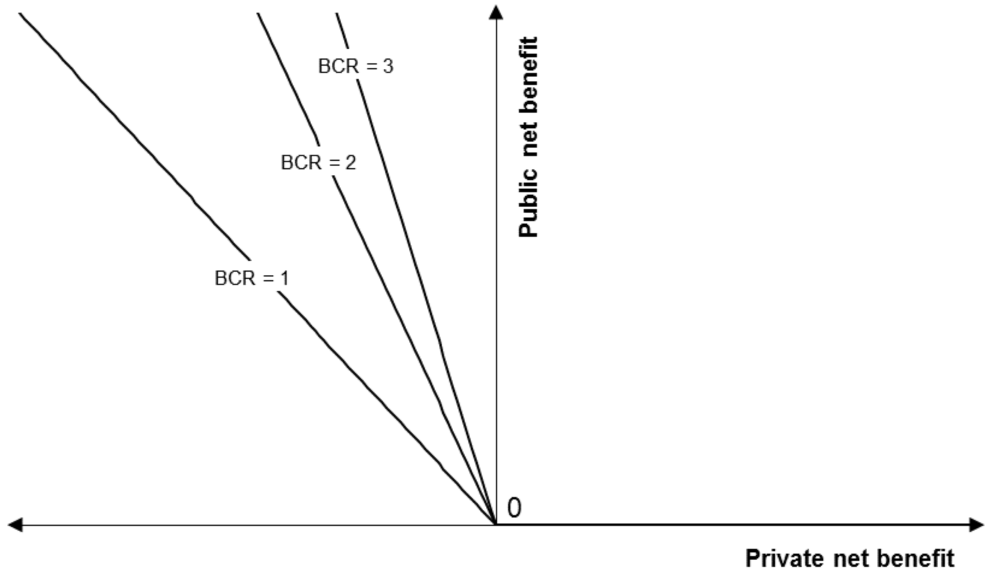

Figure 3. Iso-BCR lines for $C_L = 0$

If a polluter-pays instrument is used, the incentive (e.g. the pollution tax) should also be equal to $-\pi_i$. If the regulator is not confident about the value of π_i, the incentive should preferably not be larger than that necessary to achieve adoption, in case the project is actually from area F, and the intervention prompts adoption of practices for which private net costs are greater than the public net benefits.

Now consider learning costs (C_L), which are defined to include all factors that inhibit the transition from current management to the new management system. It may include the cost of obtaining and analysing information about the new practice, the presence or absence of social networks that support learning, and constraints on financial equity required for up-front costs of the land-use change. The existence of positive learning costs mean that landholders may not make the transition to a new practice, even if its adoption would ultimately yield positive private net benefits.

If there are positive learning costs, it is assumed that the incentive required to prompt adoption must be increased to cover those learning costs (equation [1]). In addition, when the need for costly learning in the process of adoption is recognised, the possibility of paying incentives to cover those learning costs for projects in area B arises. Assume that if a positive incentive is provided for a change in area B, it only needs to be sufficient to offset the learning cost.

$$\sigma = -\pi_i + C_L;\ \pi_i < 0 \quad [1]$$
$$\sigma = C_L;\qquad \pi_i \geq 0$$

When we allow for the reality that learning is costly, Figure 3 is substantially affected, particularly in area B. To illustrate this, we need to make specific assumptions about the lag to adoption (in the absence of policy intervention) for different levels of π_i. In general, we would expect that the lag to adoption (λ) would be ∞ for $\pi_i \leq 0$, and would decrease at a decreasing rate as π_i rises above zero. The specific form for this relationship is an empirical question. For illustration, assume that

$$\lambda = k/(\pi_i - C_L);\ \pi_i - C_L > 0 \quad [2]$$

where k is a constant. This function is illustrated in Figure 4, for $k = 50$.

Assume that if a sufficient incentive is created (Equation [1]), then adoption of the desired land use occurs immediately. Then the public benefit resulting from this intervention (π_s) is the value of avoiding the lag illustrated in Figure 4.

$$\pi_s = \pi_u \times [1 - (1/\{1 + r\})^{\lambda}] \quad [3]$$

where π_u is the public benefit from immediate adoption of the desired land use (independent of any subsidy paid), and r is the discount rate (assumed below to be 5 per cent real). Dividing π_s by program costs (assumed to consist of the incentive, σ, plus transaction costs, C_T), Figure 5 illustrates a set of iso-BCR lines, assuming that Figure 4 holds, learning costs are $10/ha/year, and transaction costs are $2.50/ha/year. (All numerical values in Figure 5 and similar subsequent figures are expressed as annuities. Parameter values used in Figures 5 to 10 are summarized in Table 2. Calculations are available at http://cyllene.uwa.edu.au/~dpannell/archive/pub-priv.xls.) Note that if the private net benefit from adoption is zero or negative, then $\pi_s = \pi_u$, meaning that the gain from the policy intervention is the entire public benefit from the land-use change. As the level of private net benefit from adoption increases above zero, the benefit from policy intervention first rises, because of additional private benefits from the land-use change, and then falls, because the lag to adoption that is being avoided (as a result of the intervention) falls.

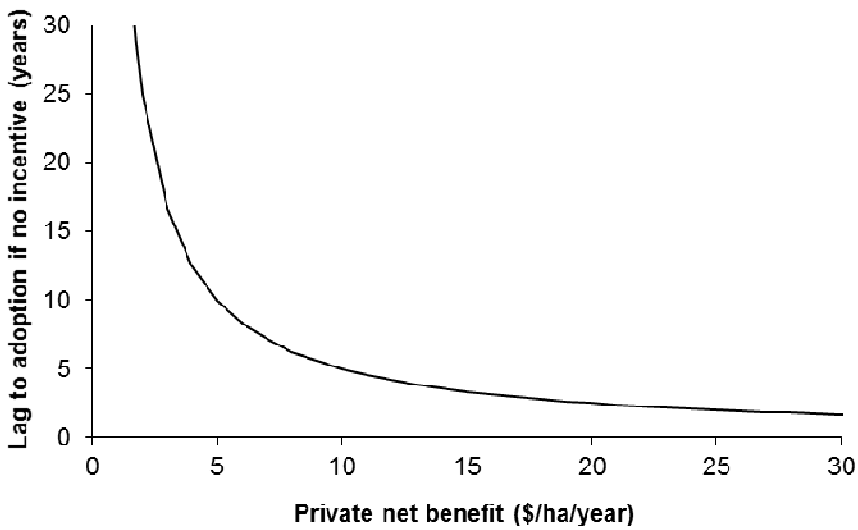

Figure 4. Lag to adoption (λ) given equation [2], for $k = 50$

Recall that as $\pi_i - C_L$ increases above zero, the level of incentive required to prompt land-use change remains constant (equal to C_L, Equation 1) while the benefits generated by the incentive (Equation 3) decrease because the adoption lag that is being avoided is shorter (Equation 2). This means that there is a break-even point above which it is not worth paying the incentive, illustrated in Figure 5 as the BCR = 1 line to the right of $\pi_i = C_L$. Because of the cost of learning, the breakeven line to the left of $\pi_i = C_L$ is shifted vertically by C_L relative to Figure 3.

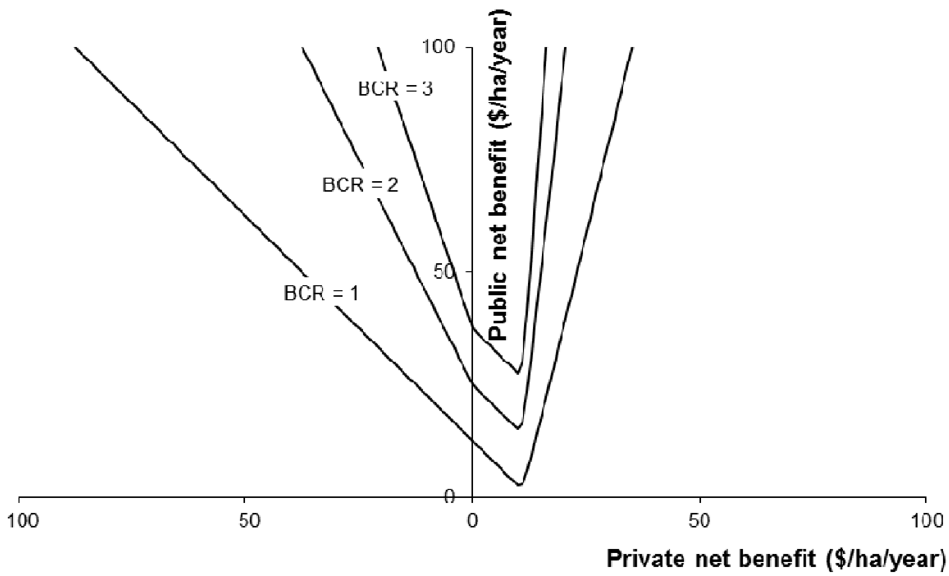

Figure 5. Benefit:cost ratios from use of positive incentives for $C_L = 10$

Table 2. Parameters used in Figures 5 to 10.

Parameter	Value
Cost of learning, equation [1] (C_L) ($/ha/year)	10
Adoption curve parameter, equation [2] (k)	50
Discount rate, equation [3] (r)	0.05
Transaction cost of positive incentives, negative incentives or extension (C_T) ($/ha/year)	2.50
Reduced adoption lag due to extension (years)	2

The higher iso-BCR lines in Figure 5 show that, for a set of projects with similar π_u, the most desirable projects, in terms of priorities for public intervention, are those for which $\pi_i = C_L$. Moving to the left of the axis, the iso-BCR lines rise because the cost of prompting adoption rises (equation [1]), while to the right, the iso-BCR lines rise because the benefit resulting from adoption falls (equation [3]).

Examining the three different BCR lines in Figure 5, for a given level of public net benefits, the BCR of applying incentives is highest where the private net benefits just offset the learning costs, so that the private net benefits of adoption are close to zero. In applying positive incentives, whatever specific policy mechanism we use, we should look for cases where the practices we hope to have adopted are borderline in their adoptability. This is where incentives would cause practice change most cost-effectively.

Extension

Relative to payment of grants to landholders, extension (e.g. education, technology transfer, communications generally) is a relatively cheap policy instrument that helps landholders to learn about the available land management practices, including practices that environmental managers would like to see adopted. Assuming that the effect of extension is to improve decision making by landholders, then only for projects that fall in area B of Figure 1 is extension able to accelerate adoption of the new land-use practices with positive public benefits (e.g. environmental benefits). Extension alone could not generate sustained adoption for projects in the left half of Figure 1 because, from the perspective of private landholders, those projects generate costs larger than their benefits.

In the simple framework of Figure 2, we did not consider the fact that, even though private net benefits from land-use change are positive in the top-right area, there may still be costs and impediments to learning that must be overcome, resulting in lags to adoption. We also did not discuss the effect that extension can have on the lags to adoption. In reality, extension may shorten, but will probably not eliminate, the lags. Finally, we did not account for the transaction cost of conducting an extension program.

If we use the illustrative adoption curve from Figure 4, and make some additional assumptions, we can map the area where extension will generate sufficient public benefits to offset the costs of the extension – where the BCR from extension is at least 1. For the purpose of illustration, assume that (a) extension reduces the adoption lag for any project by two years (e.g. see Marsh et al., 2004), (b) the real discount rate is 5%, (c) extension costs $2.50/ha/year (25 per cent of the assumed learning costs associated with land-use change, expressed in annualised form). Given those assumptions, extension could pay off for any project above the BCR =1 line in Figure 6.

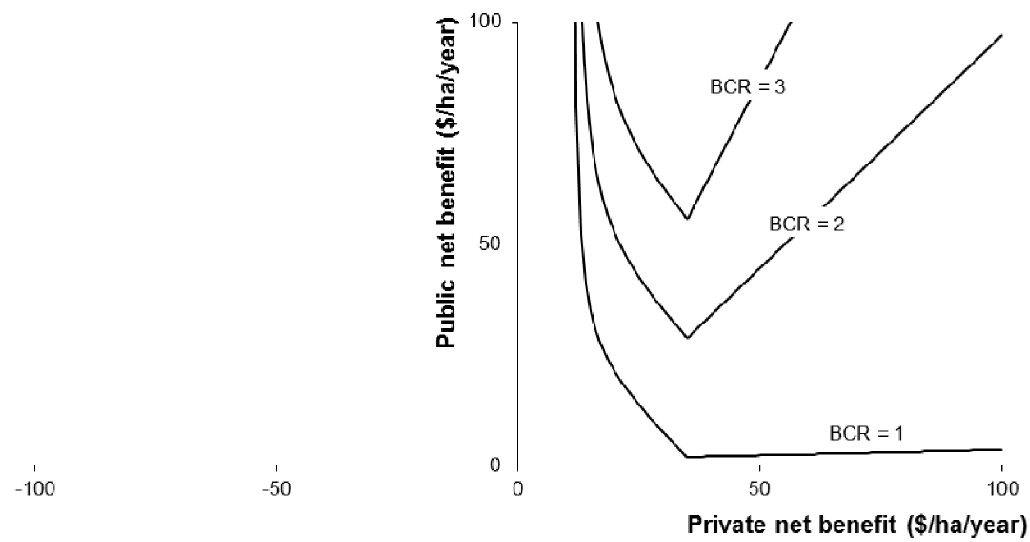

Figure 6. Benefit:cost ratios from use of extension, allowing for adoption lags, learning costs and transaction costs.

If we require higher BCRs from our investment in extension, we need to select projects that will generate higher public net benefits, and also higher private net benefits, up to a point (the point where the lag without extension is shorter than the benefit of extension). As we move further to the right side of the graph, increasing the private net benefits starts to reduce the net benefits of extension, because landholders are more inclined to adopt the new practices even without extension.

Figure 6 can be combined with the comparable graph for incentives (Figure 5) to generate a new map of where positive incentives or extension would be preferred (Figure 7). This is a modified version of the original map in Figure 2, allowing for the additional complexities we have now built in.

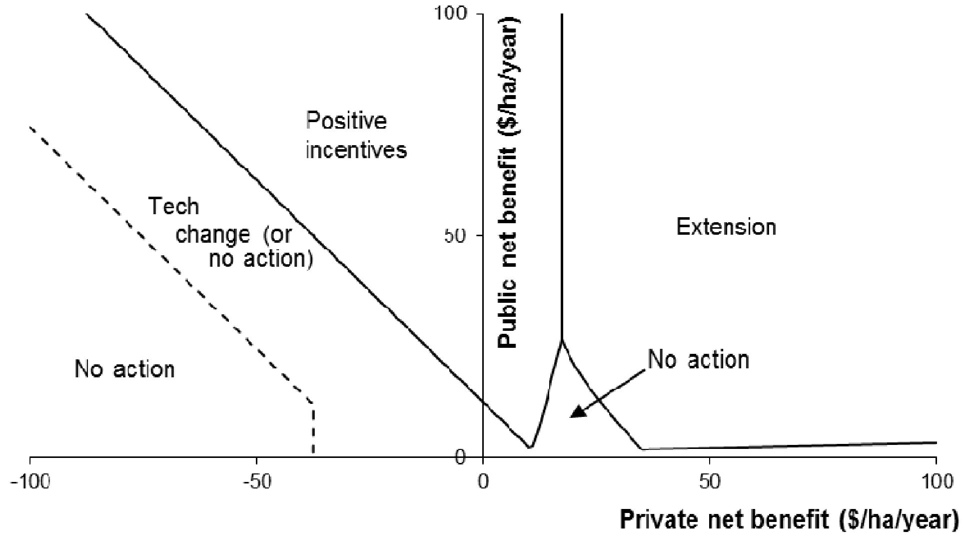

Figure 7. Revised map of efficient policy mechanisms allowing for adoption lags and learning costs.

Compared to Figure 2, Figure 7 is different in that: (a) public benefits need to be a little higher to justify positive incentives; and (b) extension is not worthwhile if public and private net benefits are both low, and is replaced by positive incentives if there are low private net benefits.

Realistically, a BCR of 1 is not sufficient to offset program fixed costs. Figure 8 shows a version of the map if we require a higher BCR of 2.0 to justify positive incentives or extension. The effect is to require higher public net benefits to justify the selection of projects. The set of desirable projects is grouped more closely around the vertical axis (they are more marginal in terms of their adoptability). Projects with low public net benefits but high private net benefits are no longer supported for extension.

Negative Incentives

'Negative incentives' means that landholders are encouraged to NOT change their land management in particular ways (e.g. removal of environmentally valuable vegetation) using tools such as command-and-control regulation, environmental taxes, or, potentially, subsidies as a reward for not changing.

The reasons for recommending negative incentives in area D of Figure 2 are (a) projects in that area generate negative public net benefits, (b) they generate positive private net benefits, so landholders are likely to adopt the changed land-use practices unless they are prevented from doing so, and (c) the public net costs outweigh the private net benefits, so there are overall benefits to be gained from preventing the land-use changes that the private landholders would like to adopt.

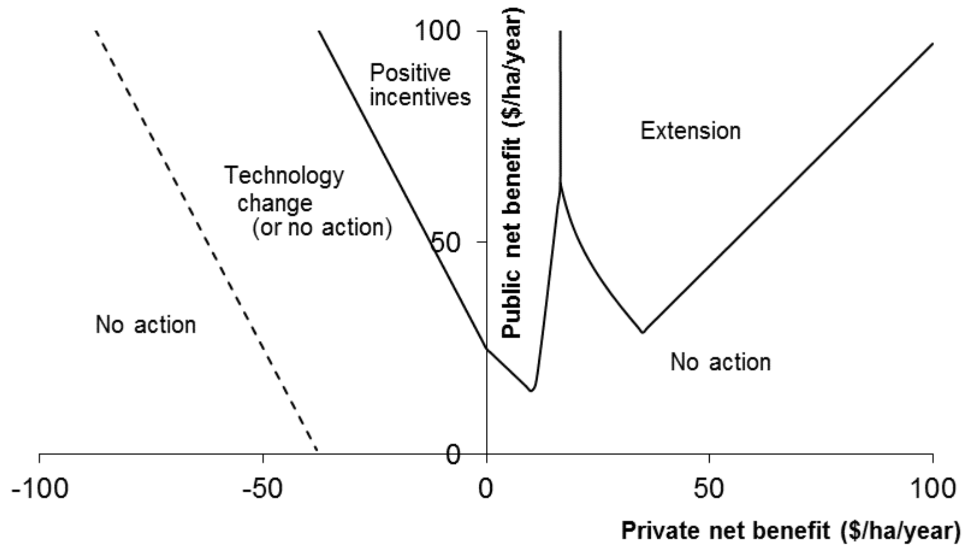

Figure 8. Revised map of efficient policy mechanisms allowing for adoption lags and learning costs, if positive incentives and extension require BCR ≥ 2.

Figure 9 shows the map for negative incentives, adjusted to account for learning costs, lags in adoption (in the absence of incentives) depicted in Figure 4, and based on the assumption that monitoring and enforcement costs the same as assumed for extension ($2.50/ha/year). The region where negative incentives yield a BCR ≥ 1 shrinks slightly, relative to Figure 2. The shrinking occurs mainly mainly because, with learning costs considered, landholders would not adopt changes with low private net benefits. (The private net benefits axis represents π_i but adoption depends on π_i - C_L.)

In almost a mirror image to the result for positive incentives, if we seek to apply negative incentives only in cases where the BCR is higher, it will be in cases where the public net costs are higher and/or the private net benefits are lower (see the BCR = 2 and BCR = 3 lines in Figure 9).

Technology Development

In this context, technology development means development of improved land management options, such as through strategic R&D, or participatory R&D with landholders. Training of landholders to improve their skills at implementing an existing land use would be treated similarly in the framework. Examples could include plant breeding and selection to generate new plant types that are both more profitable and environmentally beneficial, or farming systems research to test and improve management of the new plants in an agricultural context.

The reason for recommending technology development in the indicated areas of Figures 7 and 8 is that technology development may provide a cost-effective strategy to generate new technologies that yield positive net benefits overall. For example, technology development may improve the private net benefit of a project sufficiently to move it to the right, into the area for extension, or even no action. If the current project is in area A, such a move to the right would reduce the cost of payments to landholders (or the cost of compliance by landholders), potentially to zero. For further explanation, see Pannell (2009).

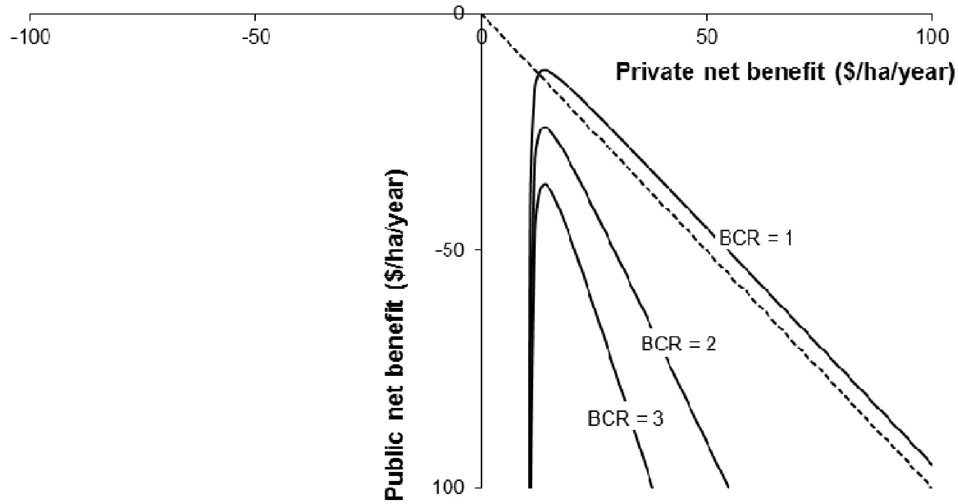

Figure 9. Benefit:cost ratios from use of negative incentives, allowing for adoption lags.

The merits of technology development as a strategy for the indicated set of projects depends on a set of additional factors that cannot be illustrated on this diagram, including: the likelihood of R&D delivering sufficiently improved technologies, the time lag until delivery of improved technologies, and the cost of the R&D. Overall, R&D does have an outstanding track record of delivering improved technologies for agriculture, but it has received little attention as a strategy for investment in environmental programs.

Of course, the potential role of technology development would not be limited to the indicated areas; it could be an option in any part of the diagram, depending on the opportunities and the costs. Given the past neglect of technology development as a strategy, there may be unexploited opportunities for cost-effective investment.

Modified Framework

Combining the refinements presented above, Figure 10 shows the modified framework, based on environmental managers requiring a BCR of at least 2.0 in order to invest in incentives or extension. This relatively high threshold BCR is used in this illustrative example in recognition that program resources are limited and that budgets are often insufficient to fund all worthwhile projects, and also in recognition of the need for benefits to outweigh the overhead costs of running the program. Broadly speaking, the higher priority projects for incentives and extension are those where private net benefits net of learning costs are closer to zero, and/or public net benefits are more extremely positive or negative.

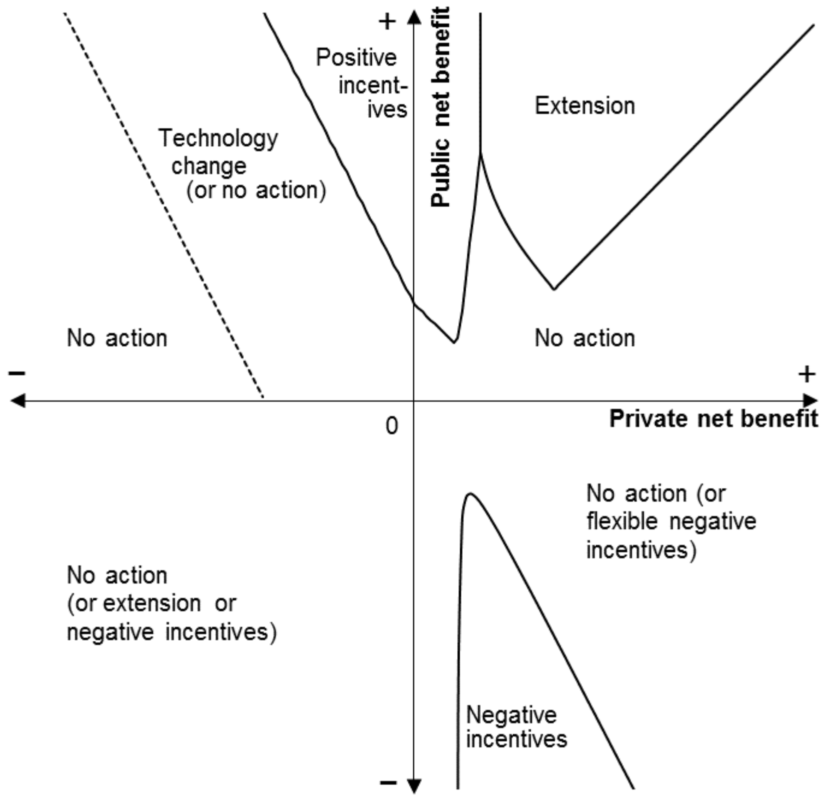

Figure 10. Efficient policy mechanisms for encouraging land use on private land, refined to account for lags to adoption and learning costs, and assuming that managers require BCR ≥ 2.0.

Sensitivity analysis

There are many opportunities for further work to enhance the framework. These include quantitative estimation of the following factors: the relationship between the private net benefits from adoption of new land uses, and the time lag to their adoption in the absence of intervention; the learning costs involved in adopting new land uses; the cost of extension per unit area of relevant land; the transactions costs of implementing different policy tools; and the cost of monitoring and enforcement when incentives are used.

As an initial step towards this, Table 3 shows results from sensitivity analysis to test the impacts of a number of parameters on results. As key parameters are varied, there are changes in the areas of Figure 10 for which positive incentives, negative incentives or extension are recommended. The table shows the percentage changes in those areas, within bounds of Figure 10, for specific parameter changes.

In general, the parameter changes investigated have only small to moderate impacts on the number of projects for which incentives would be recommended. Three of the six parameters have substantial influences on the number of projects for which extension would be recommended. These results reinforce the importance of undertaking further investigations into the actual values of these parameters, especially for recommendations about the use of extension.

Table 3. Results of sensitivity analysis.

Parameter	Change	Effect on area for which policy tools recommended (% change from Figure 10)		
		Positive incentives	Negative incentives	Extension
Cost of learning, equation [1] (C_L) ($/ha/year)	10 to 5	17	0	4
Adoption curve parameter, equation [2] (k)	50 to 75	10	-15	67
Discount rate, equation [3] (r)	0.05 to 0.075	10	-14	87
Transaction cost of positive incentives, negative incentives or extension (C_T) ($/ha/year)	2.5 to 1.5	6	8	111
Reduced adoption lag due to extension (years)	2 to 3	0	0	-13

VI. DISCUSSION

Targeting

Figure 10 has strong implications for the targeting of positive incentives, negative incentives and extension. If they are to generate substantial net benefits, these instruments need to be carefully applied to projects that fall in the indicated areas. This presumes that there are, in fact, projects available within those areas. If not, then the use of these policy instruments is not appropriate.

It is notable that the areas for positive incentives, negative incentives and extension are small sub-sets of the total. A project chosen at random has only a small chance of falling into any one of these areas. Environmental managers need to take care to ensure that they are not applying these mechanisms to inappropriate projects. There seems a high risk of this unless they have very good information about both the public and private net benefits, or use a mechanism that reveals this information. In applying the framework to case studies in Australia, I have commonly found that funding under the National Action Plan for Salinity and Water Quality has been offered as grants to landholders (i.e. positive incentives) or used to fund extension to encourage projects that lie in the "Technology development (or no action)" area. The consequence has been low levels of land-use change, and failure of the program to meet its environmental targets.

A well designed conservation auction should identify any projects that do fall into the positive incentives area of the graph, because it will find projects that offer the highest cost-effectiveness. However, the possibility that even the best available is not good enough should be considered.

In my experience, environmental managers do try to consider the environmental (public) benefits of their funded works, but often neglect the private benefits and costs. This framework reveals that the selection of cost-effective environmental projects is perhaps even more sensitive to private net benefits than to public net benefits.

A notable implication from the framework is that projects are more likely to generate high payoffs to investment in positive incentives, negative incentives or extension if the private net benefits are reasonably close to zero. If they are close to zero, land-use change can be prompted with small incentives, or can be prevented at low cost, or extension can accelerate the adoption of practices that would not otherwise be adopted quickly.

Property rights

The recommendation of "No action" in the lower-right quadrant of Figure 10 is predicated on the current distribution of property rights. For example, if the rights rest with the landholders, under a "No action" strategy, they would be free to adopt the new land management practices and reap the available benefits, in the process generating more benefits for themselves than the costs they generate for others. The latter point means that those affected by externalities would be unwilling to fully compensate landholders for not polluting. On the other hand, if the rights rest with the public, "No action" implies that landholders would need to pay for the right to pollute, and the relative magnitudes of net benefits mean that they would be prepared to do so.

The government could potentially choose to re-allocate the rights for any project with negative public net benefits (e.g. from landholders to the public), but this would not alter the environmental outcomes compared to "no action": for projects in the lower-left quadrant, landholders would not choose to adopt the new practices irrespective of the distribution of property rights (as private net benefits are negative), while for projects in the lower-right no-action area, landholders would proceed with the projects under either distribution, including compensation to the public if necessary. (However, altering the distribution of rights would alter the distribution of wealth for some projects, and may affect the costs required for monitoring and enforcement.)

Thus using property rights allocations to manage the environment is a relatively flexible approach, in that it allows external effects to be felt by landholders, while leaving the ultimate decisions to them. The landholders can therefore weigh up whether the private net benefits outweigh the public net costs when reaching their management decisions. That is why the lower-right no-action area includes the subheading "or flexible negative incentives". Other flexible mechanisms include tradeable pollution permits, pollution taxes, subsidies and conservation auctions.

If a less flexible mechanism, such as command-and-control regulation, is used to prohibit projects with negative public net benefits, there would probably be significant net costs in the lower-right "No action" area of Figure 10. Landholders would be prevented from undertaking projects that would yield relatively large net benefits to themselves and relatively small net costs to the public.

Estimating Net Benefits

It is notable that the choice of policy response depends at least as much on the level of private net benefits from the land-use change as on the public net benefits (e.g., Figure 10). This is an important finding, particularly as some environmental managers focus predominantly on the public benefits, but pay little attention to the estimation of private net benefits. As a consequence, they are under-informed about the landholders' likely responses to any proposed changes in land use, which is one of the key factors that should influence the choice of policy response.

This begs the question, how should environmental managers estimate these costs and benefits? In the case of public net benefits, the framework does not require much additional effort from environmental managers. They are already choosing which environmental projects are of highest priority, so there must be some assessment of environmental benefits, even if only implicitly. Projects may not necessarily be ranked according to their environmental benefits with great precision, but even relatively qualitative ratings could be applied within this framework. If further precision is desired, a range of market or non-market valuation methods may be appropriate, depending on the types of benefits and costs being considered (e.g. Smith, 1996; Bennett and Blamey, 2001; Brent, 2006; Kanninen, 2007).

To estimate private net benefits, options include investing in economic modelling, surveys of farmers or farm advisers, or even simply observing farmers' current management practices (useful for those land uses whose adoption has reached a plateau). A further option is to run a conservation auction, in which landholders reveal their willingness to act in response to a subsidy level chosen by them (e.g. Latacz-Lohmann and Van der Hamsvoort, 1997; Stoneham et al., 2003; Cason and Gangadharan, 2004; Kirwin et al., 2005). Higher net private benefits would tend to arise where the opportunity cost of the management change is lower, the transition costs are lower, the new management options generate a higher income or are less risky, or the land manager obtains greater personal satisfaction from the resulting environmental benefits.

VII. CONCLUSION

In the selection of policy mechanisms to influence the management of land in order to enhance environmental or natural resource outcomes, it is important to consider the relative levels of public (external) and private (internal) net benefits from the proposed land management practices. Depending on their relative levels, it may be appropriate to use positive incentives, negative incentives, extension, technology development, or no action.

The framework highlights the importance of targeting funds in environmental programs to selected areas, based on the levels of public and private net benefits. In particular, the framework developed in this study indicates that particular mechanisms should be used as follows:

- positive incentives where public net benefits are highly positive and private net benefits are close to zero;
- negative incentives where public net benefits are highly negative and private net benefits are slightly positive;
- extension where public net benefits are highly positive and private net benefits are slightly positive;
- technology development where private net benefits are negative, but not too negative, and public net benefits are positive; and
- no action where private net benefits outweigh public net costs, where public and private net benefits are both negative, where private net benefits are sufficiently positive to prompt rapid adoption of environmentally beneficial activities, or where private net costs outweigh public net benefits (provided that technology development is not sufficiently attractive).

When considering mechanism choice and the targeting of investments, environmental managers should equally consider the levels of public and private net benefits.

References

Aidt, T. S. T. S. and J. Dutta. 2004. "Transitional Politics: Emerging Incentive-Based Instruments in Environmental Regulation." *Journal of Environmental Economics and Management* 47 (3): 458-79.

Barrett, C. B., K. Brandon, C. Gibson, and H. Gjertsen. 2004. "Locating Tropical Biodiversity Conservation Amid Weak Institutions." Bioscience 51 (6): 497-502.

Bennett, J. and R. Blamey. 2001. *The Choice Modelling Approach to Environmental Valuation*. Cheltenham: Edward Elgar.

Brent, R.J. 2006. *Applied Cost-Benefit Analysis*. Cheltenham: Edward Elgar.

Bruneau, J. F. 2004. "A Note on Permits, Standards and Technological Innovation." *Journal of Environmental Economics and Management* 48 (3): 1192-9.

Cason, T. and L. Gangadharan. 2004. "Auction Design for Voluntary Conservation Programs, *American Journal of Agricultural Economics* 86: 1211-1217.

Center for Food Safety. 2006. *Genetically Engineered Crops and Foods: Regional Regulation and Prohibition*. Washington D.C.: Center for Food Safety. http://www.centerforfoodsafety.org/pubs/Regional_Regs_Chart_6-2006.pdf (accessed 20 March 2007).

Gjertsen, H. and C. B. Barrett. 2004. "Context-Dependent Biodiversity Conservation Management Regimes: Theory and Simulation." *Land Economics* 80 (3): 321-39.

Hobley, M. 1996. *Participatory Forestry: The Process of Change in India and Nepal*. London: Overseas Development Institute.

Jensen, F. and N. Vestergaard. 2003. "Prices Versus Quantities in Fisheries Models." *Land Economics* 79 (3): 415-25.

Kabii, T. and P. Horwitz. 2006. "A Review of Landholder Motivations and Determinants for Participation in Conservation Covenanting Programmes." Environmental Conservation 33 (1), 11-20.

Kanninen, B.J. 2007. *Valuing Environmental Amenities Using Stated Choice Studies : A Common Sense Approach to Theory and Practice*. Dordrecht: Springer.

Kirwin, B., R.N. Lubowski and M.J. Roberts. 2005. "How Cost-Effective are Land-Retirement Auctions? Estimating the Difference Between Payments and Willingness to Accept in the Conservation Reserve Program." *American Journal of Agricultural Economics* 87 (5): 1239-1247.

Knowler, D. and B. Bradshaw. 2006. "Farmers' Adoption of Conservation Agriculture: A Review and Synthesis of Recent Research." *Food Policy* 32: 25-48.

Latacz-Lohmann, U. and C. Van der Hamsvoort. 1997. "Auctioning Conservation Contracts: Theoretical Analysis and Application." *American Journal of Agricultural Economics* 79: 407-418.

Marsh, S.P., D.J. Pannell and R.K. Lindner. 2004. "Does Extension Pay? A Case Study for a New Crop, Lupins, in Western Australia."*Agricultural Economics* 30: 17-30.

Ostrom, E., J. Burger, C. B. Field, R. B. Norgaard, and D. Policansky. 1999. "Revisiting the Commons: Local Lessons, Global Challenges." *Science* 284: 278-82.

Pannell, D.J. 2004. "Heathens in the Chapel? Application of Economics to Biodiversity." *Pacific Conservation Biology* 10 (2/3): 88-105.

Pannell, D.J. (2009). Technology change as a policy response to promote changes in land management for environmental benefits, *Agricultural Economics* 40(1), 95-102.

Pannell, D.J., G.R. Marshall, N. Barr, A. Curtis, F. Vanclay and R. Wilkinson. 2006. "Understanding and Promoting Adoption of Conservation Practices by Rural Landholders." *Australian Journal of Experimental Agriculture* 46 (11): 1407-1424.

Productivity Commission 2004. *Impacts of Native Vegetation and Biodiversity Regulations*. Melbourne: Productivity Commission, Report No. 29.

Skonhoft, A., and J.T. Solstad. 1998. "The Political Economy of Wildlife Exploitation." *Land Economics* 74 (Feb.): 16-31.

Smith, V.K., 1996. *Estimating Economic Values for Nature: Methods for Non-Market Valuation*. Cheltenham: Edward Elgar.

Stoneham, G., V. Chaudhri, A. Ha and L. Strappazzon. 2003. "Auctions for Conservation Contracts: An Empirical Examination of Victoria's BushTender Trial." *Australian Journal of Agricultural and Resource Economics* 47: 477-500.

Weitzman, M. L. 2002. "Landing Fees vs Harvest Quotas with Uncertain Fish Stock." *Journal of Environmental Economics and Management* 43 (2): 325-38.