

# Environmental Markets and Landholders: Property Right Allocations when there is Economies of Scope in Provision

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## 1.0 Introduction

Many environmental problems including nature conservation, water quality and land degradation are due to the production and consumption decisions made by a range of agents in the economy. Water quality, for example, is influenced by the waste management practices of public and private enterprises and by the land-use practices of landholders in water catchments. These agents are typically categorised as either point-source or diffuse emitters of pollution. The contribution of these agents to pollution varies from site to site. For example, diffuse sources contribute ninety per cent of total nitrogen load exported to the Gulf of Mexico (Doering et. al. 1999) whereas in Port Phillip Bay Australia, the contribution of point and diffuse-source emissions is shared equally (Argent and Mitchell 1998).

Acting in their own interests, agents make choices that meet private goals but may fall short of society's expectations about the environment. This problem is not new and policy makers have employed a range of mechanisms including education and awareness programs, legislation and planning, input subsidies and tax incentives to address them. More recently, there has been interest in applying market-based mechanisms to environmental problems including tradable emission permits (see Tietenberg 1985) and auctions of conservation contracts (see Latacz-Lohmann and Van der Hamsvoort 1997). This has occurred for two reasons. The first is that economists now understand much more about missing markets and have developed mechanisms to deal with asymmetric information problems where they exist (see Myerson 1999). The second is that there is a much higher probability that environmental scientists and engineers can provide the information needed to make market-based approaches viable.

If a complete set of markets for environmental goods and services were to be developed, there could be a number of important institutional problems concerning the interaction of point-, and diffuse-, source emitters. One of these problems relates to the situation where an action by a diffuse source (for example, a landholder) could provides multiple benefits, in other words, there is economies of scope in provision. Heaney, Beare and Bell (2000) have estimated the impact of one land management action — planting trees<sup>1</sup> — on the rate of land degradation due to salinisation, the volume of runoff water into water catchments used for irrigation and the impact on in-stream salinity. The introduction of trees could also influence carbon sequestration, nutrient movement, and in some cases improve the supply of habitat. Hampicke and Roth (2000) state that farmers are “joint producers of private commodity goods...and of public goods associated with the countryside and conservation”.

In his seminal article, Coase (1960) argued that when property rights were well defined and transaction costs were zero, private agents would efficiently bargain to solve an externality problems. Further, given zero transaction costs, the manner in which property rights were defined affected the distribution, but not the level, of economic-surplus gains. Subsequently, economists have found certain conditions under which the distribution of rights amongst agents does matter. For example, Hahn (1984) examined the effect of market power on tradable permits. He showed that the allocation of tradable permits will affect their subsequent utilization, and hence the efficiency of the relevant market. Anderson (1991) buttressed Hahn’s result in the case of market power in a fisheries tradable quota system.

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<sup>1</sup> Trees increase evapo-transpiration and reduce accessions to groundwater.

Generally however, these papers have focused on the allocation of one sort of right (a fishing quota, or an emissions quota, etc.) amongst multiple agents. They have not focused on the allocation of property rights when one action produces two different goods (economies of scope). Economies of scope, and its effect on the nature of equilibrium, has been extensively analysed by Baumol, Panzar and Willig (BPW, 1988). Yet their analysis—which is mostly in terms of two goods—assumes that both goods are sold into competitive private markets.

In this paper a simulation model is used to examine the question of how property right structures affect policy outcomes when one action produces both a private good, and a public good. Briefly, a tradable permits market is added to the Latacz-Lohmann and Van der Hamsvoort (1997) model of auctions for conservation contracts to provide an analytical framework encompassing a more complete set of environmental markets. This hypothetical economy is then used to explore the implications of economies of scope in environmental good provision and the ensuing property right questions that policy-makers would need to consider.

## **2.0 The market for environmental goods and services**

There are three players in our model. *Landholders* provide services that produce three goods: agricultural output; biodiversity and mitigation of pollution (emissions). Each landholder decides on the amount of land allocated to agriculture, biodiversity and mitigation. We assume that they can produce biodiversity and mitigation jointly; there is economies of scope in provision. Although we focus on an example using

biodiversity and mitigation, our model could represent other public-to-private good interactions, such as salinity-to-carbon sequestration.

*Point source emitters* (PSEs) operate in the first instance within in a tradable emissions market for which there is a legislated cap on aggregate emissions and individual firms hold property rights to pollute (see Tietenberg 1985). We assume that point source emitters express their willingness to pay and willingness to supply mitigation as a formal demand and supply curves for abatement and pollution respectively. Point source emitters can also buy mitigation from landholders where it is offered at competitive prices. Therefore, if PSEs can buy offsets to pollution (ie, mitigation) at a relatively cheap price then they can reap a ‘consumer surplus’ from trade. Point source emitters would buy mitigation from landholders in order to expand production beyond the constraint imposed by the legislated cap.

We assume that the *agency* targets biodiversity as a public good. It does this using an auction mechanism advocated by Latacz-Lohmann and Van der Hamsvoort (1997). In other words, the agency calls for a certain amount of biodiversity from farmers. Each farmer decides on the price at which he is willing to offer up land—away from agriculture—towards biodiversity. For example, land might be allocated to the conservation of native vegetation (flora), and the provision of habitat for native fauna. When the agency buys biodiversity, it may receive—as a byproduct—mitigation. For example, if a farmer takes a unit of land out of agricultural production, this reduces his total volume of fertiliser and herbicide use. This, in turn, reduces the runoff of these substances into a stream. We use a model of this environmental market to consider two approaches to the allocation of property rights. First, the agency takes possession of any mitigation it receives through the purchase of biodiversity; the

‘agency property right’ case (APR). In APR, the agency buys biodiversity and receives some mitigation as a by-product. Farmers effectively sell one environmental good in this scheme: biodiversity. That is, they never ‘own’ the mitigation that they produce. Hence farmers analyse the agency’s request for land to biodiversity, and then bid based on their forgone agricultural profit.

Second, the agency allows farmers to sell mitigation directly to point-source emitters; the ‘farmer property right’ case (FPR). In FPR, farmers first look at the relative returns from agriculture and mitigation, decide on the amount of land to allocate to both, and hence decide on the output of both goods. Then, the agency calls for the allocation of land to biodiversity. Farmers consider what bid to put into the auction, given their joint agriculture-plus-mitigation profits.

FPR implies that farmers have information about the quantity of *mitigation* they provide through the allocation of land to biodiversity. This may not be the case if the agency uses some sophisticated central process (like hydrological modelling) to determine mitigation effects. The case where farmers don’t have this information could be seen as the situation in APR.

We use simulation to analyse the effect—on economic surplus—of the different property rights structures (APR versus FPR). We consider the economic surplus outcomes in the light of agency incentives. Since the agency effectively works as a market player for mitigation its incentives may not align with that of economic efficiency. This has interesting implications for institutional design.

In Section 3 we present our model. In Section 4 we give the results followed by a brief discussion. In Section 5 we provide a summary, and point to some areas for further research.

### 3.0 Model

We explain our model in three parts. In Section 3.1 we do two things: first, we consider the base case (where there are no environmental schemes operating) from the perspective of all three players; second, we analyse each farmer's bidding strategy in a biodiversity auction. We analyse each farmer's bidding strategy because in both schemes—APR (Section 3.2) and FPR (Section 3.3)—the agency uses an auction to buy biodiversity. We provide information about our measures of economic surplus throughout, which we then use in Section 4 to examine results.

#### 3.1 The Base Case

Initially, we assume that farmers produce agricultural output,  $q_a$ , to maximise profit. Each farmer's skill level is denoted by  $A$  and he allocates,  $V_a$ , land to agricultural production. The price of agricultural output,  $P_a$ , and the rental price on each unit of land,  $w$  are exogenously determined. The production function is assumed to be concave of the form:

$$q_a = AV_a^t \tag{1}$$

where  $t \in (0,1)$  is a parameter defining the agriculture-wide state of technology. The profit derived from using the profit-maximising amount of land  $V_a^*$  is given by  $\pi_0$  :

$$\pi_0 = P_a A (V_a^*)^t - w V_a^* \tag{2}$$

This is a farmer's profit in the absence of any environmental schemes, and it will serve as our reference point—in terms of farmer surplus—when we introduce environmental policies. Neither the agency nor PSEs derive any surplus beyond the competitive market equilibrium prior to the introduction of the environmental scheme. Hence, both the agency and PSEs' gain is measured from a base of zero.

### Farmers' Bidding Strategies in an Auction

A farmer always bids, in an environmental auction, according to his forgone profit ( $\pi_f$ ). In APR, the farmer does not own mitigation, and hence he bids according to forgone agricultural profit. By contrast, in FPR the farmer considers forgone profit from two outputs: agriculture plus mitigation. The farmer owns mitigation and bids according to forgone profit, agriculture plus mitigation, since if he does not bid, he could still produce two goods. For the latter, land is—in BPW parlance—a 'public input' in that it can be transferred to biodiversity without altering mitigation output (up to a point)<sup>2</sup>.

Latacz Lohmann and Van der Hamsvoort (1997) derive optimal bidding strategies for (say) a farmer in two cases (i) where he is risk neutral; and (ii) where he is risk averse. In this paper, we follow their approach, and assume that each farmer is risk neutral<sup>3</sup>. Hence a farmer's optimal bid price  $p^*$ , is:

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<sup>2</sup> BPW defined public inputs as inputs that "...once they are acquired for use in producing one good, they are available costlessly for use in the production of others" (p. 76).

<sup>3</sup> Even though some authors—such as Bond and Wonder (1980) and Quiggin (1981)—have argued that farmers are risk averse, Latacz-Lohmann and Van der Hamsvoort found that this assumption did not affect their modelling results.



$$p^* = \max\left(\frac{\pi_f + \bar{p}}{2}, \underline{p}\right) \quad (3)$$

$$s.t. \quad p^* \geq \pi_f$$

where farmers have an expectation about the maximum acceptable bid price,  $\bar{p}$  and the minimum acceptable bid price,  $\underline{p}$ . Equation (3) says that each farmer's bid is a linearly increasing function of his profit forgone, and the expected bid cap. The constraint states that a farmer's bid price will never be below his profit forgone.

In our model, we assume that farmers expectations of the distribution of farmers' average profit forgone of the program is the same for all farmers (see Section 4).

### **3.2 The Agency Property Right (APR) Model**

In this section we consider the case where the agency has the property right to mitigation provided by farmers. Modelling the level of mitigation associated with different land-use changes is assumed to occur centrally (an agency) due to high costs and specialised technical requirements.

There are several reasons why the agency may retain the right to sell mitigation. First, the community may perceive farmers as part of the polluting group, and giving them the right to mitigation could be seen as unfair; why should those who have contributed to the problem, then be allowed to profit from its alleviation?

Second, the agency may envisage that when it pays for biodiversity, mitigation has come at zero marginal cost to the farmer, and therefore, that the farmer has no logical right to it.

## Ecosystem Services in APR, Biodiversity Auction in APR

### **Biodiversity**

We assume that in the auction, the agency targets a land for allocation to biodiversity, denoted  $B$  (we comment on the effect of relaxing this assumption in Section 4). We assume that the value of biodiversity is difficult to measure, and hence the government takes a safe minimum standard approach<sup>4</sup>: it sets the physical target for biodiversity ( $B$ ), and minimises the cost of achieving this target.

The agency calls for bids from farmers to provide biodiversity services and visits each expression of interest (site) to determine the units of land that would be useful from the agency's biodiversity perspective, denoted  $V_b$ . The agency writes a contract against  $V_b$  and any related management commitments for successful farmers (bids).

The biodiversity value of different land units will vary by location, species etc. The agency gives land allocated to biodiversity a score, which we denote  $b \in [1,100]$ . This value denotes the payoff received by the agency—in biodiversity change units—if the farmer were successful in his bid. The farmer considers their new profit if they were to allocate the land to biodiversity:

$$\begin{aligned} \pi_o^{new} &= P_a A(V_a^{new})^t - wV_T \\ \text{s.t. } V_a^{new} &= V_T - V_b \end{aligned} \tag{4}$$

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<sup>4</sup> For a discussion on the use of safe minimum standards see Bishop (1978).

where  $V_T$  is total land, and  $V_a^{new}$  is the land left for agriculture after the farmer has allocated  $V_b$  to biodiversity<sup>5</sup>.

Each farmer will bid according to (3):

$$p^* = \max\left(\frac{[\pi_0 - \pi_0^{new}] + \bar{p}}{2}, \underline{p}\right) \quad (5)$$

$$s.t. \quad p^* \geq \pi_0 - \pi_0^{new}$$

The agency arranges farmers' bids from highest to lowest according to a biodiversity benefits index (BBI),  $BBI = \frac{b}{p^*}$ . The agency chooses bids such that—when ranked

from highest to lowest—they provide,  $\sum_i b_i = B$  where  $i$  refers to a particular farmer's

bid. If successful, a farmer's post-auction profit would be:

$$\pi_1 = \pi_0^{new} + p_s^*$$

where  $p_s^*$  is a successful bid price. The equation says that a successful farmer would receive his agricultural profit, plus his (accepted) bid price.

### **Pollution Mitigation**

The above model is effectively that given by Latacz Lohmann and Van der Hamsvoort (1997). However, in our model the allocation of land to biodiversity also provides mitigation. As a farmer takes land out of agriculture and puts it into biodiversity this affects the amount of agricultural production, and hence reduces

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<sup>5</sup> We assume that land is fixed for the farmer given his  $A$  parameter.  $V_T$  here is equal to  $V_a^*$  from (2).

damage. We assume that the damage,  $D$ , caused by agriculture has an increasing marginal effect<sup>6</sup> for each farmer:

$$D(V_a) = BV_a^\gamma \quad (\gamma > 1)$$

where  $B$  and  $\gamma$  are parameters.

$B$  captures the specific circumstances of the farmer, for example, whether he is near a river, or close to an important conservation resource, etc.  $\gamma$  is a sector-wide parameter. Assuming that  $\gamma > 1$  gives the damage function its increasing marginal effect.

We call a reduction in pollution ‘mitigation’, denoted by,

$$q_m = D(V_T) - D(V_a^{new}) \quad (6)$$

The maximum reduction in output (and damage) for any farmer is bounded by his pre-policy output (and damage) level:  $\max(q_m) = D(V_T)$

An agency running an auction for biodiversity will receive mitigation as a by-product. If there is an effective mitigation market in progress, then the agency can sell mitigation units into the market, and recoup some of its biodiversity cost<sup>7</sup>.

The agency’s aggregate supply of mitigation will equal the sum of all mitigation it picks up from the biodiversity auction. We can write this as:

$$Q_m^s = \sum_i q_{m,i}$$

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<sup>6</sup> The damage function is increasing as land used for mitigation increases.

<sup>7</sup> Remember that we are assuming the agency has centralised information that it does not reveal to anybody else.

We assume that PSEs' demand for mitigation is of the form:

$$Q_m^d = \delta + \lambda P_m$$

where  $Q_m^d$  is the aggregate demand for mitigation,  $P_m$  is the price of mitigation and  $\delta, \lambda$  are parameters. In this situation the price is set passively by the intersection of the (perfectly inelastic) supply curve, and the demand curve formed by PSEs' willingness to pay for mitigation. The equilibrium values for quantity and price are denoted as  $Q_m^*$  and  $P_m^*$ , respectively.

#### Farmers in APR

After the auction, a successful farmer's net surplus position—relative to the pre-policy situation—is given by:

$$F_i = \pi_1 - \pi_0 \quad \text{for the } i^{\text{th}} \text{ farmer}$$

Since there are diminishing returns to land—as the farmer spreads his fixed level of human capital over a larger and larger area—the marginal profit per unit of land declines. The agency requests a piece of land,  $V_{bl}$ . The farmer analyses this request in the context of his agricultural production. His bid is a linear function of forgone agricultural profit. To the extent that the farmer can bid above his forgone profit and be successful in the auction, he will be able to make 'information rents'. However, the farmer realises that a higher bid lowers his probability of being successful.

Unsuccessful farmers default back to agricultural production on their whole farm, therefore, for these farmers  $V_T = V_a^*$ , and profit is given by  $\pi_0$ . Hence for

unsuccessful farmers  $F_i = 0$ . Aggregate farmer surplus is the sum of every individual farmer's surplus. For these farmers, aggregate change in surplus is given by:

$$F_s = \sum_i F_i$$

### The Agency in APR

The agency's surplus,  $A_s$ , is determined by  $C(B)$ , the cost of achieving the biodiversity cap,  $B$ , and the revenue that the agency receives from selling any mitigation. The total cost to the agency of achieving the biodiversity target is equal to

$$C(B) = \sum_i p_{si}^*$$

where  $p_{si}^*$  denotes a successful bid price for the  $i$ th farmer.  $C(B)$

ignores transaction costs. The agency's surplus is given by:

$$A_s = Q_m^* P_m^* - C(B) \tag{7}$$

the revenue from the sale of mitigation less the cost of the biodiversity bids. Below, when we compare the two property right structures—APR and FPR—we hold the biodiversity target constant at  $B$ .

### PSEs in APR

For PSE's the benefit of APR is determined by the difference in their willingness to pay for mitigation, versus the equilibrium mitigation price. In other words it is a standard consumer surplus calculation. For the linear case we have described this is given by:

$$PSE_s = [(-\delta / \lambda) - P_m^*] \times Q_m^* \times 0.5 . \tag{8}$$

## Total Surplus in APR

We can now state how the efficiency of different property right allocations may be calculated. Total surplus,  $TS$ , is calculated as:

$$TS = A_S + F_S + PSE_S \quad (9)$$

Equation (9) is the general form of our surplus calculations in both APR and FPR. However, in the two schemes, the cost of biodiversity,  $C(B)$ , and the price and quantity of mitigation— $P_m^*$  and  $Q_m^*$  respectively—will vary due to the incentives faced by farmers. We now turn to FPR to examine exactly how farmers incentives are altered.

### **3.3 The Farmer Property Right (FPR) Model**

In the above model, the agency buys biodiversity, takes any mitigation that is provided in the process, and sells it to PSEs who value mitigation offsets. In other words, the agency owns the property right to mitigation.

However, an alternative model is one where farmers know exactly how much mitigation any given action would provide, and can therefore sell it directly to PSEs.

Prior to considering a scheme where farmers play jointly in a mitigation and biodiversity market, we consider the case where a mitigation market operates independently of a biodiversity market.

#### The Mitigation Case

Given our assumption above—that the quantity of mitigation is a function of the reduction in agricultural production—it is clear that each farmer will compare the

relative returns from land allocated to agriculture, to the return that he can get from reducing production and recouping a price for each mitigation unit. In doing so, a farmer will take the price of mitigation as constant. Therefore, each farmer will maximise:

$$\pi_2 = P_a q_a + P_m q_m - wV_T. \quad (10)$$

The farmer will compare the marginal benefit from increasing mitigation to the marginal cost of increasing mitigation. Hence the farmer moves to where the marginal benefit of mitigation equals the marginal cost of mitigation:

$$\frac{\partial D}{\partial V_{am}} P_m = \frac{\partial q_a}{\partial V_{am}} P_a \quad (11)$$

where  $V_{am}$  is the land dedicated to agriculture in the mitigation scenario. The solution of (11) is given by:

$$V_{am}^* = \left( \frac{P_a t A}{P_m \gamma B} \right)^{\frac{1}{\gamma-t}} \quad (12)$$

which is a direct comparison (ratio) of the relevant benefits from agriculture, to those of mitigation. Note that the price of land,  $w$ , is excluded from (12) since the farmer takes his amount of land as fixed when deciding to allocate between agriculture and mitigation.

The land allocated to mitigation is the land leftover after calculating the optimal agricultural allocation:  $V_m^* = V_T - V_{am}^*$ .

We can substitute (12) into (10) and find a farmer's new profit level as:



$$\pi_2 = P_a q_a (V_{am}^*) + P_m q_m (V_T - V_{am}^*) - wV_T. \quad (13).$$

The farmer makes a surplus in excess of the agriculture-only case, which is given by  $M_s = \pi_2 - \pi_0$

### The Joint Mitigation Plus Auction Scheme

We saw in APR that when entering the biodiversity auction, a farmer will base his bid on his change in agricultural profit. In the FPR model, a farmer's basis for bidding will be the profit he could have made from agriculture plus mitigation, from (13). Again, we assume that the farmer uses a risk neutral bidding strategy.

In FPR we assume that there is a two part process. First, each farmer decides on the amount of land that he would allocate to mitigation, using (12). Second, the farmer receives a visit from the agency that points out specific land units which could be allocated to biodiversity.

We assume that each farmer—after seeing the land that is valuable to the agency—would put this same land towards mitigation (take it out of production). This is rational from the farmer's point of view, since in a risk neutral bidding strategy, the farmer bids near, but not quite at, cost. Hence, by allocating the same land to mitigation and biodiversity, the farmer is more likely to be successful in the auction. Thus, the farmer has an incentive to jointly produce biodiversity and mitigation.

In a joint mitigation-plus-biodiversity situation, the agency may request either:

- An amount of land for biodiversity that is smaller than a farmer would have allocated to mitigation, where the agency requests  $V_{b2} < V_m^*$ .

- An amount of land for biodiversity that is larger than a farmer would have allocated to mitigation, where the agency requests  $V_{bl} > V_m^*$ .

If the agency requests an amount of land  $V_{b2}$ , that is less than  $V_m^*$ , a farmer can ‘costlessly’ transfer this land to biodiversity (if the land identified by the agency is the same land the farmer has committed to mitigation). This is the “*public input*” nature of the land allocated to mitigation - the farmer has capacity to use the land twice.

However, when the farmer is asked to provide more land to biodiversity than he already provides to mitigation, such as  $V_{bl}$ , he must divert land from agriculture.

The general expression for each farmer’s new profit level, contingent on  $V_b$  relative to  $V_m^*$ , is:

$$\pi_{amb} = \begin{cases} P_a q_a (V_{am}^*) + P_m q_m (V_T - V_{am}^*) - wV_T & V_b < V_m^* \\ P_a q_a (V_T - V_b) + P_m q_m (V_b) - wV_T & V_b > V_m^* \end{cases} \quad (14)$$

and so the expression for forgone profit is:

$$\pi_f = \pi_2 - \pi_{amb}$$

which can be substituted into (4) to give each farmer’s risk neutral bid price.

### Farmers in FPR

In FPR a farmer that is successful in the auction will receive his bid price,  $p_s^*$ , and hence his profits will be:

$$\pi_3 = P_a q_a + P_m q_m + p_s^* - wV_T \quad (15)$$

Farmers unsuccessful in the auction will choose  $V_{am}^*$  as per (12).

A successful farmer's change in surplus given by:

$$f_{FPR,S} = \pi_3 - \pi_0 \quad (16)$$

An unsuccessful farmer's change in surplus is:

$$f_{FPR,U} = \pi_2 - \pi_0 \quad (17)$$

which is the same as in the mitigation case. The aggregate farmer surplus in the FPR mitigation plus biodiversity policy— $F_{FPR}$ —is the summation of  $f_{FPR}$  across all farmers (both successful and unsuccessful).

### Agency and PSE Surplus in FPR

The basic form of the agency and PSE surplus is the same as in the APR situation (given by (7) and (8) respectively). However, in FPR each farmer chooses the amount of mitigation he sells, and this affects his bid price in the biodiversity auction. Hence, farmers react differently in FPR. Farmers' different strategies feed directly into the surplus of the agency by affecting the price the agency pays for biodiversity. The agency is also affected by the fact that it no longer sells mitigation (it does not receive mitigation revenue). Farmers' different strategies in FPR also affect PSEs by altering the quantity and price of mitigation. In the next section, we examine exactly how these factors play out to alter aggregate surplus from the two schemes.

## 4.0 Results

We ran a simulation model using an *Excel* spreadsheet. We will present the effect on economic surplus of the two property right structures that we have discussed throughout the paper: APR and FPR.

We ran our model using a range of parameter values. However, for brevity we present results that assume the price of agricultural output ( $P_a$ ) is constant and equal to two, the wage rate ( $w$ ) is also constant and equal to one, and the agriculture wide state of technology ( $t$ ) is constant and equal to 0.6. We assume that  $B$  is the same for all farmers and equal to unity (so that differences across farms are determined by their human capital parameter,  $A$ ). Each farmer calculates  $\bar{p}$  as the average forgone profit plus 40 per cent, and  $\underline{p}$  as the average forgone profit minus 40 per cent<sup>8</sup>. We discuss the results assuming different values for the ‘damage parameter’,  $\gamma$ : low (1.1), medium (1.3) and high (1.5)

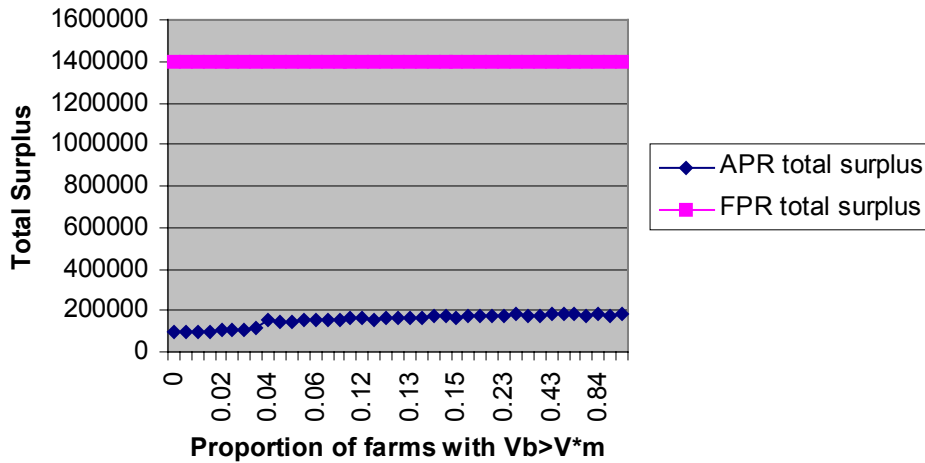
#### **4.1 Total Economic Surplus**

Given the above parameter values, total economic surplus is always greater in FPR. Assuming medium damage, total economic surplus is, on average, 3.4 times greater than under APR<sup>9</sup> (Figure 1). The distribution however varies across the players (see subsequent sections).

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<sup>8</sup> This is consistent with Latacz-Lohmann and Van der Hamsvoort (1997).

<sup>9</sup> (average FPR surplus - average APR surplus)/average APR surplus



**Figure 1: total surplus (medium damage)**

The reason the total surplus for FPR is generally greater becomes clear if we consider the nature of the two systems. In FPR, farmers are able to choose the profit maximising quantity of land to allocate to mitigation, given the mitigation price in the tradable permit market. When the agency holds the property right, the agency decides on the quantity of mitigation produced. Yet the agency does not consider market factors; the agency chooses the amount of mitigation only residually, or as a by-product its biodiversity demand. In APR, the agency under supplies mitigation. This result holds for most parameter values except for one special case, which is analysed in Section 4.6.

As long as the biodiversity auction is well designed, farmers are limited in their ability to ‘double dip’ in FPR: they are limited in their ability to charge twice for the use of their one piece of land. Under FPR, a farmer will maximise profit via his choice of mitigation and agriculture, given the price of mitigation in the tradable permit market. Given those units of land are also suitable for biodiversity, the farmer

can costlessly transfer that land to biodiversity<sup>10</sup>. A well designed biodiversity auction will enable the agency to force bids down towards zero (the farmer's opportunity cost). Hence, under FPR the agency will pay less for a given amount of biodiversity.

#### 4.2 Farmer Economic Surplus

The damage parameter ( $\gamma$ ) affects farmer surplus under the two property right regimes. Assuming that the damage parameter is high or medium ( $\gamma=1.5$  or  $1.3$ ), farmers are always better off under FPR. When damage is medium, farmers surplus is, on average, 6.08 times greater than APR (Figure 2).

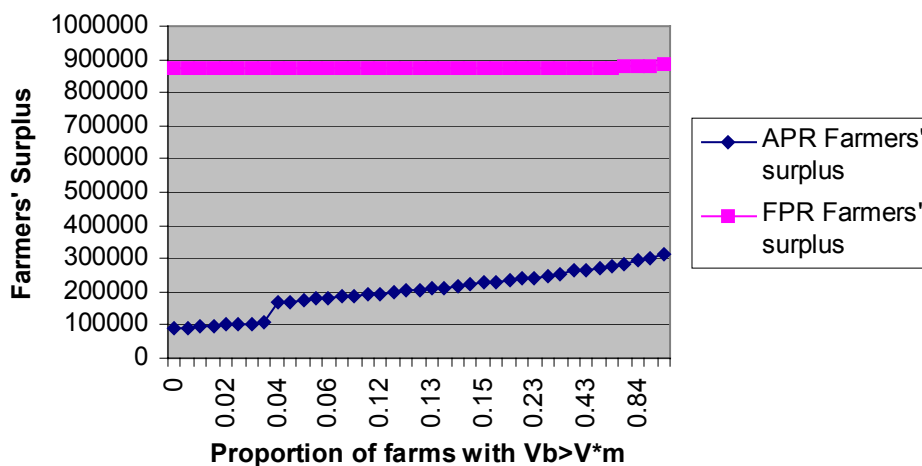
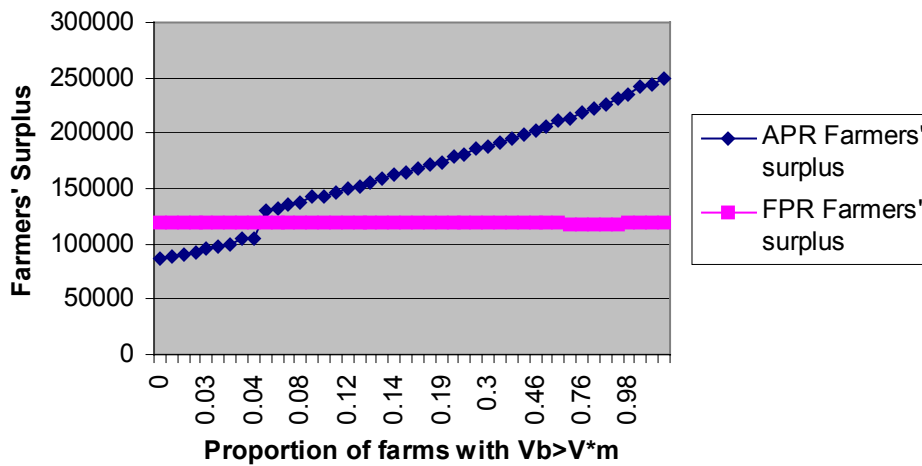


Figure 2: aggregate farmers' surplus (medium damage)

<sup>10</sup> In the model there are unilateral economies of scope not bilateral economies of scope. Therefore, not all land set-aside for mitigation will be suitable for biodiversity.

If the damage parameter is *low* ( $\gamma = 1.1$ ) then farmers are generally better off in APR, unless the proportion of farms where  $V_b > V_m^*$  is low—less than or equal to 4.1 per cent (Figure 3).



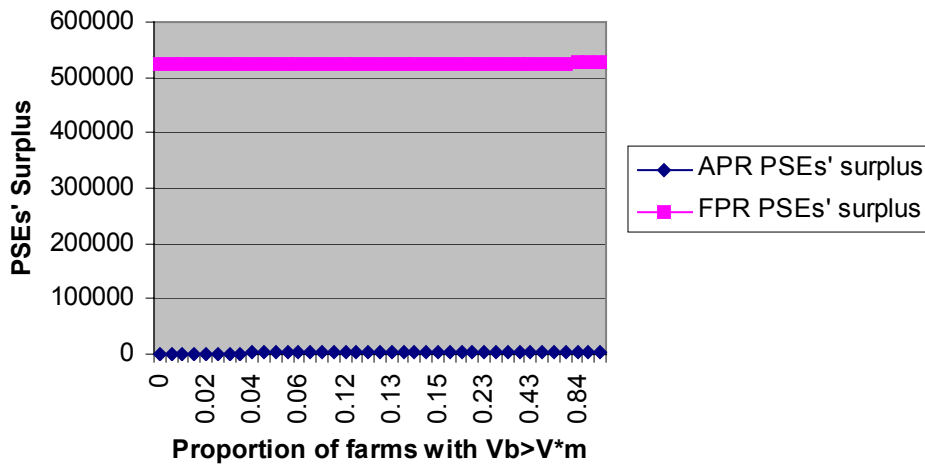
**Figure 3: aggregate farmers' surplus (low damage)**

Farmers' generally prefer FPR when the damage parameter is relatively high because FPR allows them to determine their profit maximising quantity of mitigation. If a farmer's agricultural production has only a small impact on pollution, then he is not able to supply much mitigation. Hence, the value of being able to choose his mitigation level (ie, FPR) is diminished; the inefficiency from the agency choosing the quantity of mitigation—as opposed to market factors—is reduced.

### **4.3 Point-Source Emitter Economic Surplus**

Point-source emitters always prefer FPR. When the damage parameter is medium, point source emitters surplus is, on average, 247 times greater under FPR (Figure 4).

Point-source prefer FPR because farmers, generally, supply more mitigation in FPR relative to APR. Hence, the price of mitigation is pushed down.



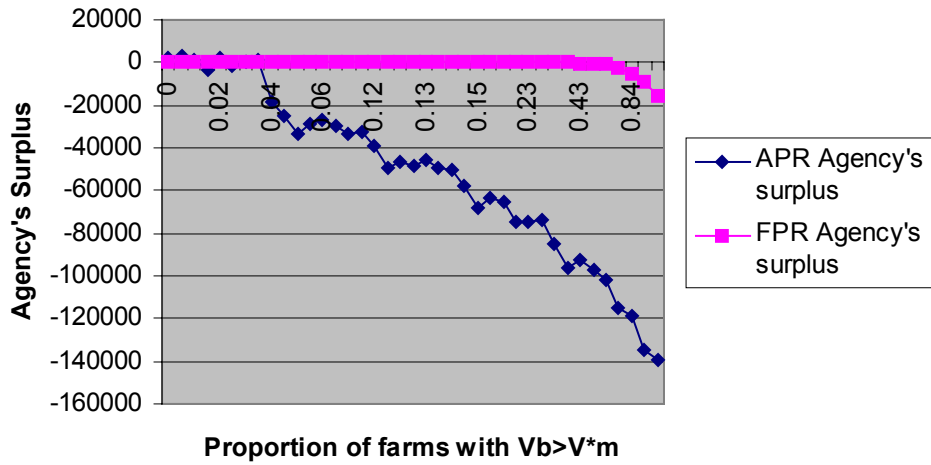
**Figure 4: aggregate PSEs' surplus (medium damage)**

#### 4.4 Agency Economic Surplus

The damage parameter has an important influence on agency surplus, and therefore the agency's choice of property right structure.

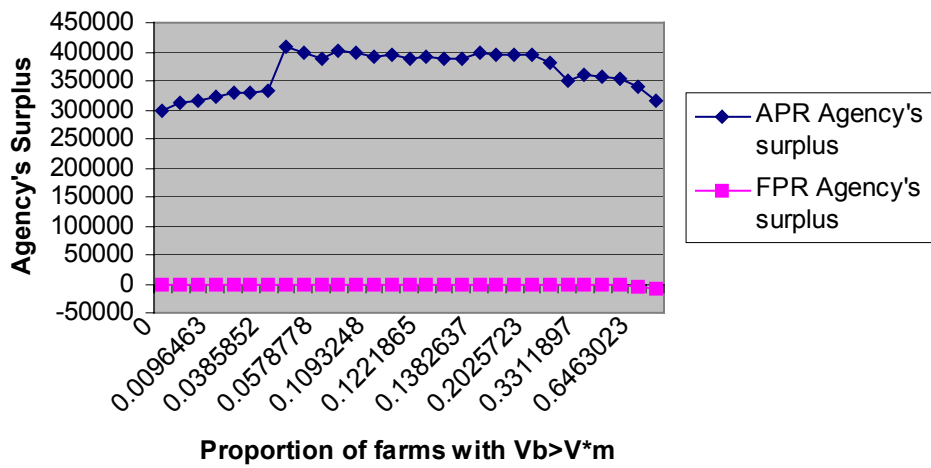
If the damage parameter is *medium*, then the agency generally prefers FPR. Figure 5 shows that when the proportion of farms where  $V_b > V^*_m$  is greater than 3.8 per cent, the agency surplus is greater under FPR.





**Figure 5: agency's surplus (medium damage)**

By contrast, if the damage parameter from agriculture is *high* ( $\gamma = 1.5$ ), then the agency always receives a larger surplus if it holds the property right (APR), as shown in Figure 6.

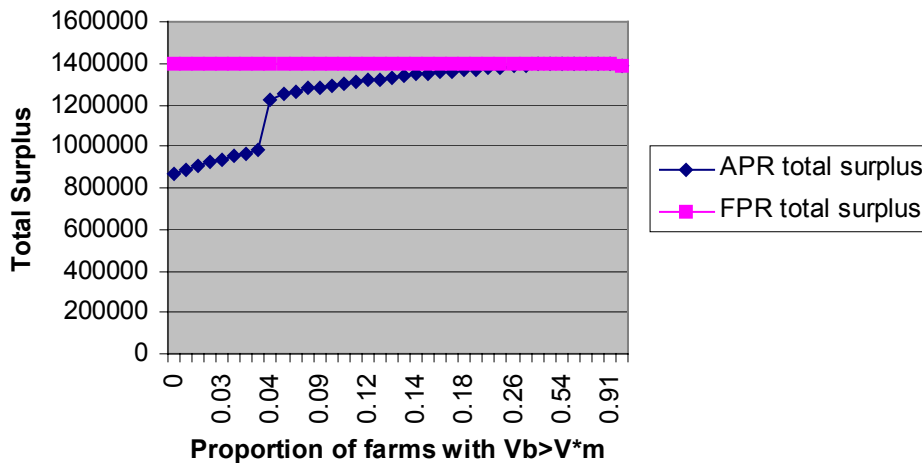


**Figure 6: agency's surplus (high damage)**

The agency gains a larger surplus if it holds the property right, as damage from agriculture increases, because this allows the agency to sell more mitigation credits into the tradable permit market. The agency uses these receipts to offset the cost of purchasing biodiversity. If damage from agriculture is lower, then the agency receives (and sells) less mitigation, hence it moves to a lower net-budget position.

#### 4.5 A Special Case

There is only one case in our model, that we know of, where the two property right structures will provide equal economic surplus gains (Figure 7). This special case has two requirements which must be satisfied when the agency holds the property right to mitigation. First, there is a large proportion of bids where  $V_b > V_m^*$ ; and second, the agency targets *all* the biodiversity available. Consider these in turn.



**Figure 7: total surplus in the special case**

If  $V_b < V_m^*$ , then we know that an individual farmer will provide more land to mitigation if he holds the property right as opposed to the agency. Yet he provides the

same amount of biodiversity in both schemes. If  $V_b > V_m^*$  however, then a farmer provides the same amount of mitigation and biodiversity in both property right structures. Therefore, when there is a large proportion of farms with  $V_b > V_m^*$ , the superiority of the farmer holding the property right—which is due to the fact that it usually provides more mitigation—is eroded.

The second requirement is that the agency must target *all* biodiversity available. That is, for farms who can provide both mitigation and biodiversity under economies of scope, the agency must buy the sum-total of biodiversity change available. The reason for this is that if the agency targets just less than the total, then there will be at least one farm who, in the structure where farmers hold the property right, would provide mitigation that would not be picked up when the agency holds the property right.

This second requirement is highly unlikely to hold in practice: the agency cannot hold a credible auction when it intends to accept all bids. An auction relies on competitive behaviour. If landholders realised that the agency were accepting all bids, then they would hardly bid in a risk neutral fashion. At best, the agency would be able to hold such an auction once. Thereafter, it would be public knowledge that any bid were acceptable, and landholders would bid accordingly.

#### **4.6 Discussion**

As stated in the previous section, as the damage parameter (from agriculture) increases, the agency has a greater incentive to hold the property right to mitigation. Even though there would (generally) be an efficiency loss under APR. The community may reinforce this agency incentive: they may perceive the divestment of

pollution rights to farmers as unfair, since farmers would benefit from reducing pollution which they should never have produced in the first place.

Under APR, the agency may also have incentive to alter its scoring index towards mitigation. There are two reasons for this. First it could provide the agency with greater revenue. Second, the agency may perceive that it could correct—via its scoring system—for the efficiency losses in APR that are due to the under-supply of mitigation.

The agency, however, would face considerable information costs in attempting to mimic FPR. The system is efficient when farmers hold the property right because farmers hold private information on agricultural technology, and hence the profit maximising allocation of land to mitigation. The agency would need to discover this private information for heterogenous farmers and then attempt to purchase the optimal aggregate quantity of mitigation. In addition to mimicking market forces, the agency would need to ensure that it meets its biodiversity target. This system may incur significant transaction costs.

An issue the agency may need consider in FPR is the potential risk faced by point-source emitters. When point-source emitters purchase mitigation from farmers, there is a need for some kind of certification process; the point-source emitter would want security that the farmer would undertake prescribed actions, and hence produce mitigation. If mitigation from farmers were a relatively riskier proposition than permits in from the tradable-permit market, then we would expect their price to differ accordingly. Ideally, permits from farmers would pose no additional risk or responsibility for a point-source (see Solomon and Jarvie 1998).

## **5.0 Summary and Further Research**

### **5.1 Summary**

Many environmental problems are due to the economic decisions made by point and diffuse source emitters of pollution. The economics of information, and knowledge development in the physical sciences, has equipped policymakers with an additional suite of environmental policy tools to engage different sources of pollution in environmental management. Two such policy mechanisms are tradable emission permits and auctions of conservation contracts.

Environmental markets, however, raise important institutional questions with respect to the interaction of agents. One important question is the allocation of property rights when an agent can potentially generate more than one good from a single action: economies of scope. Previous research has considered the situation where one action produces two private goods (BPW 1988). Economies of scope in private-public good provision, however, would be an important consideration for environmental issues such as biodiversity-nitrogen mitigation and salinity-carbon dioxide sequestration.

Using a simulation model, we have shown that it is generally better for farmers to own the property right a private good, even if this is provided jointly with a public good. The intuition for this result is clear: when farmers have the property right to the private good, they efficiently allocate land to it; they maximise the economic surplus in the mitigation market. However, if the agency takes the property right to the private good, it derives an amount of mitigation residually, from its purchase of

biodiversity. In most cases the agency will under supply mitigation, hence the economy will forgo gains from trade.

The other key aspect of this result is that the agency will pay less for biodiversity when farmers own the right to their own mitigation. Farmers will take account of the fact that land allocated to mitigation already receives a price in the market. In the model land is—in BPW parlance—the ‘public input’; it can be costlessly transferred from one activity to another. A competitive biodiversity auction will exploit this costless transfer from mitigation to biodiversity (albeit imperfectly).

Our results imply that an agency concerned with efficiency should have a very strong bias in favour of allocating property rights of private market goods to private market players, even if these private goods are produced jointly with public goods.

## **5.2 Further Research**

Our model suggests that who gets the property right for mitigation—the agency or the landholders—does matter. However, we have assumed that the transaction costs of joining point and diffuse sources in a trading environment are zero.

To empirically examine the benefits of the two property right allocations would require data on a variety of variables. First, a policy maker would need data on the demand curve, and supply curve, of mitigation. This would help the policy maker value the likely magnitude of the gains from trade in mitigation. This information would, however, generally be private, and hence difficult to obtain.

Even if a policy maker could understand the magnitude of the gains from trade, he would still need to know the relative transaction costs of joining point and non-point sources in the two schemes. If transaction costs of FPR are high, this may reverse the results in this paper. For example, if joint biodiversity-mitigation provision provides only a small part of the overall mitigation market, then the gains from allocating rights to landholders may not be as great as the transaction costs of allocating those rights (these transaction costs come from the agency informing each landholder about his quantity of mitigation, and enforcing any commitments a landholder makes). If (say) an auction for biodiversity were already under way, then this would contain a range of certification processes. It *may* be easier to just sell the mitigation coming from the prescribed biodiversity actions, rather than going the next step of informing landholders of their action-quantity interaction, and monitoring their mitigation activity.

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