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Direct vs Indirect Payments for Environmental Services: The Role of Relaxing Market Constraints

by

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Direct vs Indirect Payments for Environmental Services: The Role of Relaxing Market Constraints[*]

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Abstract

Ferraro and Simpson (2002) argue that when markets are competitive, direct payments for environmental services are more cost effective in achieving environmental goals than indirect payments, say, for capital. However, when eco-entrepreneurs face non-price rationing in input or output markets, as is typical for credit in developing countries for example, we show that interventions which relax constraints can be more cost-effective than direct payments. One corollary of this is that such indirect payments can be preferred to direct payments by interveners (e.g. NGOs) and eco-entrepreneurs alike. Both of these outcomes are more likely when constraints are severe.

1   Introduction

The term 'Payments for Environmental Services' (PES) defines a wide range of incentive mechanisms to address the underlying causes of environmental degradation by inducing behavioural changes among local actors. There are numerous examples of how payments from beneficiaries within a locality, river-basin, region or even globally have been implemented in attempts to overcome environmental externalities of one kind or another. There are global and multilateral mechanisms such as the Clean Development Mechanism of the Kyoto Protocol and the Global Environment Facility, as well as more localised PES schemes such as the Mexican watershed scheme [1]. In addition to varying in their geographical scope, PES schemes also vary in the nature of the incentive provided and hence in their effectiveness in any given circumstance. One common distinction is between 'direct' and 'indirect' payments. The purpose of this paper is to shed further light on the relative cost effectiveness of these direct and indirect PES.

Examples of direct payment schemes include the Costa Rican PSA scheme and the Sloping Lands Conversion Programme in China, both of which offer compensation to farmers directly for each unit

of land reforested or conserved (e.g. Pagiola, 2008; Xu and Cao, 2002). Indirect payment schemes provide incentives via some associated input to production. These so-called 'joint-production' activities include selective logging, non-timber forest products (NTFP) and eco-tourism (see Kotchen, 2005; Donovan et al., 2006; Macqueen et al., 2008). Recent theoretical and empirical work has naturally shaped the views of the institutions involved in implementing PES schemes, as well as the design of PES schemes on the ground. For obvious reasons, perhaps the most influential contributions in this respect have been those which address the question of the relative cost effectiveness of direct versus indirect payments[2].

One virtually unequivocal answer to this question can be found in an oft-cited and influential paper by Ferraro and Simpson who conclude: 'Conservation practitioners should be wary of adopting indirect payments' (Ferraro and Simpson 2002, p345, henceforth F&S). F&S reach this conclusion by employing duality theory to analyse the mechanics of direct and indirect payments to an 'ecological entrepreneur', for whom conserved land is an input to a eco-friendly production process, e.g. ecotourism. Although their approach presupposes perfectly elastic supply in input and output markets and profit maximising behaviour by a price taking entrepreneur, their conclusion appears to be remarkably robust, even when some of these assumptions are relaxed[3]. One corollary of this result is that, in the absence of side payments, the preferences of the NGO and eco-entrepreneur are generally opposed. The NGO will prefer the cost-effective direct payments, while the eco-entrepreneur will prefer the indirect approach, since it profits from the additional payments required. An alternative interpretation of this result is that, in a developing country context, there is a tension between environmental and poverty alleviation objectives.

It is well documented, however, that among the many market imperfections found in developing countries quantity constraints and non-price rationing are among the most common. Input and output quotas are obvious examples and, at the extreme, markets may be missing completely. Beyond this, perhaps the most frequent example of non-price rationing in developing countries is credit-rationing. While there are several definitions of credit rationing, it is usually thought of as a situation in which the borrower's private demand is higher at the current rate of interest than the loan offered by the lender (Petrick 2005) [4]. This description of developing countries has lead to frequent calls in development policy circles for the relaxation of constraints, particularly in relation to credit (e.g. Azam et al., 2001; Vakis et al., 2004). While such issues are frequently discussed in the context of agricultural production, similar problems undoubtedly beset the 'eco-entrepreneurs' that are the focus of many PES schemes, and were the subject of analysis by F&S.

In the context of joint-production enterprises, the implications for PES schemes are obvious: indirect payments which relax quantity constraints offer an important opportunity to expand ecological entrepreneurship and generate environmental services. Indeed, there are already numerous examples of this kind of intervention in the arena of PES in which NGOs or governments provide assistance to relax certain constraints, rather than direct incentive payments. One example, in the context of credit, is the Brazilian government's programme, FNO-Especial, which provides credit to small forest enterprises based in the Amazon that have environmental and social goals (Campos et al., 2005)[5]. In other cases contributions come in the form of complementary inputs such as tourism infrastructure, product marketing and processing facilities (see for example, Wunder, 2000; MacQueen et al., 2008). All of which gives rise to another important question: In the presence of quantity constraints, which is more cost effective? Direct payments or indirect payments which relax constraints? This paper goes part way to answering this question.

In order to make direct comparisons with F&S we return to the parsimony of their benchmark model of a donor/NGO and an eco-entrepreneur each with perfect information. Our sole addition to

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the model is a quantity constraint on an input to the production process, the relaxation of which is the objective of the NGO's indirect payments scheme. This quantity constraint is open to a rather general interpretation: a credit constraint, an input quota, and analogous arguments can be made for constraints on output. We apply the work of Fulginiti and Perrin (1993, henceforth F&P) who extended duality theory to the constrained profit function. The results of the analysis are revealing and run counter to F&S in two senses. Firstly, direct payments are shown to have no systematic cost advantage over indirect payments which relax constraints. Secondly, there are instances when the NGO and the eco-entrepreneur both prefer indirect payments. Within the confines of the model these two outcomes are more likely when rationing is severe.

The paper is organised as follows. Section 2 describes the model, while Section 3 analyses the overall cost effectiveness of each intervention. Sections 4 and 5 analyse the preferences of the NGO and eco-entrepreneur respectively, while Section 6 concludes.

2   A Model of PES with Constraints

2.1   Background

The role of market imperfections of one sort or another has already been addressed in the literature on PES. Ferraro and Simpson (2005) discussed the implications of market power for eco-entrepreneurs, while 'non-separability' among eco-entrepreneurs has been discussed by Muller and Albers (2004). An equally relevant issue in developing countries is the issue of non-price rationing. Micro-credit rationing and input and output quotas are common in developing countries, particularly in the agricultural sector, and the underlying reasons for these contraints are numerous (see e.g. Colman et al, 2005; Alvarez et al., 2006; Petrick, 2005; Azam et al., 2001)[6]. For instance, asymmetric information (resulting in adverse selection and/or moral hazard), pervasive risk, limited collateral and enforcement costs conspire to ensure that lenders ration credit in both formal and, albeit to a lesser extent, informal markets (Azam et al., 2001)[7]. As such, credit-rationing represents an important example of non-price rationing in developing countries (Binswanger and Rosenzweig, 1986; Hoff and Stiglitz, 1993).

Such constraints obviously limit productivity. Where inputs are constrained or markets for inputs are missing entrepreneurs fail to reach their potential. Similarly, where credit is rationed, underinvestment and inability to smooth production over time are common consequences (Petrick, 2005)[8]. Quantity constraints are frequent in joint-production enterprises also. For instance, there are often missing markets for the necessary inputs, such as the skills required to develop business plans, viable market contacts and quality products (RCW, 2007). Credit-rationing is also likely due to the risks inherent in joint production, insecure tenure and asymmetric information between lenders and borrowers (Ascher 1994; RCW, 2007)[9]. In the same way that such constraints are often the focus of policy recommendations in development circles, indirect PES aimed at relaxing constraints on eco-entrepreneurs could well be a cost effective alternative to direct PES. We now develop a formal analysis of this question.

2.2   The Model

In order to assess the relative cost effectiveness of direct payments and indirect payments to relax constraints, we follow closely the model of F&S. We have a profit-maximising eco-entrepreneur (henceforth, firm) that operates an 'ecologically benign' production process with two variable inputs

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to production, forest and capital. 'Forest', F, represents any ecological attribute useful in the generation of an eco-friendly output. 'Capital', K, represent some arbitrary input. Thus, a quantity, Q, of an eco-friendly product is produced using a production technology, $f(K, F)$. This technology represents an economic activity such as eco-tourism that allows environmental services, for instance biodiversity, to flow from the forest used in eco-production activities. The market prices of output, capital, and forest, are P_Q, P_K, and P_F, respectively, where P_F is the opportunity cost of using forest in eco-production. Following F&S, we assume that K is a technical complement to forest in eco-production, i.e. $\frac{\partial F}{\partial P_K} < 0$[10]. Moreover, as in F&S, we also assume that a unit of forest in eco-production provides the same quantity and quality of environmental services as a unit of conserved forest. In the absence of outside intervention, the firm uses and thus conserves forest for eco-production. The decision of the firm, therefore, concerns the quantity of forest to allocate to eco-production given that its cost as an input to production is P_F.

We depart from the benchmark of F&S by assuming capital, K, is subject to non-price rationing and limited to $\bar{K}$. As well as reflecting credit-rationing or input quotas, this constraint could also approximate missing markets $\left(\bar{K} = 0\right)$. This approach differs from the market imperfections previously addressed in relation to PES, but is perhaps closest to the analysis of non-separability by Muller and Albers (2004) in which market constraints are addressed in the context of a utility maximising household. However, while Muller and Albers focused on the response of constrained households to conventional PES schemes and 'agricultural development programmes', our focus is on the cost effectiveness of relaxing quantity constraints[11]. Henceforth, we refer to the latter policy as 'indirect payments' since it is an alternative form of indirect PES.

The return to the model of F&S, and the focus on profit rather than utility maximisation, allows us to obtain general results concerning the cost effectiveness of these interventions in a reasonably tractable manner. For simplicity, we assess cost effectiveness in the context of a constraint on inputs, although parallel arguments apply to output constraints. Fortunately, the theory of firm behaviour under quantity constraints is already well developed and we apply the work of Fulginiti and Perrin (1993) to analyse constrained profit functions.

Define the constrained profit function as:

$$\Pi^c \left(P_Q, P_F, P_K; \bar{K}, z\right) = \max_F P_Q f\left(F, K\right) - P_F F - P_K \bar{K} \tag{1}$$

This can be contrasted to the unconstrained profit function $\Pi^u \left(P_Q, P_F, P_K; z\right)$ which describes the solution to the unconstrained problem. It is straightforward to show that the constrained profit function is related to the unconstrained profit function in the following way (see Appendix A for details):

$$\Pi^C \left(P_Q, P_F, P_K; \bar{K}, z\right) = \Pi^U \left(P_Q, P_F, P_v; z\right) + \left(P_v - P_K\right) \bar{K} \tag{2}$$

where P_v is the 'virtual' or shadow price of capital, that is, the price which would induce an unrestricted firm to choose the quantity $\bar{K}$. Each value of $\bar{K}$ has a unique virtual price. Figure 1 shows the virtual prices for input and output quotas respectively. Also shown in Figure 1 is the quantity $\left(P_v - P_K\right)$, which is the often called the 'quota rent'. This is an important determinant of the results that follow.

Following F&S we assume a donor (henceforth, 'NGO') wants to induce greater forest conservation than the firm would find privately beneficial under prevailing market conditions. In F&S, the NGO has two options for inducing greater conservation: subsidies to 'Forest' or 'Capital' inputs: direct or indirect payments respectively. In the case presented here, the NGO also has two options: 1) direct payments in the form of a subsidy to forest land, or; 2) indirect provision of forest land
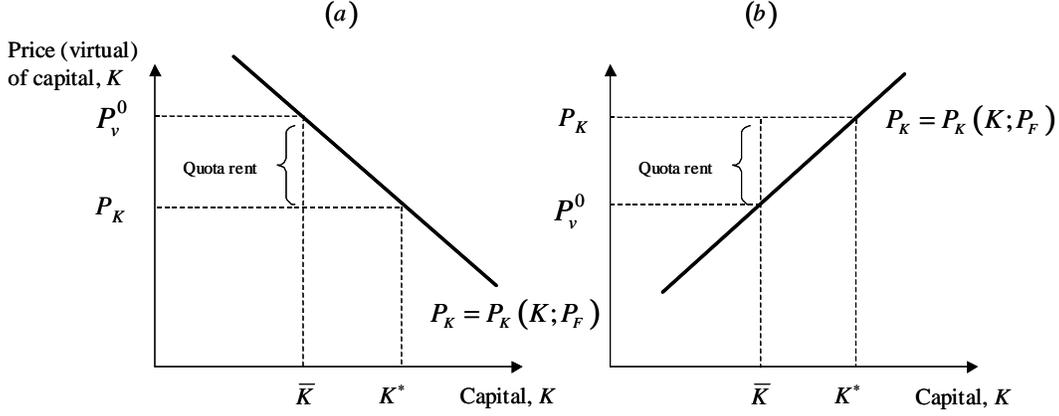
Figure 1: Virtual prices and quota rent for (a) rationed input and (b) rationed output.

via relaxation of the constraint on capital, $\bar{K}$. The latter could involve the provision of inputs as opposed to cash subsidies to capital (or output).

We follow F&S and compare the relative cost effectiveness of policies in achieving a unit change on forest land. From Hotellings Rule applied to the constrained profit function, and the derivative of the constrained profit function with respect to the constrained input, $\bar{K}$, yield (see Appendix A or F&P, p99):

$$-\Pi_F^C = F$$

$$\Pi_{\bar{K}}^C = (P_v - P_K)$$

Choosing dP_F and dK so as to induce a one unit change in forested land, F, gives the following relationship[12]:

$$dF = 1 = -\Pi_{FF}^c dP_F = \frac{\partial F^C}{\partial P_F} dP_F = -\Pi_{F\bar{K}}^c dK = \frac{\partial P_v}{\partial \bar{K}} dK \tag{3}$$

Following F&P, who describe the hessian of the constrained profit function in terms of the derivatives of the unconstrained function, the impact of the indirect policy can be expressed as:

$$1 = -\Pi_{F\bar{K}}^c dK = \frac{\Pi_{Fv}^u}{\Pi_{vv}^u} dK \tag{4}$$

where the subscript v refers to the derivative with respect to the 'virtual' price of capital, P_v

The construct of virtual prices and the representation in (4) are convenient since they allow the analysis to be undertaken using the unconstrained profit function, making the results more directly comparable to F&S. Equations (3) and (4) exploit the duality between the derivative of the constrained profit function with respect to K and the unconstrained profit function with respect to P_v. To be clear, the derivative of the constrained profit function with respect to the virtual P_v yields the unconstrained demand for capital K, while the derivative of the constrained profit function with respect to $\bar{K}$ yields the virtual/shadow price.

We now proceed by determining the cost effective intervention, and then analyse the NGO's and firm's preferred interventions.

3   Cost Effective Forest Policy

For direct payments, the cost to the NGO and the impact on firm profits can be described in a similar manner to F&S. The indirect policy of relaxing capital constraints requires the purchase of inputs by the NGO. We undertake the analysis assuming that the unit resource cost of capital is the underlying market price P_K. Questions remain concerning the share of the costs and benefits of this policy between the firm and the NGO, but this only becomes important when discussing the intervention preferred by each party. It is also likely that the cost of transacting in each market differs. For ease of presentation, we assume for the moment that transactions costs, be they fixed or variable, are the same for each intervention[13].

Using the relations between the constrained and unconstrained profit functions allows the cost effectiveness analysis to be undertaken in *virtual* price-space. Appendix B shows that the incremental cost (dC) of using indirect payments rather than direct payments is given by[14]:

$$dC = \frac{dK}{2}\left[-dP_v^I - dP_v^D\right] - \left(P_v^0 - P_K\right)dK \tag{5}$$

This expression has clear parallels with F&S[15]. Whereas F&S compare the cost effectiveness of direct and indirect payments by comparing the quantities of capital needed in each case, here the comparison is made in terms of changes in *virtual* prices. The term dP_v^I is the change in the virtual price as a consequence of relaxing the constraint on capital, $\bar{K}$. The term dP_v^D is the change in the virtual price of capital as a consequence of the direct subsidy to forest land. Given the assumptions, the former is negative and the latter is positive.

As shown in Appendix B, the first term in (5) is positive since it has the same sign as the determinant of the Hessian of the constrained profit function. The second term is the quota rent associated with the intervention and is positive as explained above. Hence, the sign of dC is indeterminate. If (5) is positive, then direct payments outperform indirect payments in terms of cost effectiveness. Further manipulations yield the following approximation for the marginal cost:

$$\frac{dC}{dK} = P_K - \frac{1}{2}\left(P_v^{1I} + P_v^{1D}\right) \tag{6}$$

This leads to Proposition 1:

Proposition 1 : *When the unit resource cost of capital is P, indirect payments to relax input constraints will be more cost effective than direct payments to forest land when P is less than the*
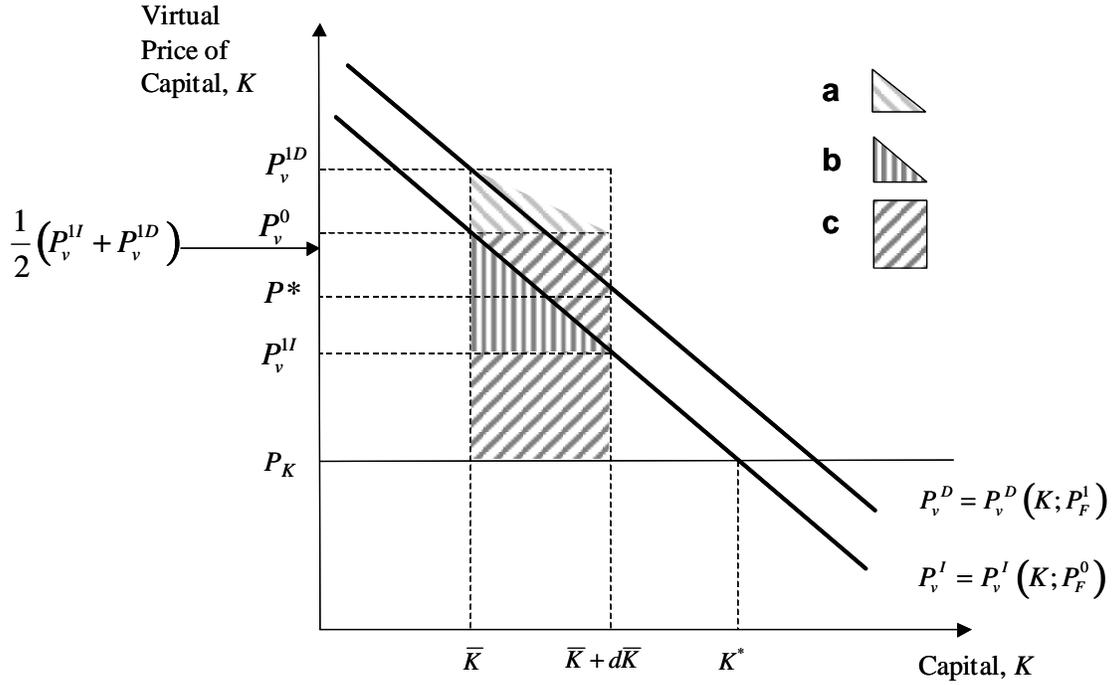
Figure 2: Direct v indirect -payments for capital, K: A severe constraint

average of the terminal virtual price under direct and indirect payments: P_v^{1D} and P_v^{1I} respectively. That is:

$$P < \frac{1}{2}\left(P_v^{1I} + P_v^{1D}\right)$$

Proof. This follows from (6). ■

Figures 2 and 3 provide a graphical comparison of direct and indirect payments under the assumption that the NGO can choose either one or the other intervention. Figure 2 illustrates the analysis for the case of a severe input constraint. In this case $P_K \ll P_v^{1D}, P_v^{1I}$, and it is obvious that indirect payments are preferred to direct payments[16]. Graphically, the second term on the RHS of (5), the quota rent, is given by c in Figure 2. $\frac{1}{2}dP_v^I dK$ is given by (negative) area b. $\frac{1}{2}dP_v^D dK$ is given by (negative) area a. Relative cost effectiveness is given by a comparison of areas a and $(b+c)$. In this case, the area $(b+c)$ represents the additional profits to the firm and is clearly large and positive.

Figure 3 shows a case at the other extreme in which the NGO would effectively 'over-egg the pudding' in order to achieve its environmental services target. Although the quota rent exists, area c, it is much smaller than the large and negative deadweight loss, area b. This loss outweighs the deadweight loss under direct payments, given by area a. In addition to this, capital is increased beyond what would be efficient in the absence of constraints (K^*), thereby causing a social loss. Here, direct payments are more cost effective.
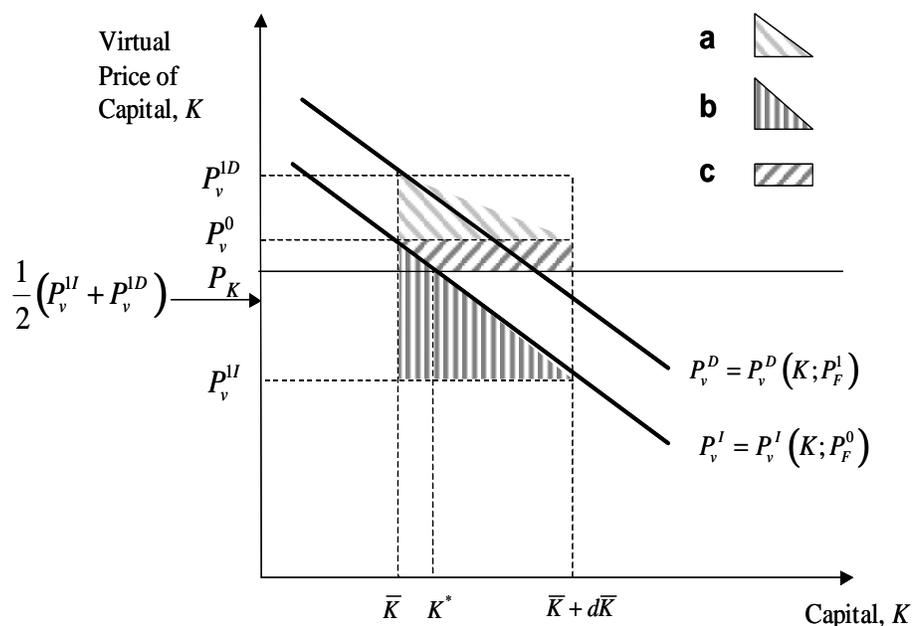
Figure 3: Direct v indirect payments for capital, K: A minor constraint

F&S compared the deadweight loss associated with direct and indirect payments when markets function properly. Loosely speaking, in the context of Figures 2 and 3 F&S compared areas a and b and showed that the former is almost always smaller than the latter. Where markets are constrained however, the quota rent, area c, must also be considered.

What Proposition 1 and Figures 2 and 3 show is that when constraints are severe, other things being equal, indirect payments to relax constraints can be more cost effective than direct payments. This finding differs from F&S and illustrates an important example in which direct payments are not preferred to indirect alternatives. Effectively, the quota rent represents a reduction in the funds required to achieve the targeted change in forest land under indirect payments, compared to direct payments, where no such rents are released.

The preceding analysis also presents the possibility that a fully informed NGO could obtain a kind of *optimum optimorum* by employing a combined payments strategy. That is, by first removing the constraint by providing capital at the world price in the quantities desired by the firm, and then subsidising forest land directly. The theory as it stands suggests that the firm would purchase K^* of capital, from which point, it would be cost effective to subsidise forest land directly à la F&S. Once again, the cost effective combined strategy will depend on the severity of the constraint.

Of course, there are many possible behavioural and informational assumptions that could be explored. The presence of rents suggests the possibility of arbitrage between each party and that the analysis of bargaining power could be apposite. The presence of credit rationing points to an analysis of informational asymmetries, and a discussion of the ability of the NGO to overcome these asymmetries and relax the constraint. We return to this discussion in the conclusion but for now

we remain with the simple framework and analyse the conditions under which the NGO and firm prefer direct or indirect payments.

4 The NGO's Preferred Policy

The NGO must pay either $-dP_F F$ with direct payments, or $P_K dK$ under the indirect policy of relaxing the constraints. The NGO will prefer direct payments if:

$$-dP_F F < P_K dK \tag{7}$$

Appendix C shows that this condition becomes:

$$\frac{\eta^u_{KF}}{\eta^c_{FF}} < \eta^u_{KK} + \frac{1}{K}\frac{\partial K^u}{\partial P_v}\left(P^0_v - P_K\right) \tag{8}$$

where η^c_{ij} is the absolute value of the constrained elasticity of demand for input i with respect to price of input j, and η^u_{ij} is the unconstrained equivalent[17]. This is a convenient form for the result since it reveals the dependence on the *virtual* price elasticity of demand for capital: η^u_{KK}, and the quota rent associated with the constraint $\left(P_v - P_K\right)$. The result is analogous to that of F&S, but introduces some important differences[18]. This leads to Proposition 2:

Proposition 2 *If the eco-entrepreneur is a profit maximiser and subject to a quantity constraint in an input market, an **indirect** policy that relaxes the constraint in the input market will be the NGO's preferred policy to increase forest cover if:*

1. *The quota rent associated with the constraint is large:* $\left(P^0_v - P_K\right)$;

2. *The resource cost of the constrained input is low:* P_K *is low;*

3. *The demand for capital is highly inelastic with repect to its own (virtual) price:* η^U_{KK} *is small.*

Proof. : This follows from inspection of (8), noting that $\frac{\partial K^u}{\partial P_v} < 0$ and $\left(P^0_v - P_K\right) > 0$ for inputs. See also Appendix C. ∎

In a world of perfect markets, the NGO will almost always prefer the direct to the indirect approach, as shown in F&S. When constraints exist in input markets, this conclusion is no longer robust. When a severe constraint exists and the quota rent is large, the NGO will prefer to relax input constraints rather than subsidise forest. This preference is also enhanced by the fact that the constrained own price elasticity of demand for forest land is smaller than the unconstrained: $\eta^c_{FF} < \eta^U_{FF}$. This means that a larger subsidy is required for a given response. Both of these features can conspire to make indirect payments more preferable.

5 The Eco-entrepreneur's Preferred Policy

When the firm is constrained in an input market, for small changes in P_F or K, the firm's profits will change respectively as follows:

$$d\Pi^C_F = \frac{\partial \Pi^C}{\partial P_F}dP_F = -dP_F F$$

Figure 4: NGO and eco-entrepreneur's preferences over PES.

$$dΠ_K^C = \frac{∂Π^C}{∂K} dK = P_v^0 dK$$

where the latter comes from Equation (17) in Appendix A, and assumes that the firm receives the additional inputs for free (does not pay P_K). Hence the firm prefers direct payments if:

$$-dP_F F > P_v^0 dK \tag{9}$$

This immediately leads to Proposition 3:

Proposition 3 *: Three outcomes are possible: i) the NGO prefers direct payments and the firm prefers indirect payments; ii) Vice versa, and; iii)* **Both** *NGO* **and** *firm prefer* **indirect** *payments.*

Proof. : Inspection of (9) and (7), and noting $P_v^0 > P_K$ reveals : i) if $-dP_F F < P_K dK$, the NGO prefers direct payments and the firm prefers indirect payments; ii) The reverse is true if $-dP_F F > P_v^0 dK$, and; iii) if $P_v^0 dK > -dP_F F > P_K dK$, then both NGO and firm prefer indirect payments. ∎

Figure 4 elaborates on Proposition 3, and shows the intermediate values of the cost of the direct payments $(-dP_F F)$ at which the NGO and firm will both desire indirect payments. The area of agreement is large when the quota rent is large, that is, when the input constraint is severe. One interpretation of this result is that environmental and poverty alleviation objectives need not be in tension. Where constraints are severe, indirect payments not only provide cost effective provision of forest land in this case, but they also provide the largest transfer to eco-entrepreneurs. There is a certain amount empirical evidence to support this point (e.g. Groom et al 2008).

6 Conclusion

In this paper, we compared the cost-effectiveness of direct payments for environmental services with indirect payments which relax quantity constraints. The quantity constraint can be understood to

represent any type of non-price rationing of inputs and outputs. One example is an input/output quota, but in practice such a constraint could also characterise a missing market. However, a more compelling example in a developing country context is that of credit-rationing. Cost effectiveness is investigated using duality theory via analysis of the constrained profit function allowing direct comparisons to be drawn with the results obtained by Ferraro and Simpson (2002) using the unconstrained profit function.

The underlying premise of F&S is that donor funds are directed towards the eco-output price or facilitate the acquisition of complementary inputs such as tourism infrastructure, product marketing and processing facilities. Local agents such as communities faced with cheaper inputs or higher output prices will therefore increase production, hence increasing the demand for intact ecosystems as an input to production. The key assumption is that, prior to the intervention, agents face perfectly elastic supply or demand and can buy profit maximising quantities of the inputs they need at prevailing market prices.

In our model extension, we instead assume that the firm's inputs or output is subject to a quantity constraint or some form of non-price rationing. We then show how relaxing the quantity constraint on capital might affect the cost-effectiveness of joint production vis-à-vis direct payments for forest. We also discuss the preferences of the NGO and firm for each type of intevention. Our results differ from F&S on two counts. First, direct payments are not systematically more cost-effective than indirect payments and second, there are instances when both parties prefer indirect payments. Within the limited context of our model, both outcomes are more likely when rationing is severe.

Quantity restrictions and other forms of non-price rationing appear to be very common among small-scale entrepreneurs in developing countries, with perhaps credit rationing as the most obvious example. While credit rationing may be as pertinant an issue in eco-production as in agriculture, where constraints on credit for eco-entrepreneurs are relaxed there may still be problems in accessing other inputs necessary for production. In fact attracting credit may be contingent on having access to other inputs in the first place (RCW, 2007). A number of questions follow. First, what kinds of inputs are these and how constrained are they in the real world? Second, how far can such constraints be used to explain the supposed dearth of successful eco-entrepreneurs in Africa, Asia and Latin America in a rapidly expanding global market for eco-products as indicated by the RCW (2007)? Answering these questions may help to gauge the relevance of our model and its results for policy.

The answer to the first question may depend on the eco-production process under consideration, although some generalisations can be made. In Suriname, for example, a bioprospecting agreement between local tribes and the International Cooperative Biodiversity Group (ICBG), a US government-funded programme, led to the provision of inputs to local communities in the form of training, information and technology transfer (Guérin-McManus et al., 1996). These inputs were an integral part of the drug development process, for example, in the extraction of plant chemicals from organic matter. In this and other cases such as those involving selective logging or the production of NTFP, there exists a need to support first-stage processing on a small scale, for example by facilitating the acquisition of simple grading, processing or packaging techniques.

As a result of small-scale production of natural products, and regional and seasonal variability in supply quality and quantity, it is often difficult to reach a scale of production that is of commercial interest to the buyers in domestic or international markets. One way of dealing with and overcoming both the quality and scale problem has been for firms to group together as cooperatives or associations These is often initiated or at least enabled by third parties such as donors

and NGOs (MacQueen et al., 2008). Moreover, eco-products generally cater to niche markets and despite rapid growth in recent years are still typically found in developed rather than developing or emerging markets. This suggests that at least some inputs to joint production may not be easily available via the market, particular more the intangible ones such as skills development and technology transfer, and may partially explain why they tend to be supplied directly by third parties. The same could be said of interventions to relax constraints on output.

The United Nations Conference on Trade and Development's (UNCTAD) BioTrade Initiative[19] recorded that eco-entrepreneurs often lack clear business plans with well-elaborated product and market-chain analyses. They also lack links with existing enterprises that create backward linkages and involve business managers in programme design and training. Obtaining market information, establishing transport links and promoting trade effectively is often difficult and costly. For example, in the Cuyabeno Wildlife Reserve in Ecuador, the Cofans of Zabalo independently operate all eco-tourism services, with complementary marketing and transport logistics inputs from a larger, tourism services firm (Wunder, 2000). In Indonesian Borneo, marketing and transport networks were established by the local NGO, SHK-Kaltim, so that high-quality rattan from the interior could be transported and sold in national and international markets. A number of rattan-producing villages share the same networks.[20]

Turning to the case of credit rationing, one interpretation of the results above is that NGOs should involve themselves in providing more credit to eco-entrepreneurs. Indeed, historically this has been a common policy prescription in development circles and there are numerous examples of subsidised credit schemes, even in the realm of PES (e.g. Petrick 2004, Campos et al., 2005). However, by and large, the history of such schemes is littered with defaults, losses and eventual failure (Petrick 2005). In part this is a consequence of failure to understand the complex causes of credit rationing and the fact that credit rationing often represents a constrained Pareto optimum. For instance, Ghosh et al. (2000) show that where moral hazard is the cause, additional credit need not lead to Pareto improvements and suggest that such strategies will be resisted by existing lenders. Rather, interventions should target the root cause of market constraints by reducing asset inequality, increasing bargaining power for borrowers and improving credit information networks. While these are not simple recommendations to act upon, successful micro-finance projects do exist.

In conclusion, the empirical evidence described above demonstrates that a number of interventions have attempted to boost eco-production activities and increase the area of forest being preserved via indirect payments to relax underlying constraints. Our model shows that it is not surprising that such interventions exist, since they are cost effective where constraints are severe. Of course, careful empirical research is needed to compare these outcomes to various counterfactuals. Nevertheless, the overall recommendation is that NGOs would be well advised to identify the cause of limited eco-production before intervening. In the perfect world, this points to direct payments for land as suggested by F&S. In the constrained world, relaxing constraints could well be cost effective.

Appendices

A   Constrained and Unconstrained Profit Function

Fulginiti and Perrin (1993) analyse the profit function when one of the inputs is constrained. Their analysis completely characterises the Hessian of the constrained profit function in terms

of derivatives of the unconstrained profit function with respect to prices of unconstrained inputs and 'virtual' prices of constrained inputs.

We explore their approach using our simple model.

$$\Pi^U \left(P_Q, P_F, P_K; z\right) = \max_{K,F} P_Q f\left(F, K\right) - P_F F - P_K K \tag{10}$$

This defines the unconstrained profit functions in which the firm is free to choose the variable inputs, F and K subject to the fixed inputs, z. Now, suppose that one of the inputs, K is constrained such that $K = \bar{K}$. The constrained profit function can be written as:

$$
\begin{aligned}
\Pi^C \left(P_Q, P_F, P_K; \bar{K}, z\right) &= \max_{F} P_Q f\left(F, \bar{K}\right) - P_F F - P_K \bar{K} \\
&= \Pi^P \left(P_Q, P_F; \bar{K}, z\right) - P_K \bar{K} \tag{11}
\end{aligned}
$$

where $\Pi^P \left(.\right)$ is the partial profit function. To define the relationship between constrained and unconstrained profit functions it is useful to define 'virtual' price, P_v, of K as the price that would induce the firm to choose $\bar{K}$:

$$P_v = P_v \left(P_Q, P_F; \bar{K}, z\right) \tag{12}$$

This yields:

$$
\begin{aligned}
\Pi^U \left(P_Q, P_F, P_v; z\right) &= \max_{K,F} P_Q f\left(F, K\right) - P_F F - P_K K \\
&= \Pi^P \left(P_Q, P_F; \bar{K}, z\right) - P_v \bar{K} \tag{13}
\end{aligned}
$$

which gives a formal definition of $P_v : \Pi_v^u = \bar{K}$[21]. This gives the following relationship between Π^u and Π^c at P_v :

$$\Pi^U \left(P_Q, P_F, P_v; z\right) = \Pi^C \left(P_Q, P_F, P_v; \bar{K}, z\right) \tag{14}$$

and from (11) and (13) we get:

$$\Pi^C \left(P_Q, P_F, P_K; \bar{K}, z\right) = \Pi^U \left(P_Q, P_F, P_v; z\right) + \left(P_v - P_K\right) \bar{K} \tag{15}$$

Using this relation it is possible to derive the following relationships which are used in the derivations in the text (See Fulginiti and Perrin, 1993, p.99):

$$\Pi_F^c = \Pi_F^u + \left(\Pi_v^u - \bar{K}\right) \frac{\partial P_v}{\partial P_F} = \Pi_F^u \tag{16}$$

$$\Pi_{\bar{K}}^c = \left(P_v - P_K\right) + \left(\Pi_v^u - \bar{K}\right) \frac{\partial P_v}{\partial \bar{K}} = \left(P_v - P_K\right) \tag{17}$$

More importantly, the Hessian of the constrained profit function can be defined in terms of the second own and cross price derivatives of the unconstrained profit function. The results for inputs F and $\bar{K}$ are:

$$\Pi_{\bar{K}\bar{K}}^c = - \left(\Pi_{vv}^u\right)^{-1} \tag{18}$$

$$\Pi_{F\bar{K}}^c = -\Pi_{Fv}^u \left(\Pi_{vv}^u\right)^{-1} \tag{19}$$

$$\Pi_{FF}^c = \Pi_{FF}^u + \Pi_{Fv}^u \left(\Pi_{vv}^u\right)^{-1} \Pi_{vF}^u \tag{20}$$

Were we to present the results for the output Q, the signs in (19) and the second term on the right had side of (20) would change.

B   Cost Effectiveness of Direct and Indirect Payments: Proof of Proposition 1

Following F&S we can make a second order approximation for the change in profits when additional forest is provided by direct means. Dropping z for brevity we get:

$$\Pi^c \left(P_Q, P_F + dP_F, P_K; \bar{K}\right) \approx \Pi^c \left(P_Q, P_F, P_K; \bar{K}\right) + \Pi_F^C dP_F + \frac{1}{2}\Pi_{FF}^C \left(dP_F\right)^2$$

The total cost of the intervention can be calculated by subtracting from thie expression the overall cost of the direct payments intervention to the NGO. The cost of DP is given by the RHS of the following expression, where F_0 is the initial level of forest cover, and the RHS is the deadweight loss[22]:

$$\Pi^c \left(P_Q, P_F + dP_F, P_K; \bar{K}\right) - \Pi^c \left(P_Q, P_F, P_K; \bar{K}\right) + \left(F_0 + \frac{\partial F}{\partial P_F}dP_F\right)dP_F$$

$$\approx \frac{1}{2}\frac{\partial F}{\partial P_F}\left(dP_F\right)^2 \tag{21}$$

Following the same procedure yields an expression for the change in profits following indirect payments to relax capital constraints:

$$\Pi^c \left(P_Q, P_F, P_K; \bar{K} + d\bar{K}\right) \approx \Pi^c \left(P_Q, P_F, P_K; \bar{K}\right) + \Pi_{\bar{K}}^C d\bar{K} + \frac{1}{2}\Pi_{\bar{K}\bar{K}}^C \left(dK\right)^2$$

$$\approx \Pi^c \left(P_Q, P_F, P_K; \bar{K}\right) + \left(P_v^0 - P_K\right)dK + \frac{1}{2}\Pi_{\bar{K}\bar{K}}^C \left(dK\right)^2$$

Subtracting the resource cost of the policy, which in Section 3 is assumed to be $P_K dK$, yields the net profits[23]:

$$\Pi^c \left(P_Q, P_F, P_K; \bar{K} + dK\right) - \Pi^c \left(P_Q, P_F, P_K; \bar{K}\right) - P_K dK$$

$$\approx \frac{1}{2}\frac{\partial P_v}{\partial \bar{K}}\left(dK\right)^2 + \left(P_v^0 - P_K\right)dK \tag{22}$$

where P_v^0 is the initial virtual price of capital at $K = \bar{K}$. The RHS of (21) is a welfare triangle. The RHS of (22) contains the welfare triangle and an expression representing the quota rent: $\left(P_v^0 - P_K\right)$, the latter being the marginal value of relaxing the constraint. These terms are explained graphically in Figures 2 and 3 in the text.

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The proof of expression (5) is as follows. Taking the RHS of (22) from the RHS of (21) gives the following expression:

$$\frac{1}{2} \left[\frac{\partial F}{\partial P_F} (dP_F)^2 - \frac{\partial P_v}{\partial K} (dK)^2 \right] - \left(P_v^0 - P_K \right) dK \qquad (23)$$

Note that the change in the virtual price of capital as a result of the indirect payments, dP_v^I, is given by:

$$dP_v^I = \frac{\partial P_v}{\partial K} dK \qquad (24)$$

Similarly, the change in the virtual price as a result of the direct payments is given by[24]:

$$dP_v^D = -\frac{dP_F}{dK} \qquad (25)$$

Using relation (3) the first term in square brackets of (23) reduces to dP_F. It is then easy to see via substitution of (24) and (25) that (23) becomes:

$$\frac{1}{2} \left[-dP_v^D dK - dP_v^I dK \right] - \left(P_v^0 - P_K \right) dK$$

which is one step from (5).

The proof of expression (6) comes from noting that $dP_v^I = P_v^{1I} - P_v^0$ and $dP_v^D = P_v^{1D} - P_v^0$.

C   The NGO's Preferences: Proof of Proposition 2

The NGO prefers direct payments if $-dP_F F < P_K dK$. Noting from (3) and (4) that $dP_F = -\frac{1}{\Pi_{FF}^c}$ and $dK = \frac{\Pi_{vv}^u}{\Pi_{Fv}^u}$, this becomes:

$$\frac{F}{\Pi_{FF}^c} = \frac{-F}{\partial F^c / \partial P_F} < P_K \frac{\Pi_{vv}^u}{\Pi_{Fv}^u} = P_K \frac{-\partial K^u / \partial P_v}{-\partial F^u / \partial P_v}$$

Taking the reciprocal and multiplying both sides by P_F gives:

$$-\frac{\partial F^c}{\partial P_F} \frac{P_F}{F} > \frac{-\partial F^u / \partial P_v}{-\partial K^u / \partial P_v} \frac{P_F}{P_K}$$

Given symmetry of the unconstrained profit function we have: $\partial F^u / \partial P_v = \partial K^u / \partial P_F$. Inserting this, multiplying top and bottom by K and rearranging yields (8)[25]:

$$\frac{\eta_{KF}^u}{\eta_{FF}^c} < \eta_{KK}^u + \frac{1}{K} \frac{\partial K^u}{\partial P_v} \left(P_v^0 - P_K \right)$$

D   References

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Notes

[1] See Wunder (2005) for a review of PES schemes.

[2] For empirical work see e.g.: Wätzold and Drechsler, (2005); Wätzold and Schwerdtner, (2005); Xu and Cao (2001); Drechsler et al., (2007). For theoretical work see e.g.: Ferraro and Simpson (2002, 2005), and; Muller and Albers (2004).

[3] Ferraro and Simpson (2005) acknowledge that their original analysis neglects some important features that characterize activities in in developing countries, in particular missing and imperfect markets for inputs and outputs. Typically self-sufficiency/autarkic production arises where markets are missing for inputs or outputs, or where significant transactions costs exist (Key et al 2000). In the context of such 'non-separable' households producing environmental services, Muller and Albers (2004) find that, with the exception of the trivial case where there are no markets for households' output (consumption goods), direct payments generally out-perform indirect payments adding further weight to F&S's (2002) result.

[4] Ghosh et al., (2000) make the distinction between macro and micro-credit rationing. The former is where sections of the economy are rationed or excluded from credit, this being the lenders response to adverse selection. The definition in the text is classic micro-credt rationing. The causes and implications of each are generally different. Of course, credit rationing is often present in developed economies also. See Petrick (2004) for a discussion of credit rationing in Poland for instance. For recent empirical examples of credit rationing issues in developing countries, see Mohieldin and Wright's (2000) study of Egypt, and Barslund and Tarp's (2007) study of Vietnam.

[5] There are many other examples. For instance, in the Lacandon forest of Mexico, eco-entrepreneurs receive credit from the Fondo Nacional de Empresas en Solidaridad (National Fund of Enterprises in Solidarity) to buy new boats, outboard motors, and equipment for an eco-tourism venture (Hernandez-Cruz et al., 2005). NTFP collectors in India received credit support from a government-run programme (Bhattacharya and Hayat, 2004). Around the world, other programmes are run by organisations such as the Global Environment Facility and the Asian Development Bank (RCW, 2007).

[6] Micro-credit rationing, which places limits on borrowers below first best levels, is to be understood as distinct from macro credit rationing where sections of society are randomly denied credit (Ghosh et al 2000).

[7] Azam et al. (2001) show how informal markets can reduce informational asymmetries and reduce credit rationing via social networks and lower interest rates. However, where formal credit markets ration supply, and households turn to credit sources in the informal sector. these sources are also often subject to rationing (Ghosh et al., 2000).

[8] Petrick (2004) provides a simple theoretical model of the agricultural household which illustrates this obvious point.

[9] Of course, property rights to ecosystems such as forests are typically insecure and hence cannot generally be used as collateral (e.g. Ascher, 1994).

[10] Without this assumption, a constraint on capital promotes forest cover compared to the unconstrained outcome.

[11] Muller and Albers (2004) model agricultural development programmes as increasing productivity of agricultural production (e.g. $f(F, K)$) through a multiplicative parameter α, such that production is measured as $\alpha f(F, K)$.

[12] Note that: $\Pi_{FF}^C = \frac{\partial^2 \Pi^C}{\partial P_F^2}$ and $\Pi_{KK}^C = \frac{\partial^2 \Pi^C}{\partial K^2}$

[13] As discussed by Key et al. (2000), transactions costs have fixed and proportional dimensions. In this sense we could define the price paid by the NGO as $P^* = P_K(1 + \delta)$, where δ represents the proportional transaction cost. The overall cost of the intervention could also include a fixed element, R, reflecting search costs relative to the direct intervention. We also ignore costs associated with the implementation of the contract in each case. The model could be extended to include such costs, but this is left for future work.

[14] Throughout the superscript 0 refers to the pre-intervention level of a variable and superscript 1 refers to the post-intervention level. Similarly, I refers to indirect intervention and D refers to direct intervention.

[15] F&S show that direct payments are always more cost effective than indirect payments and that the cost saving is proportional to:

$$\frac{dP_K}{2}\left[dK^I - dK^D\right]$$

where dK^I is the change in capital under indirect payments, dK^D is the change in capital under direct payments and dP_K is the subsidy to capital.

[16] Figure 2 also shows that if the resource cost of the intervention rises to P^* the cost advantage for indirect payments declines.

[17] Elasticities are defined as follows: $\eta_{ij} = -\frac{\partial x_i}{\partial p_j}\frac{p_j}{x_i}$. Note that $\eta_{KF}^u, \eta_{FF}^c, \eta_{KK}^u > 0$.

[18] F&S show that in the case of perfect markets the NGO will prefer the direct payments if the following inequality holds:

$$\frac{\eta^u_{KF}}{\eta^u_{FF}} < 1 \tag{26}$$

which is always the case for homothetic technologies. Numerical counter examples for some non-hoothetic technologies were not found by F&S either.

[19] Since its launch in 1996, the UNCTAD BioTrade Initiative has been promoting sustainable biotrade in support of the objectives of the Convention on Biological Diversity. Since 2003 the BioTrade Initiative has also hosted the BioTrade Facilitation Programme (BTFP) which focuses on enhancing sustainable bio-resources management, product development, value adding processing and marketing. See: http://www.biotrade.org.

[20] See: http://www.worldwildlife.org/bsp/kemala/kpshk.htm

[21] Where $\Pi^u_c = \frac{\partial \Pi^u}{\partial P_V}$.

[22] This is equivalent to expression A4 in F&S, corrected only by the absence of the minus sign on the RHS.

[23] Note that $\Pi^C_{\bar{K}} = (P_v - P_K)$ and $\Pi^C_{\bar{K}\bar{K}} = \frac{\partial P_v}{\partial K}$ in the case of a constrained input (Fulginiti and Perrin 1993).

[24] The laborious algebra is as follows: $dP^D_v = \frac{\partial P_v}{\partial P_F} dP_F$, which noting equation (17) and using symmetry can be written as $dP^D_v = \Pi^C_{F\bar{K}} dP_F = -\frac{\Pi^u_{Fv}}{\Pi^u_{vv}} dP_F$. Given (4) this can be written as $dP^D_v = -\frac{dP_F}{dK}$. Details can be found in Fulginiti and Perrin, 1993, p99.

[25] Note that the numerator of the RHS of (8) is equal to $-\frac{\partial K^u}{\partial P_v} \frac{P_K}{K}$, which would be the point elasticity at P_v but for the fact that it is evaluated at P_K. Noting that $P_K = (P_v + P_K - P_v)$ the numerator becomes:

$$\eta^u_{KK} + \frac{1}{K} \frac{\partial K^u}{\partial P_v} (P_v - P_K)$$

From this point it is easy to get (8).