Chapter 28
Designing Environmental Instruments to Finance Agricultural Intensification Through the Clean Development Mechanism: Direct Cost Subsidy Versus Tax Cut Under Asymmetric Information

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Abstract Various agreements addressing climate change plead for the adoption of innovative green technologies to reduce production of greenhouse gases responsible for global warming. Yet, the most successful instrument so far, the Clean Development Mechanism (CDM) is at pains to succeed in small, developing countries facing sustainable development problems like food security. Worse, while the CDM succeeded in financing agricultural projects, few are funded in small, developing countries.

A tax cut is one innovative financial scheme that many countries enact in their investment code to promote environmentally sound technologies. Tax cuts return a portion of investment costs to firms that implement green innovations, which ultimately reduces investment costs and so adds to their net benefits. We compare this scheme to a direct cost subsidy designed to offer firms access to capital at a lower interest, for their capacities to boost the use of CDM in agriculture. This paper shows that the narrow scope of tax cuts compared to direct cost subsidies make corporate tax relief inadequate for the needs of developing countries. We also show that while both schemes are equally efficient under perfect conditions and asymmetric information, the direct cost subsidy is more appropriate to further environmental and sustainability goals like food security in developing countries where informational problems are pervasive. Empirical results support these results (**JEL:** D61, D82, G21, O13, Q01, Q54, Q55.)

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28.1 Introduction

There are many instruments to finance the mitigation of climate change. With finance in mind, the Copenhagen Summit, the fifteenth Conference of Parties (COP15) on Climate Change, made the recommendation that a common fund of US$100 billion per year over the post-Kyoto period (2013–2020) be created to help poor and emerging countries adopt costly, but eco-friendly technologies (Article 8 of the Treaty) (UNFCCC 2009). These technologies are aimed at reducing the production of greenhouse gases (GHG) responsible for global warming.

To be sure, innovative instruments to support eco-friendly technologies already exist. One such instrument is the well-known Clean Development Mechanism (CDM) designed to finance climate mitigation efforts. The CDM was created within the framework of the Kyoto Protocol to promote low-carbon projects and reduce harmful gas emissions. It is one of three market-based instruments of the Kyoto Protocol beside the Joint Implementation and Emission Trading instruments designed for developed countries (UNFCCC 2008; Olawuyi 2009; Zhang and Wang 2011).

The CDM was designed to provide an incentive for governments and companies in industrialized countries to invest in GHG reduction projects in developing countries and be credited by issuance of marketable Certified Emission Reductions (CER). However, records show that small, developing countries rarely use CDM. From the start of the Protocol in 2005–2012, the entire continent of Africa accounted for only 3.6 % of the 2,386,899 kiloCERs produced compared to the five CDM giant countries, China, India, South Korea, Brazil, and Mexico, which account for more than 80 % of the total production. As well, China, Brazil, India, Mexico, and Malaysia account for 79 % of agricultural projects. For instance, out of 8,868 CDM-financed projects, only 259 are in Africa, of which 74 are in South Africa (UNEP RISOE Centre, CDMpipeline.org, June 2013). In total, 122 of the 150 eligible non-annex I countries hosted CDM projects by 2012 (see also Winkelman and Moore 2011). Agricultural land-use projects are particularly scarce under the CDM, even though such projects sequester carbon in soils, and can boost fertility, agricultural productivity, food security, and alleviate poverty in developing countries (Larson et al. 2011). Mitigation opportunities in agriculture are numerous, including agricultural residue management, manure, composting, crop management, integrated pest management, integrated management of wastes in livestock production, agroforestry, land use, irrigation, and mangroves. In addition, agriculture accounted for roughly 12 % of anthropogenic GHG emissions, a significant sector. However, by 2012, the mitigation impact in agriculture is only 8 % of the total (Larson et al. 2011; Godfray et al. 2010). Authors often attribute the low reach of CDM to factors linked to high transaction costs of investing in projects in small, developing countries (Michaelowa and Jotzo 2003; Ahonen and Hamekoski 2005; Olawuyi 2009; Larson et al. 2011).

So lowering the carbon mitigation cost expected from an annex I country investing in a developing country may not be sufficient to attract carbon investors. The problem is therefore how to design environmental instruments that mitigate the effects of transaction costs and encourage environmental innovations with a broad reach for application in specific contexts in developing countries. This question is especially important for agricultural land-use projects that are complex and costly to implement, mainly due to uncertainties about net emission outcomes and the permanence of sequestration. These uncertainties lead to steeper monitoring, measurement, and implementation costs, all of which make agricultural land use projects less attractive to investors (Larson et al. 2011). Nonetheless, agricultural mitigation interventions are a key element of adaptation because climate change is expected to have adverse effect on food security, especially in sub-Saharan Africa (Schmidhuber and Tubiello 2007).

One solution to promote low carbon projects is to reduce the costs of green technological change that CDM investors incur in small, developing countries. The financial instruments available for this purpose include subsidizing investments through reduction of capital costs, such as reducing interest rates, and tax cuts.

We propose the interest rate bonus as a direct cost subsidy scheme because the informal economies of developing countries offer huge numbers of eligible firms. In West Africa, for instance, banks and microfinance institutions (MFI) come into contact with hundreds of thousands of small- and medium-sized enterprises. Their reach as a proportion of population served in 2003 was 25 % for MFIs and 8 % for banks (PASMEC 2005). Thus, finance is a suitable channel to finance green projects. Moreover, pairing microfinance and climate mitigation is an efficient way to establish a virtuous link between poverty alleviation and environmental protection. Studies abound confirming that microfinance enables the poor, who are excluded from classical financing systems, to access funding and improve their well-being (Woller and Woodworth 2001; Paxton 2002; Ruben and Clercx 2003; Khandker and Faruqee 2003; Shaw 2004).

One version of the tax cut instrument consists of deducting a fraction of the costs of a new investment from a firm's benefit tax for a given period of time, which would reduce its investment costs through savings on corporate taxes (Hall and Jorgenson 1967; Muet and Ayouvi-Dovi 1987). Tax cuts are widely used to promote green investments. In Benin, for example, the investment code and its implementation agency, the "Centre de Promotion des Investissements" directs a tax cut policy for new investment projects.[1] This Code excludes any activity having negative effects on the environment and health of populations from receiving a fiscal discount. Benin is not unique, as many developing countries authorize tax cuts or subsidies in their investment code to promote the adoption of eco-friendly technologies. The list includes Algeria, Burkina Faso, Cameroon, The Central

[1] Law n° 90-002 of May 9th, 1990, in the Investments Code, modified by law 90-033 of December 24th, 1990.

African Republic, Congo, Côte d'Ivoire, Gabon, Mali, Morocco, Nigeria, Democratic Republic of Congo, Senegal, South Africa, Tunisia, and Uganda.

This paper compares direct cost subsidies through interest rate reduction and corporate tax cuts with respect to their reach and efficiency under asymmetric information. Specifically, it aims to examine whether we can construct a direct cost subsidy scheme that is equally efficient as the tax cut scheme.

Environmental economists evaluate environmental policies using criteria such as cost effectiveness or efficiency, incentive compatibility, ethics, breadth of distribution, equity and broader economic stabilization concerns, and administrative feasibility and flexibility (Bohm and Russell 1985; Xepapadeas 1991; Baumol and Oates 1993; Sterner 2003).

An environmental instrument is cost-effective if it achieves a set of environmental goals at the least cost. Such effectiveness represents a type of static efficiency based on fixed technology and discharge location (Bohm and Russell 1985). An instrument is dynamically efficient if, in the long run, it does not impede adaptation and innovation of complying agents to an evolving world. The instrument must be adapted to the national and local economy and should provide incentives for those who comply with it to give their maximum effort. Direct cost subsidies and tax cuts fulfill one aspect of dynamic efficiency: they make relatively few informational demands on an environmental authority, thereby allowing firms to make private decisions regarding the choice of the best technology to curb emissions or to produce a public good (Baumol and Oates 1993).

An instrument is incentive-compatible if the agents involved (e.g., polluters, victims, regulators) have an incentive to disclose information and act as intended. Indeed, implementing an instrument requires data and predictive modeling skills. Because the information on cost and corporate benefit necessary to implement our two schemes are private and may be manipulated by firms, we choose to compare them in an asymmetric information setting. This choice is particularly important for developing countries where there are often considerable information asymmetries, high transaction costs, considerably complex project evaluation procedures, and a lack of local experience with such work (Kirsten and Karaan 2005; Stiglitz 1985; Furubotn and Richter 2005; Williamson 2005; Miller 2005). In such contexts, institutions are reluctant to engage in innovative projects.

An instrument satisfies equity concerns if the parties involved perceive the distribution of costs and benefits as fair. The ethical aspects of such financial instruments emerge from the choice between two views: seeing environmental damage as a crime against nature or other persons, versus seeing environmental damage as a good that can be bought (Bohm and Russell 1985). For our instruments, we must take the second view.

Economic stabilization concerns relate to the use of environmental instruments to further employment, growth, and trade. Finally, regarding administrative feasibility and flexibility, an instrument must be practical and incur no excessive monetary or informational costs in its operation. In other words, the institution implementing the instrument should minimize transaction costs in management and monitoring. An instrument is flexible if it gives the polluter a broad set of choices to achieve its environmental goal.

To be sure, these criteria are related, and what criterion is advanced depends on the instrument and the stakeholders involved. For instance, once a goal is set, difference between efficiency in execution and cost effectiveness disappears. Functions that a planner maximizes to achieve efficiency may directly include distributional and equity issues. In a decentralized economy, the criterion of incentive compatibility is achieved by leaving some rent to more informed stakeholders, i.e., by sacrificing some efficiency (Laffont and Martimort 2002).

Existing literature offers analytical frameworks to compare environmental instruments. Weitzman (1974) created a framework to compare taxes and quotas as instruments to control the production of goods under imperfect information or uncertainty. He preferred the quota as a planning instrument if and only if its benefit function exhibits more curvature than the cost function around the optimal output level, i.e. uncertainty on the (steeper) marginal benefit function has greater effect on profit than uncertainty on the (flatter) marginal cost function. Anyanga (2010) compared foreign direct investment (FDI) and debt financing to develop environmentally sound technologies. He found that debt financing fares better than FDI because it requires coping only with adverse selection concerning the firm's own productivity. FDI, however, not only shares this hidden information problem, but also the moral hazard problem concerning an outside investor's control of a local project. As communication channels for information proliferate, more informational rents must be given away.

This study employs the principal-agent analytical framework to understand the relative reach and efficiency of direct cost subsidies and tax cuts. We present this framework in Sect. 28.2, and use it in Sects. 28.3 and 28.4 to evaluate the instruments' comparative reach and efficiency under perfect and imperfect information. Our results show that under asymmetric information, we can construct a direct cost subsidy scheme equally efficient as a tax cut scheme, but with a broader reach through the informal economies of developing countries. Section 28.5 presents empirical results that show how the pervasiveness of information asymmetry (i.e. the presence of informal sector as a major constraint) may impede the production of agricultural CERs through CDM. Section 28.6 offers concluding remarks.

28.2 Analytical Framework and Model

28.2.1 Notation

We use the following notation throughout the paper:

e = quantity of the environmental good (e-good); for example, emission reductions produced along with an ordinary or dirty good (d-good) taken as the numeraire (price = 1).

θ = coefficient of pollution of the dirty good.

α = cost efficiency parameter for the production of the e-good; α is private information to the firm. We assume that the firm can be of two types: a low-cost type (α_1) with probability q, or a high-cost type (α_2) with probability of $(1-q)$ and $\alpha_2 > \alpha_2$. A type-α_1 firm is more efficient in producing the environmental good than a type-α_2 firm.

r = the unit cost of investment capital, including transaction costs.

b = the interest rate discount. If r = b, the whole interest is subsidized.

m = the tax cut rate for new investment.

t = the tax rate on corporate profits.

f = the per-unit gain from selling the e-good by the Principal, such as through an emissions reduction market. It may also be interpreted as the social value of the e-good for the Principal. The value of f is net of administrative costs.

v = price per unit of the e-good paid by the Principal to the Agent. One obvious assumption is that $f > v$.

$c(e)$ = the production cost of the green good, e, such as the cost of using a depollution technique (operating + abatement cost). It has the following regular properties. The first and the second derivatives of $c(.)$ with respect to e are positive: $c_e(.) > 0$, $c_{ee}(.) > 0$; moreover, $c(0, b; r) = c_e(0, b; r) = 0$; $c(.)$ is a negative function of $b(c_b(.) > 0)$.

K = fixed initial investment cost of acquiring and installing the new technology. We assume K is public information. This is a reasonable assumption because green technology is usually imported into developing countries and thus the investor country or the government knows its price. We assume that the Principal provides the green technology. He is then concerned with the type of firm with which he contracts, hence the necessity to consider a setting of asymmetric information.

Thus, the total cost of using the new green technology is: $K + (1 + r - b)c(e)\alpha$, private information to the firm. We assume that the firm either borrows or draws on internal funds to finance the new technology's operation. The firm claims opportunity cost for internal funds.

28.2.2 Setting

We consider a setting with two agents: a climate fund manager or a climate investor (an environmental protection agency, regulator or private investor) designated P (Principal), and a firm designated A (Agent). P, possessing all of the bargaining power, has three instruments available to implement its goals: one main instrument IC, (initial contracting) and two complementary instruments, DCS (Direct Cost Subsidy) and TC (Tax Cut).

1. *Initial Contracting (IC)*: P provides the A with the new technology, A produces the environmental good (e-good), and sells the quantity of e-good produced to P at the price v;

2. *Direct Cost Subsidy (DCS)*: P supports access to capital at a lower interest rate or capital cost;
3. *Tax Cut (TC)*: firms that implement green innovations are returned a proportion m of their investment costs, which adds to their net benefits.

In practice, IC, DCS, and TC work similarly to a subsidy to further environmental goals. As well as an ordinary, dirty good (d-good) sold in markets, all firms produce an environmental good (e-good), that is costly for firms but is a positive argument for the utility function of P. There are many ways to understand the quantity e of the environmental good. We assume it to be a separable, non-joint product from an allocable factor (Beattie and Taylor 1993), supplied by firms which, in producing it, incur abatement and operating costs measured in terms of a quantity of their ordinary product (the numeraire). Examples of e-good production include the greening of a production process, acquiring environmental protection devices, or afforestation projects, such as building a carbon sink to compensate for a separate firm's pollution. This example has relevance to Benin, for example, where the largest contributors to greenhouse gas emissions are land and forest allocations (73 %) and agriculture (21 %) (FEM 2008).

We assume that firms receive no direct earnings from environmental productions but bear costs in the form of implementation, administration, and transaction costs, as well as forgone benefits from alternative land uses such as crop and livestock production. Therefore, an environmental agency or investor may encourage e-good production by compensating firms through payment for the e-good produced at price v. That is why direct cost subsidies and tax cuts are seen as complementary instruments to boost e-good production.

Because of separability assumptions, we will concentrate only on e-good production and ignore the d-good sector. P's problem is that the operating cost of the green technology by each firm is private information in such a way that a more efficient type-α_1 firm can present itself as a less efficient type-α_2 firm and obtain the latter's contract. This is rational from the firm's standpoint because if it succeeds in getting the contract it desires, it will bear only the cost $\alpha_1 c(e_2)$ of producing e_2 while receiving compensation for $\alpha_2 c(e_2)$. This is an instance of hidden information commonly known as adverse selection. The environmental agency must discriminate between the two types of firms so that each receives the appropriate type of contract among our three financing instruments. We account for the moral hazard problem that may occur if A accepts the contract but does not fulfill or partially fulfills its share of the agreement (Salanié 1994; Furubotn and Richter 2005; Laffont and Martimort 2002). The events are timed as follows:

1. The polluting firm learns its type, $\alpha \in \{\alpha_1, \alpha_2\}$;
2. P proposes a menu of IC with complementary contracts $[e(\alpha), b(\alpha)]$ for direct cost subsidy or a menu of IC with $[e(\alpha), m(\alpha)]$ for tax cut;
3. The polluting firm accepts one contract or rejects them all;
4. Nature intervenes;
5. The polluting firm and P realize their payoff.

28.2.3 Theoretical Model

From the IC, a firm of type i obtains a first-period profit (net of taxes) given by the following equation:

$$\Pi_i(\alpha_i) = (1-t)[ve_i - (1+r)\alpha_i c(e_i)] \tag{28.1}$$

P (the environmental investor) obtains the following payoff from this type:

$$U_P(\alpha_i) = fe_i + t[ve_i - (1+r)\alpha_i c(e_i)] - K \tag{28.2}$$

For a private investor, the tax revenue does not enter the objective function of P.

We assume that the investment lasts for only one time period per investor. In many African investment codes, tax cuts are actually a one-time return on imported goods. Since K is constant for an assumed standard investment, it will not affect the optimal values. So we ignore it in the subsequent development.

If agent i benefits from both complementary instruments ($b, m > 0$), his payoff $\Pi_i(.)$ is given by the following equation:

$$\begin{aligned}\Pi_i(e_i; m, b, \alpha_i) = {} & [ve_i - (1+r-b)\alpha_i c(e_i)] - t[ve_i - (1+r-b)\alpha_i c(e_i)] \\ & + m(1+r-b)\alpha_i c(e_i)\end{aligned}$$

The payoff is collected as follows:

$$\Pi_i(e_i; m, b, \alpha_i) = (1-t)[ve_i - (1+r-b)\alpha_i c(e_i)] + m(1+r-b)\alpha_i c(e_i) \tag{28.3}$$

The net gain that P extracts from the contracts is given by this equation:

$$U_P(.) = \underbrace{fe_i}_{(i)} + \underbrace{t[ve_i - (1+r-b)\alpha_i c(e_i)]}_{(ii)} - \underbrace{ve_i}_{(iii)} - \underbrace{b\alpha_i c(e_i)}_{(iv)} - \underbrace{m(1+r-b)\alpha_i c(e_i)}_{(v)}$$

$U_P(.)$ consists of five terms: (i) the revenue from sales of the e-good, (ii) corporate tax revenue, (iii) less the payment for the e-good, (iv) the cost of the tax cut, and (v) the direct subsidy cost.

$U_P(.)$ is collected as follows:

$$U_P(.) = fe_i - v(1-t)e_i - [(1+r-b)(\mathrm{t}+m) + b]\alpha_i c(e_i) \tag{28.4}$$

We use specific functional forms for the increasing marginal cost function to obtain conclusive and clear results. Thus, we use the cost function (28.5):

$$c(e_i) = \frac{1}{2}\left(\frac{e_i}{\theta}\right)^2 \tag{28.5}$$

We interpret θ as a parameter reflecting the firm's size and the polluting capacity. As is often assumed in environmental literature, decreases in marginal cost for target emissions are embodied in θ.[2] With specification (28.5), (28.3) and (28.4) become

$$\Pi_i(.) = (1-t)\left[ve_i - \frac{1}{2}(1+r-b)\alpha_i\left(\frac{e_i}{\theta}\right)^2\right] + \frac{1}{2}m(1+r-b)\alpha_i\left(\frac{e_i}{\theta}\right)^2 \quad (28.3')$$

$$U_P(.) = fe_i - v(1-t)e_i - \frac{1}{2}[(1+r-b)(\mathrm{t}+m)+\mathrm{b}]\alpha_i\left(\frac{e_i}{\theta}\right)^2 \quad (28.4')$$

Payoffs (28.3′) and (28.4′) accommodate the situation whereby the project holder benefits simultaneously from a tax cut and a direct cost subsidy. A general framework may consider the situation where the second instrument, if available, magnifies the effects of the operational instrument in which any project holder may be involved. In case of this twin implementation, one instrument can function as a parameter for comparative static analysis. Nevertheless, we chose to analyze the two instruments separately to sharpen their comparison.

The following definitions, (e_b, b) and (e_m, m), complete the analytical framework to compare contracts. The variables e_b and e_m are, respectively, the quantity of the e-good produced under the direct cost subsidy and the tax cut schemes.

Definitions (R) Instrument 1 has more reach for P than instrument 2 if its constraint-delimited implementation space is broader than 2's.

(E) Instrument 1 is more efficient for P than instrument 2 if the payoff to P is greater under 1 than under 2.

Under this framework, we can now analyze the problem of the environmental investor, which consists of comparing the reach and efficiency of the two instruments. We begin by analyzing their performance under a scenario of perfect information as a benchmark.

28.3 Comparative Performance of the Two Instruments Under Perfect Information

In the direct cost subsidy scheme only ($b > 0$ *and* $m = 0$), the problem of the environmental investor under perfect information is given by:

$$\underset{e,\,b\geq 0}{Max}\left\{fe_i - v(1-t)e_i - \frac{1}{2}[(1+r-b)\mathrm{t}+\mathrm{b}]\alpha_i\left(\frac{e_i}{\theta}\right)^2\right\} \quad (28.6)$$

[2] While the functional form of the production technology of the e-good retains the essential properties that such a function might have, things can be more complicated depending on the available depollution technique, the quota of emissions authorized and the production progress of the d-good (see Dasgupta and Heal 1979, for some hints).

subject to

$$ve_i - \frac{1}{2}(1 + r - b)\alpha_i\left(\frac{e_i}{\theta}\right)^2 \geq 0 \tag{28.7}$$

In the tax cut scheme only ($b = 0$ *and* $m > 0$), the problem of the environmental investor under perfect information is given by:

$$\underset{e,m \geq 0}{Max}\left\{fe_i - v(1-t)e_i - \frac{1}{2}(1+r)(t+m)\alpha_i\left(\frac{e_i}{\theta}\right)^2\right\} \tag{28.8}$$

subject to

$$ve_i - \frac{1}{2}(1 + r)\alpha_i\left(\frac{e_i}{\theta}\right)^2 \geq 0 \tag{28.9}$$

Constraints (28.7) and (28.9) are conditions for the participation of firm i in the environmental contract. The value of any external option is normalized to 0. In the programs, the environmental investor chooses the optimal level of both the e-good and the instrument. So an increase in the level of the instrument has the advantage of broadening the feasibility space and possibly the optimum quantity of the e-good for DCS. But it narrows the feasibility space of the TC scheme. In any case, this increase is costly for the environmental investor, whence the necessity to choose the instrument's optimal level.

Constraint (28.9) needs more detailed explanation. The TC scheme is applicable only if the firm's corporate benefit is known and positive. This has implications for the relative reach of both schemes.

Define:
$B^* =$ set of e such that (28.7) holds
$M^* =$ set of e such that (28.9) holds

Proposition 1 B^* contains M^* ($B^* \supset M^*$); that is, DCS has more reach than TC under perfect information.

Proposition 1 is easily proved by noticing that if constraint (28.9) holds, we have:

$$0 \leq ve_i - \frac{1}{2}(1+r)\alpha_i\left(\frac{e_i}{\theta}\right)^2 < ve_i - \frac{1}{2}(1+r-b)\alpha_i\left(\frac{e_i}{\theta}\right)^2$$

Proposition 1 asserts that the number of firms eligible for the DCS scheme is greater than the number of firms eligible for the TC scheme. In Benin, for example, the limited effects of the national investment code's incentives are noticeable by the small number of projects that benefit from TC. Since 1991, an average of only nine projects per year have benefited from the implementation of the code (authors' data). Furthermore, the TC scheme is only available for firms that are subject to corporate tax in the first place. This instrument is inaccessible to informal

Table 28.1 Optimal levels of e-good and compensation under perfect information

Variable	Direct cost subsidy (DCS)	Tax cut (TC)
Production of the e-good (e^*)	$e_b^* = \frac{\theta^2[2f-v(1-t)]}{2(1+r)\alpha_i}$	$e_m^* = \frac{\theta^2(2f-v(1-t))}{2(1+r)\alpha_i}$
Discount	$b^* = (1+r)\left[1-\frac{2v}{2f-v(1-t)}\right]$	$m^* = (1-t)\left[1-\frac{2v}{2f-(1-t)v}\right]$
Payoff for the principal	A	B (=A)

firms lacking adequate accounting systems, thus resulting in its low reach. Large and formally organized firms pay such taxes, but the bulk of firms, comprised of small and micro-enterprises, are liable only for a formula tax.[3]

The number of participating firms affects the environmental investor's total revenue, and is thus likely to have global efficiency impacts. One may ask if, for any individual firm that contracts with the environmental investor, there is an efficiency difference in using DCS versus TC. The solutions to the problems of the moral hazard scenario are summarized in Table 28.1.

Proposition 2 If both are feasible, *DCS* is equivalent to *TC* for P under perfect information.

The proof of this proposition is straightforward. Replacing e, b, and m with their optimal values in P's payoff function for both DCS and TC attains the same payoff. One way to obtain this result is to observe the structure of the two payoffs. For P's payoffs, we have:

$$A = U_P(\mathrm{e}^*, \mathrm{b}^*) = fe_i - v(1-t)e_i - \frac{1}{2}[(1+r-b)\mathrm{t} + \mathrm{b}]\alpha_i\left(\frac{e_i}{\theta}\right)^2 \quad \text{and}$$

$$B = U_P(\mathrm{e}^*, \mathrm{m}^*) = fe_i - v(1-t)e_i - \frac{1}{2}(1+r)f(\mathrm{t}+m)\alpha_i\left(\frac{e_i}{\theta}\right)^2$$

Since $e_b^* = e_m^*$, we obtain $A = B$ by proving that $(1+r-b)\mathrm{t}+\mathrm{b} = (1+r)(t+m)$ or that $b(1-t) = (1+r)m$.

This proposition basically states that the optimal use of DCS and TC under perfect information yields the same static efficiency for P. Moreover, they lead to the same quantity of the e-good. Thus, wherever and whenever TC cannot be applied, such as an informal economy, DCS can attain the same environmental goal.

The following section explores whether these results hold in scenarios of asymmetric information.

[3] In Benin, the informal sector provides 40 % of GDP and 90 % of employment (Charmes 1999).

28.4 Comparative Performance of the Instruments Under Adverse Selection

Recall that, under adverse selection, we assume that firms can be of two types, type-α_1 with probability q, and type-α_2 with probability $(1-q)$. Table 28.1 shows how the optimum quantity of the e-good depends on α_1. More efficient firms produce a larger quantity of the e-good. Thus, the environmental investor must have a mechanism that offers the appropriate contract, (e_i, b_i) or (e_i, m_i), to each type of firm based on the cost incurred from using green technology and producing environmental goods.

The payoff for a type-α_1 firm takes the following form[4]:

$$\Pi(\alpha_i) = (1-t)\left[ve_i - \frac{1}{2}(1+r-b)\alpha_i\left(\frac{e_i}{\theta}\right)^2\right] + \frac{1}{2}m(1+r-b)\alpha_i\left(\frac{e_i}{\theta}\right)^2 \quad (28.10)$$

and the corresponding payoff for the environmental investor is:

$$U(\alpha_i) = fe_i - v(1-t)e_i - \frac{1}{2}[(1+r-b)(\mathrm{t}+m)+\mathrm{b}]\alpha_i\left(\frac{e_i}{\theta}\right)^2 \quad (28.11)$$

The investor has a prior distribution on the values of α and selects the contract that maximizes his expected payoff $E(U(\alpha)) = \mathrm{qU}(\alpha_1) + (1-q)U(\alpha_2)$.

For notational simplicity, let $e(\alpha_i) = e_i, b(\alpha_i) = b_i$ and $m(\alpha_i) = m_i$ *for* $i = 1, 2$.

The general problem of the risk-neutral[5] environmental investor is given by

$$\underset{e_1, e_2, b_1, m_1 \geq 0}{Max}\{qU_1(e_1, b_1, m_1) + (1-q)U_2(e_2, b_2, m_2)\} \quad (28.12)$$

subject to

$$\Pi_1(e_1, b_1) \geq 0 \quad (28.13)$$

$$\Pi_2(e_2, b_2) \geq 0 \quad (28.14)$$

$$\Pi_1(e_1, b_1, m_1) \geq \Pi_1(e_2, b_2, m_2) \quad (28.15)$$

$$\Pi_2(e_2, b_2, m_2) \geq \Pi_2(e_1, b_1, m_1) \quad (28.16)$$

For the maximization problem, constraints (28.13) and (28.14) are individual participation constraints: no firm will accept participation in an environmental program that offers no opportunity for profit. Constraints (28.15) and (28.16) regard

[4] The subscript y is omitted because y is not a choice variable (see the separability assumptions in Sect. 28.3).

[5] One can assume that an agency acting on behalf of a number of people is risk neutral given its capacity to disperse risk among numerous stakeholders (Arrow and Lind 1970).

incentive compatibility: no firm of a given type can gain by presenting itself as another type – lying. Incentive compatibility constraints derive from the revelation principle, which states that instead of using complicated messages, forcing the firms to reveal their true nature causes no loss of generality (Dasgupta et al. 1979). However, we have associated with this a cost referred to as an “information rent”. Such an optimization problem is usually solved by recognizing that some constraints should be held strictly (Laffont and Martimort 2002; Cornes and Sandler 1996; Salanié 1994).

First, given the parameters of the problem, we can produce the following equations from 28.14 and 28.15:

$$\Pi_1(e_1, b_1, m_1) \geq \Pi_1(e_2, b_2, m_2) > \Pi_2(e_2, b_2) \geq 0 \tag{28.17}$$

Equation 28.14 should hold equally at the optimum level because we will otherwise be able to increase e_1 and e_2 by a sufficiently small constant amount without violating any constraints. If this is possible, it contradicts the fact that we are at the optimum. Because constraint (28.14) binds at the optimum, we can ignore constraint (28.13), which according to condition (28.17) should hold strictly.

Because constraint (28.13) is not binding, the more efficient firms (associated with cost parameter α_1) obtain a strictly positive rent, while the less efficient firms (associated with cost parameter α_2) have a rent of 0. This is the informational rent that the environmental investor is forced to pay to the most efficient type of firm to eliminate possible incentives to receive additional subsidies by misrepresenting itself as less efficient (m_2 and b_2 to produce e_2, instead of m_1 and b_1 to produce e_1). The environmental investor realizes this by imposing constraint (28.15) at the optimum level: the more efficient firm achieves nothing by lying.

Second, (28.15) cannot be non-binding; that is, we cannot have

$$\Pi_1(e_1, b_1, m_1) > \Pi_1(e_2, b_2, m_2) > \Pi_2(e_2, b_2) = 0 \tag{28.18}$$

In fact, if (28.18) holds, we can allow a small increase in e_1 without violating any constraints but with the possibility of increasing P’s optimal value, which indicates that we were not previously at the optimum. Thus, Eq. 28.15 should be binding.

Third, from (28.14) and (28.18), we establish Eqs. 28.19 and 28.18 holds strictly:

$$\Pi_2(e_2, b_2, m_2) = 0 > \Pi_2(e_1, b_1, m_1) \tag{28.19}$$

Equation 28.19 states that the higher-cost firm will never misrepresent itself as a low-cost firm. If it were to try, a negative payoff would result. Thus, the threat of misrepresentation comes only from the low-cost firm, which then requires an incentive like a strictly positive rent, to keep it from lying.

We therefore rewrite the problem of the environmental investor as follows:

$$\underset{e_1, e_2 \geq 0}{Max} \{qU_1(e_1, b_1, m_1) + (1-q)U_2(e_2, b_2, m_2)\} \tag{28.12'}$$

$$\pi_2(e_2, b_2) = 0 \tag{28.14'}$$

$$\pi_1(e_1, b_1, m_1) = \pi_1(e_2, b_2, m_2) \tag{28.15'}$$

The solutions to the problem under imperfect information may be obtained by request from the authors. The results lead to proposition 3.

Proposition 3 Under asymmetric information, DCS and TC are equivalent and are equally less profitable for the environmental investor than their uses under perfect information.

The mathematical expression of the informational rent is too complex to display here. However, when available, the two instruments are again equivalent regarding efficiency when technological cost carries information asymmetry. The presence of informational rent means that information asymmetry controls P's bargaining power.

An efficient firm receives more compensation while continuing to produce the same perfect information level of e-good. An inefficient firm's production and compensation are distorted away from perfect information levels. Interestingly, the loss P incurs due to information asymmetry is the same whether he uses DCS or TC.

28.5 An Empirical Test of the Model

28.5.1 Empirical Model

We shall use a structural approach to analyze empirically information asymmetry's effect on the production of CER and agricultural credits of emission reduction (ACER). It aims at testing the effectiveness of the constraints imposed by the informality of the developing countries' economies on the production of CER and ACER that necessitates subsidy schemes to encourage environmental investors.

We derive the econometric model for observed ACER directly from the underlying theoretical model. The previous theoretical analyses show that conditions of identifying green projects (q) are major determinants of the production of green goods in developing countries. We build an empirical econometric model to test this. Our identification strategy controls for confounding variables that are correlated with both ACER and the causal variable, which are the conditions of identifying a project.

The process of producing ACER under the CDM includes an expression of intent, contracting, producing, evaluation, and certification by an independent third party. We may assume that there is a continuum of countries based on their unobservable production of ACER. Among these countries, we can distinguish:

– countries that have already produced some quantity of ACER,
– countries that have projects in the pipeline but do not as yet receive any ACER,

– countries that seriously consider entering the ACER production process, and
– countries that do not even think about starting the process.

Thus the supply of agricultural green projects and each country's degree of interest in CDM that we name $ACER_i^*$ is an unobservable latent variable. We accordingly specify the empirical model to be estimated as:

$$ACER_i^* = \alpha + \rho q_i + \delta' X_i + u_i \tag{28.20}$$

Where:

i refers to countries, $ACER_i^*$ is the desired certified emissions credits produced by country i, q is quality of proposed projects, X_i is vector of control variables, α, ρ, δ are parameters, and u the error term.

Since $ACER_i^*$ is not observable, we cannot estimate the empirical model (28.20). However, the actual certified quantity of $ACER$ is observed. So the model to be estimated becomes:

$$\begin{cases} ACER_i = \alpha + \rho q_i + \delta' X_i + u_i \;\; if \;\; ACER_i^* > 0 \\ ACER_i = 0 \;\; if \;\; ACER_i^* \leq 0 \end{cases} \tag{28.21}$$

Since many countries with $ACER_i^* > 0$ supply no $ACER$, the dependent variable is censored at zero, so the empirical model requires a censored regression such as the Tobit model. Furthermore, because q enters nonlinearly in the optimal production level of greed good, we use a functional log-linear form for the empirical model.

28.5.2 Data

28.5.2.1 Data Sources

Data to estimate empirical model (28.21) came from databases compiled by UNFCC and the World Bank. The World Bank database is built from the Enterprise Survey (ES) on a World Bank Group website (www.enterprisesurveys.org). The ES data contain indicators computed from a firm-level annual survey of representative samples of an economy's private sector business owners or top managers. The transaction cost indicators measure the quality of the business climate, defined as the collective set of incentives which establish the 'rules of the game' to which economic actors must adhere. As such, they measure actual transaction costs and the quality of the business environment that existing firms experience. ES data covers bribery, licensing, infrastructure, trade, land and permits, taxation, informality, access to finance, costs of inputs/labor, corruption, business-government relations, and innovation and technology.

UNFCCC website (www.unfccc.org) contains data on CER and carbon stocks. We compute agricultural CER from the paper by Larson et al. (2011).

28.5.2.2 Measurement of ACER

We use *ACER* for the year 2010. We recovered these series in the paper by Larson et al. (2011) who follows the United Nations' Food and Agriculture Organization (FAO) in defining an agricultural project as a project that uses agricultural residuals, outputs, or agricultural processes to directly or indirectly reduce greenhouse gas emissions.

28.5.2.3 Measurement of Asymmetric Information Variable *q*

The probability that the proposed project variable q will select the efficient firm can be measured by the percentage of abandoned or rejected projects in each country. Since such data are not available, we use INFORMC, the percentage of firms that identify competitors' informal sector practices as a major constraint.

28.5.2.4 Control Variables *X*

Our control variables' vector *X* contains only one variable: total CO_2 emission in 2004. Following the literature on the Kuznets curve for environmental pollution, gross domestic product could have been another control variable. But GDP turned out to be highly correlated with CO_2 emissions. Indeed, multicolinearity is common in data on investment climate because macroeconomic trade policy, microeconomic framework, and enabling infrastructure variables are closely interdependent (Olawuyi 2009). GDP is then abandoned as control variable to avoid multicolinearity.

Another control variable is transaction cost, for which there can be many proxies. Following Antinori and Sathaye (2007), we distinguish four factors that may affect the transaction costs defined in the Coasian sense as costs of exchange: (1) Individual characteristics, such as each firm's opportunity costs, experience, skills, and personal networks; (2) Characteristics of the good traded; (3) Form of exchange, such as a formal or informal market, pecuniary or barter exchange, specific contract clauses and terms for a trade; and (4) Institutional setting, the social and legal environments of a given country. Because the certified *CER* is a standardized good and the exchange is formal, such as on the CDM market, we chose a transaction cost variable based on the first and the fourth factors they list, which is measured by the ES variable bribery in infrastructure on the Incidence of GRAFT index. This index is the proportion of instances in which firms were either expected or requested to supply a gift or informal payment when applying for six different public services (electrical connection, water connection, phone connection, construction permit, import license, operating license).

28.5.2.5 Sample of Countries Covered

Since the sample of countries covered each year is different for the ES database, our selection of a sample of countries is a trade-off decision between sample size and year. Unfortunately, the number of countries covered per year is often small. To increase the size of the sample, we average the different variables over the periods 2003–2007 and 2009–2010. We exclude the year 2008 because of a methodological heterogeneity used then, compared to other years. We end up with a sample of countries that covers 100 non-annex I countries of the Kyoto Protocol: 41 African, 20 American, 28 Asian, 6 European and 5 Oceanic.

28.5.2.6 Description of the Data

Figure 28.1 depicts percentages of global average levels of CER and ACER, and Table 28.1 gives the descriptive statistics on the model variables for the five continents. Asia produces CERs better than any other continent, certainly due to its major nations being the major producers of CO_2 among developing countries. This suggests that CO_2 emission level is a major determinant of CER production.

Average figures show that Africa strives to surpass Asia to improve the quality of business environment as measured by bribes (GRAFT).[6] Data show that despite some European and Oceanic countries being closer to potential CDM host countries located in these continents, access to CDM appears a competition between African, American, and Asian countries. We therefore reduce the estimate of the empirical

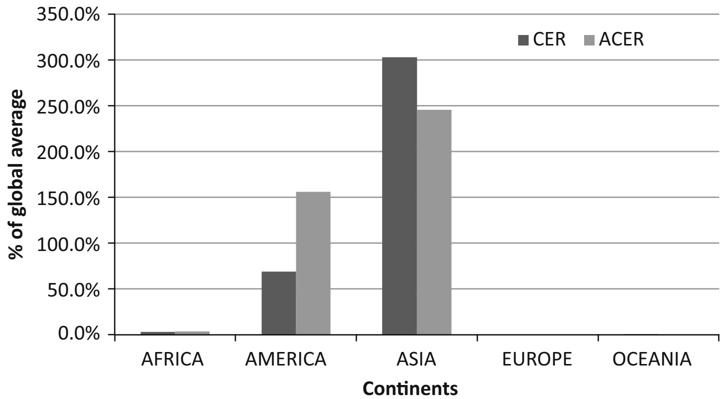

Fig. 28.1 Average production of CER and ACER per continent as percentages of global averages

[6] We recall that as concerning the interpretation of the variables, more means heavier constraint for GRAFT.

model to the sample including only African, American, and Asian countries. Figure 28.1 shows that productions of CERs et ACERs are mostly located in Asia and America.

28.5.3 Empirical Econometric Results

Table 28.2 shows the results of the econometric empirical estimates of model (28.21). The likelihood ratio and F tests show that both models are highly significant (1 %), meaning that the variables the models include explain a significant proportion of the variations in the dependent variable (CER).

The coefficient of GRAFT is significantly different from 0 with the expected negative signs. This suggests that infrastructural bribery (GRAFT) is a major obstacle to CER production in developing countries. The coefficient of INFORMC is negative but insignificant meaning that the informality/asymmetric information is not a major constraint for agricultural CER production. Well, the coefficient of INFORMC is negative and significant for the model of total CER meaning that the informality of the economy is a major constraint to the utilization of CDM by the host countries.

Another important result is the grandfathering effect. Results show that countries with an initially high stock of CO_2 or high mitigation potential before CDM inception benefit more from the mechanism than less polluted countries. This result may be explained by the fact that it is easier and cheaper for developed countries, designated operating entities, and host developing countries to produce CER in countries where the CO_2 stock is already abundant (Michaelowa et al. 2003). Indeed, developed countries decide which developing countries are least costly and risky to cooperate with in producing emission reduction credits. Results show that their strategy considers developing countries with high mitigation potentials because of high initial CO_2 emissions as low-risk investments (Olawuyi 2009).

Table 28.2 Empirical econometric results (N = 81)

	Dependent variable: logarithm of the quantity of ACER (LnACER)	
Log of independent variables	CER	ACER
GRAFT	−5.62 (1.60)***	−6.61 (2.16)***
INFORMC	−0.16 (0.10)*	−1.31 (3.47)
CO2	3.35 (0.70)***	3.09 (0.91)***
CONSTANT	−11.79 (8.03)	−9.70 (15.57)
Likelihood ratio	41.70***	26.46***
Pseudo R^2/adjusted R^2	0.14	0.09

Standard errors are in *parentheses*

*, **, *** indicate statistical significance at 10 %, 5 % and 1 % levels, respectively

These results appeal for special strategies to encourage CER production and agricultural CER in smaller countries across the developing world. Key among these strategies are measures to improve information about and proliferation of efficient technologies, improve the investment climate, reduce transaction costs, promote effective legal mechanisms to curb corruption, and improve the quality of CDM projects.

28.6 Conclusions

We have shown that there is, in principle, no difference in efficiency between a direct cost subsidy and a tax cut to finance green projects. Under asymmetric information conditions, however, the environmental investor's bargaining power is decreased because he must leave some rents to better-informed firms. The results suggest that direct cost subsidies are more suitable for informal developing economies.

Our empirical results confirmed that the informality of the developing countries' economy is a serious obstacle to the production of CER. Using CDM to address agricultural intensification and combat food insecurity, a direct cost subsidy scheme is well-suited to contexts where the economy is largely informal and the reach of a tax cut scheme will be relatively low. In contrast, tax cut schemes may be the better of the two options in largely formal economies, due to the lack of additional transaction costs. Thus, a good environmental action plan should propose a range of schemes among which each firm can choose according to its circumstances.

References

Ahonen H-M, Hamekoski K (2005) Transaction costs under the Finnish CDM/JI Pilot Programme; Department of Economics and Management, University of Helsinki and Finnish CDM/JI Pilot Programme, Finnish Environment Institute (SYKE), Helsinki. http://www.helsinki.fi/taloustiede/Abs/. Accessed 12 July 2012

Antinori C, Sathaye J (2007) Assessing transaction costs of project-based greenhouse gas emissions trading; Environmental energy technologies division; Ernest Orlando Lawrence Berkely National Laboratory

Anyanga JO (2010) Financing investment in environmentally sound technologies: foreign direct investment versus foreign debt finance. Resour Energy Econ 32:456–475

Arrow KJ, Lind RC (1970) Uncertainty and the evaluation of public investment decisions. Am Econ Rev 60(3):364–378

Baumol JB, Oates WE (1993) Economics, environmental policy, and the quality of life. Gregg Revivals, England

Beattie BR, Taylor CR (1993) The economics of production. Krieger Publishing Company, Malabar

Bohm P, Russell CS (1985) Comparative analysis of alternative policy instruments, handbook of natural resource and energy economics, vol I. In: Kneese AV, Sweeney JL (eds) North-Holland, Amsterdam

Charmes J (1999) Gender and informal sector. ILO, Geneva
Cornes R, Sandler T (1996) The theory of externalities, public good and club goods. Cambridge University Press, Cambridge
Dasgupta PS, Heal GM (1979) Economic theory and exhaustible resources. Cambridge economic handbooks
Dasgupta P, Hammond P, Maskin E (1979) The Implementation of social choice rules: some general results on incentive compatibility. Rev Econ Stud 46(2):185–216
FEM-Fonds pour l'Environnement Mondial (2008) Examen de portefeuilles-pays du FEM: Bénin (1991–2007), Bureau de l'évaluation du FEM
Furubotn EG, Richter R (2005) Institutions and economic theory: the contribution of the new institutional economics. University of Michigan Press, Ann Arbor
Godfray HCJ et al (2010) People food security: the challenge of feeding 9 billion. Science 327:812–818
Hall RE, Jorgenson DW (1967) Tax policy and investment behavior. Am Econ Rev 57(3):391–414
Khandker SR, Faruqee RR (2003) The impact of farm credit in Pakistan. Agric Econ 28 (3):197–213
Kirsten J, Karaan M (2005) The economics of institutions: a review. In: The economics of institutions: theory and applications to African agriculture, University of Pretoria, pp 24–61
Laffont J-J, Martimort D (2002) The theory of incentives: the principal-agent model Princeton. Princeton University Press, Princeton
Larson DF, Dinar A, Frisbie JA (2011) Agriculture and the clean development mechanism. Policy research working paper 5621. The World Bank Development Research Group Agriculture and Rural Development Team
Michaelowa A, Jotzo F (2003) Impacts of transaction costs and institutional rigidities on the share of the clean development mechanism in the global greenhouse gas market. http://www.uni-regensburg.de/Fakultaeten/WiWi/buchholz/forschung/AVR/Rostock/VortragRostock/. Accessed 11 July 2012
Michaelowa A, Stronzik M, Eckermann F, Hunt A (2003) Transaction costs of the Kyoto mechanisms. Climate Policy 3:261–278
Miller GJ (2005) Solutions to principal-agent problems in firms. In: Menard C, Shirley MM (eds) Handbook of new institutional economics. Springer, Dordrecht, The Netherlands, pp 349–370
Muet P-A, Avouyi-Dovi S (1987) L'effet des incitations fiscales sur l'investissement. Revue de L'OFCE 18:149–174
Olawuyi DS (2009) Achieving sustainable development through the clean development mechanism: legal and institutional issues considered. Afr J Int Com Law 17(2):270–301
PASMEC (Programme d'appui aux structures mutualistes d'épargne et de crédit, BCEAO) (2005) Observatory 2003, Dakar, Sénégal
Paxton J (2002) Depth of outreach and its relation to the sustainability of MFIs. Saving Dev 26 (1):65–85
Ruben R, Clercx L (2003) Rural finance, poverty alleviation, and sustainable land use. J Microfinance 5(2):77–100
Salanié B (1994) Théorie des contrats, collection "Economie et Statistiques Avancées". Economica, Paris
Schmidhuber J, Tubiello FN (2007) Global food security under climate change. PNAS 104 (50):19703–19708
Shaw J (2004) Microenterprise occupation and poverty reduction in microfinance programs: evidence from Sri Lanka. World Dev 32(7):1247–1264
Sterner T (2003) Policy instruments for environmental and natural resource management; resources for the future. The World Bank, Swedish International Development Cooperation Agency, Washington, DC
Stiglitz J (1985) Information and economic analysis: a perspective. Econ J supplement 95:21–41
UNFCCC- United Nations Framework Convention on Climate Change (2008) Clean development mechanism in brief. UNFCCC.ORG

UNFCCC (2009) Accord de Copenhague. Copenhague, Danemark. http://unfccc.int/resource/docs/2009/cop15/fre/. Accessed 12 July 2012

Weitzman ML (1974) Prices vs quantities. Rev Econ Stud 41(4):477–491

Williamson O (2005) Transaction cost economics. In: Menard C, Shirley MM (eds) Handbook of new institutional economics. Springer, Dordrecht, The Netherlands, pp 41–68

Winkelman AG, Moore MR (2011) Explaining the differential distribution of clean development mechanism projects across host countries. Energy Policy 39:1132–1143

Woller G, Woodworth W (2001) Microcredit as a grass-roots policy for international development. Policy Stud J 29:267–282

Xepapadeas AP (1991) Environmental policy under imperfect information: incentives and moral hazard. J Environ Econ Manag 20:113–126

Zhang J, Wang C (2011) Co-benefits and additionality of the clean development mechanism: an empirical analysis. J Environ Econ Manage 62(2):140–154