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DEVELOPING COUNTRIES' RESPONSE TO THE CLEAN DEVELOPMENT MECHANISM UNDER IMPERFECT INFORMATION AND TRANSACTION COSTS

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Developing countries are struggling for finding resources to finance their adaptation to or mitigation of the effects of climate change. In that spirit, the Copenhagen summit, the fifteenth Conference of Parties (COP15) can be seen as a success since it ended with an important promise of creation of a common fund of $US 100 billions per year over the period 2013–2020 to help poor and emerging countries to support adoption of costly but eco-friendly technologies. However, implementation of former instruments shows mixed results. In this paper, we show that transaction costs effect dominates asymmetric information effect in impeding some developing countries to benefit from the clean development mechanism, one of the instruments of the implementation of the Kyoto Protocol. Thus environmental instruments may be useless if they are not supplemented by policies to reduce transaction costs in the host countries.

Keywords: Climate change; clean development mechanism; information asymmetry; transaction cost; developing countries.

JEL Codes: D23, D82, O13, Q01, Q54, Q55

1. Introduction

One of the well-known mechanisms to finance climate mitigation efforts is the Clean Development Mechanism (CDM). The CDM is an instrument created within the framework of the Kyoto Protocol in order to promote low carbon projects for reducing harmful gas emissions. This is one of the three market-based instruments of the Kyoto Protocol besides the Joint Implementation and Emission Trading instruments designed for developed countries.

The CDM, contained in the Article 12 of the Kyoto Protocol enacted in 1997, was designed to provide an incentive for governments and companies in industrialized countries to invest in greenhouse gas (GHG) reduction projects in developing countries and be credited by issuance of marketable Certified Emission Reductions (CER). This is the baseline-and-credit scheme for developing countries opposed to the cap-and-trade scheme for developed countries. While this market mechanism permits to the developed countries to achieve their emissions' targets with great flexibility and at lower costs, it is also intended to help accomplish sustainable ecological, economic and social development in developing countries, i.e., creating co-benefits (Olawuyi, 2009; Zhang and Wang, 2011).

Developing countries like those in sub-Saharan Africa (SSA) have minimal impact on global warming, but have the opportunity to participate in mitigation efforts by preserving their forests and waters. If these countries succeed in attracting CDM projects, this will reduce the fear that climate funds crowd out other development aids especially for poverty alleviation, a risk increased by the misalignment of the mechanism with and its nonintegration into sector strategies (McGray *et al.*, 2007; World Bank, 2010). However, data to date do not seem to dispel this fear. In fact, records show very low use of CDM by many developing countries. From the start of the Protocol in 2005 to 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. For instance, out of 8868 CDM-financed projects, only 259 are in Africa, of which 74 are in South Africa (UNEP RISOE Centre, CDMpipeline.org, June 2013). This is to be expected. In fact, Jung (2006) offers a classification of countries according to their attractiveness for CDM projects using criteria of mitigation potential, institutional CDM capacity, and general investment climate. From this classification, only South Africa among the countries in SSA is classified as very attractive.

Indeed, to gain from CDM which is a market instrument, developing countries should vie for investments from developed countries guided by cost-benefit analysis. Yet, some potentially benefiting countries are handicapped by an unfriendly business environment with high transaction costs, weak national capacity for project elaboration, complicated procedures, low range of eligible projects, among other factors identified as key constraints to the use of CDM by developing countries (Michaelowa and Jotzo, 2003; Ahonen and Hamekoski, 2005; Olawuyi, 2009). According to World Bank (2010), project-based approach of the CDM consisting in certifying projects on case by case imposes high transaction costs and administrative burdens that significantly limits the CDM's potential to transform long-term emission trends. To prove that reductions are real, measurable, verifiable and additional to what would have occurred without the project (UNFCCC, 2008), CDM projects typically pass six steps that all entail transaction costs[1]: project concept, methodology development, project design, project validation (with acceptance by the host country), project registration,

[1]Transaction cost is defined as the cost of running an organization, i.e., the costs of information search, negotiation, monitoring and enforcement of contracts (Arrow, 1969).

monitoring and verification of emissions reductions, issuance of CERs (Chadwick, 2006; Michaelowa and Jotzo, 2003; Peng *et al.*, 2006; Satoguina, 2006). These costs are likely to be prohibitive for small countries with many sources of market imperfections such as massive inadequate state intervention, structural rigidities (rigid and inadequate taxation), fluctuating and uncertain markets, and difficulties in procurement of inputs and in updating technologies (Kirkpatrick and Weiss, 1996; Brent, 1998). The importance of information imperfection regarding failure and malfunction of markets and other institutional mechanisms is well known (Stiglitz, 1985; Furubotn and Richter, 2005; Williamson, 2005; Miller, 2005).

While transaction costs are widely cited by authors as key determinants of returns on investments in the CDM markets, it is not well-known how these costs combine with imperfect information to worsen the situation of small developing countries. Indeed asymmetric information may be a source of transaction costs (Malin and Martimort, 2000), but transaction cost is a broad concept and go beyond asymmetric information. In this paper, we try to separate the effect of asymmetric information from the effect of (other) transaction costs so as to determine the urgent policy needs. Using new data collected mostly from the World Bank and UNFCCC surveys, we found empirically that transaction costs effect dominates asymmetric information effect in impeding small developing countries to supply credits of emission reduction as expected by CDM.

The rest of the paper is organized as follows. We present in Sec. 2 an analytical model which enables to construct an index of comparison of asymmetric information effect and transaction costs effect. Sections 3 and 4 develop and implement an empirical model to measure these effects. The final section distils key conclusions and messages.

2. Analytical Framework

2.1. *Setting and notations*

We consider a setting with two agents: an environmental protection agency or environmental investor named P(Principal) and a project holder named A(Agent). P supplies to A an amount of capital K to invest in (or to serve to compensate A for) environmental innovations within normal business activities. All firms produce, in addition to ordinary goods sold in markets, an environmental good e that is costly for the firms, but which is a positive argument of the profit function of P. The environmental good e may be interpreted in many ways. Here, we assume that it is a nonjoint, separable product from an allocable factor (Beattie and Taylor, 1993) supplied by firms which should give up a quantity of their ordinary product as opportunity cost (forgone benefits from alternative land uses such as cropping and animal breeding, implementation, administration, and transaction costs). Examples of production of good e include greening of production process by installing environmental protection devices, and allocating a portion of land to maize production and another part to an afforestation project.

We assume that supplying firms have no earnings from the environmental production. That is why the environmental agency should encourage production of e through a transfer of capital to the firms in the form of compensation. In such a context, P offers to a firm i contracts of form (K_i, e_i) which is an endowment of capital K_i for producing a quantity e_i of environmental good (green good) by choosing appropriate technology.

We consider that the cost function of producing e takes the form $\alpha_i g(e_i)$.[2] α_i is the cost parameter of firm i. We assume that $g(\cdot)$ has the following regularity properties: $g(0) = g'(0) = 0$, $g'(e) > 0$ if $e \neq 0$ and $g''(e) > 0$, where g' and g'' are the first and second derivatives of $g(\cdot)$. This cost represents the forgone benefits from abandoning partially or totally the production of the market good named m. We assume that an investor faces a project holder that can be of two types: One of low-cost (α_1) with probability q and another of high-cost (α_2) with probability $(1 - q)$, and $\alpha_2 > \alpha_1$. The most efficient type in terms of production of e is the first type α_1.

The problem is that the technology used by each firm is a private information such that there is incentive for the most efficient firm α_1 to present itself as a least efficient firm α_2 to get the contract (K_2, e_2), knowing that it will only bear the cost $\alpha_1 g(e_2)$ to produce e_2. This is an instance of hidden information, a specific manifestation of adverse selection. The environmental agency would like to avoid that behavior by discriminating between the two types of firm so that each receives the appropriate contract. But as we will see, this discrimination cannot be perfect given informational asymmetries (Salanié, 1994; Furubotn and Richter, 2005).

Let us note U_P the profit obtained by P for ordering to firm i quantity e_i of green good and paying K_i to compensate firm i. U_P is given by:

$$U_P = fe_i - K_i. \tag{1}$$

f is the price of green good e (for example the price of one metric ton of CO_2 emission reductions) sold in international green good markets.

Let Π_i be the profit per period for a project holder i who receives compensation K_i to produce the quantity e_i of environmental good:

$$\Pi_i(e_i, K_i; \alpha_i) = K_i/(1 + \theta) - \alpha_i g(e_i). \tag{2}$$

θ is the transaction cost parameter ($\theta \geq 0$) which increases with transaction costs (project preparation and implementation costs, monitoring costs, including taxes and 2% contribution to the adaptation fund incurred by the environmental investor) (Mathy, 2004). Transaction costs are born by both environmental investors and project holders in host countries but in our formulation investors bear these costs indirectly (Ahonen and Hamekoski, 2005; Michaelowa *et al.*, 2003).

[2]We slightly abuse notations by taking e as the green good itself and its quantity.

Equations (1) and (2) embody the following simplifying assumptions:

(1) The two technologies producing e differ only in terms of production costs of green good and the firm's total production cost function is assumed separable in market and greed goods.
(2) The investment lasts for only one time period.
(3) The investor and the project holder are risk neutral.

The timing of compensation may be a relevant issue. If it comes after the quantity the green good is known by both parties, the issue of adverse selection is resolved. In our formulation, we assume that compensation is paid ex-ante. This means for instance that project holders produce credits of emissions reductions (CER) for an environmental investor who (partially) advances funding and collects the CERs to sell on the CDM market. Thus the timing of the events discloses as following:

(1) The environmental investor presents a set of contracts (K_i, e_i) to a project holder.
(2) The project holder i chooses one contract.
(3) The environmental investors transfers compensation K_i to the project holder i.
(4) Production of green good is realized and the investor collects and sells the quantity of green good produced.

Under this setting, we can now analyze the problem of the environmental investor in a situation of imperfect information. But first we analyze the situation of perfect information as a benchmark.

2.2. *The case of perfect information*

With perfect information, the problem of P who holds all the bargaining power with a typical firm i is specified as follows:

$$\underset{e_i, K_i \geq 0}{\text{Max}} (fe_i - K_i) \tag{3}$$

$$\text{Subjected to :} \quad K_i/(1+\theta) - \alpha_i g(e_i) \geq 0. \tag{4}$$

Constraint (4) stands for condition of participation of firm i to the contract for the production of green good. The value of any external option for the project holder is normalized to 0.

The solution of program (3)–(4) is given in Appendix A.1. The obvious Proposition 1 states the importance of transaction costs (see Eq. (A.5) and the following remark for the proof). If these costs are extreme, they can undermine the success of the CDM, and possibly the success of the Kyoto Protocol itself (Chadwick, 2006).

Proposition 1. *Under perfect information, if the marginal cost adjusted for transaction costs for producing the green good [$G = (1+\theta)\alpha_i g'(e_i)$] is greater than the price of green good (f) the project holder produces no green good. Moreover, when*

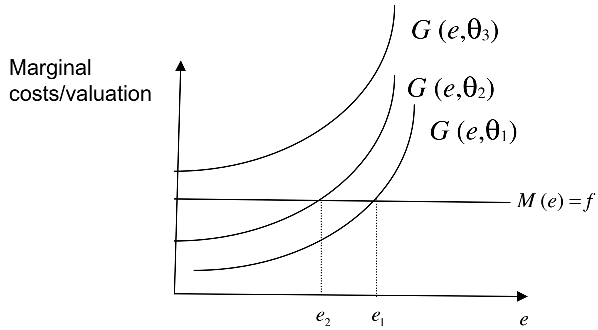

Figure 1. Equilibrium production of green good e under transaction costs.

the price of the green good is sufficient to cover the adjusted marginal cost, production of the green good falls when transaction costs rise.

Let us assume that we are in a country where the issue of transaction costs is not insurmountable so that firms produce some green good. Thus $e_i^* > 0$.[3] Comparative statics analysis of the model leads to (see Appendix A.1 and Eqs. (A.6)–(A.9):

$$\frac{\partial e_i^*}{\partial \theta} < 0, \quad \frac{\partial e_i^*}{\partial \alpha_i} < 0, \quad \frac{\partial e_i^*}{\partial f} > 0, \quad \frac{\partial K_i^*}{\partial f} > 0. \tag{5}$$

As indicated by Proposition 1, Eq. (5) show that higher transaction and technological costs, and low price of carbon lead to lower production of green good. Figure 1 illustrates Proposition 1. $M(e)$ is the marginal valuation of green good by the demanding environmental investor (here $M(e) = f$) and $G(e, \theta)$ is the adjusted marginal cost of the supplying firm or host country. If transactions costs increase passing from θ_1 to θ_2, the equilibrium quantity of green good produced changes from e_1 to e_2. Since for the same amount of capital compensation, the production of green good decreases, both the project holder and the environmental investor suffer from increasing transaction costs. When transaction cost increases further passing to θ_3, no transaction occurs, i.e., no unit of green good is produced and exchanged. It is also important to note that while higher transaction cost unambiguously decreases the production level of green good, it does not necessarily decrease compensation. This result highlights the fact that higher transaction costs may lead to efficiency loss in the production of green good.

2.3. *The case of imperfect information*

With imperfect information, the problem of the environmental investor P is to maximize the expected profit under appropriate constraints. We have the following program:

$$\underset{e_1, e_2, K_1, K_2 \geq 0}{\text{Max}} q(fe_1 - K_1) + (1 - q)(fe_2 - K_2), \tag{6}$$

[3]We star optimal values under perfect information.

$$K_1/(1+\theta) - \alpha_1 g(e_1) \geq 0, \tag{7}$$

$$K_2/(1+\theta) - \alpha_2 g(e_2) \geq 0, \tag{8}$$

$$K_1/(1+\theta) - \alpha_1 g(e_1) \geq K_2/(1+\theta) - \alpha_1 g(e_2), \tag{9}$$

$$K_2/(1+\theta) - \alpha_2 g(e_2) \geq K_1/(1+\theta) - \alpha_2 g(e_1). \tag{10}$$

In the program (6)–(10), (7) and (8) are individual rationality or participation constraints: no firm will accept to participate in an environmental program unless it achieves non-negative profit. Constraints (9) and (10) are incentive-compatible or truth constraints: no firm of a given type can gain by presenting itself as another type, i.e., by lying.

An analysis of the model at equilibrium indicates some intermediary results for this kind of problem (Laffont and Martimort, 2002; Cornes and Sandler, 1996; Salanié, 1994). First, constraint (8) should bind at optimum, i.e., firms of type α_2 have no rent. If not, one would have from (8) and (9):

$$K_1/(1+\theta) - \alpha_1 g(e_1) \geq K_2/(1+\theta) - \alpha_1 g(e_2) > K_2/(1+\theta) - \alpha_2 g(e_2) > 0. \tag{11}$$

Inequality (11) would allow a slight increase in the same amount of e_2 and e_1 without violating any constraint of the system. We would have thus succeeded by this increase to improve the optimal value of the environmental agency, contradicting the idea that we were previously at the optimum. This intermediary result shows that constraint (7) holds strictly and can be ignored in the optimization process. Thus the most efficient firm has an informational rent. It benefits from this rent because it can present itself as a least efficient firm in order to be allocated a contract designed for the least efficient type. The firm would gain by lying because:

$$K_2/(1+\theta) - \alpha_1 g(e_2) > K_2/(1+\theta) - \alpha_2 g(e_2) = 0.$$

In a way, the creation of rent for the efficient type in the presence of information asymmetry is an instance of transaction cost as Malin and Martimort (2000) define it: transaction cost is any obstacle to the utilization of the revelation principle.

Second, constraint (9) should bind at optimum, i.e., the most efficient type must remain indifferent between the two contracts. If type α_1 were not indifferent, we would have from (8) and (9):

$$K_1/(1+\theta) - \alpha_1 g(e_1) > K_2/(1+\theta) - \alpha_1 g(e_2) > K_2/(1+\theta) - \alpha_2 g(e_2) = 0. \tag{12}$$

If inequality (12) holds as it is, it would allow a slight increase in e_1 without violating any constraint, giving the possibility to increase the optimal value of the environmental investor. This would be in contradiction with the fact that we were earlier at the optimum. Because constraint (9) binds, we can write:

$$\alpha_1(1+\theta)[g(e_1) - g(e_2)] = K_1 - K_2. \tag{13}$$

Because constraint (8) binds, we have inequality (14) from (8) and (10):

$$K_2/(1+\theta) - \alpha_2 g(e_2) = 0 \geq K_1/(1+\theta) - \alpha_2 g(e_1). \tag{14}$$

Third, Eq. (14) states that a firm of type α_2 gains nothing by pretending to be a firm of type α_1. By pretending so, it runs the risk of getting a negative rent.

The previous discussion leads to rewriting program (6)–(10) as program (6′), (7′), (9′).

$$\underset{e_1, e_2, K_1, K_2 \geq 0}{\text{Max}} E(U_P) = q(fe_1 - K_1) + (1 - q)(fe_2 - K_2), \tag{6'}$$

$$K_2 - (1 + \theta)\alpha_2 g(e_2) = 0, \tag{7'}$$

$$K_1 - K_2 - (1 + \theta)\alpha_1[g(e_1) - g(e_2)] = 0. \tag{9'}$$

Assuming interior solutions, we have results derived in Appendix A.2 for program (6′), (7′), (9′).

First, $e_1^{**} = e_1^{*}$[4]: at optimum, the quantity of green good contracted with the most efficient type is equal to the quantity contracted under perfect information with the same type (see (A.18) in Appendix A.2). This result means that asymmetric information does not distort the production level of the most efficient firm.

Second, $e_1^{**} \geq e_2^{**}$: at optimum, the most efficient type would be asked to produce more green good than the least efficient type (see (A.20) and the following comment). This result states that under asymmetric information and transaction cost, the investor will structure the contract so as to bring the most efficient firm to produce more green good with appropriate compensation. Moreover, if the compensation fund is used as mandatory subsidy to produce green good, some market-like mechanism may develop between firms in the spirit of the market for pollution rights.

Third, $e_2^{**} \leq e_2^{*}$: at optimum, the quantity of green good produced by the inefficient firm under imperfect information is less than the quantity it produces under perfect information (see (A.20) and the following comment). Contrary to the most efficient type, instance of asymmetric information distorts away the quantity of green good produced by the inefficient firm from its efficient level.

Table 1 summarizes results from comparative statics analysis of program (6′), (7′), (9′) developed in Appendix A.2. Basically, the results suggest that higher transaction costs θ, higher production/technological costs of the least efficient type (α_2) (further degradation in the least efficient technology), higher probability (q) of selecting the most efficient type (broader diffusion of the low-cost technology), and lower technological costs of the most efficient type (α_1) (further improvement of the low-cost technology), lead to the decrease of the least efficient firm (type α_2)'s share in production of green good.

2.4. *A comparison criterion*

In this subsection, we ask and answer the following question: which of asymmetric information and transaction cost impede more the production of credits of emission reduction in developing countries?

[4]We double star optimal values under imperfect information.

Table 1. Determinants of production of green good under imperfect information.

Determinants	Most efficient firms	Least efficient firms
	e_1^{**}	e_2^{**}
θ	$-$	$-$
α_1	$-$	$+$
α_2	0	$-$
q	0	$-$
f	$+$	$+$

Note: $+$ = positive effect, $-$ = negative effect and 0 = no effect.

This is a difficult question because asymmetric information and transaction cost are not of the same kind and are not valued in the same unit. We resolve the difficulty by assuming that countries "invest" to reduce each obstacle until marginal cost equals marginal benefit of investment. We know that both asymmetric information and transaction cost reduce the developing country's profit directly. So the indicator that we construct responds to the following operational question: what is the effect on the production of CERs (e^{**}) of a marginal increase in transaction cost $\theta(d\theta)$ compensated by an increase in q by dq so that the total effect on the developing country's profit is 0 ($dU_P = 0$)?

We construct a comparison criterion (CCR) used to answer this operational question in Appendix A.3. The criterion is given by Eq. (15):

$$\mathrm{CCR} = \underbrace{\frac{\rho[(\rho - 1) + \varepsilon_q/\bar{q}]}{(\rho-1)^2}}_{\text{Asymmetric information effect}} + \underbrace{\varepsilon_\theta}_{\text{Transaction cost effect}}. \tag{15}$$

In formula (15), asymmetric information effect is positive while transaction costs effect is negative.

If CCR < 0, we state that transaction cost effect dominates asymmetric information effect.

If CCR > 0, we state that transaction cost effect is dominated by asymmetric information effect.

If CCR $= 0$, transaction cost effect is equal to asymmetric information effect.

We may check these conditions empirically by using the Wald test. But the problem is that every parameter of CCR is observable but the measure of technological gap ρ (a measure of cost difference between the most and least efficient types). We will simulate the Wald test by taking values of $\rho \in [1, 3]$.

3. Empirical Model and Data

3.1. *Empirical model*

We shall use a structural approach to the empirical analysis of comparison between transaction costs effect and asymmetric information effect. This strategy means that the econometric model for the observed CER is derived directly from the underlying theoretical model.

The previous theoretical analyses show that transaction costs (θ) and conditions of identification of efficient green projects (q) are major determinants of the production of green good in developing countries. To test these variables are the major determinants of production of CER, we build and estimate an empirical econometric model. Our identification strategy is to control for confounding variables that are correlated with both CER and the causal variables (transaction costs and conditions of projects' identification).

The process of producing credit from emission reduction (CER) under the CDM consists of many steps (intention, contracting, producing, evaluation, and certifying by an independent third party). We may assume that there is a continuum of countries based on their unobservable production of CER. Among these countries we can distinguish:

- countries that have already produced some quantity of CER,
- countries that have projects in the pipelines but do not get as yet any CER,
- countries that are considering seriously to enter the process of producing CER, and
- countries that do not think even about starting the process.

Thus the level of supply of green projects (degree of interest of each country in CDM) that we name CER_i^* is a latent variable and is not observable. We accordingly specify the empirical model to be estimated as:

$$\mathrm{CER}_i^* = \alpha + \beta\theta_i + \rho q_i + \delta' X_i + u_i, \tag{16}$$

where:

i refers to countries, CER_i^* is the desired certified emissions credits produced by country i, θ is transaction costs variable, q is quality of proposed projects, X_i is vector of control variables, $\alpha, \beta, \rho, \delta$ are parameters, and u the error term.

Since CER_i^* is not observable, we cannot estimate the empirical model (16). However, actual certified quantity of CER is observed. Then, the model to be estimated becomes:

$$\begin{cases} \mathrm{CER}_i = \alpha + \beta\theta_i + \rho q_i + \delta' X_i + u_i & \text{if } \mathrm{CER}_i^* > 0, \\ \mathrm{CER}_i = 0 \quad \text{if } \mathrm{CER}_i^* \le 0. \end{cases} \tag{17}$$

Since many countries with $\mathrm{CER}_i^* < 0$ supply no CER, the dependent variable is censored at zero and hence the empirical model requires a censored regression such as the Tobit model. Furthermore, since θ and q enter nonlinearly in the optimal production level of greed good, we use a functional log–log form for the empirical model. In this functional form, ε_q and ε_θ are respectively the coefficients of asymmetric information and transaction costs variables.

3.2. *Data*

3.2.1. *Data sources*

Data used to estimate empirical model (17) come from databases compiled by UNFCC and the World Bank. The World Bank database is built from Enterprise Survey (ES) and posted on the World Bank Group website (www.enterprisesurveys.org). The ES data contain indicators computed from a firm-level annual survey of representative samples of the private sector (business owners or top managers) in an economy. The indicators for transaction costs are meant to 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 as experienced by existing firms. The areas covered by ES data are 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.

3.2.2. *Measurement of CER*

The first CDM project could be registered in 2001 (World Bank, 2010) and Brazil did register the first CDM project in November 2004. However, the Kyoto Protocol entered into force in 2005. Taking that fact into account, CER is measured as the average production of CERs by each country over the period 2007–2010.

3.2.3. *Measurement of transaction costs variable θ*

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

3.2.4. *Measurement of asymmetric information variable q*

The quality of proposed project variable q (probability of selecting the efficient firm) can be measured by the percentage of projects abandoned or rejected for each country. Since such data are not available, we use innovation and technology (measured by OWEB, the percentage of firms owning website) as proxy for q.

3.2.5. *Control variables X*

Our control variables' vector X contains two variables: total CO_2 emission (CO_2) in 2004 and, the average size of firms measured by average number of permanent, full-time employees (*NEMPLOY*) for each country. Following the literature on the Kuznets curve for environmental pollution, we could have used gross domestic product (GDP) as another control variable. But it turned out to be highly correlated with CO_2 and OWEB. Indeed, with data on investment climate, multicolinearity is common because macroeconomic and trade policy, microeconomic framework, and enabling infrastructure variables are closely interdependent (Olawuyi, 2009). GDP is then abandoned as control variable to avoid multicolinearity.

3.2.6. *Sample of countries covered*

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

3.2.7. *Description of the data*

Figure 2 depicts average levels of CER and CO_2 as percentages of global averages and table Appendix A.4 gives the descriptive statistics on the model variables for the five continents. We notice that Asia fares better in producing CERs than any other continent. That is certainly due to the fact that Asia is the major producer of CO_2 among developing countries. This suggests that CO_2 emission level is a major determinant of the production of CERs.

Average figures show that Africa strives to do better than Asia to improve the quality of business environment as measured by bribes (GRAFT), but the situation is worse in Africa than in Asia concerning web connection (OWEB). Furthermore, firms'

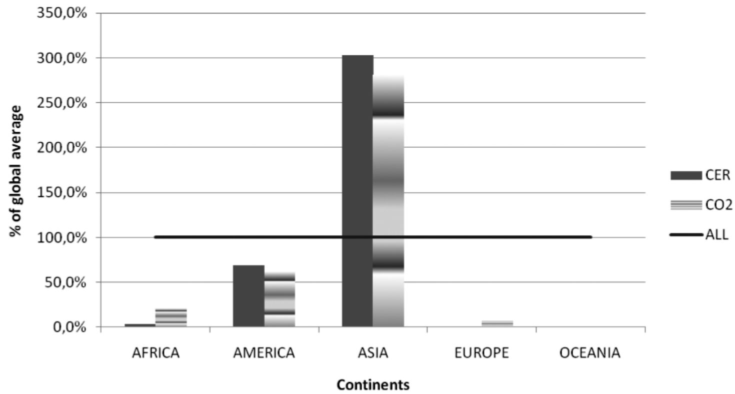

Figure 2. Average production of CER and 2004 CO_2 emissions per continent as percentages of global averages.

sizes are smaller in Africa than elsewhere but Oceania.[5] Data show that despite the fact that some European and Oceanic countries are closer to potential CDM host countries located in these continents, access to CDM seems to be a competition between African, American, and Asian countries. We then reduce the estimation of the empirical model to the sample including African, American, and Asian countries only.

4. Empirical Econometric Results

Table 2 shows the results of the econometric empirical estimation of model (17). Model 1 includes only the transaction costs and asymmetric information variables, and model 2 includes the control variables (CER and CO_2) together with the transaction costs and asymmetric information variables.

The likelihood ratio tests show that both models are highly significant (one percent level), meaning that the variables included in the models explain a significant proportion of the variations in the dependent variable (CER).

The coefficient of GRAFT is significant in both empirical models with the expected negative signs. This suggests that bribing in infrastructures (GRAFT) is a major obstacle to the production of CER in developing countries.

Another important result is the grandfathering effect. Results show that countries with an initial high stock of CO_2 or high mitigation potential before the inception of the CDM benefit more from the mechanism than countries that are less polluted. This result may be explained by the fact that it is easier and cheaper for agents involved (developed countries, designated operating entities and host developing countries) to produce CER in countries where the stock of CO_2 is abundant (Michaelowa and Jotzo, 2003). Indeed, developed countries decide on which developing countries they want to

[5]We recall that as concerning the interpretation of the variables, more means heavier constraint for GRAFT. In contrary, a high level of OWEB means a high level of internet connection, more innovation, and more information, which is good.

Table 2. Empirical econometric results (Tobit models).

Log of independent variables	Dependent variable: Logarithm of the quantity of CER (LnCER)	
	Models	
	1	2
GRAFT	−0.32**	−0.26**
	(0.13)	(0.10)
TAXADM	0.08	0.03
	(0.13)	(0.10)
FINANCEC	−0.28**	−0.15*
	(0.12)	(0.08)
OWEB		0.05
		(0.08)
CO_2		2.96***
		(0.74)
NEMPLOY		0.03
		(0.02)
CONSTANT	8.08**	−23.37***
	(3.81)	(6.99)
Likelihood ratio	13.19***	43.35***
Pseudo R^2	0.04	0.15
Wald test for CCR		
$\rho = 1.1$	$W =$	
$\rho = 1.5$		
$\rho = 2.0$		
$\rho = 3.0$		
Number of observations	80	79

Note: Standard errors are in parentheses. *, **, *** indicate statistical significance at 10%, 5%, and 1% levels, respectively.

cooperate with to produce credits of emission reductions at least costs and least investment risks. Results show that their strategy selects developing countries with high mitigation potentials (high initial CO_2 emissions) as lower risk countries (Olawuyi, 2009). These results appeal for special strategies to encourage production of CERs in smaller countries in the developing world. Key among these strategies are measures that would improve the investment climate, reduce transaction costs, lower taxes, increase access to credit, promote effective legal mechanisms to curb corruption, and improve quality of CDM projects.

5. Concluding Remarks

In this paper, we have shown theoretically and empirically that transaction costs operating directly through bribery and asymmetric information are major factors affecting negatively the supply response to CDM in developing countries. We also showed that transaction costs effect outweighs asymmetric information effect. These results are consistent with the expectations that efficient functioning of environmental instruments cannot be disconnected from the business environment in which they are implemented. In developing countries, the business environment is highly distorted by many constraints. Thus, if one wants smaller and poorer developing countries to benefit from environmental instruments designed for them, one should begin by making their investment climate attractive to CDM investments which are market driven, are in search of host countries with high potential for substantial low cost and low business risk emission reductions. This strategy can counterbalance the effect of initial endowment in CO_2 that turned out to be a major determinant of investment in production of CERs in developing countries.

Appendix A

A.1. *Perfect information program* (3)–(4)

Taking λ as the Lagrange multiplier, the Lagrange function of the program (3)–(4) is given by:

$$L(e_i, K_i; \lambda) = fe_i - K_i + \lambda\{K_i/(1+\theta) - \alpha_i g(e_i)\}.$$

Assuming interior solutions, the first-order conditions (FOC) are given by:

$$\frac{\partial L(e_i, K_i; \lambda)}{\partial e_i} = f - \lambda\alpha_i g'(e_i) = 0, \tag{A.1}$$

$$\frac{\partial L(e_i, K_i; \lambda)}{\partial K_i} = -1 + \lambda/(1+\theta) = 0, \tag{A.2}$$

$$\frac{\partial L(e_i, K_i; \lambda)}{\partial \lambda} = K_i/(1+\theta) - \alpha_i g(e_i) = 0. \tag{A.3}$$

From (A.2), we have:

$$\lambda = 1 + \theta. \tag{A.4}$$

Substituting (A.4) into (A.1), we have:

$$f - (1+\theta)\alpha_i g'(e_i) = 0. \tag{A.5}$$

If $f \prec (1+\theta)\alpha_i g'(e_i)$, then $e_i = 0$, firm i produces no quantity of e-good.

Totally differentiating (A.5), we have:

$$\frac{de_i^*}{d\theta} = \frac{-g'(e_i^*)}{g''(e_i^*)(1+\theta)} < 0, \quad \frac{de_i^*}{d\alpha_i} = \frac{-g'(e_i e_i^*)}{g''(e_i^*)\alpha_i} < 0, \quad \text{and}$$
$$\frac{de_i^*}{df} = \frac{1}{g''(e_i^*)\alpha_i(1+\theta)} > 0. \tag{A.6}$$

Totally differentiating (A.3) and taking into account (A.6), we have:

$$\frac{\partial K_i^*}{\partial \theta} = \alpha_i g(e_i) + (1+\theta)\alpha_i g'(e_i)\frac{\partial e_i^*}{\partial \theta}, \tag{A.7}$$

$$\frac{\partial K_i^*}{\partial \alpha_i} = (1+\theta) g(e_i) + (1+\theta)\alpha_i g'(e_i)\frac{\partial e_i^*}{\partial \alpha_i}. \tag{A.8}$$

Signs of (A.7) and (A.8) are undetermined.

$$\frac{\partial K_i^*}{\partial f} = (1+\theta)\alpha_i g'(e_i)\frac{\partial e_i^*}{\partial f} > 0. \tag{A.9}$$

A.2. *Imperfect information program (6′), (7′), (9′)*

Taking ϕ and γ as Lagrange multipliers, the Lagrange function of program (6′), (7′), (9′) is given by:

$$\begin{aligned} H = {} & q(fe_1 - K_1) + (1-q)(fe_2 - K_2) + \phi[K_2 - (1+\theta)\alpha_2 g(e_2)] \\ & + \gamma\{K_1 - K_2 - (1+\theta)\alpha_1[g(e_1) - g(e_2)]\}. \end{aligned} \tag{A.10}$$

Assuming interior solutions, the FOC are given by:

$$\frac{\partial H(e_1, K_1, e_2, K_2; \phi, \gamma)}{\partial e_1} = qf - \gamma(1+\theta)\alpha_1 g'(e_1) = 0, \tag{A.11}$$

$$\frac{\partial H(e_1, K_1, e_2, K_2; \phi, \gamma)}{\partial e_2} = (1-q)f - \phi(1+\theta)\alpha_2 g'(e_2) + \gamma(1+\theta)\alpha_1 g'(e_2) = 0, \tag{A.12}$$

$$\frac{\partial H(e_1, K_1, e_2, K_2; \phi, \gamma)}{\partial K_1} = -q + \gamma = 0, \tag{A.13}$$

$$\frac{\partial H(e_1, K_1, e_2, K_2; \phi, \gamma)}{\partial K_2} = -(1-q) + \phi - \gamma = 0, \tag{A.14}$$

$$\frac{\partial H(e_1, K_1, e_2, K_2; \phi, \gamma)}{\partial \phi} = K_2 - (1+\theta)\alpha_2 g(e_2) = 0, \tag{A.15}$$

$$\frac{\partial H(e_1, K_1, e_2, K_2; \phi, \gamma)}{\partial \gamma} = K_1 - K_2 - (1+\theta)\alpha_1[g(e_1) - g(e_2)] = 0. \tag{A.16}$$

From (A.13) and (A.14), we have:

$$\gamma = q \quad \text{and} \quad \phi = 1. \tag{A.17}$$

Thus:

(a) (A.11) and (A.17) give:

$$(1+\theta)\alpha_1 g'(e_1) = f. \tag{A.18}$$

Equation (A.18) is exactly the same condition obtained in the case of perfection information for a firm of type α_1. Thus we conclude that the value of e_1 does not differ in equilibrium whether we have perfect information or imperfect information, i.e., $e_1^{**} = e_1^{*}$.

From condition (A.18) we deduce immediately the following comparative static results:

$$\frac{de_1^{**}}{d\theta} < 0, \quad \frac{de_1^{**}}{d\alpha_1} < 0, \quad \frac{de_1^{**}}{df} > 0 \quad \text{and} \quad \frac{de_1^{**}}{dq} = \frac{de_1^{**}}{d\alpha_2} = 0. \tag{A.19}$$

(b) (A.12) and (A.17) give:

$$(1+\theta)\alpha_2 g'(e_2) = \frac{\alpha_2(1-q)f}{(\alpha_2 - \alpha_1 q)} = \left[1 - \frac{q(\alpha_2 - \alpha_1)}{(\alpha_2 - \alpha_1 q)}\right] f < f = (1+\theta)\alpha_1 g'(e_1). \tag{A.20}$$

Comparing condition (A.20) to condition (A.18), knowing that $\alpha_2 - \alpha_1 q > 0$ because $0 \leq q \leq 1$, $\alpha_2 - \alpha_1 > 0$ and that $g'(\cdot)$ is increasing in e, we can assert that $e_2^{**} < e_2^{*}$ and $e_2^{**} \leq e_1^{*}$.

These results mean that the least efficient type produces under asymmetric information a quantity of green good that is lower than the quantity that it would produce under perfect information. The quantity of green good produced by the least efficient type is also inferior to the quantity produced by the most efficient type.

The following comparative static results are deduced from (A.20):

$$\frac{\partial e_2}{\partial \theta} < 0, \quad \frac{\partial e_2}{\partial \alpha_1} > 0, \quad \frac{\partial e_2}{\partial \alpha_2} < 0 \quad \frac{\partial e_2}{\partial q} < 0 \quad \text{and} \quad \frac{\partial e_2}{\partial f} > 0. \tag{A.21}$$

A.3. *Derivation of a comparison criterion*

At optimum, we have:

$$\begin{aligned} E(U_P^{**}) &= q(fe_1^{**}(f,q,\theta) - K_1^{**}(f,q,\theta)) + (1-q)(fe_2^{**}(f,q,\theta) - K_2^{**}(f,q,\theta)), \\ E(U_P^{**}) &= q\{fe_1^{**}(f,q,\theta) - K_1^{**}(f,q,\theta) - fe_2^{**}(f,q,\theta) + K_2^{**}(f,q,\theta)\} \\ &\quad + fe_2^{**}(f,q,\theta) - K_2^{**}(f,q,\theta), \end{aligned} \tag{A.22}$$

$$\left.\frac{dq}{d\theta}\right|_{dU_P(q,\theta)=0} = -\frac{\begin{array}{c} q[fe_{1\theta}^{**}(f,q,\theta) - K_{1\theta}^{**}(f,q,\theta) - fe_{2\theta}^{**}(f,q,\theta) + K_{2\theta}^{**}(f,q,\theta)] \\ + fe_{2\theta}^{**}(f,q,\theta) - K_{2\theta}^{**}(f,q,\theta) \end{array}}{\begin{array}{c} fe_1^{**}(f,q,\theta) - K_1^{**}(f,q,\theta) - fe_2^{**}(f,q,\theta) + K_2^{**}(f,q,\theta) \\ + q[fe_{1q}^{**}(f,q,\theta) - K_{1q}^{**}(f,q,\theta) - fe_{2q}^{**}(f,q,\theta) + K_{2q}^{**}(f,q,\theta)] \\ + fe_{2q}^{**}(f,q,\theta) - K_{2q}^{**}(f,q,\theta) \end{array}}. \tag{A.23}$$

In the absence of information, we may assume that $q = 0$ (only the least efficient technology is diffused and used), i.e., all projects are of type α_2.

Thus (A.23) becomes:

$$\left.\frac{dq}{d\theta}\right|_{\begin{cases} dUP(q,\theta)=0 \\ q=0 \end{cases}} = -\frac{(fe_{2\theta}^{**} - K_{2\theta}^{**})}{f(e_1^{**} - e_2^{**}) - (K_1^{**} - K_2^{**}) + (fe_{2q}^{**} - K_{2q}^{**})}, \tag{A.24}$$

$$E(e^{**}) = qe_1^{**}(q,\theta) + (1-q)e_2^{**}(q,\theta), \tag{A.25}$$

$$\frac{dE(e^{**})}{d\theta} = \{e_1^{**} + qe_{1q}^{**} - e_2^{**} + (1-q)e_{2q}^{**}\}\frac{dq}{d\theta} + qe_{1\theta}^{**} + (1-q)e_{2\theta}^{**}. \tag{A.26}$$

Substituting (A.24) in (A.26), we have:

$$\left.\frac{dE(e^{**})}{d\theta}\right|_{\begin{cases} dU_P(\theta,q)=0 \\ q=0 \end{cases}} = \underbrace{\frac{-(e_1^{**} - e_2^{**} + e_{2q}^{**})(fe_{2\theta}^{**} - K_{2\theta}^{**})}{f(e_1^{**} - e_2^{**}) - (K_1^{**} - K_2^{**}) + (fe_{2q}^{**} - K_{2q}^{**})}}_{\text{Asymmetric information effect}} + \underbrace{e_{2\theta}^{**}}_{\text{Transaction cost effect}}. \tag{A.27}$$

When $q \to 0$, the environmental investor assumes that there are only projects of type α_2, he realizes the first-best, i.e., condition (A.5) verifies. Then from (A.5), (A.15) and (A.16), we have:

$$f - (1+\theta)\alpha_2 g'(e_2^{**}) = 0, \tag{A.28}$$

$$K_1^{**} = (1+\theta)\alpha_1 g(e_1^{**}), \tag{A.29}$$

$$K_2^{**} = (1+\theta)\alpha_2 g(e_2^{**}), \tag{A.30}$$

$$K_{2q}^{**} = (1+\theta)\alpha_2 g'(e_2^{**})e_{2q}^{**}, \tag{A.31}$$

$$K_{2\theta}^{**} = \alpha_2 g(e_2^{**}) + (1+\theta)\alpha_2 g'(e_2^{**})e_{2\theta}^{**}, \tag{A.32}$$

$$K_1^{**} - K_2^{**} = (1+\theta)\alpha_1[g(e_1^{**}) - g(e_2^{**})]. \tag{A.33}$$

Substituting for K_i^{**} from (A.28)–(A.27), A.27 becomes:

$$\left.\frac{dE(e^{**})}{d\theta}\right|_{\begin{cases} dU_P(\theta,q)=0 \\ q=0 \end{cases}}$$
$$= \underbrace{\frac{-(e_1^{**} - e_2^{**} + e_{2q}^{**})[(f - (1+\theta)\alpha_2 g'(e_2^{**}))e_{2\theta}^{**} - \alpha_2 g(e_2^{**})]}{(1+\theta)\alpha_2 g'(e_2^{**})(e_1^{**} - e_2^{**}) - (1+\theta)\alpha_1[g(e_1^{**}) - g(e_2^{**})] + [(f - (1+\theta)\alpha_2 g'(e_2^{**}))e_{2q}^{**}]}}_{\text{Asymmetric information effect}}$$
$$+ \underbrace{e_{2\theta}^{**}}_{\text{Transaction cost effect}}$$

Whence:

$$\left.\frac{dE(e^{**})}{d\theta}\right|_{\begin{cases} dU_P(\theta,q)=0 \\ q=0 \end{cases}} = \frac{1}{(1+\theta)} \underbrace{\frac{(e_1^{**} - e_2^{**} + e_{2q}^{**})\alpha_2 g(e_2^{**})}{\alpha_2 g'(e_2^{**})(e_1^{**} - e_2^{**}) - \alpha_1[g(e_1^{**}) - g(e_2^{**})]}}_{\text{Asymmetric information effect}} + \underbrace{e_{2\theta}^{**}}_{\text{Transaction cost effect}}. \quad \text{(A.34)}$$

Taking the following functional form for the cost function:

$$\alpha_i g(e_i) = \frac{1}{2}\alpha_i e_i^2. \quad \text{(A.35)}$$

We have from (A.5):

$$e_1^{**} = \frac{f}{(1+\theta)\alpha_1} = \frac{\alpha_2}{\alpha_1} e_2^{**}. \quad \text{(A.36)}$$

And from (A.34) to (A.36), we have:

$$\left.\frac{dE(e^{**})}{d\theta}\right|_{\begin{cases} dU_P(\theta,q)=0 \\ q=0 \end{cases}} = \frac{1}{(1+\theta)} \underbrace{\frac{(e_1^{**} - e_2^{**} + e_{2q}^{**})\alpha_2 e_2^2}{2\alpha_2 e_2^{**}(e_1^{**} - e_2^{**}) - \alpha_1[e_1^2 - e_2^2]}}_{\text{Asymmetric information effect}} + \underbrace{e_{2\theta}^{**}}_{\text{Transaction cost effect}}. \quad \text{(A.37)}$$

Or

$$\left.\frac{dE(e^{**})}{d\theta}\right|_{\begin{cases} dU_P(\theta,q)=0 \\ q=0 \end{cases}} = \frac{1}{(1+\theta)} \underbrace{\frac{(e_1^{**} - e_2^{**} + e_{2q}^{**})e_2^{**} e_1^{**}}{(e_1^{**} - e_2^{**})^2}}_{\text{Asymmetric information effect}} + \underbrace{e_{2\theta}^{**}}_{\text{Transaction cost effect}}. \quad \text{(A.38)}$$

Note $\rho = \frac{\alpha_2}{\alpha_1} > 1$ is a measure of technological gap between the most and the least types. This is a measure of cost difference. Using ρ, (A.24) and (A.38) become respectively:

$$\left.\frac{dq}{d\theta}\right|_{\begin{cases} dUP(q,\theta)=0 \\ q=0 \end{cases}} = \frac{\rho}{(1+\theta)(\rho-1)^2}, \quad \text{(A.39)}$$

$$\left.\frac{dE(e^{**})}{d\theta}\right|_{\begin{cases} dU_P(\theta,q)=0 \\ q=0 \end{cases}} = \underbrace{\frac{\rho(\rho e_2^{**} - e_2^{**} + e_{2q}^{**})}{(\rho-1)^2(1+\theta)}}_{\text{Asymmetric information effect}} + \underbrace{e_{2\theta}^{**}}_{\text{Transaction cost effect}}. \quad \text{(A.40)}$$

Or in general terms:

$$\left.\frac{dE(e)}{d\theta}\right|_{\begin{cases} dU_P(\theta,q)=0 \\ q=0 \end{cases}} = \underbrace{\frac{\rho\left[(\rho-1)e + e_q\right]}{(\rho-1)^2(1+\theta)}}_{\text{Asymmetric information effect}} + \underbrace{e_{\theta}}_{\text{Transaction cost effect}}. \quad \text{(A.41)}$$

Noting:

ε_q = elasticity of e with respect to q, and
ε_θ = elasticity of e with respect to θ,

we have (assuming $1+\theta \approx \theta$):

$$\left.\frac{dE(e)}{d\theta}\right|_{\begin{cases} dU_P(\theta,q)=0 \\ q=0 \end{cases}} = \left\{ \underbrace{\frac{\rho\left[(\rho-1)+\varepsilon_q/q\right]}{(\rho-1)^2}}_{\text{Asymmetric information effect}} + \underbrace{\varepsilon_\theta}_{\text{Transaction cost effect}} \right\} \frac{e}{\theta}. \tag{A.42}$$

Our criterion to compare transaction cost effect and asymmetric information effect is:

$$\text{CCR} = \underbrace{\frac{\rho\left[(\rho-1)+\varepsilon_q/\bar{q}\right]}{(\rho-1)^2}}_{\text{Asymmetric information effect}} + \underbrace{\varepsilon_\theta}_{\text{Transaction cost effect}}, \tag{A.43}$$

with:

$\bar{q}$ = average asymmetric information indicator.

A.4. *Descriptive statistics on the variables*

CONTINENTS		CERs	GRAFT	OWEB	NEMPLOY	CO_2
AFRICA	Mean	40781.25	15.82	17.34	33.65	22421.12
	Std. Dev.	195007.42	13.06	10.41	39.94	70377.72
	N	41	39	41	41	41
AMERICA	Mean	854995.03	6.06	42.72	43.03	67912.61
	Std. Dev.	2558233.86	3.99	17.50	23.56	117453.51
	N	20	19	20	20	20
ASIA	Mean	3750668.21	25.10	28.10	96.13	306020.16
	Std. Dev.	13163794.49	18.51	15.84	104.05	974461.75
	N	28	22	26	28	28
EUROPE	Mean	0.00	8.85	49.53	51.58	7499.60
	Std. Dev.	0.00	9.56	15.17	24.47	9148.81
	N	6	6	6	6	6
OCEANIA	Mean	1777.50	10.69	25.39	17.99	471.19
	Std. Dev.	3974.61	7.81	11.08	13.76	792.88
	N	5	5	5	5	5
ALL COUNTRIES	Mean	1237995.29	15.28	27.75	53.31	108934.36
	Std. Dev.	7149126.93	14.44	17.55	67.12	528461.39
	N	100	91	98	100	100

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