ECONOMIC INCENTIVES FOR POLLUTION CONTROL IN DEVELOPING COUNTRIES: WHAT CAN WE LEARN FROM THE EMPIRICAL LITERATURE?

JEL classification: Q28, Q53

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Abstract. *This review seeks to analyze the implementation of Market Based Instruments (MBIs) in developing countries. The focus is mostly (but not exclusively) on the empirical literature. The evidence is that MBIs have played a role in pollution reduction. However, this conclusion is mostly based on evidence from one country – China. Moreover, these tools seem to be used in conjunction with command and control instruments.*

Keywords: *Market based policies, economic-incentives, pollution taxes, permits*

1. Introduction

Some of the most challenging environmental problems are nowadays located in developing countries. Air and water pollution, for instance, have reached very high levels in these areas of the world. The reduction of pollution is therefore of paramount importance. Historically, this objective has been targeted by the implementation of Command and Control (CAC) approaches, such as limits and standards. The observed results, however, are in general not very encouraging (Eskeland and Jimenez, 1992; Russell and Vaughan; 2003; Blackman 2009). One possible alternative way to deal with enviromental problems is the implementation of market-based instruments. Market-based instruments are said to "harness market forces" (Stavins, 1991) so that they use market signals to affect behaviour (of both consumers and firms) towards pollution control. They are also called Economic Incentives for pollution control (EI) and include pollution charges or levies, taxes and tradable permits. This stresses the way in which MBIs achieve pollution control. They create an incentive for firms, by imposing an implicit or explicit price on emissions, so that it is beneficial to clean up more provided that a sufficiently low-cost method (technology or process) is available. From a theoretical standpoint, "when properly designed and implemented, market-based instruments allow any desired level of pollution clean-up to be realized at the lowest overall cost to society, by providing incentives for the greatest reductions in pollution by those firms that can achieve these reductions most cheaply" (Stavins, 2003 p. 359). These instruments equalize the incremental amount that firms spend to reduce pollution - their marginal cost [Montgomery (1972), Baumol and Oates (1988),

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Tietenberg (1995)]. In the literature, MBIs are traditionally opposed to the so-called Command and Control (CAC) instruments. This view is, however. somewhat inaccurate. In many circumstances these tools are complementary. Moreover, the success of MBIs depends upon a well-functioning monitoring and command and control system (including properly functioning institutions). Moreover there are situations in which a command and control action (through setting up standards) can be superior to MBI. This is particularly true when (the marginal) abatement cost of pollution is less responsive than environmental damage. It should be also noted that CAC approaches may be sensible as an initial approach. This is specially the case when there is limited information and the environmental damage is important. In addition, the costs of an MBI approach "are assumed to exceed the operating costs of a system of fixed standards" so for there to be cost savings "there must exist some heterogeneity among firms i.e. if options for reducing pollution are limited or potential trading pools are small, the gains from a more market-oriented approach may not justify the costs (Romstad, 1999, p52). A quintessential characteristic of the command and control methods is that they set a uniform standard (both in terms of performance and of technology standards[1]) and compel firms to share the pollution-control burden. Setting performance standards can limit emissions of some pollutants. However, this is achieved with no (or little) consideration of the possible cost heterogeneity involved. Holding all firms to the same target can be expensive and counterproductive (Stavins, 2003). Some technology, appropriate in one situation, may not be appropriate (or as mentioned cost-effective) in another. Thus, controlling costs differs enormously from one firm to another due to the firm's production characteristics. It is maintained that to achieve pollution control, CAC seems to impose a relatively high cost for firms (Pandey, 2005). The cost of controlling emissions may differ greatly among firms and even among sources within the same firm. An example is reported by Tietenberg (1985). In this survey of eight empirical studies of air pollution control it was found that the ratio of actual, aggregate costs of the conventional, command-and-control approach to the aggregate costs of least-cost benchmarks ranged from 1.07 for sulphate emissions in the Los Angeles area to 22.0 for hydrocarbon emissions at all domestic DuPont plants. In essence, there may be little financial incentive for businesses to exceed their control targets, and "both technology-based and performance-based standards may discourage adoption of new technologies" (Stavins 2003). Command-and-control approaches could, in theory, achieve this cost-effective solution, but this would require that different standards be set for *each* source of pollution. To achieve this target, policy makers or institutions need to find out information about the compliance costs *each* firm faces. This may be a very challenging goal. Market-based instruments provide for a cost-effective allocation of the burden of pollution control without having access to both these piece of information. For these reasons command and control methods seems to be rather complex to implement.

There are therefore some relevant theoretical reasons to consider MBIs "superior" to CAC. Successful implementation is a different thing though. For example, banning leaded petrol or banning hazardous waste is far superior to MBIs in dealing with those problems and often CAC and MBIs are best used together. In other words, in reality most of the time CAC and MBIs do co-exist. For instance, regulators establish a specific level of pollution (or standard) and apply a fee for the amount of pollution above that threshold. Moreover, MBIs can have considerable problems of implementation too. This can be particularly relevant in developing countries where institutional

[1] Technology-based standards specify the method and or equipment that firms can use. A performance standard, instead, sets a uniform control target for firms, while allowing some flexibility in how this target is met.

capabilities may be weak and markets imperfect. This review seeks to analyse the implementation of MBIs in developing countries. What do we know about the use of these tools for pollution control? What are the instruments that have been implemented more successfully and where? This paper attempts to answer these questions by screening the evidence on the use the MBIs. The focus is mostly on the empirical literature. Previous reviews have appeared in the literature.

In the last ten years we have observed a dramatic increase in available data and simultaneous blossoming of econometric analysis from developing countries. It therefore seems very appropriate to update the state of our knowledge with this information.

This paper proceeds as follows. The next section will provide a brief background on MBIs. Section 3 will present the quantitative evidence grouped for type of instrument (e.g. fees, charges and taxes). Section 4 will present evidence of the interaction with other instruments. Section 5 concludes the paper by offering some final remarks.

2. MBIs: implementation and issues

Both CAC and MBIs can be classified considering different criteria. Table 1 (adapted from Blackman and Harrington, 2001) provides a classification in two categories: direct and indirect instruments.

Tab. 1 - Classification of instruments

Regulatory Tool	Direct Instruments	Indirect Instruments
Economic Incentives	Emission fees Marketable permits	Taxes Subsidies
Command and Control	Emissions Standards	Technology Standards

The former require that the regulators will monitor the emission while the latter does not. As mentioned earlier, CAC instruments dictate how much to abate and what abatement technology to use instead of simply creating financial incentives for firms to abate. So for instance emissions standards are direct instruments that require both identification of the amount of pollution and monitoring from the regulator. The above classification is very useful. It identifies some of the general benefits of some MBIs (e.g. flexibility and efficiency) specially when we consider two of the most important dimensions of environmental regulations: *monitoring* and *enforcement*. Fees or levies can be grouped in one specific category: the charge system where. pollution charges, via either fees or taxes applied on the amount of pollution that a firm or source generate are, in essence, what economists would call *Pigovian*[2] taxes. Both a charge system and a tax system use financial instruments to persuade polluters to reduce pollution. In both situations, the regulator attempts to make pollution more costly to the polluter. Because of the charge, the firm has the incentive to reduce emissions to the point where its marginal abatement cost is equal to the fee (or tax) rate. The tax should be set equal to the marginal benefits of clean-up at the efficient level of clean-up. In the case of charges. the regulator sets up a standard for the pollutant and the plant pays a penalty charge for when they exceed the standard. The Chinese Pollution Levy

[2] Pigovian taxes are named after the economist Arthur Pigou; they are taxes levied on a market activity that generates pollution or negative externalities.

System is one of the most comprehensive emission charge systems in the developing world. The imposition of a fee requires the measurement of mass emissions or effluent. This can be more or less complex depending on the pollutant. For instance, some air pollutants are more difficult to monitor than water pollutants. The regulator, moreover, has to set the appropriate fee level and collect the amounts due. Charges on air emissions can be difficult to implement because of difficulties in measuring emissions. While emission standards in most nations are expressed in terms of concentrations, not mass, only fairly crude estimating techniques normally are used to calculate payments due (Anderson, 2002). Besides this, a charge system can be complex to coordinate when there are many different pollutants from different sources.

Deposit-refund systems require a monetary deposit at the time of sale of a product. This deposit is eventually returned when the item is returned. This scheme has been implemented successfully in many high income countries. For instance in the United States, deposit-refund systems have been applied to control the disposal of lead-acid batteries and products containing potential pollutants such as aluminium and glass cans, pesticide, containers, and tyres. The private sector often creates and manages a disposal system. This system helps to subsidize the return of recyclable products. Deposit refund systems thus appear to be most appropriate instruments for discrete, solid commodities. They, however, may have a high cost of implementation. For instance, collecting, refunding deposits on the sale of individual products, returning product for disposal can all be expensive activities. Among middle-income countries, South Korea has one of the most exhaustive deposit systems. This program affects a multitude of products (from packaged paper to televisions, and washing machines).

As mentioned above, taxes are very similar to charges. They, however, are indirect instruments. There is therefore no need for the regulator to determine the abatement level. This makes them easier to implement. Taxes seem appropriate in the context of fuel use and choice. The issue of air pollution control has been addressed in the context of policies aimed at discouraging the use of private transportation during peak hours.

This is because collection would be implemented via tax collection institutions (Blackman and Harrington, 2000). Moreover, consumption of fuel is usually much easier to monitor than emissions. Taxes generate revenues for governments. These revenues can be used to fund investment in projects. Nevertheless, taxes can be politically difficult to put in place. Taxes need to be, in fact, high enough to create a disincentive that then translates into environmental effects. Moreover, there is also the possibility that the taxes will be regressive, hence affecting particularly the poorer part of the population. Decision makers may find this not particularly appealing. if taxes are regressive, they would impose a larger burden on the poorest part of the population. Taxes should, therefore be rejected on distributional grounds. Using household survey data from Costa Rica, Alpizar and Carlsson (2003) tested the incidence of fuel tax. They found that the effect of a 10 percent fuel price rise through all types of direct and indirect spending would be slightly regressive, the magnitude of this combined effect would be modest. They conclude that distributional concerns need not rule out using fuel taxes to address pressing public health and safety problems, particularly if gasoline and diesel taxes can be differentiated.

Besides these points the successful implementation of taxes needs proper enforcement. An example is given by the "forestry tax" in use in Brazil and Colombia. This tax is charged for wood consumption when the extraction is not compensated by reforestation activities. This may be seen as an incentive to curb deforestation. Its enforcement however has been very weak. Therefore the tax did not seem to affect the deforestation rates nor provide important budgetary benefits.

Subsidies could also be used to induce reductions in pollution. Among the subsidies that are used at all levels of government to help manage environmental pollution are grants, low-interest loans, favourable tax treatment, and preferential procurement policies for products believed to pose relatively low environmental risks. Subsidies for environmental management are however sometimes criticized because of their welfare implications but also because they can be seen as a "prize" given to polluters. Thus the subsidy is helping to bear the costs that should be the responsibility of the polluter. Other environmentally related subsidies, such as federal support for timber harvesting in the national forests, also are criticized because they have proven harmful to the environment. Nonetheless, subsidies have become a fairly common tool for managing the environment at every level of government. Eliminating environmentally harmful subsidies can be even more effective when used to improve environmental quality. In the early 1990s, the World Bank made the phase-out of pesticide subsidies a condition for new lending to Egypt. The use of pesticides dropped by nearly 70% over the subsequent five years.

Among the direct instruments, tradeable permits have been attracting much attention. They basically thrive on the creation of a market for pollution. In theory, they can achieve the same cost-minimizing allocation of the control burden as a charge system, while avoiding the problem of uncertain responses by firms (Stavins, 2003). In a tradable permit system, an allowable overall level of pollution is established and subsequently allocated among firms in the form of permits. Firms that keep their emission levels below their allocated level may then sell their surplus permits to other firms or use them to offset excess emissions in other parts of their facilities (Stavins, 2003). As we will see in the next sections, quantitative evidence on the use of this tool is extremely scarce in developing countries. Permits require both a strong regulatory and enforcement capacity to be in place. This usually comes with administrative complexity that may not be at hand in the developing world. This, in fact, may be the key reason why these tools have not been adopted more widely in OECD countries. During the last 20 years OECD countries have experimented MBIs for pollution control. Charges and fees are the most popular tools (both emissions and product charges). For instance emission charges levied on air and water pollutants have been applied in more than 21 countries. Carbon taxes in Denmark, Norway, and Sweden are intended to have an incentive effect, in addition to a revenue-generating effect, but it has been difficult to determine their actual impacts (Blackman and Harrington 1999). Claims have been made that the Swedish and Norwegian taxes have reduced carbon emission (Larsen and Nesbakken 1997). Stronger evidence is on the reduction in water pollution. The Netherlands, for instance, has assessed that effluent fees on heavy metal discharges from large enterprises, and organic discharges from urban and farm households, and from small, medium, and large enterprises have reduced total organic discharges by one-half, and industrial organic emissions by 75 percent (World Bank, 2000). The most ambitious implementation of MBIs has been the control of sulphur dioxide (SO2) emissions in the context of acid rain reduction under Title IV of the *Clean Air Act* amendments of 1990 in the USA. In the first stage the allowance trading program was assigned to 263 most polluting units. Then in successive stages it was extended to other units. These units could emits SO_2 units in relation to the permits assigned by the US Environmental Protection Agency (EPA). Units were allowed to trade the permits or bank them in order to promote cost-effectiveness. The results of the program were satisfactory. Target emissions reductions were achieved. An estimated cost saving of $ 1 billion annually was also reported (Stavins, 2003). While the implementation of these tools has become very widespread, it should be noted that there is no tendency, however, towards replacing the basic regulatory approach with a purely economic one. 'Economic instru-

ments are complements mostly and substitutes only sometimes for other types of approaches' (OECD, 1994, p. 187).

Table 2 presents a success matrix for the implementation of MBIs. It summarizes the activities and requirements for implementing these instruments. It also highlights the conditions for success (e.g. how important is the possibility of monitoring data or enforcing compliance) and the strengths and weaknesses of these policies. Table 3 maps the application of the tool in relation to the type of pollution. It also lists the existing application in developing countries.

Tab. 2 - Success matrix for implementation of MBIs

MBIs	Activities and requirements for establishing and implementing the instrument	Conditions for success	Strengths	Weaknesses
Charge system	The regulator needs to set up the rules clearly Collection of the revenue	Monitoring - Data on pollutant must be available - Enforcing Compliance	Charges - proportional to Pollution	More complex to coordinate with different sources of pollution Monitoring and enforcing are costly activities Institutional integrity must be very high
Deposit Refund	The regulator needs to set up the rules clearly Collection of the revenue	Front end charge (deposit) combined with refund payable when quantities are turned in for recycling. Participation of households	Low legal, institutional and political barriers. No need for monitoring when voluntary	More difficult to enforce because of the voluntary nature of the scheme High cost of implementation
Taxes	The regulator needs to set up the rules clearly Collection of the revenue	Enforcing Compliance	Multiple sources of pollution No need to identify an abatement level No Monitoring data Available Easier to manage Generate Revenues	Do not always incentivate adoption of abatement technologies May affect non - targeted activities Institutional integrity must be very high Politically difficult to accept Distributional Impacts can be distortive
Subsidies	The regulator needs to set up the rules clearly	Monitoring data on pollutants must be available Enforcing Compliance	Incentive to actually change system	Tax payer gets part of the pollution burden
Tradable permits	The regulator needs to set up the rules clearly	Enforcing compliance Data needed for initial allocation Tracking system required Enforcing compliance	Flexibility in the application Cost savings for the regulator Less efficient units of production are likely to stop operating	Regulatory requirements are considerable Consistent legal framework -Political resistance

The reduction in market friction can serve as a market-based policy instrument to reduce pollution. In such cases, substantial gains can be made in environmental protection simply by reducing existing obstacles to market development and functioning. As indicated by Anderson (2002) and Stavins (2003) three main types of market friction can be identified:
(1) market creation for inputs/outputs associated with environmental quality,
(2) liability rules; and
(3) information programs, such as energy-efficiency product labelling requirements.

Market creation is a tool that aims to facilitate the voluntary exchange of rights (i.e. water rights). This is to promote more efficient allocation and use of scarce natural resources. Liability rules encourage firms to consider the potential environmental damage of their decisions. This can be a very effective tool for control in the context of very toxic or hazardous material. Firms have a strong incentive to consider the full implications (in terms of societal risks) of the use of some specific materials. The transactions costs associated with litigation, however, can be very high. Poorly informed markets are less likely to result in an efficient allocation of resources. Product labelling or certification is a way to address this issue and deliver relevant information to the consumer.

While in theory there is a very large set of instruments that can be used the adoption of these policies has been patchy. Most important – for the scope of this survey – the evidence based on econometric analysis is not particularly substantial. We therefore extend the scope by including also some selected case studies.

3. Evidence based on quantitative studies

As mentioned earlier, while command and control approach may work reasonably well for large and highly visible sources of pollution, high costs may affect its implementation. MBI approaches also seem to address small sources of pollution (i.e. households that are not easily controlled by traditional forms) and provide a stimulus for technological change and innovation in pollution control. In general, MBIs may differ from traditional command and control requirements in terms of their information and enforcement requirements, as well as of institutional, political, and other demands. Among incentive-based instruments, there is tremendous variation in the prerequisites necessary for successful implementation (Anderson, 2002). These initiatives aim to improve the environmental effectiveness of regulatory strategies as well as to reduce compliance costs. Environmental fees, charges, and taxes are largely interchangeable in terms of their effects. Pollution reduction can be achieved through environmental levies on inputs, outputs, or on pollution generated by sources. Developing countries have imposed a great variety of such levies. Levies on inputs and products generally are the most easy to collect but are more removed from the actual decision to pollute, weakening the incentive. We follow Anderson (2002) in presenting the requirements imposed by fees on regulators and communities:

- Measurement of mass emissions or effluent
- Setting appropriate fee level
- Collecting amounts due, and
- Disposition of the amounts collected

The Chinese Pollution Levy System is one of the most comprehensive emission charge systems in the developing world. It requires the availability of data monitoring. It is one of the oldest schemes in place and it has been criticized from different angles. For instance, it has been

argued that charges are too low to directly affect polluting behaviour. About three-fourths of levy payments were returned to sources for pollution-control investments and those investments are believed to have had an impact on emissions. The remainder pays for environmental management at the local and regional level. Thus, the Chinese levy can be thought of as "a hybrid policy" with a substantial subsidy component (Anderson 2002). This system has been studied widely in the empirical literature. The paragraph below summarizes the empirical finding related to it.

Tab. 3 - Tool, pollution type and existing application*

MBIs	Issue or source of pollution	Application in Developing Countries
Charge system	Industrial air and water pollution from mostly large units of production.	**China** Colombia Philippines Malaysia Ecuador Mexico
Deposit Refund	Waste management households (glass and plastic, car batteries)	Sri Lanka Mexico Colombia Ecuador Jamaica Venezuela Taiwan Korea
Taxes	Air pollution mostly from large units Fuel use Traffic congestion Halting deforestation via a "Forestry tax"	**Chile** Thailand Kenya Mexico Brazil
Subsidies	Air pollution from both large and small units -Used to incentivate reforestation and adoption of cleaner technolologies	**Chile** **Brazil** Colombia Ecuador Kenya Mexico Tanzania
Tradable permits	Air pollution from both large and small units Water use by large and small farmers -Car use/ congestion in megacities	Chile Singapore Mexico

* in **bold** evidence based on quantitative studies. Details of these studies are reported in sections 3.1, 3.2 and 3.3.

3.1. Evidence based on pollution levy and pollution fees or charges

David Wheeler and his associates provide an assessment of the Chinese levy system in a set of papers. The first paper considered in this survey was published in 1996 as a World Bank Policy Research Working Paper. This is the first attempt to study the levy system systematically. The authors begin by considering most of the criticisms of the system (i.e. it is arbitrarily administered and ineffective). The charge system covers hundreds of thousands of factories. They also observe that strictness of enforcement may vary widely, so factories in different regions face very different penalties for polluting. The paper provides an empirical test of the levy system using a provincial level panel database for the period 1987 - 1993. It analyses the water pollution levy

(so no conclusions may be drawn for air pollution, solid waste, or emissions from facilities). The database is very rich as it incorporates information from many thousands of factories over a seven-year period. This is a period in which we witnessed great changes in China's economy.

The econometric analysis focuses on two measures of environmental performance: intensity of industrial emissions (provincial emissions/output) for organic water pollution, and the effective water pollution levy rate (provincial levy collections per unit of above-standard wastewater discharge). The analysis considers that in each region and period, the effective levy rate and pollutant discharge are jointly determined by the intersection of environmental demand (ED) and supply (ES) functions. The ED function relates industrial pollution intensity to the local price of pollution. It reflects the economics of cost-minimizing abatement by industry, and is formally equivalent to the marginal abatement cost (MAC) function. The ES function specifies the pollution price imposed by the community as damage rises. The equilibrium pollution is reached at the intersection of ED and ES is therefore not necessarily optimal pollution (at the intersection of ED and MSD). The results suggest that the water pollution levy system is neither arbitrary nor ineffective. Across provinces and over time, variations in the effective levy rate are well-explained by proxies for local valuation of environmental damage and community capacity to enforce local norms. Results also suggest that the emissions intensity of Chinese industry was highly responsive to these increases. From 1987 to 1993, provincial pollution intensities fell at a median rate of 50% and total discharges declined at a median rate of 22%. These results are, however, based upon a province level database. As reported by the authors the effective levy also serves as a proxy for enforcement of quantity-based standards. It is possible that a province with a higher levy enforcement rate is also enforcing command-and-control regulation more effectively. This would result in a coefficient estimate that is possibly biased upward. Moreover, the lack of individual data may mask time-invariant firm level heterogeneity. This would again result in biased coefficient estimates.

The same authors addressed a similar research question in a second working paper in 1999. In this paper, the authors expand and deepen the analysis in the following ways. First, they decompose industry's response to the levy into two components: pollution intensity of process production and degree of end-of-pipe (EOP) abatement. Second, they used a new database for 3,000 polluting plants. They find that the elasticity of TSP intensity with respect to the air levy is about -0.65, while the elasticity of COD intensity with respect to the water charge is about -0.2. The decomposition of effects suggests that most of the air levy's impact is through process adjustment, while the water levy has most of its impact at the end-of-pipe. This paper presents a clear improvement with respect to that of 1996. mostly, because of the larger database at the lower lever of aggregation. However, should be noted that TSP is only one specific type of air pollutant (not SO2 or CO2). However, the cross-sectional nature of the analysis does not allow a control for time- invariant unobserved heterogeneity. The estimated parameters must be therefore interpreted with some degree of caution.

Wang (2002) used the same database to understand what is the response to pollution regulations. The focus again is on the pollution charge instrument. The impacts of pollution regulation on abatement expenditures are thus examined for one thousand large and medium Chinese industrial polluters. This paper stress the issue of endogeneity of the wastewater generated, the tonnes of chemical oxygen demand generated, and the pollution charge rate. These endogenous variables are combuned with exogenous variables in each of the models. Additional variables included income, education, industrial share of total GDP, population density, per capita complaints on pollution, and average COD discharge concentration.

The results show that plant-level expenditures on end-of-pipe wastewater treatment are strongly responsive to the pollution charges. The estimated elasticities of operation cost and new investment with respect to pollution price are 65 and 27%, respectively. Other command-and-control regulatory approaches, however, are not found to have systematic and significant impacts on abatement expenditures. While the endogeneity treatment provides a better alternative to the estimation exercise presented in the earlier paper, the lack of reported testing on the validity of the instruments makes the assessment of the analysis difficult.

In another follow up paper (using again the same data from 3000 Chinese factories) Wang and Wheeler (2005) estimate an econometric model of endogenous enforcement in which factories' levy rates and emissions are jointly determined by the interaction of local and national enforcement factors, abatement costs and regulator–manager negotiations that are sensitive to plant characteristics. Their findings stress the significant deterrent impact of a system that combines progressive financial penalties and self-reporting with few options for contesting regulatory decisions - this despite the prevalence of state enterprises and developing-country conditions. Interestingly, they also find that pollution control through financial incentives has a much greater impact on production processes than on end-of-pipe abatement. More specifically, they estimated a noticeable elasticity (-1.08) for water pollution. For air pollution, the estimated elasticity of -0.65 implies that emissions decline by about 0.65% for each 1% increase in the effective levy rate. For SO2 emissions alone, the estimated elasticity is again noticeable (-1.03). Therefore, firms' response to the water pollution levy is focused on process change, rather than end-of-pipe removal.

A similar water pollution scheme was adopted in Colombia. The Colombia discharge fee program, despite a set of serious problems that limited its success in some regions, (i.e. widespread non-compliance by municipal sewerage authorities, and a confused relationship between discharge fees and emissions standards) seem to have achieved its targets. Indeed, in some watersheds, pollution loads dropped significantly after the program was introduced (Blackman, 2009). For instance, in the ecologically sensitive area of the Rio Negro watershed, water pollution from industrial sources was reduced by 28 % (Sterner, 2003).

Water effluent charges have also been experienced in Central European and Eastern countries. In Poland, a revenue raising charge to provide funds for environmental protection and water management on a national, provincial and municipal scale was implemented. Pollutants targeted include BOD, COD,[3] suspended solids, chloride and sulphate ions, heavy metal and volatile compounds. In 1996 BOD decreased by 11,000 tons and insoluble substance by 71,000 tons (OECD 1999, p.92). Similar actions were taken in Latvia and Estonia. In Latvia the water effluent charge referred to 36 pollutants. Rates can differ and are based on two criteria: the level of hazardousness of the category and the type of recipient. For instance, BOD, phosphorus and nitrogen are classified as moderately hazardous and are charged 30 LVL (0.047 euro) per kg. Non-compliance is penalized with a three-fold rate. (Speck et al., 2006).The revenues from the wastewater charges are then shared between national environmental funds and municipal funds/budgets and are used to finance environmental improvements. The results in terms of reduction of pollution do not seem very strong though. A similar situation appears in Estonia, where the water charge system has been in place for much longer. Over the 18 years that they have been used, the environmental fees have contributed 4.3 billion *kroons* to the state budget, which has

[3] BOD and COD are acronyms for Biochemical oxygen demand and Chemical oxygen demand. They inform on the physico-chemical properties of water samples.

been invested in the environmental protection of Estonia. A range of projects have been supported. These include the construction of a large number of waste water treatment plants and utilities, drinking water pipelines, waste disposal sites and more. Existing fees however have had lower environmental effects than expected.

Malaysia was one of the first countries to use effluent charges (paired with licensing) to control pollution from the palm oil industry (World Bank, 1997). The Philippines instituted environmental fees for wastewater discharge from industrial sources in 1997 (World Bank 1997). Evidence from one area (Laguna Lake) shows that BOD discharges from affected plants dropped 88 percent between 1997 and 1999 (World Bank 2000).

Evidence that MBIs matter in determining firms' environmental performance was found in a study on the Brazilian industrial sector (Seroa da Motta, 2006). This paper uses data drawn from a survey of the Brazilian National Confederation of Industries (CNI) undertaken in the period August–September 1998. The survey inquired into the situation of respondents related to the year 1997 and, for some financial variables, to 1996. The survey target was to generate insights that would allow governmental and development agencies to evaluate strategies, policies and instruments to enhance environmental management (captured by a set of proxies). It is found that besides the characteristics of the firm (e.g. size, sector and foreign ties, demands from communities) market incentives are also very important determinants of environmental performance. Cost savings on inputs and subsidized credit are also found to be important. However, data are, again, from a cross section database. This implies that the coefficient estimates can be biased because of unobserved time-invariant firm level heterogeneity. Moreover, important information regarding the survey are missing in the paper. Nor is endogeneity addressed. Therefore, these coefficient estimates should be interpreted very carefully.

A better data collection is offered by Pandey (2005). The basic premise of this paper is that the lack of reliable information on the nature and magnitude of emissions/discharges from various industrial sources may flaw the ability of regulators to formulate cost-effective strategies for industrial pollution control. This article, therefore, uses the Industrial Pollution Projection System database to estimate the industrial pollution load and the associated abatement cost, which can be used to design cost-effective strategies for pollution control. The article also illustrates the cost-effectiveness of market based instruments such as effluent charge vis-a`-vis regulation.

Xu et al. (2010) use production data from 34 paper mills in two representative provinces to examine the abatement efficiency and effectiveness of the levies. It uses a distance function to determine individual output-based and revenue-based shadow prices for each mill during the years that the levies were the main environmental incentive. The output-based shadow prices for pollutants display no recognizable trends over time and they are very different for firms in different locations. The revenue-based shadow prices are widely variable between mills and locations as well. These findings indicate that the marginal opportunity costs of abatement were also widely divergent and that there was no trend toward improved abatement efficiency. It should be stressed that this method did not use econometric methods to estimate the coefficients.

It is important to mention the work by Bhat and Bhatta (2004). This paper focuses on the externalities deriving from aquaculture and formulates an interactive model of non-renewable and renewable resources to characterize land allocations between aquaculture and agriculture in an ecologically and economically sustainable fashion. Through an empirical application, various economic and policy circumstances that affect the optimal land allocation mix are evaluated. The aquaculture industry must address two economic effects: off-site negative effects on renewable food and other coastal resources, and on-site self-pollution of shrimp ponds. Current regulatory

and land-use policies are inadequate to address these effects. Water effluent discharge is different in that sampling and flow measurement are relatively inexpensive. At Laguna Lake in the Philippines, a sophisticated effluent discharge fee system with high fee levels has proven effective in limiting BOD discharge.

Blackman (2009) analyzed the implications of Columbia's discharge fees programme. Again it should be noted that these results are not based upon econometric models. This paper is actually based on a variety of primary and secondary data. It finds that in its first 5 years, the Colombia discharge fee program was beset by a number of serious problems including limited implementation in many regions, widespread non-compliance by municipal sewerage authorities, and a confused relationship between discharge fees and emissions standards. The key finding is that in some watersheds, pollution loads dropped significantly after the program was introduced.

3.2. Evidence based on taxes

Taxes are very important MBIs. They have less monitoring involvement and create an important incentive that could indeed affect behaviour.They can, moreover, provide government with important opportunities of revenue generation. However, taxes may also have some negative feedback in terms of regulators' or governments' popularity. Another reason why taxes are seen as inappropriate is that they are potentially regressive. For instance a tax on fuel: a common argument against raising fuel taxes is that poor households would bear most of the burden - it would therefore be unfair on the poorest part of the population. This question is addressed directly by Blackman et al (2009). The study analyses the incidence of a fuel tax in Costa Rica. It uses household survey data and income-outcome coefficients to analyse fuel tax incidence. It finds that the effect of a 10 percent fuel price rise through direct spending on gasoline would be progressive, its effect through spending on diesel – both directly and via bus transportation – would be regressive (mainly because poorer households rely heavily on buses), and its effect through spending on goods other than fuel and bus transportation would be relatively small, albeit regressive. It concludes that distributional concerns need not rule out using fuel taxes to address pressing public health and safety problems, particularly if gasoline and diesel taxes can be differentiated.

Another analysis by Alpizar and Carlsson (2003) focuses on transport choices by commuters in Costa Rica. The paper analyze a group of policies aimed at discouraging the use of private transportation during peak hours, both directly and indirectly, by increasing the attractiveness of the only available substitute, the bus. A choice experiment is constructed to analyse by how much is the choice of travel mode for commuters to work sensitive to changes in travel time, changes in costs for each mode and other service attributes. This information is then used to identify the most suitable combination of policies dealing with air pollution and congestion in the typical developing country context of metropolitan Costa Rica. The analysis is implemented through a choice experiment. Fuel taxes can also be useful to incentivate technological change. This is the case if firms are quite responsive to changes in relative prices.. In 1990, a study by USAID, estimated that by the age of seven, Bangkok children collectively suffer a loss of up to 700,000 IQ points as a result of elevated blood-lead levels (O'Connor, 1998). This research prompted the Thai Government to introduce unleaded petrol at a slight discount relative to leaded petrol, subsidizing the former from a surtax on the latter (O'Connor, 1998). Moreover, from September 1993, the Thai Government introduced a regulation requiring that all cars sold in Thailand, from that date forward, should be equipped with a catalytic converter. Both these measures resulted in the market share of unleaded petrol rising to almost 50% of the market for petrol in the following few years" (O'Connor, 1998: 98).

Coria (2009) brings some evidence from Santiago, Chile. The paper presents an analysis of technology choice tested via a Hazard model. The findings stress that indirect regulations might stand a better chance of being effective in promoting environmental targets. A large response of the rate of switching to the lower price of natural gas in Santiago was found. This supports the use of taxes on non-clean fuels. Even if they do not create incentives to abate emissions per se they might create incentives to use cleaner fuels and to reduce emissions. This also promotes ease of administration (Blackman and Harrington, 2000). Indeed, consumption of fuel is usually much easier to monitor than emissions. And the existing government tax collection institutions can be used. The authors argue that "these two aspects seem quite correlated to the success of the implicit tax on "non-natural gas fuels" and to the failure of quantity policies in Santiago.

4. Interaction with other methods

While the focus of this survey is assessing the empirical evidence on the effectiveness of MBIs, it seems appropriate to devote some space to the alternative methods for pollution control. The interested reader may refer to Blackman 2009. These methods have in fact been screened widely by the empirical literature. After the seminal paper by Pargal and Wheeler (1996) much attention has been devoted to the so called *informal*, *voluntary* or *informational* polices. In some way they can provide an alternative or a complement to the more traditional approaches to environmental performance (via adoption of better technologies and/or environmental standards). Attention to these method has been stimulated by the World Bank. As Blackman (2009) put it: "the World Bank has probably been the most visible and vocal advocate of environmental policy innovation in developing countries."

In fact, during the 1990s, the Development Research Group at the World Bank conducted a series of studies of the impact of non-regulatory pressures on environmental performance. This process is also called informal regulation. The work of the group originated a flow of data collection and papers. The book,published in 2000 and entitled *Greening Industry: New Roles for Communities, Markets, and Governments* (World Bank 2000) encapsulates this effort. The authors concluded: "Overall, the proliferation of innovative channels for reducing emissions has created a new model for pollution control in developing countries. In this model, regulation is information-intensive and transparent. As environmental agencies exert influence through formal and informal channels, they become more like mediators and less like dictators. Community representatives take their place at the negotiating table, along with regulators and factory managers. Market agents make their presence felt through the decisions of consumers, bankers, and stockholders."

A1996 paper by Hettige et al. reviewed evidence drawn from three empirical studies of plant-level abatement practices conducted 1992–1994. The analyses test the importance of plant characteristics, economic considerations and external pressure in determining environmental performance. The results consistently show that pollution intensity is negatively associated with scale, productive efficiency, and the use of new process technology. It is strongly and positively associated with public ownership, but foreign ownership has no significant effect once other plant characteristics are taken into account. Among external sources of pressure, community action, or informal regulation, emerges as a clear source of inter-plant differences in all three studies. The results suggest that local income and education are powerful predictors of the effec-

tiveness of informal regulation. They also show that existing formal regulation has measurably beneficial effects, even when it is quite weakly developed. Dasgupta and associates addressed these issues in a series of papers. They used new survey evidence from Mexico (Dasgupta et al. 2000) to analyse the effects of regulation, plant-level management policies, and other factors on the environmental compliance of Mexican manufacturers. A two-stage least squares method for econometric estimation was used. and consistent parameter estimates in presence of endogeneity were provided. Results suggest that environmental management has a strong, independent effect on compliance, even after we control for simultaneity and take many other determinants of emissions intensity into account. It concludes that in developing countries with weak regulation, the carrot of subsidized environmental management training may provide a useful complement to the uncertain stick of conventional enforcement.

Dasgupta et al. (2001) investigated the role of inspection on environmental performance in China. They present an empirical analysis of the impact of monitoring and enforcement activities on the environmental performance of polluters. The paper explores the impact of both inspections and pollution charges on the environmental performance of polluters in China. Results indicate that inspections dominate and better explain the environmental performance of industrial polluters. The role of capital markets was investigated in another 2001 paper. This paper shows that capital markets in Argentina, Chile, Mexico, and the Philippines do react to announcements of environmental events, such as those of superior environmental performance or citizens' complaints. Public disclosure mechanisms in developing countries may be a useful model to consider, given limited government enforcement resources.

Foulon et al. 2002 provided an empirical analysis of the impact of both traditional enforcement and information strategies within the context of a single program. It provides insights on the relative impact of the traditional (fines and penalties) and emerging (public disclosure) enforcement strategies. It presents evidence that the public disclosure of environmental performance does create additional and strong incentives for pollution control.

Managi and Kaneko 2008 analysed how the performance of environmental management has changed over time using province level data for 1992–2003. Mixed results for environmental performance are shown using non-parametric estimation techniques. It is found that the environmental performance index, abatement effort, and increasing returns to pollution abatement play important roles in determining the pollution level over the period of the study.

While the role of public disclosure was analysed by Garcia et al. by studying the differences in firms' responsiveness to PROPER, Indonesia's public disclosure program for industrial pollution control. They use plant-level data to relate short- and longer-term environmental responses to facility characteristics. The results revealed that foreign-owned firms were consistently more likely to respond to the environmental rating scheme, compared to private domestic firms. The role of press is analysed by Kathuria (2007). He offers a test of the hypothesis that the press can act as an informal agent of pollution control. This hypothesis is tested using monthly water pollution data from four hot spots in the state of Gujarat, India for the period 1996 to 2000.[5] The results show that the press can function as an informal regulator if there is sustained interest in news about pollution. However, the attention and treatment of endogeneity seems not very robust.

[5] A comprehensive review of alternative pollution control policies is Blackman (2010).

5. Conclusion

The purpose of this paper is to provide a survey of Market Based Instruments (MBIs) for pollution control and draw some conclusions on their successful implementation in developing countries. This review has mostly focused on papers that present econometrics analyses from developing countries. Screening the existing literature, it is found that pollution charges and fees have had an impact on curbing both air and water pollution. Interestingly, the reductions that have been found for both water and air pollutants seem to be of a similar size. In addition, charges seem to work for pollution that is generated by both small and by large units. This indicates that these MBIs can offer a valuable means of reducing pollution.. The charge system, however, requires means for monitoring data and institutional capacity to enforce compliance. The regulator has to set an appropriate level of fee and collect the amounts due. Moreover, charges on air emissions can be difficult to implement because of problems of measurement. They also can be difficult to administer when facing a large set of different pollutants from different sources. It should be stressed that most of this empirical evidence relies on evidence from one single country: China. Because of the specificity of the Chinese context, it is, therefore, difficult to generalize these findings. We therefore expanded the scope of the review by including evidence based on case studies from both developing and developed countries. Again, the evidence (mostly on effluent charge) indicates that water pollution has been declining in a range of different countries including Colombia, Philippines, Estonia and Latvia.

Empirical evidence highlight that taxes, also, can be very useful in reduction of air pollution. The reduction seems to work through substitution and incentives in switching to cleaner energy. As for the charge system, to be effective it is necessary to enforce compliance. However, taxes seem to have a larger set of benefits. They generate revenues and they may be easier to manage. Their collection could be implemented via the tax or finance department rather than the environmental regulator. The key question, though, is their suitability in a development context and their implications in terms of distributional equity. It is important that the most vulnerable component of the population would not be adversely affected by it. Alongside fees and taxes, subsidies are also found to be an important tool to achieve reductions in pollution. These include grants, low-interest loans, favourable tax treatment, and preferential procurement policies for products believed to pose relatively low environmental risks. These, of course, still require monitoring capability and enforcement of compliance. Subsidies for environmental management are, however, costly and can be criticized because of their welfare implications. They can, indeed, be seen as a "prize" given to polluters. The subsidy is helping to bear the costs that should be the responsibility of the polluter. Eliminating environmentally harmful subsidies can be even more effective when used to improve environmental quality. Prime examples are the removal of subsidies on fertilizers, and leaded petrol.

There are grounds to suggest that successful implementation of MBIs can play a key role in reducing pollution. However, this does not mean that regulatory efforts are not useful. It should be noted that MBIs very rarely work in isolation. In reality, CAC and MBIs co-exist. Thus, regulators establish a specific level of pollution (or standard) and apply a fee for the amount of pollution that is above that threshold. It is, in general, complex to disentangle the implications of different tools. The positive results of MBIs can, therefore, be biased upwards. A balanced mix of regulatory measures and MBIs will effectively achieve pollution reduction targets. From the standpoint of the implementation in developing countries, the effectiveness of both MBIs and CAC can be undermined. Monitoring environmental performance and enforcing compliance

are crucial stages for the success of the policy. The successful achievement of these stages can be affected by a host of problems. Regulatory institutions in can be weak, understaffed and with lack of resources. This can impair both monitoring and enforcement phases. Moreover, developing countries often have a large set of very small firms that are more difficult to monitor. Firms' location may also be spatially dispersed. Recent findings on the relevance of *informa*l, *voluntary* or *informational* polices, however, seem to indicate that these can both lower the regulator's burden on monitoring and compliance and increase the extent of pollution control. We need, therefore, to analyse all polices in conjunction rather than in isolation. Some technical caveats should be raised. Most of the empirical evidence relies on cross sectional evidence from China. Some caution should be exerted when one aims to generalize the results. Also, given that most of these analyses lack a time-dimension we cannot draw the dynamic implications of MBIs. The availability, in the future, of larger databases with time-dimensions and from different countries will be critical for assessing the role of these tools.

It should also be stressed that while, in theory, there is a very large set of potential instruments, policies have focused on a few specific instruments. This may be due both to lack of administrative capacity and to the level of development of markets. It may also be due to the fact that more sophisticated MBIs (i.e. permits) still require both a strong regulatory and enforcement capacity. . This stresses again the necessary coordination of regulatory process and market -based instruments. The lessons learned from the experience of developed and OECD countries can be valuable in this process.

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