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Economic Instruments for Water Pollution Control Policy making issues: Experiences from Colombia

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Economic Instruments for Water Pollution Control

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Abstract

As part of the pollution control effort several developing countries have established economic-based initiatives to improve environmental quality. In this study the Colombian water pollution charge, which was implemented in 1997, is analyzed. The two key questions that this study attempts to answer are: 1) Does the performance of the pollution charge program in Colombia undermine the notion that economic instruments are not feasible in developing countries? 2) Which factors determine the performance of the water pollution charge program across regional environmental agencies in Colombia?

The answer to these questions provides valuable information for developing countries looking for more efficient and optimal ways to approach pollution control. These questions are answered through the analysis of data from the first five years of the program's implementation (1997-2002). The data sample is composed of 255 polluters in three representative environmental agencies: CORNARE, CORALINA and CODECHOCO.

The findings suggest that the success of the Colombian case contradicts the economic theory notion that economic instruments are unfeasible in developing countries. Even though, the water pollution program was not successful across all regional environmental agencies in Colombia, there are regional environmental agencies where the program was successful in reducing pollution levels. This success is related to the overcoming of the unfavorable circumstances by such agencies.

It was also found that the factors that seem to explain the differences in the performance of water pollution charge program across national environmental agencies are related to social, economic and institutional aspects, such as: economic subactivity, percent amount collected by the environmental agency, basin group, program cost, GDP, min rate, fee invoiced, percent amount collected and basin group.

It is suggested that the economic theory can be reconciliated with the findings of this study by qualifying the different regional environmental agencies in Colombia as “developed” and “developing”. It can be said that “developing” agencies present unfavorable circumstances that limit their effectiveness for the application of economic instruments.

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Introduction

A challenge faced by developing countries is finding ways to develop economically and at the same time maintain adequate environmental quality. As part of the pollution control effort several developing countries have established economic-based initiatives to improve environmental quality. In this study the colombian water pollution charge is analyzed. The water pollution charge in Colombia, offers an opportunity to learn efficient and optimal ways to approach the environmental problems in developing countries.

The belief that developing countries cannot afford high levels of environmental quality because it will mean lower monetary incomes and lessened capacity to support their populations, is probably the most frequently point of view mentioned by scholars (Field, 2002:416). From this point of view, developing countries perceive the concern for the environmental quality and sustainability as a burden, additional to their struggle to escape from poverty and meet higher economic standards.

Another point of view on this matter is that the environment and economic growth are not so much substitutes as they are complements (Field, 2002:417). Development and environmental degradation are reciprocally related because productivity depends on natural resources condition. Present and future generations depend of natural resources to maintain the economic productivity. Therefore not only the economic production will have an impact on the environment but also environmental degradation will have a negative impact on the economic productivity.

To find best public policies to use under the circumstances of developing countries is a challenge for policymakers. In developing countries, there are several economic, social and political conditions considered to be significant impediments for better environmental management and, particularly, for implementation of economic mechanisms to control pollution. These conditions are related to the lack of human and institutional capital (e.g. corruption, institutional capacity, tightness of budget, among others).

Despite this situation, Latin American countries have been increasing their interest in reducing pollution during the last decades and thus the interest of using economic instruments towards reducing pollution levels. Colombia is one of the countries that has implemented economic mechanisms, aiming at a more efficient pollution control. As part of the pollution control effort, in 1997 the pollution charge system was implemented in Colombia. This program has been catalogued by several scholars, policy makers and organizations as a successful program reducing water pollution levels.

In this study the colombian water pollution charge is analyzed. This analysis is framed in two questions:

First, does the performance of the pollution charge program in Colombia undermine the notion that economic instruments are not feasible in developing countries? this question is answered in order to make a contribution to the debate over the effectiveness or the ineffectiveness of economic instruments in developing countries because of the lack of institutional and human capital.

Second, this study aims to respond to the question -Which factors determine the performance of the water pollution charge program across regional environmental agencies in Colombia? In particular, this study looks to address and analyze the differences in the outcomes during the first five years (1997-2002) of program implementation by the regional agencies.

This work is presented in four chapters. In Chapter I, the theory of mechanisms to control pollution is reviewed. Two of the most common mechanisms to control pollution -command and control and market based- are presented. Chapter I also presents a literature review about market based mechanisms to control water pollution in developing countries. In chapter II, the antecedents, legal foundation, implementation and results of the water pollution program in Colombia is explained. In Chapter III, the research analysis an results are presented. Finally, in chapter IV, conclusions and policy-making recommendations are offered. These policy recommendations aim to help the design and implementation of future economic instruments, in particular for water pollution programs in developing countries.

Chapter 1

Literature Review

1.1 Approaches to Environmental Pollution Regulation

The environmental regulation has different approaches including command-and- control regulation; economic-based instruments; moral suasion and government production or expenditure. In table 1.1 a summary of the different approaches are presented. This study focuses attention upon the command-and-control and economic-based approaches.

Command and control or direct controls modes of regulation have been the traditional approach. They have been dominant in environmental protection programs, and only until early 1970s did legislators and regulators begin to use marketplace and other incentive-based approaches in environmental regulation. Since then, and particularly over the past two decades, the economic incentives have emerged as a significant trend in regulation worldwide, first in industrialized countries and later on in developing ones (NAPA, 1994:1), (Stavins and Whitehead, 1996:1) and (Acquatella and Bárcena, 2005:27).

Some reasons for this change in trend are related to the limitations in the command-and-control approach to achieve the goals of environmental quality improvement NAPA (1994:1) and Gunningham, Sinclair, and Grabosky (1998:68). These limitations can be detected in the fact that the employment of this approach is often administratively complex and costly. Also, this approach may hold back technological innovation in cases when it is used over a long period of time (NAPA, 1994:1). Additionally, this change in trend is explained by the attractiveness of economic instruments as policy instrument in both theory and practice (Stavins and Whitehead, 1996:1). For instance, their flexibility and possibility of funding for environmental programs allow countries to control pollution while generating economic resources to finance programs driven to improve the quality of the environment.

Table 1.1: Policy Instruments to Reduce Pollution

Policies	Instruments
Market-based incentives	Effluent charges; tradable permits; deposit reform systems; input/output taxes and subsidies; subsidies for substitutes and abatement inputs.
Command and control measures	Emission regulations (source specific, non-transferable quotas); regulation of equipment, processes, inputs, and outputs.
Moral suasion/voluntary compliance	publicity; social pressure.
Government production or expenditure	Regulatory agency expenditures for purification, cleanup, waste disposal, and enforcement; regenerative activities; education and research; development of clean technologies

Sources: Eskeland and Jimenez (1992); Baumol and Oates (1975); Tietenberg (1990); Baumol and Oates (1979)

From the list of policy instruments presented in Table 1.1 the best option for environmental policy depends on the particular pollution activity and the environmental circumstances. As Gunningham et al. (1998:35) demonstrate, each category of policy instruments for regulation control has something valuable and at the same time they have substantial limitations as a 'stand alone' strategy. The authors suggest that no single instrument works well across the board and that their success depends on interests and opportunities of key players and the relation among those players.

Other authors such as Baumol and Oates (1975:125) share a similar position expressing that the optimal policy package will include a combination of many of those policy approaches. Furthermore, Baumol and Oates state that the policy instruments for pollution control are not all mutually exclusive and that it is possible to use a combination of them to control pollution. Further they note:

> "There is no panacea, no one simple approach, that is always best (or even always workable), and that is why the design of environmental policy requires such extensive analysis. " (Baumol and Oates, 1979:229)

1.1.1 Command and Control Approach

Command and control policies are traditional regulatory approaches where regulators 'command' polluting firms to 'control' their pollution by specifying what they should do - referring to quantity of pollution - and how they should do it, in other words, by setting an environmental target (NAPA, 1994:6).

As Stavins (2000) explains, in general, command and control regulations force firms to shoulder identical shares of the pollution-control burden, regardless of the relative costs to them of this burden. The regulator sets uniform standards for firms to achieve specific environmental goals. These standards include: ambient standards; technology-based performance standards; design standards; environmental management standards and product standards (Gunningham et al., 1998:40).

As noted by Stavins and Whitehead (1996) and Stavins (2000), the most prevalent are technology-based and performance-based standards. Technology-based standards specify the method, and sometimes the actual equipment, that firms must use to comply with a particular regulation. For example, all electric utilities might be required to employ a specific type of scrubber to remove particles. On the other hand, a performance standard sets a uniform control target for firms, while allowing some flexibility in how this target is met. For example, a regulation might limit the number of allowable units of a pollutant released in a given time period, but might not dictate the means by which this goal is achieved.

Command and control approach exposes limitations in the achievement of long established environmental goals[1]. These limitations are related to: complexity; costs; and holding back technological innovation.

- *The command and control approach is complex.* Using command and control mechanisms to control pollution, the regulator needs information and data to design and develop effective standards. The process of getting this data is long and expensive. Also this process is, as pointed by NAPA (1994), inherently uncertain because the private sector is unenthusiastic about collecting data on control cost. Additionally, command and control schemes require detailed knowledge of industrial processes and polluting activities. The sheer enormity or quantity of environmental statutes and associated regulations in industrialized countries makes it difficult for all the actors in the control process to comply with all obligations.

[1]For success and failure examples in the United States refer to *Traditional Regulatory Approach* in The environment Goes to Market NAPA (1994); *Economic Instruments for Environmental Regulation*Tietenberg (1990) and *Instruments for Environmental Protection Gunningham et al. (1998)*

- *The command and control approach is costly.* Holding all firms to the same target can be expensive and, in some circumstances, counterproductive. In situations with many heterogenous polluters, such as a large informal sector, and weak public administration this kind of approach does not work well. There is a high difficulty to estimate individual abatement cost by the regulator (Eskeland and Jimenez, 1992:149). Also, as the NAPA (1994)work notes, because the costs of controlling emissions may vary greatly between firms, and even within the same firm, the appropriate technology in one situation may be inappropriate in another. Tietenberg (1990) addresses some empirical examples that show that the excess cost are typically very large compared with those in economic instrument even though, as he says, those examples overstate the cost saving that could be present in an ideal economic instrument.

- *Command and control regulations tend to freeze the development of technologies.* They allow little flexibility in the means of achieving goals because the standards discourage exploration of new technologies and at the same time little or no financial incentive exists for businesses to exceed their control targets. As Stavins and Whitehead (1996:5) explain:

> "A business experimenting with a new technology may be rewarded by being held to a higher standard of performance, but is not given the opportunity to benefit financially from its investment, except to the extent its competitors have even more difficulty reaching the new standard."

1.1.2 Economic Instruments for Pollution Control

Market-based instruments are regulations that encourage behavior through price signals rather than through explicit instructions on pollution control levels or methods (Stavins, 2000:31). Furthermore, those instruments refer to laws, rules and procedures with explicit environmental objectives designed to produce signals directed to economic agents, reflected in changes of relative prices of inputs and/or products, affecting their costs and those processes, which they intervene.

The World Health Organization (WHO) and United Nations Environmental Programme (UNEP) in their Guide to the Use of Water Quality Management Principles (1997) state that economic or market-based instruments rely on market forces and changes in relative prices to modify the behavior of public and private polluters in a way that supports environmental protection or improvement. Then, the basic purpose of those instruments is to influence costs and benefits and the profitability of alternative processes or technologies, as well as the relative prices of products, raw materials, or other inputs in order to induce economic agents to take environmentally sound decisions and contribute to reduce overall levels of environmental deterioration (UNEP, 2001).

Economic instruments work indirectly as instruments for environmental control influencing decisions of firms and households. They can be designed to be complementary to other instruments with similar goals as command and control or as direct agreements to reduce emissions with the industry. These policy instruments are described by, WHO/UNEP (1997) as “harnessing market forces” because if they are properly implemented, they encourage firms, through economic incentives, to undertake pollution control efforts that are both in their financial self-interest and that will collectively meet policy goals.

In table 1.2 a list of the most significant categories of economic instruments is presented. This list is and adaptation of the categories identified in the revised literature, particularly of the economic instrument categories presented by Gunningham et al. (1998); Rietbergen-McCracken and Abaza (2000) and Panayotou (1998).

Table 1.2: Economic Incentives for Pollution control

Category	Instruments
Property and user rights	Property, tenure, concessions.
Market creation	Water markets, tradable permits, insurance.
Fiscal instruments	Pollution taxes, input taxes, import tariffs, financial aid in stalling new technology, subsides for environmental research.
Charge systems	Effluent charges, user charges, product charges, impact fees, access fees.
Financial instruments	Financial subsidies, reimbursement systems, compliance incentives, soft loans and grants, sectorial/revolving funds.
Liability instruments	Liability insurance legislation
Deposit refund system	Deposit-refund schemes to encourage recycling, environmental performance bonds.

Sources: Rietbergen-McCracken and Abaza (2000); Panayotou (1998); Gunningham et al. (1998)

Economic instruments have practical strengths as well as weaknesses. Both have been demonstrated in both developed and developing countries, through several studies such as the UNEP (2002) case studies. When properly applied, economic instruments have a number of advantages when compared to command-and-control instruments, some of those advantages refer to:

- *The economic approach allows more flexibility in how the environmental goal is reached.* Economic mechanisms impose a cost on pollution-causing activities leaving it to individual firms to decide for themselves how to achieve the required level of environmental quality. In this way, the individual agents can use their information to select the best means of meeting an emission reduction level (Gunningham et al., 1998).

- *Economic mechanisms are cost-effective.* As NAPA (1994:11) points out, these mechanisms have the potential to make pollution control economically advantageous to commercial organizations and to lower pollution abatement costs. They can reduce pollution at less cost than traditional regulatory means, they are driven to find the level where the polluter pays the exact price for the pollution valued on the basis of its damage to others. In other words, economic mechanisms provide incentives for the use of cost effective ways of attaining the desired levels of emissions; their rationale of direct price/cost signals encourage decision makers to determine what action is best. Furthermore, as noted by NAPA (1994:10):

  > "the totality of the individual responses should result in a reduction in pollution at a cost that is lower than the alternative, since only those polluters that find it cheaper to do so so will undertake abatement."

  Another aspect of cost-effectiveness of economic instruments is described by

Stavins (2000:33): Market-based instruments require fewer total economic resources to achieve the same level of pollution control, compared with command-and-control approach, because rather than equalizing pollution levels among firms (as with uniform-pollution standards), market-based instruments equalize the incremental amount that firms spend to reduce pollution, i. e marginal cost.

- *They incentive the development of pollution control technology.* The economic instruments create dynamic incentives for investments to innovate and continually improve environmental technology, generating both environmental and financial benefits ("win-win")UNEP (2002).

> "Under command and control approach technological changes discovered by the control authority typically lead to more stringent standards (and higher costs) for the sources. Sources have little incentive to innovate and good deal of incentive to hide potential innovations from the control authority. With emission trading, on the other hand, innovations allowing excess reductions create saleable emission credits." (Tietenberg, 1990:28)

- *Economic instruments provide the government with a source of revenues that can be used for pollution control programmes.* Moreover, they allow the substitution of traditional ways to raise revenue (Tietenberg, 1990:p 23) , decreasing distortions of resource allocation and inefficiency created by this aspect.

- *Economic Instruments can be applied to a wide range of environmental problems.* They can involve varying degrees of incentives, information, and administrative capacity for effective implementation and enforcement.

- *Economic Instruments offer an opportunity to overcome the barriers of lack of information.* Economic incentive approaches offer a unique opportunity for regulators to solve the fundamental dilemma that they have to face with lack of sufficient information to allocate the responsibility for control cost-effectively. Tietenberg (1990:21) points out that, economic instruments create a system of incentives in which those who have the best knowledge about control opportunities, the environmental managers for the industry, are encouraged to use that knowledge to achieve environmental objectives at minimum cost.

  Also, because the economic instruments eliminate the requirements for detailed information on each individual source, the barriers of lack of information are easier to overcome, given that the amount of individual information required will be smaller. This aspect will also contribute to lower the administrative complexity.

On the other hand, economic instruments also have disadvantages. One of them is addressed by Stavins and Whitehead (1996), who argue that the actual effects over the environmental quality cannot be as precisely predicted as with the command and control approach since each source has more flexibility in defining its own solution.

Another disadvantage is noted by Gunningham et al. (1998). The authors note that economic instruments are not self-enforcing and may involve considerable control cost. The authors point out that one recent study concluded that there is no reason to expect administrative costs to be generally lower than those of regulatory instruments.

In this respect, the statement of Huber, Ruttenbeek, and Motta (1999) gives some clarity. According to the author, administration cost associated with economic instruments may be higher, given that monitoring requirements and other enforcement activities remain as command-and-control mechanisms, and additional administration efforts may be required to cope with the design and institutional changes arising from the introduction of economic instruments.

1.1.3 Water Pollution Charges

As defined by UNEP (2001), the charge is a monetary expression of the environmental damages that are perceived from the community. The charge or tax can be defined as a "price" to be paid on the use of the environment. Pollution charge systems assess a fee or a tax based on the amount of pollution that a company generates rather than simply charging based on its pollution-generating activities. (UNEP, 2001)

Consequently, it is worthwhile for a company to reduce pollution to the point at which its marginal cost of control is equal to the pollution-tax rate. By internalizing the previously external pollution costs, firms will control pollution to differing degrees, with high-cost controllers controlling less, and low-cost controllers controlling more. Baumol and Oates (1975:102) have shown that, assuming cost-minimization behavior by producers, effluent charges are the least-cost method of achieving the target.

On the other hand, the regulator confronts the challenge of setting the tax amount. As Stavins and Whitehead (1996:10) suggest, ideally the tax level will be where the tax equals the benefits of a cleanup. However, policy makers have a difficult time knowing beforehand how firms will respond to a given level of taxation, so it is difficult to know with precision what level of cleanup will result from any given charge. The regulator faces the dilemma of setting a low or high fee, if the fee is low the environmental quality will not improve, since the improvement in many cases depends on the level at which the effluent charge rate is set.

The rule for determining environmental goals and pollution charges, is described by the World-Bank (2000). This rule is to find the point where the Marginal Abatement Costs equals the Marginal Social Damage for water pollution (MAC = MSD). At this point, neither increasing nor decreasing pollution will improve social welfare. This "golden rule" provides a good framework, in the real world the actual levels are determined through the political process. Concrete information about lives lost, fisheries destroyed, and other damage can play some role, but it will never be the sole determining factor. Policymakers have to seek consensus on environmental goals and then use the available regulatory instruments to pursue them.

The four main types of charges used for controlling pollution are:

1. *Effluent charges.* Charges which are based on the quantity and/or quality of the discharged pollutants.

2. *User charges.* Fees paid for the use of collective treatment facilities.

3. *Product charges.* Charges levied on products that are harmful to the environment when used as an input to the production process, consumed, or disposed

4. *Administrative charges.* Fees paid to authorities for such purposes as chemical registration or financing licensing and pollution control activities.

Tietenberg (1990:429) notes that economists typically consider two types of effluent charges. First, an efficiency charge, designed to produce an efficient outcome by, as explained in the Section 1.1.2, forcing the polluter to pay or compensate for the damages caused. Second, a cost-effective charge driven to achieve a predefined ambient standard at the possible control cost. The author states that in practice few implemented programmes fit either of those two designs.

As Sterner (2003) notes, even though taxes and charges are used interchangeably, they have some differences. Taxes are usually used for political purposes rather than as administratively decided fees. Another difference is that taxes typically go to the treasury rather than being earmarked for local or sectorial use. As the author describes, many politicians have encountered considerable resistance to environmental taxes because in many countries money that goes to the central treasury is perceived as being lost. On the other hand, a charge system is more accepted because money stays within the sector or region. The revenue from charges is typically earmarked for specific environmental purposes rather than contributed to the general revenue as a means of reducing the reliance on taxes that produce more distortions in resource allocation (Tietenberg, 1990:p 430). Furthermore, some authors such as Arjona, Molina, Castro, Castillo, and Arbelaez (2000) claim that the best results in the implementation of water pollution programs comes from the programs where the revenues from the charge system stay in the region to be invested with similar environmental and economic interests.

Emissions charges have been used by several countries to control both air and water pollution. In this study I will focus on the use of those charges to control water pollution. Examples of the use of economic instruments for this purpose can be found in France, Italy, Germany, the Netherlands, Sweden, Holland, Japan, Chile, Mexico, Costa Rica, among other countries. [2]

The literature on the advantages of discharge fees focuses on their efficiency, flexibility, and revenue (Sterner, 2003) and (Blackman, 2005). These advantages were discussed in Section 1.1.2 and the same analysis applies for water pollution charges.

[2]See Tietenberg (1990); Hahn (1989); Arjona et al. (2000) for details of the emissions charges in those countries.

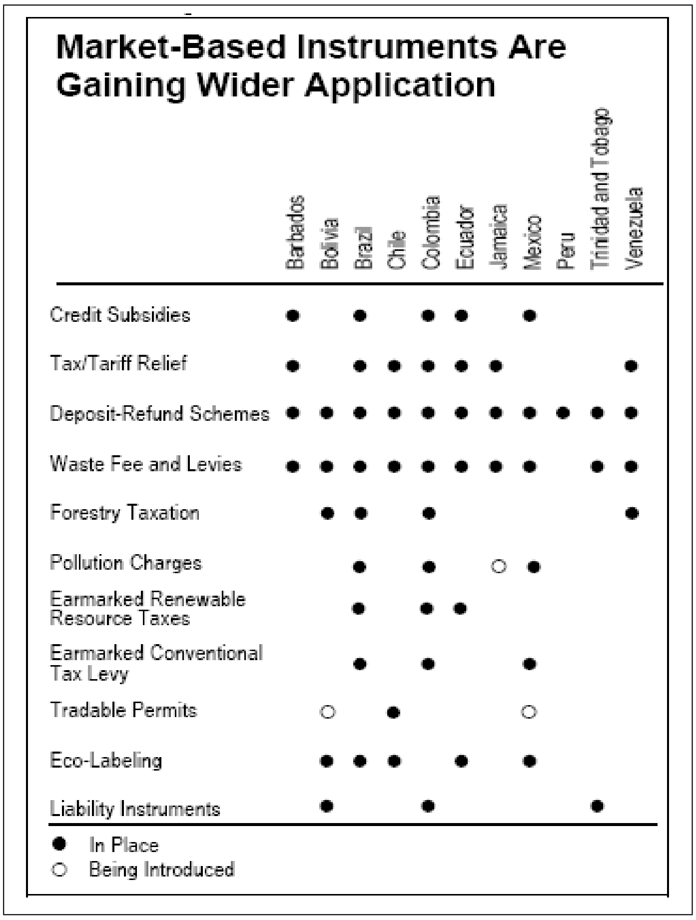
Various case studies highlight evidence that suggests that effluent charges can be effective in reducing levels of waste emissions. Some of those cases are described by Baumol and Oates (1979). Among those examples are West Germany and the United States: the control of pollution in the Ruhr Valley is a German successful case of treating pollution.

There is also literature addressing common problems in implementing discharge fee systems in developing and countries in transition. Overall these case studies show that the effluent charges can be reasonably effective to improve water quality. However, it is necessary to set the rate at a sufficiently high level so that it becomes an effective incentive for abatement. A literature review addressing the characteristics and challenges confronted by developing countries and countries in transition in implementing economic instruments and, particularly, water pollution charges is presented in Section 1.2.

In developing countries many social, economic and political factors are distinctively different from those in developed countries. These factors define the priorities in policy making. For instance, in developing countries, the creation of employment and income opportunities can be a factor defining the policy making agenda within a country. Arjona et al. (2000) says, in developing countries the opportunity cost of capital is too high - the financial resources have to guarantee the development of health, education, infrastructure, and of other socio-economic variables. The environment and the environmental challenges, thus, may not gain the attention they need.

Despite this hypothesis that developing countries are not interested in pollution control (Sterner, 2003) and that command-and-control is still the dominant trend in most developing countries. Field (2002) says that the use of economic instruments is at the top of the agenda of the environmental management sector in an increasing number of developing countries and emerging economies all over the world (UNEP, 2001:5.41). For instance figure 1.1 shows Latin American and Caribbean countries that are using different market base instruments for environmental policymaking.

Figure 1.1: Application of Economic Instruments in Latin American and Caribbean Countries



Market-Based Instruments Are Gaining Wider Application

	Barbados	Bolivia	Brazil	Chile	Colombia	Ecuador	Jamaica	Mexico	Peru	Trinidad and Tobago	Venezuela
Credit Subsidies	●		●		●	●		●			
Tax/Tariff Relief	●		●	●	●	●	●				●
Deposit-Refund Schemes	●	●	●	●	●	●	●	●	●	●	●
Waste Fee and Levies	●	●	●	●	●	●	●	●		●	●
Forestry Taxation		●	●		●						●
Pollution Charges			●		●		○	●			
Earmarked Renewable Resource Taxes			●		●	●					
Earmarked Conventional Tax Levy			●		●			●			
Tradable Permits		○		●				○			
Eco-Labeling		●	●	●		●		●			
Liability Instruments		●			●					●	

● In Place
○ Being Introduced

Source: Da Motta et al. (1999)

1.2 Economic Instruments in Developing Countries

Before the mid 90s, there was little documentation of experiences with economic mechanisms in developing countries. As noted by Eskeland and Jimenez (1992:145) there were no rigorous studies of pollution control in developing countries, but there was a convincing casual evidence that environmental regulations were badly designed or enforced. Rietbergen-McCracken and Abaza (2000) also identify a similar problem, but as they note this trend has been changing with collaborative works by several researchers in a wide range of developing countries and countries in transition (CITs). Also, with the help of some international organizations, such as the United Nations Environment Programme (UNEP), the World Bank, the World Health Organization (WHO) the documentation became more prevalent. In this regard, regional and national organizations have also been taking a role. Such as the case of Latin America, the Inter-American Development Bank and the Economic Commission for Latin America and the Caribbean (CEPAL) that have been leading the research in economic mechanisms. Examples of studies on economic mechanisms, conducted in developing countries, are presented below.

UNEP has conducted numerous country studies on economic instruments. For example in 2002 the UNEP (2002) published case studies conducted in Philippines, Kenya, Chile, Uganda, Bangladesh and Mauritania. These studies are undertaken by policy research institutes familiar with local conditions and priorities involving a broad range of stake holders, including relevant government ministries. This approach ensures that results are founded on reliable national data and realistic policy recommendations.

Rietbergen-McCracken and Abaza (2000) presents an extensive analysis of economic incentives for pollution control in developing countries. This work is a compendium of the lessons learned in the developing countries that have implemented economic instruments for pollution control. The authors recognize that the economic, social and political conditions, of developing countries and countries in transition worldwide, strongly influence the way in which these instruments can be used. The authors found that the majority of cases deal with some form of environmental tax or charge.

The the growing number of case studies about the experience from developing countries offer policymakers a comprehensive view of challenges and legacies they have in order to use environmental policymaking to improve environmental quality and welfare (e.g. the compilation of studies by da Motta (2001)) by highlighting a number of common problems implementing market base mechanism to control pollution in developing countries.

The common problems in developing countries are characterized by some unfavorable circumstances, confronted by policymakers, that make the effective application of economic instruments limited. These weaknesses are the consequences not only of lack of economic strength and capital input, but also of scientific and technological backwardness and the dearth of human resources. Some of the unfavorable circumstances or limitations are exposed by WHO/UNEP (1997); Blackman (2005) and Eskeland and Jimenez (1992). The compilation elements/constrains for the effective application of most economic instruments in developing countries are:

1. *Weak institutional capacity*: Economic instruments cannot be implemented successfully without pre-existing appropriate standards and effective administrative, monitoring, and enforcement capacities. Moreover, there is little difference,

if any, in the monitoring and enforcement capability required of government for regulatory and economic instruments. If there is uncertain monitoring and weak enforcement, there is little or no reason for an organization to report its discharges and pay a fee.

The institutional weakness also is related to under-funding, inexperience, unclear jurisdiction and lack of political will. Institutional strengthening involves improving the legal and regulatory framework to ensure sustainable management of water resources and the protection of aquatic ecosystems. Thus, the organizational strengthening involves improving the capacity of the groups of people in administrative or functional structures to apply the regulatory framework and the administration of the implementation tools.

Russell (2001:343) describe three areas of institutional capacity that determine the success of implementation of economic instruments, since those demand high levels of institutional capacity, which is likely to be the scarcest resource in developing countries Russell (2001:356). First, do the necessary laws exist? For example , do laws cover the forms of pollution discharge and renewable resource damage that are to be policy targets? Do those laws make the connection between development projects and the environment? Second, how unified is the structure that will turn the laws into specific economic incentives? Will those laws be enforced? A minimal promising structure would seem to be one in which there is a pollution control agency, with full sectorial and geographic coverage; a natural resource management agency; and some sort of coordinating body that brings these agencies together with the development planning agency. Third, do the agencies have the skilled people available to implement the laws? This could include lawyers who write regulations or technical specialist in the field, for example.

The institutional capability is very important to implement and operate economic instruments. As noted by NAPA (1994), the institutional design, staffing, and culture needed to implement and administer economic instruments is different from those of command and control. Staff with a disciplinary mix may be appropriate for the success of the programs.

2. *Inadequate co-ordination:* Institutional co-ordination is an important prerequisite for the effective application of most economic instruments. In the case of water management, however, there is often a traditional rivalry between the environmental and water and sanitation agencies. This may be due to a number of reasons such as political power and differing goals and perspectives. Nonetheless, the structure of an effluent charge system involves parameters and information that are more in the domain of the environmental agencies, while the implementation of the system is largely the responsibility of the water and sanitation companies. Unless the relevant agencies are well coordinated, the application of effluent charges will be undermined (Margulis, 1994).

3. *Economic instability:* Economic stability is critical for the effectiveness of economic instruments. Although regulatory instruments probably depend less on the level of economic stability in a country, charges and taxes are highly dependent on it. In addition, capital and credit market are characterized by risk, uncertainty and in developing countries, making it difficult to borrow money to finance abatement, for example.

4. *Government resistance or inertia:* In some countries, there is a general per-

ception by environmental agencies that the use of economic instruments will not only weaken their control over polluters, but that they will have to share their control with economic ministries, who are usually responsible for creating new taxes or charges. The application of economic instruments, therefore, is likely to make environmental agencies even weaker than they already are in most countries. Moreover, the results in terms of pollution levels would be less certain. In other countries, where regulators have relied on standards, inspections and penalties for managing pollution, there is a reluctance to try a new approach unless it is clearly demonstrated to be better than the existing regulatory system.

5. *Resistance by polluters:* In developed countries, as in industrial ones, industrial polluters often have resisted economic instruments because they believe that they have greater negotiating power over the design and implementation of regulations than they do over economic instruments. Moreover, local industries rightly assume that it is easier to avoid compliance with a standard where there is poor monitoring and enforcement capacity, than to avoid fiscal and incentive mechanisms where there is less flexibility.

6. *Tightness of budget for environmental issues*: Environmental control is too costly, budgets are often tight and developing countries often concentrate on other development priorities (Eskeland and Jimenez, 1992).

7. *Lobbying by powerful interest groups, and limited public support and participation*: If the environmental agency has little staff and other resources, the monitoring equipment is expensive and staff are underqualified and underpaid, then the risks of deceptive lobbing or even corruption are particularly high

(Sterner, 2003:317).

8. *Weak Environmental Regulatory Infrastructure:* Blackman (2005) and Eskeland and Jimenez (1992) describe how many of the developing and transitional countries that have experimented with discharge fees lack the infrastructure needed to set fees, monitor emissions and damages, invoice polluters, and collect payment. This infrastructure includes reasonably capable environmental regulatory, judicial, and legislative institutions and political support for enforcing discharge fees. In addition, most agencies in developing countries have few employees, who sometimes have little technical training and equipment as well as limited legal authority (Sterner, 2003).

   Eskeland and Jimenez (1992) argue that in practice, monitoring emissions and damages at the source may be costly, so the emissions can only be imperfectly monitored. As the authors comment this happens in industrialized countries, such as the USA; as well as in developing countries where this situation can be worse, since the regulatory agencies are weaker than those in the developed countries. Also, in developing countries, the informal sector, composed of small or home-based businesses, makes monitoring difficult. Sterner (2003).

9. *Low Fee Levels*: to maximize efficiency, economic theory dictates that discharge fees are set at the level where marginal abatement costs are equal to marginal environmental damages. In practice, however, developing countries have not been able to follow this prescription because they lack requisite information about pollution abatement and environmental damage functions. Probably just as important, political pressure from water polluters limits their ability to set substantive fees. Hence, in many countries, discharge fees have not been high

enough to create incentives for pollution abatement and have mainly served as a mean of raising revenue (Blackman, 2005:2).

10. *Uncertainty*: Eskeland and Jimenez (1992:158) note that the effects of environmental policies may depend on events that are difficult to predict, and of which there is little information in developing countries. For example, difficulty to adjust by the polluters and population the health of the population may change the effects of a particular policy such as air pollution.

11. *Non Competitive Market Structure*: The implementation of market-base mechanisms assume that markets are competitive; but it is not always the case. As Eskeland and Jimenez (1992:160) indicate, in industrialize countries utilities are examples of monopolies. On the other hand, in developing countries the market failures are related to small markets, tariffs, high transportation cost and limited access to credit.

These unfavorable circumstances that make the effective application of economic instruments limited, had led to the notion that economic instruments are not feasible in developing countries. At the same time, the increasing documentation from developing countries experiences with market base mechanisms, present evidence that even though there are shortcomings between the environmental economy theory and the practice, in some developing countries market-based mechanisms have generally been successful in improving the environment.

For instance, China charges for pollution appears to be working satisfactorily. China, whose principal source of energy is coal, has record air pollution in its cities. Its rivers and streams are also badly polluted. This situation has been widely reported. In this case China began testing a sulphur tax in nine towns and two provinces.

With the programm atmospheric concentration of SO2 have fallen by 30 percent and the frequency of acid rain precipitations has declined by 17 percent . The charge system has also succeeded in gathering funds and allocating them for anti-pollution investment. (Potier, 1995).

Also, the Colombian water pollution charge program has been pointed out as a successful example where an economic instrument is effective reducing water pollution, in studies conducted by organizations such as: the World-Bank (2000), the Colombian government (Colombian Ministry of the Environment, 2002), the United Nations Economic Commission for Latin America and Caribbean(ECLAC/CEPAL) and The Andean Center for Economics in the Environment (CAEMA/ACEE) (2001).

The existence of unfavorable circumstances that make the effective application of economic instruments limited in developing countries and the findings about the success of market-based mechanisms in some developing countries, lead to the first research question:

> Does the performance of the pollution charge program in Colombia undermine the notion that economic instruments are not feasible in developing countries?

Chapter 2

Water Pollution Charge Program in Colombia

The Colombian case has been selected to evaluate the argument that the implementation of economic instruments presents difficulties in developing countries, as described in section 1.2. Colombia is one developing countries that has implemented economic mechanisms aiming at more efficient pollution control. Colombia has been adopting different economic instruments for pollution control such as credit subsides, tax/tariff relief, deposit-refund schemes, forestry taxation, waste fees, liability instruments, and pollution charges (Huber et al., 1999). Currently, tradable permits are being introduced.

The Colombian water pollution charge has been selected as case of study because it has been pointed out as a successful instrument for reducing water pollution levels. The Colombian water pollution charge program has received positive reviews by organizations such as the World-Bank (2000), the Colombian government (Colombian Ministry of the Environment, 2002), the United Nations Economic Commission for Latin America and Caribbean(ECLAC/CEPAL) and The Andean Center for Economics in the Environment (CAEMA/ACEE) (2001). Those studies point out the program as a successful example where an economic instrument is effective reducing pollution. Also, it is worthy to mention that among economic incentives policies described in section 1.1.2, pollution charges and marketable permits have received the most recent attention in developing countries (Blackman, 2005).

Control of water pollution in Colombia, as in several countries, rises as a need to reduce not only the negative effects that it has in the environment but also the perversive effects that it has over the population wellbeing. In this chapter, water pollution problems in Colombia and their effects on the environment and the population, are presented. In Section 2.2, a brief description of the legal foundation for water pollution control, in particular for the pollution charge program, is presented. In sections 2.3 and 2.4 the implementation and results of the program are reviewed.

2.1 Antecedents

Colombia has problems with ground water pollution and surface water pollution. Despite the lack of information on groundwater quality, some aquifers are clearly polluted. Sources of this pollution include agricultural run off, septic tanks, land fills and the infiltration of coastal aquifers by seawater (Blackman, 2005).

Evidence suggest that in Colombia most of the water pollution (80%) comes from non-point sources or diffuse sources. It originates from many places, or from a widespread area and it is caused by rainfall moving over and through the ground (e. g oil, grease, and toxic chemicals from urban runoff). A smaller percentage, 20%, of Colombia's water pollution comes from point sources, which comes from specific points (e. g. discharges from wastewater treatment plants and operational wastes from industries). Non-point sources are much more difficult to control, as Blackman (2005:6) notes,

> "In Colombia -as in most countries with significant agricultural sectors-

> non point sources are responsible for the majority of certain types of water pollution. Unfortunately, non-point sources are particularly difficult to control. As a result, policy makers tend to focus on point sources".

The municipal or domestic sector - effluents from households collected by public sewer systems from the towns and urban settlements- according to several analysis, is the leading contributor to point sources water pollution. In Colombia, a significant percent of the waste water is not collected into municipal sewer systems (Blackman, 2005). For example, Colombia has 60% coverage of sewer system, with a 79% coverage at the urban level. But only 12% of the 60% of waste water collected is treated (Santamaría and Villa, 2004:75). Also, the municipalities lack of wastewater treatment plants and if they have treatment plants, they operate poorly; as of 1999 16% of the 1089 Colombian municipalities had operating treatment plants (Blackman, 2005).

On the other hand, industrial sources not only contribute organic matter but also chemicals, toxics, and heavy metals to the water pollution. In Colombia most of the industrial wastewater, as it happen with the domestic one, is not treated. As Blackman (2005:7) repots,

> "According to IDEAM (2002b), a report on the state of environmental quality in Colombia's urban areas, in 66% of 66 cities studied, no industries treated wastewater. In 23% of the cities, less than 50% did. In 7. 5% of the cities between 50 and 100% did, and in only 3. 1% of the cities did 100% of the industries treat their wastewater."

As a result, many of Colombia's most important rivers such as Bogotá, Cali, Cauca, Medellín, de Oro, Lebrija, Pasto, Pamplonita, Combeima, and Otún, are severely polluted (Blackman, 2005:6).

This water pollution situation has effects related to people's health, the increasing in abatement costs of the water, devaluation of lands close to polluted water streams, reduction in the tourist and recreational activities, reduction on fishing, and effects on farming (Arjona et al., 2000). For instance, the lack of access to safe water and sanitation cause water and sanitation-related diseases, which diarrhoea and cholera are among the most common. Many people use completely untreated or poor treated water taken directly from rivers. As a result, thousands of children die every day from diarrhoea. In Colombia diseases, related to contaminated water are the main cause of death in children up to 14 years old. According to the Pan American Health organization in 2000, Colombia had 4. 8 million children under 5 years old. The infant mortality rate was 21 deaths per 1, 000 live births and ranged from 17 in Bogotá to 29 in the coastal area. In this age group, the prevalence of diarrhea was 13. 9%. Also in 1998, Colombia presented intestinal infectious diseases such as the cholera reporting in 1998 a total of 445 cases and 7 deaths.

To improve the situation the Colombian government has launched different kinds of pollution control policies: command and control and economic mechanisms. The command and control policies consist in discharge standards, where all dischargers of liquid wastes need a discharge permit from their regional environmental authorities. As described by Blackman (2005:7) this policy does not specify pollution abatement methods, equipment or strategies; also none of Colombia's discharge standards are industry-specific.

Colombia was under mechanisms of command and control for the control of the pollution since 1977 and as the statement by the Vice Minister of Environment Fabio Arjona Hincapie (World-Bank, 2002) express: The experience that we had with command and control mechanisms in 23 years, we have had little pollution control results and really high costs of pollution reduction. In general, command and control policy have preformed quite poorly. Some of the reasons for this outcome are described by Blackman (2005:8) and they include:

- Inadequate inventories of dischargers. Situation that leads to un-existence or outdated information necessary to control pollution.

- Low or incomplete permit level. Only 31% of permits requested by the facilities have been issued.

- Inefficiency by the regional environmental agencies to confer permits to the solicitant facilities and low monitoring. It leads to less than half of polluting facilities were inspected.

In addition to the command and control policies, Colombia adopted the discharge fee program as part of economic mechanisms to control water pollution. The initial charges are limited to two water pollutants:

- Biological oxygen demand (BOD) a measure of the oxygen used by microorganisms to decompose organic waste.

- Total suspended solids (TSS) a measure of the mass of fine inorganic particles suspended in the water.

2.2 Legal Foundation

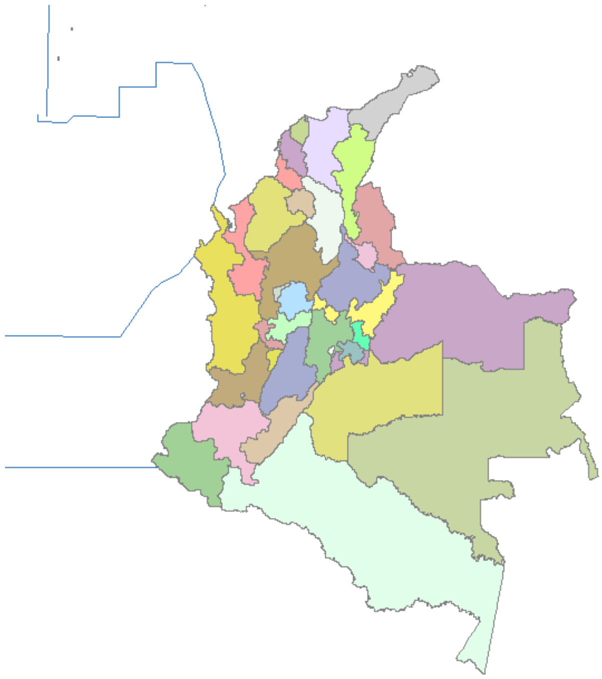
Colombia has a decentralized environmental management system, with the Ministry of Environment as the main regulatory authority and the Regional Autonomous Corporations as environmental agencies at the regional level. The Ministry of Environment was established by Colombia's Congress in 1993. Among its functions are the formulation, managing, orientation and coordination of environmental policies, programs and tools driven to the preservation and restoration of the environment (Colombian Ministry of the Environment, 2006).

The Law 99 in 1993 confers the regional environmental agencies with the maximum authority at the regional level. There are 33 regional environmental agencies, distributed in 26 Regional Autonomous Corporations (CAR) and seven Sustainable Development Corporations(CDS) with considerable fiscal and policy autonomy. Additionally, there are six Urban Environmental Authorities (AAU) in Colombia's most populous cities. As Blackman (2005:7) states CARs, CDSs and AAUs, are the front line of pollution control in Colombia, being responsible for implementing and enforcing programs and policies designed by the Ministery of the Environment.

The legal foundation for water protection in Colombia starts with Law 2811 of 1974 -The Renewable Resources and Environmental Protection National Code- in which pollution charges are introduced as fees for direct or indirect use of the environment -water, air, fisheries, and forests- for profitable activities. Immediate implementation of the program did not happen because it calls for legislation to define profitable activities(Santamaría and Villa, 2004:78). The very few applications of these charges were implemented with a cost-recovery approach attempting to cover the operating costs of monitoring systems. (Huber et al., 1999:31)

In 1984, the use of water was regulated with Law 1594. Pollution charges were further defined, such as how to calculate and how and how often to pay. But the implementation of the program was not successful because of the complex process and amount of information necessary to calculate the fee. (Santamaría and Villa, 2004:78)

Figure 2.1: Colombia's Regional Environmental Agencies



Source: Colombian association of regional environmental agencies (ASOCAR)

In 1993, new environmental legislation (Law 99/93) was passed in Colombia. In this legislation, pollution charges are defined according to the value of environmental services and the cost of environmental damages. As Huber et al. (1999:32) points out, the new criteria attempt to bring charge levels to optimum levels, in the Pigouvian sense, measured by economic welfare losses. Also, it eliminates the cost-recovery limitations of charges, which now may be set on a tax level basis.

Finally, Law 901 of 1997, established a nationwide pollution charge program for water pollution. The fee is set for all types of activities, not only for profitable ones (Santamaría and Villa, 2004:80). The program, according to Arjona et al. (2000:10) was designed and implemented to face three constrains: 1) the lack of information about the cost for pollution and the abatement cost in each watershed; 2) the institutional instability of the environmental agencies; and 3) the inflexibility in regulations present because of the decades of command and control approaches [1].

Law 901 of 1997 includes the following key provisions listed by Blackman (2005)and Sterner (2003):

- *Discharge inventory and baseline.* Consisting in the development of inventories of all facilities discharging BOD and TSS, by CARs and AAUs, and the establishment of a baseline discharge levels for each pollutant.
- *Pollution reduction targets.* CARs and AAUs are to delineate water basins in their jurisdictions and set five-year pollution reduction goals for aggregate discharges into each basin. It is worthy to mention that these goals are to be set by the boards of directors of each CAR or AAU, and well as representatives of national and local governments, key productive sectors, and environmental nongovernmental organizations. The pollution reduction goals are to take into account the environmental and social damages generated by pollutants as well as differences across regions in pollution assimilation capacity, socioeconomic conditions, and the opportunity costs of resources.
- *Fee setting.* Colombian ministry of the environment is to establish a minimum discharge rate for all facilities in the entire country. This fee can be adjusted upwards in each water basin based on a specified formula (see Appendix 1 for details). In essence, the formula adjusts the fee upwards by a multiplicative factor of 0. 5 for each semester (six-month period) that the pollution reduction target is not met.

[1]These three constrains are further analyzed in section 1.2

- *Monitoring and invoicing.* CARs and AAUs are to monitor facilities' discharges every six months relying on facility self-reports (based on approved sampling methods) verified by random checks. Invoices and payments are to be made monthly.

- *Relationship between discharge permits and fees.* Paying discharge fees does not exonerate facilities from the responsibility of complying with permits or CAC emissions standards. In theory then-that is, assuming that dischargers are complying with emissions standards-discharge fees only apply to those discharges remaining after the standards have been met.

- *Reporting.* Each semester, CAR and AAU directors have to present to both their board of directors and to MMA a report detailing pollution loads, invoicing and collections.

Additional characteristics of Colombia's water pollution charge program, not expressed in law 901of 1997, are:

- The pollution charge program supports "regional decontamination funds" used for local environmental projects, after some portion was diverted to fund agency budgets.

- The pollution goal is to be modified every five years -by boards of directors of each regional environmental agency, representatives of national and local governments, key productive sectors, and environmental nongovernmental organizations- because the economic, social and environmental conditions change over time at all levels (evolution of clean technologies, environmental preferences of the communities) Arjona et al. (2000).

2.3 Implementation

The main goal of Colombian water pollution charge is to cause reduction of pollution discharge levels and, as a secondary goal, to generate financial resources designate to fund activities and projects that have environmental purposes (Colombian Ministry of the Environment, 2002).

With this vision the water pollution program was implemented in 1997 by seven regional pollution control authorities. The rest of the regional environmental agencies were implementing the program through the following years. The first regional pollution control authority to implement water pollution charge was CORNARE, which started billing local factories for emissions in 1998. By 2001, 24 out of the 33 regional environmental agencies in Colombia had implemented the program with different results. As it is noted in Arjona et al. (2000:31), after three years of program implementation, the program was not adopted by the total regional environmental agencies; despite the constant training, implementation and evaluation before the final stage of the program, which is the real pollution reduction. Even though, in general the program, during its first five years seem to be successful, reflected in the achievement of the pollution reduction goals (World-Bank, 2000).

Providing technical assistance was one of the initiatives of the Ministry aimed to help the discharge fee system implementation across regional environmental authorities national wide (Blackman, 2005). The technical assistance included the development of a implementation manual identifying the tasks the regional environmental agencies needed to accomplish the discharge system implementation. Also, the organization of expert groups provided guidance on implementation. The ministry of the environment arranged a series of seminars to disseminate technical information and the best practices about the program among the agencies. In the same trend, key private-sector program participants, such as National Federation of Coffee, were targeted through series of workshops to building program credibility.

The water pollution charge implementation was promoted in the most capable regional environmental authorities first as a way to generate early successes. In this way, the Colombia Ministry of the Environment was able to create a top-down technical assistance program, among CARs and AAUs, using the CARs with the most successful programs (e. g CVC, CORNARE and CARDER).

2.4 Results

Evaluations and analysis of the program for water pollution control in Colombia have been conducted by several organizations and authors such as the World Bank (1999) and (2000);the United Nations Economic Commission for Latin America and the Economic Commission for Latin America ECLAC/CEPAL (2000); Colombia's Ministry of the Environment (2002); CAEMA(2001); Acquatella (2001); and Blackman (2005). These studies are based on preliminary data from the first five years of the program(1997 until 2002).

In such analysis, the positions about the results of pollution fees implementation are presented mainly as successful or mostly successful in reducing water pollution. In this context some works also explain, as a success factor, how the program has strengthened the institutional capacity of the pollution control agencies in the regions. Nevertheless, the studies also address some problems of the program.

Regarding the success of the water pollution charge program reducing BOD and TSS levels, several studies conducted find that the program was responsible for significant reductions. According to the water charge program evaluation conducted by Colombian Ministry of the Environment (2002), the nine CARs that implemented properly the charge programm presented a reduction of 27% in BOD and 45% in TSS levels. The industrial sector presents the highest reduction levels with 50.6% in BOD and 58.4% in TSS.

The Andean Center for Economics in the Environment (CAEMA/ACEE) (2001) evaluated the impact of the fee program on discharges in three regional environmental authorities: CVC, Cornare, and DADIMA during the period 1997 to 2000. This case study shows that with the discharge fee program, the reduction in the pollution levels was higher than those obtained with command and control policies.

Likewise, Sterner (2003) claims that Colombia provides a interesting example of environmental fee that is working despite what at least some outsiders might think of as a difficult policy environment. Sterner (2003) analyzes one of Colombia's regional environmental agencies, CORNARE, showing that this agency reduced by 28% BOD pollution from one of the basins within six months of implementing the charge. One aspect the author emphasizes is that the collected charges from industry, in CORNARE, works as a way to fund environmental projects and at the same time, strengthens the regional environmental agency.

> "Collected charges from industry have provided funds not only for environmental investments in the industries but also for staffing the environmental agencies. This element of long -run capacity building is hoped to strengthen the institutions so that they will be better equipped to manage other sectors later" (Sterner, 2003:324).

Sterner (2003) concludes that some of the features key to the success of the charge program in CORNARE - which reduced BOD discharges by 62% and TSS discharges by 90% from 1997 to 2000 - at least during the first five years refers to:

- A high level of knowledge and commitment on the part of local staff that was highly capacitated to implement the program. As Blackman (2005:19) notes, CORNARE is recognized as one of Colombia's stronger CARs that, as CVC, strictly enforced discharge standards before it began setting up its discharge fee program for the Negro River in late 1997 and before it began invoicing in 2000.

- Solid support by Colombian Environmental Ministry.

- Good technical information and data on pollution. It was corroborate by the present study, which included CORNARE in the analysis because it was one of the environmental agencies that presented a more complete information about polluters and pollution discharges, program costs, quality of basins, among other data.

- A relatively small region, which may facilitate monitoring.

- Good working relationship with the polluting industry. As it is mentioned in the evaluation by The Andean Center for Economics in the Environment (CAEMA/ACEE) (2001), reductions in BOD and TSS discharges in some environmental agencies such as CORNARE may have been partly due to a series of clean production agreements signed with water dischargers immediately before the discharge fee program began. It shows strength in CORNARE's institutional capacity and also how this CAR was working closely with the industries even before the implementation of the discharge fee.

Besides the significant reduction of BOD and TSS reported by Regional environmental agencies such as CORNARE, CDMB, CORPOURABA and CVC (Arjona et al., 2000), the success of the water pollution charge in general across Colombia according to scholars and policy makers highlight the following trends,

- The water pollution fee program has produced a change in attitude and mentality about pollution by regulators and regulated actors. For instance, in the evaluation commissioned by CEPAL (2000), (Arjona et al., 2000) points out that one of the results of the program is that regulated organizations have become more conscious regarding their pollution problems as a result several companies are studding for the first time cost-effective options to reduce pollution. Furthermore, before, the program pollution issues were under the company's low range technicians. Now, the pollution problem is discussed by company managers. It gives more relevance to the pollution problem and the ways to reduce it.

- The water pollution charge programm allowed the creation of 27 community projects for water pollution control (Colombian Ministry of the Environment, 2002). The process of these community includes the participation by public and private polluters, NGOs and universities in setting reduction goals of water pollution.

- The discharge fee program permitted the improvement and development of information about water resources. Water resources' data bases have been created and updated as a requirement by the polluters with the regional environmental agencies and by those with the Ministry of the environment.

- The pollution charge program became an important source of financial resources. Higher financial resources increase environmental investment, strengthen environmental initiatives and minimizing the impact of financial resource crisis and reducing dependence on national budget.

- The The Andean Center for Economics in the Environment (CAEMA/ACEE) (2001) report acknowledges that pollution charges contributed to the implementation of clean production solutions, by the companies, to decrease pollution levels. For example, in CVC, one of the regional environmental agencies, reductions in discharges from sugar processing plants and the paper industry were due to implementation of pollution prevention measures and clean technologies (versus end-of-pipe treatment). It is worthy to mention that because the implementation of pollution prevention measures and clean technologies, sugar companies were able to reduce pollution even during periods where they have an increase in the production (e. g the sugar industry growth during 1998-1999 was 5. 6%.

- The discharge fees created incentives for polluters to cut emissions in a cost effective manner as well as for regulatory authorities to improve permitting, monitoring, and enforcementBlackman (2005).

On the other hand, some of the problems with the water pollution fee program, described by scholars and policymakers, include:

- Slow and limited implementation in some regional environmental authorities. As it is noted in Arjona et al. (2000:31), after three years of program implementation the program was not adopted by the total regional environmental agencies, in 2000 54% of the regional environmental agencies had a pollution reduction goal and a 16% was in process to implement the program. This performance was presented despite the constant process of training, implementation and evaluation provided by the Ministry of the Environment and also by the strongest regional environmental agencies. Also, by 2000, 30% of the environmental agencies have invoiced the polluters (The Andean Center for Economics in the Environment (CAEMA/ACEE), 2001). In 2002, 24 CARs (72. 7%) invoiced and 21(63. 6%) collected. This situation show collection lagging behind invoicing Blackman (2005:13).

- Some water companies initially presented resistance to the fee mechanism because the fee was seen by these companies as an additional cost where the utility company is the one that has to pay the fee. This situation has been improving through technical accords among different institutions such as the Ministry of the Environment, Potable Water and Sanity Regulatory Commission and National Department of Planning (Arjona et al., 2000).

- Noncompliance by the majority of Municipalities and utilities companies (Colombian Ministry of the Environment, 2002) . In 65% of the regional environmental agencies, the domestic sector delay or do not pay the pollution fee arguing in several occasions that they do not have resources to pay. In the remaining agencies, 35% the environmental authorities have been the creation of funds by the CARs to co-finance waste water treatment plants. During 1997-2002, the municipalities were invoiced for over one third of all discharge fees and from this amount they only paid 40% (Blackman, 2005:15). This situation created tension among the industry and agriculture sector that complies with the policy.

The industrial sector have argued that they are being punished for the failure of municipal sewage authorities to control their discharges, given that the fee increases every semester because the reduction target is missed (Blackman, 2005:16).

- Low collection rates. Only 33.8% of the fees invoiced were collected by the regional environmental agencies during 1997-2002 (Colombian Ministry of the Environment, 2002). Blackman (2005:15), reports even a lower collection rate of 27%, ranging from a low of 1% for CARSUCRE, CORPOAMAZONIA and CORPOCESAR to a high of 95% for CDMB and 54% for CORNARE.

- As it is mentioned by The Andean Center for Economics in the Environment (CAEMA/ACEE) (2001:10), some of the regional environmental agencies where the polluters are strong/powerful, the reduction goal is negotiated taking into account the effort at the individual not the general effort possible for the basin. Blackman (2005:14) argue that this situation is reflected in the significant differences in pollution reduction goals. For example, the author notes that CORMACARENA's BOD goal is 80% while CARDIQUE is 3% as for 2001 period.

The review of the Colombian case exposes that the water pollution program performed differently across regional environmental in Colombia. This finding leads to the second research question:

WHICH FACTORS DETERMINE THE PERFORMANCE OF WATER POLLUTION CHARGE PROGRAM ACROSS REGIONAL ENVIRONMENTAL AGENCIES IN COLOMBIA?

Chapter 3

Research Analysis and Results

3.1 Research Design

3.1.1 Methodology

This study aims to answer the following questions:

- Does the performance of the pollution charge program in Colombia undermine the notion that economic instruments are not feasible in developing countries?
- Which factors determine the performance of the water pollution charge program across regional environmental agencies in Colombia?

These questions are answered through the analysis of data from the first five years of implementation of the program (from 1997 until 2002). [1]

The unit of analysis are the regional environmental agencies and the corporate units they supervise. The data sample is composed by 255 corporations/polluters in three representative environmental agencies:

- Corporación Autónoma Regional de las Cuencas de los Ríos Negro y Nare, CORNARE.

[1]The second phase of the program, that starts with the reform introduced by Decree 3100 of 2003 and Decree 3440 of 2004 is not analyzed because the program established by those regulations is too new, and therefore there is not enough data collected, to evaluate it.

- Corporación para el Desarrollo Sostenible del Archipiélago de San Andrés, Providencia y Santa Catalina, CORALINA.

- Corporación Autónoma Regional para el Desarrollo Sostenible del Chocó, CODECHOCO.

In 2002, Colombia's Ministry of the Environment presented an evaluation of the water pollution charge program. In that evaluation, the Ministry of the environment divided the regional agencies into three categories (A, B and C) according to how effective they were in implementing and executing the charge program. Group A being the ones presenting the best performance and C being the worst. Performance was measured in terms of:

- Length of time conducting the program.

- Effort made to implement all the key aspects of the program.

- Quality of monitoring, as well as quality of data, of discharge levels of pollutants and their corresponding polluters.

- Invoice enforcement and money collection.

Nine out of 32 of the regional environmental agencies were in group A; 13 were in group B and 10 were in group C.

For this study, one regional environmental agency was selected from category A (CORNARE), and two from category B (CORALINA AND CODECHOCO). The selection was made upon data availability, difference in financial capacity and differences in diversity and culture of the regions where they operate. No environmental agency was selected from category C because the environmental agencies from this category have poor or no data.

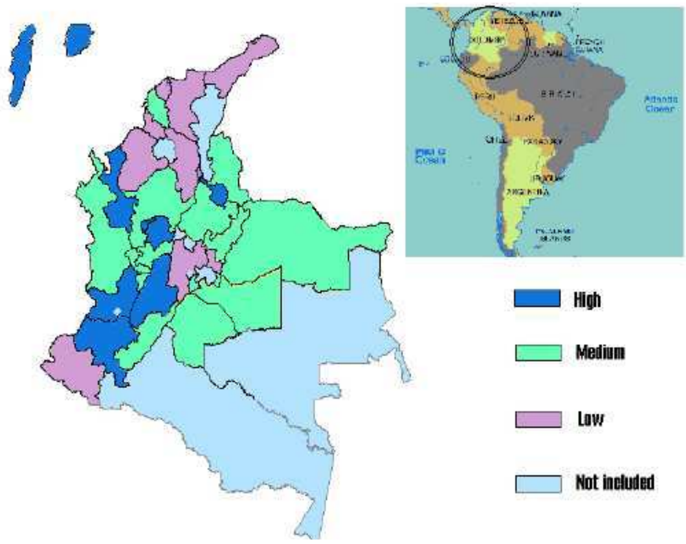


Figure 3.1: Regional environmental agencies administrative performance

The data used in this study is mainly secondary data. It was collected primarily from the periodical reports that the regional environmental agencies have to present to Colombian Environmental Ministry - these agencies had to report every six months before the 2003 reform and annually after it- and from the data bases of the environmental agencies. The periodical reports include information about polluters within each regional environmental agency domain, such as polluter's economic activity, discharges of BOD and TSS, among others. The reports also include data at the environmental agency and basin level such as program's monitoring costs and pollution reduction goal respectively. The data base quality was improved by identifying duplicated (inconsistent) cases, i.e. same polluter for one period, and checking if it was possible to distinguish the entries and name them differently. Also, the data base was aggregated through time improving it completeness.

The data was obtained from the office of Economic Analysis of Colombian Environmental Ministry, referred by two people who worked in the discharge fee program: Thomas Black and Luis Fernando Castro. Thomas Black was Chief of the Office of Economic Analysis Ministry of Environment during 1996 to 2000, designing and implementing economic instruments for pollution control, including the water discharge fee program. Luis Fernando Castro was director of Pollution Control at CORNARE. Both people also participated in 2002 discharge fee program evaluation, for which the data that each agency reported was used.

The described data was complemented by other studies about this topic. Especially, the national evaluation of the pollution charges conducted by the Colombia's environmental agency in 2002 Colombian Ministry of the Environment (2002). Additional documentation includes studies from the Andean Center for Economics in the Environment (CAEMA), World Bank- The Economics of Industrial Pollution Control Research Program, The Inter-American Development Bank (IDB), Colombia National Administrative Department of Statistics (DANE) and The Latin-American and Caribbean Economic Commission- Sustainable Development commission (CEPAL).

3.1.2 Definition of Variables

Dependent variables:

The list of dependent variables considered in the study are related to water pollution, measured by levels of biochemical oxygen demand (BOD) and total solids suspended (TSS).

BOD and TSS definition

Biological Oxygen Demand (BOD) refers to the amount of oxygen that would be consumed if all the organisms in one liter of water were oxidized by bacteria and protozoa (ReVelle and ReVelle, 1988). Biological Oxygen Demand (BOD) is a measure of the oxygen used by microorganisms to decompose organic waste. When BOD levels are high, dissolved oxygen (DO) levels decrease because the oxygen that is available in the water is being consumed by the bacteria. Since less dissolved oxygen is available in the water, fish and other aquatic organisms may not survive. The BOD is measured either in milligrams per liter (mg/L) or percent saturation. Milligrams per liter is the amount of oxygen in a liter of water. Percent saturation is the amount of oxygen in a liter of water relative to the total amount of oxygen that the water can hold at that temperature.

Total Suspended solids (TSS) TSS is a measure of the mass of fine inorganic particles suspended in the water. TSS concentration has two important ecological impacts. First, TSS attenuates light, decreasing the light reaching the sediment. Second, phosphorus is absorbed onto sediment surfaces. High TSS concentration removes dissolved inorganic phosphorus from the water column, potentially reducing algal growth. The mass of fine inorganic particles suspended in the water, TSS, is typically expressed in milligrams per liter or mg/l.

The dependent variables are divided in two groups:

1. **Water pollution control performance indicator**(Reduction BOD Group).

   Measurement Level: Nominal.

   Values: Increase, decrease, no change

   The indicator shows the performance of each polluter related to BOD and TSS pollution: polluters that presented an increase in the levels of water pollution, polluters that increased the levels of water pollution and polluters that presented no change in the water pollution levels

2. **Level of achievement of the program** (Percent Reduction BOD).

Measurement Level: Interval-Ratio

Values: Percentage number

This variable is measured as the percentage of reduction on water pollution levels, for BOD and TSS, achieved by the polluters in the five years considered. The last quantity of BOD/TSS reported was taken and it was divided by the quantity of BOD/TSS reported in 1998. 1998 was taken as the base year because in many cases the information available for 1997 was unclear or inconsistent.

Independent variables:

The independent variables were selected to measure economic aspects of the country, the characteristics of the regional environmental agencies and features of the polluters.

1. **Regional Environmental Agency** (CORNARE, CHOCO, CORALINA).

   Measurement Level: Nominal

   Values: Environmental Agency

2. **Reduction goal of BOD and Reduction goal of TSS by basin** (ReductionGoal BOD/TSS).

   Measurement Level: Interval-Ratio

   Values: Average number

   CARs and AAUs are to delineate water basins in their jurisdictions and set five-year pollution reduction goals for aggregate BOD and TSS discharges into each basin. As for the BOD reduction goals, TSS goals are set by the boards of directors of each CAR or AAU, and well as representatives of national and local governments, key productive sectors, and environmental nongovernmental organizations. The TSS reduction goals is set by each basin every five years. The reduction goal for BOD as well as for BOD is measure in percentage of reduction.

This variable is expected to reflect if the goal that controllers, polluters and community concerted is related to pollution reduction.

3. **Minimum rate of BOD and Minimum rate of TSS** (Min Rate BOD/TSS).

   Measurement Level: Interval-Ratio

   Values: Average number in Colombian Pesos

   The Minimum Rate of BOD and TSS is set every year by Colombian Ministry of the Environment for all facilities in the entire country. For this analysis the average through the ten periods was taken. This variable, as the economic theory states is relevant to pollution reduction, because if it is too low the polluter will prefer to pay the fee over reduce pollution.

4. **Regional Factor per semester** (Reg Factor).

   Measurement Level: Interval-Ratio

   Values: Number

   The regional factor is a multiplicative factor that increase 0.5 for each semester that the pollution reduction target is not met. It is used to calculate the fee each semester (see Appendix). It reflect how the group of polluters of a particular basin is performing. For this analysis the factor reported by the basin in the last (10th) semester was taken.

5. **Fee Invoiced for BOD/TSS by polluter.** (Invoice BOD/TSS)

   Measurement Level: Interval-Ratio

   Values: Number in billions of Colombian Pesos

   Every semester the CAR invoices a fee to the polluter according to the discharges he made, the minimum rate and the regional factor. See Appendix A

6. **Total Fee Invoiced by polluter.** (Total Invoice)

Measurement Level: Interval-Ratio

Values: Number in billions of Colombian Pesos

This variable is calculated adding Invoice BOD and Invoice TSS

7. **Percent amount collected by polluter** (Perc Collected).

   Measurement Level: Interval-Ratio

   Values: Percentage

   The amount collected is the quantity each polluter pays to the CAR in response to the fee invoiced by it. The percentage amount collected is calculated by dividing total amount collected during 1997-2001 by total invoice. The information for the collected was not available for each pollutant(BOD and TSS) it was aggregated. This variable not only reflects the capacity of the regional environmental agency to collect the fee but also how strong the agency is to do it. As it was discussed, collection is an element of long-run capacity building so that they will be better equipped to manage other pollution issues. This variable also tell us about the relationship between the agency and the polluters and about funding in the agency for investments. For instance, if the percentage of this variable is low it mean that the agency is not strong to collect, that the agency does not has effective mechanisms of collection, or that the agencies does not recognize the control agency authority. The data was filtered by this variable because in the process of data cleaning, outliers were observed. Those outliers did not make sense because they say that there were polluters that pay more that 150% even 500% to the agency, and we know that it would be unlikely to happen when companies are trying of maximize profits and minimize costs.

8. **Program cost per year by environmental agency** (Prog Cost).

Measurement Level: Interval-Ratio

Values: Average number in billion of Colombian pesos

The water pollution charge program represent some administrative and operative costs to the agency (e.g cost of monitoring and take water samples, wage of technicians, economist, etc). This variable can reflect how well the environmental agency disposed of personnel to implement, operated and evaluated the program. You should expect that if the agency does not have adequate personnel and instruments, the program will not succeed.

9. **Region's per-capita GDP** (GDP).

   Measurement Level: Interval-Ratio

   Values: Average number in million of Colombian pesos

   A region's gross domestic product (GDP) is one of several measures of the size of its economy. The GDP divided by the population or per-capita GDP gives you an idea of how wealthy the people are on average. This variable was introduced in the analysis to check if the economic situation of the region cause ant change in the reduction of water pollution.

10. **Basin**.

    (BasinG1, BasinG2, BasinG3, BasinG4)

    Measurement Level: Nominal

    Values: see Table 3.1

    There are a total of 14 basins for all three agencies selected for this study. For the regression purposes, they were recorded into a four groups using compare mean analysis(One way ANOVA), basins with no significant difference in their means were put together. Additionally, the decision tree technique was applied

Table 3.1: Basins by Environmental Agency and group

Basin	Environmental Agency	BOD Group	TSS Group
RioBueyPie	Cornare	1	1
RioClaroCo	Cornare	1	2
RioMagdalena	Cornare	2	3
RioNare	Cornare	2	3
RioNegro	Cornare	3	4
RioNus	Cornare	2	3
SamanaNorte	Cornare	2	2
SamanaSur	Cornare	2	1
Atrato	Choco	4	2
Darien	Choco	4	3
Pacifica-Baudo	Choco	4	1
Acuifero	Coralina	2	2
Mar	Coralina	1	3

to create basin groups. To enter the four basin categories into the regression model, the four categories were recoded into dummy variables.

11. **Economic activity of polluter by agency**

(Agroindustry, Industry, Domestic).

Measurement Level: Nominal

Values: Agriculture-industry, Industry and Domestic

Each polluter was classified into an economic activity category named Agro-industry, Industry or Domestic. This variable reflects the economic activity that each company has and also characterize the environmental agency region as more agricultural, industrial or domestic In other words this variable also give us information at the regional level. To enter the three economic activity categories into the regression model, the four categories were recoded into dummy variables.

12. **Economic sub-activity of polluter by agency**.

(EconSubActG1, EconSubActG2, EconSubActG3, EconSubActG4)

Measurement Level: Nominal

Values: see table 3.2

There are a total of 10 economic sub-activities for all three agencies. For the regression purposes, they were recorded into a four groups using compare mean analysis(One way ANOVA), and sub-activities with no significant difference in their means were put together. Also, the decision tree techniques was applied to determine the best combination of sub-activities for each group. To enter the four sub-activities categories into the regression model, the four categories were recoded into dummy variables.

Table 3.2: Economic Sub-activities

Economic Sub-activity	BOD Group	TSS Group
Fishery	2	1
Poultry	2	2
Flower Industry	3	3
Utilities Companies	1	3
Hotels and Tourism	2	4
Industry and Agricultural Industry	4	2
Institutions	3	1
Municipalities	2	4
Slaughter Houses	1	1
Textile	3	1

3.1.3 Method of Analysis

3.1.4 Decision Tree

First decision trees are constructed to predict the dependent variables Reduction BOD Group and Reduction TSS Group, in terms of the independent variables (e.g. see the tree $\mathcal{T}_{BOD}$ shown in Figure 3.2.1).

A decision tree is a flow chart or diagram representing a classification system or predictive model. The tree is structured as a sequence of simple questions, and the answers to these questions trace a path down the tree. The end point reached determines the classification or prediction made by the model, which can be a qualitative judgment or a numerical forecast. A decision tree can be learned by splitting the source set into subsets based on an attribute value test(Breiman, Friedman, Olshen, and Stone, 1984).

This process is repeated on each derived subset in a recursive manner. The recursion is completed when splitting is either non-feasible, or a singular classification can be applied to each element of the derived subset.

To construct a two decision trees, CART, a well-know and widely used commercial software package, is used. It has different options that determine the way the decision tree is generated as well as the final tree obtained. In CART there is a pay off and a cost associated to each tree generated. The pay off is related to how many cases are classified correctly, the cost is related to how big is the tree, how small (number of cases) are the terminal nodes and how well the nodes split the data. The options in CART are basically to choose the parameters of a cost function and the pay off function. The options considered here are the four combinations obtained by giving the same or different costs for the misplaced cases (It can make sense to have a bigger cost assigned to a decreasing case placed as increasing than as not change), and by choosing the pay off function being *information gain* or *Gini impurity*. In this work only the generated decision tree for the case of equal costs for different misplacement and Gini impurity method is presented, because the four different trees obtained only present small differences.

The quality of a decision tree is measure in terms of the prediction error. To measure the prediction error the tree is tested in new data (different from the one used to construct the tree). When constructing the tree, CART divides the data in two sets, a *sample data set*, used to construct the tree, and a *test data set*, used to test the tree (e.g. see Table 3.3 and 3.5).

The most valuable information contained in the decision tree is the emphvariable importance, a measure of how much a variable influences the decisions taken in the tree. The variable importance hints to which independent variables best explain the dependent one. The decision tree also hints to how the nominal variables could be grouped. In this work, the information obtained from four different decision trees where used in conjunction to the information from the one-way ANOVA to define the different groups for the variables Economic Sub-Activity and Basin.

3.1.5 Bi-variate and Multivariate Analysis

This study also used SPSS software package to obtain bi-variate and multi-variate analysis of the variables. The bi-variate techniques used were one-way analysis of variance and and Pearson Correlation Coefficients to check relationship between the independent variables and the dependent variable regarding the reduction of BOD and TSS levels. The Pearson correlation coefficient indicates the strength and the direction of the relationship between the dependent and independent variables. The multi-variate technique used was a linear regression to produce a more efficient and precise explanation of how the independents variables are related to the dependent one.

The intention of the decision tree analysis as well as the bivariate and multivariate analysis is to enhance the understanding of what kind of aspects drive pollutants to a change in the levels of pollution.

3.1.6 Limitations

The development of this study presents data limitations for a number of reasons:

The selection of the regional environmental agencies to be taking into the analysis was made not only according to how effective they were implementing and executing the charge program, but also according to availability of information. This process required the search for information in all regional environmental agencies, which have implemented the program, and then discard those that lack on information. The three environmental agencies, CORNARE, CODECHOCO and CORALINA were the ones with the most complete data.

In the same trend, the study presents limitations availability and quality. For instance, for bivariate analysis it is important to have the data for all the years that are going to be analyzed. If there is not complete data for a year from a particular source, that case is discarded. To solve this problem, aggregation was needed. Data for each variable was aggregated through time and depend. This procedure also solved the problem with some of the variables that were aggregated already and it was impossible to be disaggregated.

There was also a lack of reliable inventories and databases. There were some inconsistencies in data report, which detracts from reliable data standards. Some values present a sudden change in order of magnitude for a particular time entry. It is not clear if this type of error could have been produced at the time of typing the data or if it can be a problem in the procedures that the regional environmental agencies use to report the data.

Also, as Blackman (2005:1) states, the results that can be derived from the data base used “are not necessarily as impressive as they appear for two reasons. First, they are based on data that is self reported by dischargers...Second, the reductions in BOD and TSS are not necessarily due solely to economic incentives generated by discharge fees -they also reflect the impact of CAC and pollution prevention programs". As the author discusses in detail, the effectiveness of verification of the data -by CARs, the Ministry of the Environment and the a government official- varies across CARSs. Despite this problem, as the author also states, the size of the measured reduction in BOD and TSS are so large that the results should show significant impact in pollution reduction.

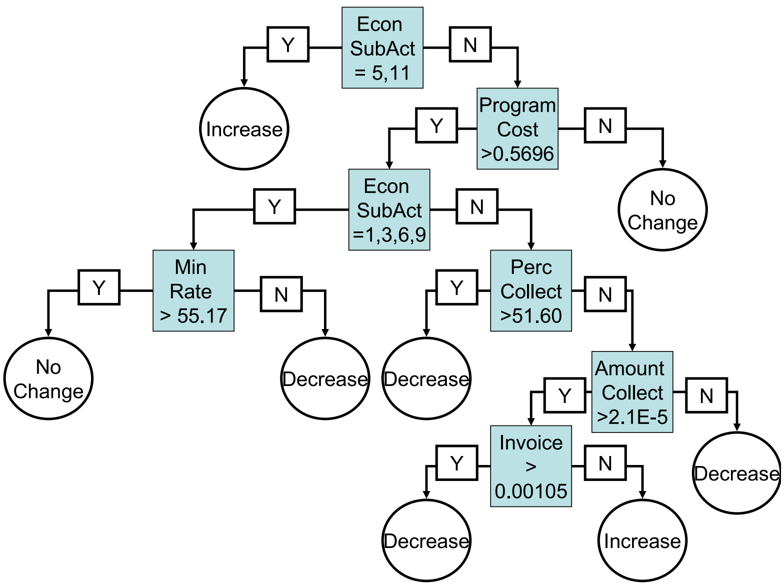
Finally, some of the variables that according to the literature review were important to determine the success of the program were not included in the present model analysis because lack of data to do so. Such is the case of information about municipal waste water treatment plants. Scholars and policy makers point out this factor as a key difficulty for water pollution reduction.

3.2 Results BOD Model

3.2.1 Decision tree analysis

The tree $\mathcal{T}_{BOD}$ illustrates how decision trees make predictions. For instance' given a (new) polluter' with Economic Subactivity 11 (Slaughter House)' $\mathcal{T}_{BOD}$ predicts that its pollution level would increase. As another instance' given a polluter with Economic Subactivity 6 (Hotels and Tourism)' $\mathcal{T}_{BOD}$ will look at the average program cost for the corresponding environmental agency; if it is bigger than 0.5696' $\mathcal{T}_{BOD}$ would predict that the polluter's pollution level would not change. On the other hand if the program cost is smaller than 0.5696' $\mathcal{T}_{BOD}$ will look at the min rate for BOD set by the environmental agency. If it is bigger than 55.17' $\mathcal{T}_{BOD}$ would predict not change in the pollution levels' while in the other case it would predict a decrease of them.

Figure 3.2: Decision Tree for Reduction BOD Group



The prediction errors on the sample data and test data for $\mathcal{T}_{BOD}$ are shown in Table 3.3.

Table 3.3: Prediction Errors on sample data and test date for the tree $\mathcal{T}_{BOD}$

Misclassification for Learn Data				**Misclassification for Test Data**			
Class	N Cases	N Mis-Classed	Percent Error	Class	N Cases	N Mis-Classed	Percent Error
Increase	49	8	16.33	Increase	49	12	24.49
No Change	107	20	18.69	No Change	107	29	27.10
Decrease	95	13	13.68	Decrease	95	16	16.84

The scores for variable importance for $\mathcal{T}_{BOD}$ are given in Table 3.4. The first five variables that best explain the dependent one' Reduction BOD Group' are: program cost' GDP' economic sub-activity' minimum rate BOD and amount collected.

Table 3.4: Scores for variable importance $\mathcal{T}_{BOD}$

Variable Importance	
Variable	Score
Prog Cost	100.00
GDP	92.94
Econ SubAct	82.44
Min Rate BOD	71.95
Amount Collected	65.09
Perc Collected	52.73
BASIN	44.26
Num Periods	37.80
Env Agency	37.59
Invoice BOD	15.71
Econ Activity	3.08
Reg Factor	3.02

The decision tree also hints to how the nominal variables could be grouped. For example' $\mathcal{T}_{BOD}$ hints to separate the variable Econ SubAct in the groups $\{5'11\}$' $\{1'3'6'9\}$ and $\{4'7'8'12\}$.

3.2.2 Bi-variate Analysis

One-way ANOVA

One-way analysis of variance (ANOVA) was used to explore the relationship between the dependent variable: percent reduction BOD (interval/ratio) and the independent variables: economic subactivity and basin (nominal). Testing the hypothesis that the average percent reduction BOD is equal within economic sub-activities groups and within basins, see Table B, we found that for: a) the first case F=4.666 and the level of significance = 0.000 (<0.05) and b) the second case F=4.824 and the level of significance was 0.000 (<0.05). In both cases there is enough evidence to reject the null hypothesis that the means are equal among economic sub-activities and basins respectively.

Looking for the groups with similar means we were able to construct new basin categories with similar reduction BOD average. This process was complemented by the decision trees procedures.

Pearson correlation coefficients

Pearson correlation coefficients technic was used to examine relationship between the independent variables and the dependent ones regarding the reduction of BOD levels.

Based on the significance level smaller than 0.05, showed in Table B, there is enough information to reject the null hypothesis that there is no linear relationship between percentage reduction in BOD and Min Rate BOD, Prog Cost, GDP, Perc Collected, CORNARE, CHOCO, EconSubActG1, BasinG1, BasinG2, BasinG3 and BasinG4. Additionally, the positive sing of the correlation coefficient observed tell us that the direction of that linear relationship is:

- Positive for Min Rate BOD, Prog Cost, GDP, Perc Collected, CORNARE, BasinG1 and BasinG3.
- Negative for CHOCO, EconSubActG1, BasinG2, BasinG4

3.2.3 Multi-variate Analysis: linear regression

Linear regression is used to analyze the relationship between the independent variables and two different dependent variables: Reduction BOD group and Percent Reduction BOD.

Dummy variables were recorded for the different groups of Econ Activity, Env Agency, Econ Sub-activity and Basin variables (see Section 3.1.2).

To generate both models, the enter procedure was used. This procedure included all the independent variables in the regression. It was checked that tolerance level for multi-collinearity or all the variables was larger than 0.1. Independent variables that presented a tolerance lower than 0.1, were excluded. The variables excluded, in both models were: Total Invoice, Amount Collected, Min Rate BOD, Prog Cost, CORNARE and CHOCO.

The variable Reduction goal of BOD was excluded because it has the same value for all the polluters in the three regional environmental agencies, so it was a constant for the model.

The remaining variables were included in a two new regressions using ENTER procedure and BACKWARD, obtaining that:

- Using ENTER procedure, the variables that best predict the changes in Percent Reduction BOD are BasinG1 and BasinG3 with significance levels for the respective t values smaller than 0.05, for all other variables the level of significance was larger than the set threshold(0.05). So, for BasinG1 and BasinG3 there is enough evidence to reject the null hypothesis that the partial coefficients of these variables are 0. See Model 1 in Table B.

Following, using BACKWARD procedure the final model, see Model 11 in Table B, is:

$$\text{Percent Reduction BOD} = -0.142 + 0.380\text{Perc Collected} \quad (3.1)$$

$$+ 0.416\text{BasinG1} + 0.264\text{BasinG3} \quad (3.2)$$

This model includes BasinG1 and BasinG3 and in addition includes Perc Collected. The corresponding t values and significance levels for each variable are: for Perc Collected 3.93 and 0.000, for BasinG1 3.482 and 0.001, for BasinG3 4.127 and 0.000. In all cases the level of significance is smaller than 0.05, so for each variable, there is enough evidence to reject the null hypothesis that the coefficient is zero.

From the slopes we can see that the relationship between Percent Reduction BOD and Perc Collected, BasinG1, and BasinG3 is positive.

The R Square = 0.218 suggest that 21.8% of the variability in Percent Reduction BOD, can be explained by the variables of the model.

- The same procedure used for Percent Reduction BOD was applied for Reduction BOD group. Using ENTER procedure first, the variables that best predict the changes in the dependent variable are Percent Collected, EconSubActG1, BasinG1 and BasinG3, see Model 2 in Table B. Next, using BACKWARD procedure the final model, see Model 10 in Table B, includes the same variables than model 2:

$$\text{Reduction BOD group} = -0.099 + 0.629\text{Perc Collected} - 0.893\text{EconSubActG1} \quad (3.3)$$

$$+ 0.495\text{Basin G1} + 0.247\text{Basin G3} \quad (3.4)$$

The corresponding t values and significance levels for each variable are as follow: for Perc Collected 4.641 and 0.000, for EconSubActG1 -6.631 and 0.000, for BasinG1 2.964 and 0.003, for BasinG3 2.386 and 0.018. In all cases the level of significance is smaller than 0.05, so for each variable, there is enough evidence to reject the null hypothesis that the coefficient is zero.

From the slopes we can see that the relationship between Percent Reduction BOD and Perc Collected, BasinG1, and BasinG3 is positive and for EconSub-ActG1 is negative.

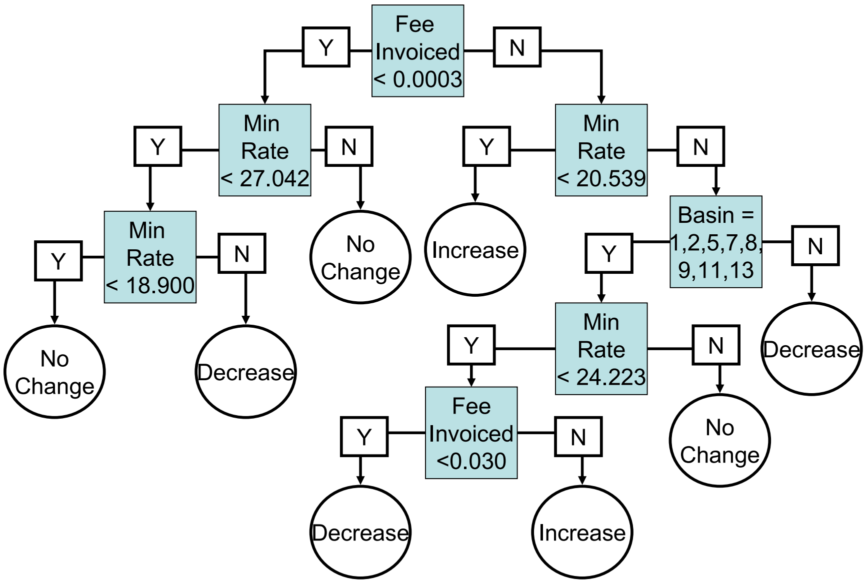
The R Square = 0.476 suggest that 47.6% of the variability in Percent Reduction BOD, can be explained by the variables of the model.

3.3 Results TSS Model

3.3.1 Decision tree analysis

The decision tree for Reduction TSS Group, $\mathcal{T}_{TSS}$, is shown in Figure 3.3. The $\mathcal{T}_{TSS}$ tree predicts that given a polluter, for instance, with a fee invoiced greater than 0.0003 billions of colombian pesos, $\mathcal{T}_{TSS}$ will look at the Min Rate of TSS; if it is smaller than 20.539 , $\mathcal{T}_{TSS}$ predicts that polluter's TSS levels would increase.

Figure 3.3: Decision Tree for Reduction TSS Group



The quality of $\mathcal{T}_{TSS}$, measure in terms of the prediction error on the sample data and test data are shown in Table 3.3.

Table 3.5: Prediction Errors on sample data and test date for the tree $\mathcal{T}_{TSS}$

In the TSS case the scores of *variable importance*, shown in Table 3.6, suggest that the two variables that influence the most the decisions taken in the tree are: minimum rate and fee invoiced.

Table 3.6: Prediction Errors on sample data and test date for the tree $\mathcal{T}_{TSS}$

3.3.2 Bi-variate Analysis results

One-way ANOVA

The ANOVA was also used to explore the relationship between percent reduction TSS (interval/ratio) and economic subactivity and basin (nominal variables). Testing the hypothesis that the average percent reduction TSS is equal within economic sub-activities groups and within basins we found that for the first case F=1.424 and the level of significance=0.178 (>0.05) and for the second case F=1.321 and the level of significance was 0.220 (>0.05). In both cases there is not enough evidence to reject the null hypothesis that the means are equal among economic sub-activities and basins respectively. Even though we were not able to use one-way ANOVA to chose groups with similar means, the selection was made using the decision trees procedure.

Pearson correlation coefficients

Pearson correlation coefficients technic was used to examine the relationship between the independent variables and the dependent ones, regarding the reduction of TSS levels.

Table C shows that the Pearson Correlation coefficient for Min Rate and BasinG3 is 0.178 and 0.212 with a significant level of 0.003 and 0.001 respectively. Based on the significance level, smaller than the set threshold 0.05, we can conclude that there is enough information to reject the null hypothesis that there is no linear relationship between percentage reduction in TSS and Min Rate and BasinG3. These two independent variables are positive related to percentage reduction in TSS, indicated by to the sing of the correlation coefficients.

On the other hand, the significant level of the rest of the variables is greater than 0.05, so there is not enough evidence to reject the null hypothesis that there is not relationship between those variables and percentage reduction in TSS.

3.3.3 Multi-variate Analysis: linear regression

Linear regression is used to analyze the relationship between the independent variables and two different dependent variables: Reduction TSS group and Percent Reduction TSS.

Dummy variables were recorded for the different groups of Econ Activity, Env Agency, Econ Sub-activity and Basin variables (For details see Section 3.1.2).

The enter procedure was used to generate reduction TSS group and percent reduction TSS models. This procedure included all the independent variables in the regression. Followed, tolerance level was checked ensuring that multi-collinearity for all the variables was larger than 0.1. Independent variables that presented a tolerance lower than 0.1, were excluded. The variables excluded, in both models were: GDP, CORNARE and CHOCO.

The variable Reduction goal of TSS was excluded because it was a constant for the model, the value for all the polluters in the three regional environmental agencies was the same.

The remaining variables were included in a two new regressions using ENTER and BACKWARD procedure, obtaining that:

- Using ENTER procedure, the variables that best predict the changes in Percent

Reduction TSS are: Min Rate TSS and Perc Collected with significance levels for the respective t values smaller than 0.05, for all other variables the level of significance was larger than the set threshold (0.05). So, there is enough evidence to reject the null Hypothesis that the partial coefficients of Min Rate and Perc Collected are 0. See Model 1 in Table C.

Following, using BACKWARD procedure the final model, see Model 1.2 in Table C, is:

$$\begin{aligned}\text{Percent Reduction TSS} = & -0.356 + 0.021\text{Min Rate TSS} \\ & + 0.187\text{Perc Collected} + 0.299\text{BasinG3}\end{aligned}$$

This model in addition to Min Rate and Perc Collected includes BasinG3. The corresponding t values and significance levels for each variable are: for Min Rate 2.455 and 0.015, for Perc Collected 1.914 and 0.057, and for BasinG3 3.101 and 0.002. In all cases the level of significance is smaller than 0.05, so for each variable, there is enough evidence to reject the null hypothesis that the coefficient is zero.

From the slopes we can see that the relationship between Percent Reduction BOD and Min Rate, Perc Collected, and BasinG3 is positive.

The R Square = 0.071 suggest that 7.1% of the variability in Percent Reduction BOD, can be explained by the variables of the model.

- The same procedure used for Percent Reduction TSS was applied for Reduction TSS group. Using ENTER procedure first, the variable that best predicts the changes in the dependent variable is Min Rate TSS, see Model 2 in Table C.

Next, using BACKWARD procedure, see Model 2.1 in Table C, the final model is:

$$\text{Reduction TSS group} = -1.014 + 0.053\text{Min Rate} + 0.510\text{Basin G3}$$

The corresponding t values and significance levels for each variable are as follow: for Min Rate 4.169 and 0.000 and for BasinG3 3.542 and 0.000. In all cases the level of significance is smaller than 0.05, so for each variable, there is enough evidence to reject the null hypothesis that the coefficient is zero.

From the slopes we can see that the relationship between Min Rate and BasinG3 is positive.

The R Square = 0.120 suggest that 12% of the variability in Percent Reduction TSS, can be explained by the variables of the model.

Chapter 4

Summary of Findings and Policy Recommendations

4.1 Summary of Findings

The conclusions of this study are derived from the studies revised in the literature review, in particular from the analysis of the studies conducted in Section 1.2 and Section 2.4, as well as from the Section 3.2 and 3.3.

Regarding the first question of study:

Does the performance of the pollution charge program in Colombia undermine the notion that economic instruments are not feasible in developing countries?

It was found that the success of the Colombian case contradicts the assumption of the economic theory because:

- Unfavorable circumstances, faced by developing countries when implementing economic-base mechanisms (described in Section 1.2), were present in the Colombian water pollution charge program. For example resistance by some water companies and low collection rates were present as pointed out by scholars and policy makers 2.4.

- Even though, the water pollution program was not successful across all regional environmental agencies in Colombia, there are regional environmental agencies where the program was successful in reducing pollution levels. Successful cases are pointed out by researchers and policy making organizations (e.g. CVC, CORNARE and CARDER). As shown in this study, water pollution charge program seems to perform differently along CARs. In particular, it is shown (Sections 3.2 and 3.3) that for BOD levels reduction , CHOCO had a poor performance and CORNARE had a good performance (See Table B). On the other hand, reducing TSS levels, CHOCO performs slightly better than CORNARE (See Table C).

- The success of the water program in some environmental agencies is related to the overcoming of the unfavorable circumstances by such agencies, as addressed in Section 2.4. Moreover, the discharge fee program helped to mitigate some of those unfavorable circumstances. For instance colombian water pollution fee program permitted the improvement and development of information about water resources and generated financial resources for further environmental investment (see Section 2.4).

Related to the second question:
Which factors determine the performance of the water pollution charge program across regional environmental agencies in Colombia?

It was found that the factors that seem to explain the differences in performance of water pollution charge program are related to social, economic and institutional aspects, such as:

1. For BOD levels: economic subactivity, percent amount collected by the environmental agency, basin group, program cost and GDP.

2. For TSS levels: min rate, fee invoiced, percent collected and basin group.

The influence of these factors is further analyzed below.

- In both the regression model for classification in reduction of BOD groups and the decision tree, the economic subactivity group 1, the utility companies and the slaughter houses, is significant. It can be seen in both models that most of the individuals on this group present an increase on BOD levels.
- The regressions models show that the basin groups 1 and 3 for BOD and group 3 for the TSS, are significant explaining the change on water pollution levels. This is an important point to explore in future studies, explaining which particular aspects of these basins are related to such significance.
- As noted by Huber et al. (1999:23), although the institutional rationalization process has progressed to accommodate both inter-sectorial and decentralized authorities, institutional fragility remains a well-recognized key barrier to successful governmental management in the region. It is important to recognize that Economic instruments are not a substitute for weak institutions or for Command and Control; some regulatory elements are inevitably required and a strong institutional base is a prerequisite to implement Economic Instruments. This is reflected in the regression where Percent Amount Collected is significant explaining the changes in BOD and TSS levels. The Percent Amount Collected not only reflects the capacity of the regional environmental agency to collect the fee but also reflects the environmental agency's strength on its relationship with the polluters and its capacity to get funding for new environmental investments.
- According to the environmental economic theory, market-oriented instruments

allow polluters and resource users to find their own best responses to the pollution restrictions, and therefore result in lower private costs than other approaches. In developing countries, institutional support plays an important role in the success of market oriented mechanisms because the market does not work perfectly. This is reflected in the data analysis. One of the findings was that when the program cost increased, the levels of BOD decreased. The cost of the program reflects the budget environmental agencies designate for the water pollution charge program. Also, as most of the studies pointed out, in the Colombian case Municipalities were one of the sectors that did not comply with the reduction goal. This was mainly a consequence of two reasons: they do not have resources to build waste water treatment facilities, or they do not pay the fees which they perceive as extra cost.

- It is worth to point out that for BOD, the economic variables Program Cost and GDP show a very different behavior in the regression analysis and the decision tree analysis. While in the regression analysis they are not significant within the 0.05 level, in the tree decision analysis they present the highest variable importance score, i.e. they are the variables that are most used to classify the polluters. This hints that these two economic variables are important in a fashion not captured by the linear regression.

- It was also found that there is a positive correlation between the Min Rate increase and the decrease of pollution levels for BOD as well as TSS. This relationship agrees with the predictions of economic theory according to which if the minimum rate is well set this variable should have a high significance explaining water pollution reduction. What was found in the BOD regression models is that this variable is not significant to explain changes in percent reduction or to determine the group of BOD reduction. From the point of view of the economic theory it can be said that it is likely that the fee is too low to produce changes in BOD-pollution behavior. On the other hand, in the TSS regression models as well as in the decision tree analysis, Min Rate is significant, both, to explain changes in percent reduction and to determine the group of TSS reduction. These results suggest that the minimum rate is well set to reduce levels of TSS.

In sum, the results presented highlight that the success of discharge fee as an economic mechanism in a developing country should be analyzed not only at national level but also at regional, basin and polluter level.

In this frame, the economic theory can be reconciliated with the findings of this study by qualifying the different regional environmental agencies in Colombia as "developed" and "developing". Changing the frame of analysis from the country level to regional agencies level, it can be said that "developing" agencies present unfavorable circumstances that limit their effectiveness for the application of economic instruments.

Another important finding, deduced from the experience of realizing this study, is that even though the discharge fee program permitted improvement and development of information about water resources, there is a long way of improvement in this area. The semestral reports each environmental agency has to present to the Ministry of the environment work as a mechanism to create, standardize and update data bases. However, there is a low percentage of regional environmental agencies with good -meaning complete, consistent, and available- information data sets about the pollution charge program, as noticed for the data base of this study. The problems presented with the data also reflect lack of systematic and qualified monitoring and feedback by the environmental agencies, the governmental auditorial entities and the public. This poor data and lack of control agree with the assumption of the economic theory about unfavorable circumstances presented in developing countries as discussed in Section 1.2.

4.2 Policy Recommendations

The policy recommendations, pointed out in this study, aim to improve the effectiveness of Pollution Charge Program in Colombia. These recommendations could also serve the increasing number of developing countries where economic instruments are at the top of the agenda of the environmental management sector.

From the conclusions obtained in this study the following policy recommendations for water pollution control are suggested.

The Colombian Ministry of Environment in conjunction with the regional environmental agencies must:

- Seek policies focused in improving the institutional capacity of (weak) environmental agencies. One possibility would be to evaluate and re-enforce the technical assistance program, conducted by the Ministry of Environment and successful CARs to assist those least successful CARs in the program's implementation.

- Include local factors in the water pollution control policy. Given that the effectiveness of the program to reduce pollution levels depends on local factors such as economic characteristics of the region, activities of polluters and characteristics of basins; policies focusing in these local factors may help improve the program performance. It can be achieved by using alternative pollution control mechanisms, such as public disclosure (see (Sterner, 2003:122)), as a complement to water pollution charge program in order to target most significant groups of polluters and to include special characteristics of certain basins.

- Develop policies aiming to improve quality and availability of information. Even though, there has been improvement and development of information about water resources the matter needs to improve. One option is to make periodical public reports of the program's performance (e.g publishing the reports each CAR presents to the ministry of the environment in the ministry web page or CARs web page). Also, in order to improve readily available information, it is necessary to improve and enforce data standardization across CARs. In this case is also important to offer technical capacitation about importance and use of the appropriate software to get such standardization.

- Support the municipalities with technical and/or financial resources. Municipalities were one of the sectors that did not comply with the reduction goals. One of the reasons for this was their lack of resources to build waste water treatment facilities. If the regional environmental agencies help them, directly or indirectly, to fund the construction of such facilities, the Municipalities will start reducing pollution and will be more motivated to look for alternative ways to fund projects related to water pollution reduction, such as the treatment plants. One of the ways in which the environmental agencies can help the municipalities to get funding is to instruct and guide them in the search of funding from other national and international entities.

- Take a lead role in cultivating the culture of public participation in environmental issues such as reduction of water pollution. The water pollution program took a step forward in public participation through the goal negotiation process, that included boards of directors of each CAR or AAU, as well as representatives of national and local governments, key productive sectors, and environmental nongovernmental organizations in the reduction goal setting. But, more policies aimed to create participation mechanisms for the community in general are needed. One option is to develop a report of regional indicators of sustainability. This report can work as an assessment of regional sustainability trends including water pollution. The purpose will be to help guide and inspire action for positive change through the regions. Its findings would serve as foundation for strategic thinking, priority setting, and action by policy makers, community leaders as well as the general public. The public participation can improve the efficacy of the pollution control program because moral and social responsibilities of polluters will gain weight trough a better informed and more participating public.

Appendix A

Discharge Fee Formulae

Discharge Fee Formulae in Decree 901 of 1997

Source: Blackman (2005:27-28)

Decree 901 of 1997 regulates Law 99 provisions on retributive fees for water discharges. It mandates that the monthly fee for pollutant j (BOD5 or TSS), TR_j, is calculated as

$$TR_j = Tr_j \times Cc_j \times T$$

where

- Tr_j = regional adjustment for quantity total discharges of pollutant j by all sources ($ /kg),
- Cc_j = daily pollution load of the substance (kg/day), and
- T = number of days of discharge.

Furthermore, C_c is calculated as

$$C_c = Q \times C \times 0.0864 \times (t/24),$$

where

- Q_j = average flow (l/s),

- C_j = concentration of the contaminating substance (mg/l),
- 0.0864 = unit conversion factor, and
- t = hours per day of discharges (h).

And Tr_j is calculated as

$$Tr_j = Tm_j \times Fr,$$

where

- Tm_j = minimum rate ($ /kg) and
- Fr_j = regional factor.

The minimum rate Tm_j is established annually by MMA. The minimum regional factor is equal to 1. It increases by 0.5 each semester (six months) until a preestablished target for total reductions of discharges by all sources is meet.

Appendix B

BOD Model

Table B.1: Descriptive Statistics Dependent Variables

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Percent Reduction BOD	255	-1.315	0.995	0.183	0.448
Reduction BOD Group	251	-1.000	1.000	0.183	0.736
Valid N (listwise)	251				

Table B.2: Descriptive Statistics Independent Interval/ratio Variables

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Invoice BOD	255	0.000	0.560	0.018	0.060
Total Invoice	255	0.000	0.663	0.024	0.077
Amount Collected	255	0.000	0.302	0.009	0.033
min rate BOD	255	39.500	66.950	52.966	8.732
Reg Factor	255	1.500	5.500	5.251	0.798
Num Periods	255	1.000	10.000	7.749	3.167
Prog Cost	255	0.019	0.146	0.103	0.044
GDP	255	0.736	2.938	1.840	0.582
Perc Collected	255	0.000	1.000	0.335	0.313
Valid N (listwise)	255				

Table B.3: Frequency Statistics for Independent Nominal Variables

		Frequency	Percent	Valid Percent	Cumulative Percent
	Env Agency				
Valid	CORNARE	191	74.9	74.9	74.9
	CHOCO	52	20.4	20.4	95.3
	CORALINA	12	4.7	4.7	100.0
	Total	255	100.0	100.0	
	Econ Activity				
Valid	Agroindustry	104	40.8	40.8	40.8
	Industry	95	37.3	37.3	78.0
	Domestic	56	22.0	22.0	100.0
	Total	255	100.0	100.0	
	EconSubAct Group				
Valid	1.00	33	12.9	13.3	13.3
	2.00	77	30.2	30.9	44.2
	3.00	77	30.2	30.9	75.1
	4.00	62	24.3	24.9	100.0
	Total	249	97.6	100.0	
Missing	System	6	2.4		
Total		255	100.0		
	Basin Group				
Valid	1.00	18	7.1	7.6	7.6
	2.00	27	10.6	11.4	19.0
	3.00	150	58.8	63.3	82.3
	4.00	42	16.5	17.7	100.0
	Total	237	92.9	100.0	
Missing	System	18	7.1		
Total		255	100.0		

Table B.4: Oneway ANOVA

ANOVA Basin

Percent Reduction BOD

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	8.789	10	0.879	4.824	0.000
Within Groups	41.173	226	0.182		
Total	49.961	236			

ANOVA Econ Subactivity

Percent Reduction BOD

	Sum of Squares	df	Mean Square	*F*	Sig.
Between Groups	8.102	9	0.900	4.666	0.000
Within Groups	49.775	258	0.193		
Total	57.877	267			

Table B.5: Pearson Correlation

	Percent Reduction BOD			Reduction BOD Group		
	Pearson Correlation	Sig. (2-tailed)	N	Pearson Correlation	Sig. (2-tailed)	N
% Reduction BOD	1.000		255	0.844**	0.000	251
Reduc. BOD Group	0.844**	0.000	251	1.000		251
Invoice BOD	0.014	0.828	255	0.030	0.636	251
Total Invoice	0.011	0.866	255	0.003	0.961	251
Amount Collected	0.073	0.248	255	0.139*	0.028	251
min rate BOD	0.157*	0.012	255	0.321**	0.000	251
Reg Factor	-0.057	0.366	255	-0.050	0.433	251
Num Periods	0.098	0.120	255	0.032	0.615	251
Prog Cost	0.301**	0.000	255	0.483**	0.000	251
GDP	0.331**	0.000	255	0.467**	0.000	251
Perc Collected	0.388**	0.000	255	0.486**	0.000	251
CORNARE	0.264**	0.000	255	0.469**	0.000	251
CHOCO	-0.330**	0.000	255	-0.502**	0.000	251
Agroindustry	0.008	0.894	255	0.012	0.845	251
Industry	0.070	0.267	255	0.188**	0.003	251
Domestic	-0.091	0.146	255	-0.236**	0.000	251
EconSubActG1	-0.316**	0.000	249	-0.598**	0.000	246
EconSubActG2	0.037	0.559	249	0.107	0.095	246
EconSubActG3	0.089	0.162	249	0.137**	0.032	246
EconSubActG4	0.113	0.075	249	0.211**	0.001	246
BasinG1	0.213**	0.001	237	0.225**	0.001	233
BasinG2	-0.208**	0.001	237	-0.267**	0.000	233
BasinG3	0.239**	0.000	237	0.356**	0.000	233
BasinG4	-0.276**	0.000	237	-0.382**	0.000	233

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table B.6: Regression Coefficients and Model Summary for Percent Reduction BOD

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
Model 1					
(Constant)	-0.071	0.492		-0.144	0.886
Invoice BOD	-0.472	0.507	-0.064	-0.931	0.353
Reg Factor	-0.073	0.068	-0.094	-1.073	0.284
Num Periods	0.024	0.015	0.148	1.597	0.112
GDP	-0.003	0.119	-0.004	-0.023	0.982
Perc Collected	0.255	0.154	0.172	1.653	0.100
Agroindustry	-0.182	0.142	-0.192	-1.281	0.202
Domestic	-0.037	0.131	-0.034	-0.282	0.778
EconSubActG1	0.116	0.231	0.088	0.503	0.615
EconSubActG2	0.233	0.138	0.236	1.686	0.093
EconSubActG3	0.264	0.146	0.257	1.801	0.073
BasinG1	0.437	0.217	0.252	2.014	0.045
BasinG2	-0.012	0.152	-0.008	-0.081	0.936
BasinG3	0.417	0.192	0.437	2.176	0.031
Model 11					
(Constant)	-0.142	0.052		-2.731	0.007
Perc Collected	0.380	0.097	0.256	3.934	0.000
BasinG1	0.416	0.119	0.240	3.482	0.001
BasinG3	0.264	0.064	0.277	4.127	0.000

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1^a	0.507	0.257	0.213	0.411052
11^b	0.467	0.218	0.208	0.412319

a. Predictors: (Constant), BasinG3, Invoice BOD , Perc Collected, Reg Factor, EconSubActG2, BasinG2, Agroindustry, Num Periods, Domestic, EconSubActG3, BasinG1, GDP, EconSubActG1

b. Predictors: (Constant), BasinG3, Perc Collected, BasinG1

Table B.7: Regression Coefficients and Model Summary for Reduction BOD Group

Coefficients

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
Model 1					
(Constant)	-0.081	0.680		-0.119	0.905
Invoice BOD	0.091	0.695	0.008	0.131	0.896
Reg Factor	-0.078	0.093	-0.062	-0.841	0.401
Num Periods	0.027	0.021	0.101	1.287	0.200
GDP	0.000	0.164	0.000	-0.003	0.998
Perc Collected	0.504	0.213	0.208	2.369	0.019
Agroindustry	-0.198	0.198	-0.127	-1.003	0.317
Domestic	-0.101	0.188	-0.056	-0.535	0.593
EconSubActG1	-0.645	0.326	-0.297	-1.981	0.049
EconSubActG2	0.216	0.195	0.132	1.107	0.269
EconSubActG3	0.268	0.205	0.159	1.306	0.193
BasinG1	0.581	0.298	0.205	1.951	0.052
BasinG2	0.049	0.208	0.021	0.237	0.813
BasinG3	0.456	0.264	0.290	1.727	0.086
Model 10					
(Constant)	-0.099	0.098		-1.012	0.313
Perc Collected	0.629	0.135	0.259	4.641	0.000
EconSubActG1	-0.893	0.135	-0.411	-6.631	0.000
BasinG1	0.495	0.167	0.175	2.964	0.003
BasinG3	0.247	0.103	0.157	2.386	0.018

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1^a	0.699	0.488	0.458	0.56254
10^b	0.690	0.476	0.467	0.55784

a. Predictors: (Constant), BasinG3, Invoice BOD , Perc Collected, Reg Factor, EconSubActG2, BasinG2, Agroindustry, Num Periods, Domestic, EconSubActG3, BasinG1, GDP, EconSubActG1
b. Predictors: (Constant), BasinG3, Perc Collected, BasinG1, EconSubActG1

Appendix C

TSS Model

Table C.1: Descriptive Statistics Dependent Variables

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Percent Reduction TSS	276	-1.259	0.997	0.226	0.466
Reduction TSS Group	271	-1.000	1.000	0.221	0.747
Valid N (listwise)	271				

Table C.2: Descriptive Statistics Independent Interval/ratio Variables

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Invoice TSS	276	0.000	0.242	0.006	0.022
Total Invoice	255	0.000	0.663	0.024	0.077
Amount Collected	255	0.000	0.302	0.009	0.033
min rate TSS	276	16.900	28.670	22.723	3.609
Reg Factor	255	1.500	5.500	5.251	0.798
Num Periods	255	1.000	10.000	7.749	3.167
Prog Cost	255	0.019	0.146	0.103	0.044
GDP	255	0.736	2.938	1.840	0.582
Perc Collected	255	0.000	1.000	0.335	0.313
Valid N (listwise)	255				

Table C.3: Frequency Statistics for Independent Nominal Variables

		Frequency	Percent	Valid Percent	Cumulative Percent
	Env Agency				
Valid	CORNARE	191	61.8	74.9	74.9
	CHOCO	52	16.8	20.4	95.3
	CORALINA	12	3.9	4.7	100.0
	Total	255	82.5	100.0	
Missing	System	54	17.5		
Total		309	100.0		
	Econ Activity				
Valid	Agroindustry	104	33.7	40.8	40.8
	Industry	95	30.7	37.3	78.0
	Domestic	56	18.1	22.0	100.0
	Total	255	82.5	100.0	
Missing	System	54	17.5		
Total		309	100.0		
	EconSubAct Group				
Valid	1	23	7.4	8.6	8.6
	2	84	27.2	31.3	39.9
	3	98	31.7	36.6	76.5
	4	63	20.4	23.5	100.0
	Total	268	86.7	100.0	
Missing	System	41	13.3		
Total		309	100.0		
	Basin Group				
Valid	1	24	7.8	10.1	10.1
	2	37	12.0	15.6	25.7
	3	26	8.4	11.0	36.7
	4	150	48.5	63.3	100.0
	Total	237	76.7	100.0	
Missing	System	72	23.3		
Total		309	100.0		

Table C.4: Oneway ANOVA

Percent Reduction TSS — **ANOVA Basin**

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.817	10	0.282	1.321	0.220
Within Groups	48.189	226	0.213		
Total	51.005	236			

ANOVA Econ Subactivity

Percent Reduction TSS

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.793	9	0.310	1.424	0.178
Within Groups	56.238	258	0.218		
Total	59.031	267			

Table C.5: Pearson Correlation

	Percent Reduction TSS			Reduction TSS Group		
	Pearson Correlation	Sig. (2-tailed)	N	Pearson Correlation	Sig. (2-tailed)	N
% Reduction TSS	1.000		276	0.857**	0.000	271
Reduc. TSS Group	0.857**	0.000	271	1.000		271
Invoice TSS	-0.069	0.255	276	-0.140*	0.022	271
Total Invoice	-0.086	0.173	255	-0.065	0.306	250
Amount Collected	-0.064	0.311	255	-0.046	0.466	250
min rate TSS	0.178**	0.003	276	0.329**	0.000	271
Reg Factor	-0.040	0.520	255	-0.037	0.556	250
Num Periods	0.050	0.426	255	-0.018	0.778	250
Prog Cost	-0.069	0.273	255	-0.069	0.276	250
GDP	-0.037	0.556	255	-0.041	0.519	250
Perc Collected	0.073	0.243	255	-0.003	0.959	250
CORNARE	-0.089	0.155	255	-0.114	0.071	250
CHOCO	0.059	0.347	255	0.071	0.262	250
Agroindustry	0.022	0.723	255	0.014	0.822	250
Industry	-0.034	0.589	255	-0.088	0.168	250
Domestic	0.013	0.834	255	0.086	0.176	250
EconSubActG1TSS	0.078	0.204	268	0.051	0.413	263
EconSubActG2TSS	0.061	0.318	268	0.015	0.809	263
EconSubActG3TSS	-0.065	0.291	268	-0.022	0.723	263
EconSubActG4TSS	-0.045	0.464	268	-0.025	0.684	263
BasinG1TSS	-0.064	0.325	237	-0.043	0.512	233
BasinG2TSS	0.002	0.978	237	-0.005	0.946	233
BasinG3TSS	0.212**	0.001	237	0.235**	0.000	233
BasinG4TSS	-0.098	0.131	237	-0.123	0.061	233

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table C.6: Regression Coefficients and Model Summary for Percent Reduction TSS

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
Model 1					
(Constant)	0.148	0.562		0.263	0.793
min rate TSS	0.019	0.009	0.145	2.157	0.032
Invoice TSS	-0.847	1.314	-0.042	-0.644	0.520
Total Invoice	-0.775	0.868	-0.133	-0.892	0.373
Amount Collected	0.384	1.990	0.029	0.193	0.847
Reg Factor	-0.020	0.062	-0.026	-0.331	0.741
Num Periods	-0.009	0.017	-0.055	-0.500	0.618
Prog Cost	-2.479	1.695	-0.237	-1.463	0.145
Perc Collected	0.344	0.169	0.228	2.030	0.044
Agroindustry	-0.001	0.110	-0.002	-0.014	0.989
Industry	-0.060	0.100	-0.062	-0.598	0.550
BasinG1TSS	-0.175	0.144	-0.114	-1.212	0.227
BasinG2TSS	-0.089	0.156	-0.069	-0.568	0.571
BasinG3TSS	0.176	0.150	0.117	1.176	0.241
EconSubActG1TSS	0.168	0.135	0.088	1.244	0.215
EconSubActG2TSS	0.043	0.088	0.042	0.483	0.630
EconSubActG3TSS	-0.052	0.082	-0.054	-0.630	0.529
Model 14					
(Constant)	-0.356	0.206		-1.724	0.086
min rate TSS	0.021	0.009	0.159	2.455	0.015
Perc Collected	0.187	0.098	0.124	1.914	0.057
BasinG3TSS	0.299	0.096	0.199	3.101	0.002

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1[a]	0.358	0.128	0.063	0.453
14[b]	0.288	0.083	0.071	0.451

a. Predictors: (Constant), EconSubActG3TSS, Invoice TSS, Reg Factor, BasinG1TSS, Perc Collected, Total Invoice , min rate TSS, EconSubActG1TSS, Industry, BasinG3TSS, BasinG2TSS, Num Periods, EconSubActG2TSS, Agroindustry, Amount Collected, Prog Cost

b. Predictors: (Constant), Perc Collected, min rate TSS, BasinG3TSS

Table C.7: Regression Coefficients and Model Summary for Reduction TSS Group

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
Model 1					
(Constant)	0.148	0.562		0.263	0.793
min rate TSS	0.019	0.009	0.145	2.157	0.032
Invoice TSS	-0.847	1.314	-0.042	-0.644	0.520
Total Invoice	-0.775	0.868	-0.133	-0.892	0.373
Amount Collected	0.384	1.990	0.029	0.193	0.847
Reg Factor	-0.020	0.062	-0.026	-0.331	0.741
Num Periods	-0.009	0.017	-0.055	-0.500	0.618
Prog Cost	-2.479	1.695	-0.237	-1.463	0.145
Perc Collected	0.344	0.169	0.228	2.030	0.044
Agroindustry	-0.001	0.110	-0.002	-0.014	0.989
Industry	-0.060	0.100	-0.062	-0.598	0.550
BasinG1TSS	-0.175	0.144	-0.114	-1.212	0.227
BasinG2TSS	-0.089	0.156	-0.069	-0.568	0.571
BasinG3TSS	0.176	0.150	0.117	1.176	0.241
EconSubActG1TSS	0.168	0.135	0.088	1.244	0.215
EconSubActG2TSS	0.043	0.088	0.042	0.483	0.630
EconSubActG3TSS	-0.052	0.082	-0.054	-0.630	0.529
Model 14					
(Constant)	-0.356	0.206		-1.724	0.086
min rate TSS	0.021	0.009	0.159	2.455	0.015
Perc Collected	0.187	0.098	0.124	1.914	0.057
BasinG3TSS	0.299	0.096	0.199	3.101	0.002

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1[a]	0.412	0.170	0.107	0.682
15[b]	0.357	0.127	0.120	0.677

a. Predictors: (Constant), EconSubActG3TSS, Invoice TSS, Perc Collected, BasinG1TSS, Reg Factor, Total Invoice , min rate TSS, EconSubActG1TSS, Industry, BasinG3TSS, BasinG2TSS, Num Periods, EconSubActG2TSS, Agroindustry, Amount Collected, Prog Cost

b. Predictors: (Constant), min rate TSS, BasinG3TSS

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