

# **Allocation of environmental goods: an analysis of emission trading**

**Diploma Thesis**

Submitted by

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# TABLE OF CONTENTS

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<b>1. INTRODUCTION.....</b>	<b>1</b>
<b>2. ENVIRONMENTAL PROBLEMS .....</b>	<b>3</b>
2.1 THE ROOTS OF ENVIRONMENTAL DEGRADATION .....	3
2.1.1 <i>Public goods</i> .....	4
2.1.2 <i>Open-access common property resources</i> .....	6
2.1.3 <i>Externalities</i> .....	7
2.2 POLLUTION AS EXTERNALITY .....	8
2.2.1 <i>The Pigouvian prescription</i> .....	10
2.2.2 <i>The Coase theorem</i> .....	11
<b>3. ENVIRONMENTAL POLICIES .....</b>	<b>17</b>
3.1 THE ROLE OF ENVIRONMENTAL POLICIES.....	17
3.2 ENVIRONMENTAL POLICIES INSTRUMENTS .....	20
3.2.1 <i>Typology of instruments</i> .....	20
3.2.2 <i>Command-and-control ‘versus’ market-based instruments</i> .....	22
3.3 THE EMISSIONS TRADING CONCEPT .....	25
3.3.1 <i>Types of emissions trading policies</i> .....	29
3.3.2 <i>Experiences with emissions trading</i> .....	31
3.3.3 <i>Bubble policy as a special case</i> .....	37
<b>4. A GAME-THEORETIC APPROACH TO EMISSIONS TRADING.....</b>	<b>40</b>
4.1 INTRODUCTION INTO COOPERATIVE BARGAINING.....	40
4.2 BUBBLE POLICY AS A BARGAINING GAME .....	42
4.2.1 <i>Structure of the game</i> .....	42
4.2.2 <i>Applying solution concepts</i> .....	48
<b>5. CONCLUDING REMARKS .....</b>	<b>57</b>

## **LIST OF FIGURES**

---

FIGURE 1: COASE SOLUTION .....	12
FIGURE 2: EMISSIONS TRADING MECHANISM .....	26
FIGURE 3: EFFICIENT BARGAINING SOLUTION.....	43
FIGURE 4: BARGAINING WHEN FIRM 1 IS MONOPOLIST .....	45
FIGURE 5: BARGAINING WHEN FIRM 2 IS MONOPOLIST .....	45
FIGURE 6: THE PARETO FRONTIER.....	46
FIGURE 7: ANOTHER VIEW OF THE PARETO FRONTIER .....	47
FIGURE 8: NASH BARGAINING SOLUTION .....	50
FIGURE 9: KALAI-SMORODINSKY BARGAINING SOLUTION .....	52
FIGURE 10: COMPARING BARGAINING SOLUTIONS .....	53
FIGURE 11: ITERATIVE BARGAINING SOLUTION .....	54
FIGURE 12: BARGAINING SOLUTION (ALLOCATION OF SURPLUS BETWEEN FIRMS).....	56

## **LIST OF TABLES**

---

TABLE 1: CLASSIC CHARACTERIZATION OF GOODS .....	5
TABLE 2: ACTIVITY, TASKS AND QUESTIONS .....	18
TABLE 3: COMMAND-AND-CONTROL VERSUS MARKED-BASED INSTRUMENTS.....	23

# 1. INTRODUCTION

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This thesis primarily focuses on emissions trading (taking the bubble policy concept as a special case) in the context of the Coase theorem, which asserts that if property rights are well defined and the parties can transact at low cost, externalities can be internalised through negotiation among the private parties, without needing a public coercive mechanism. Based on this principle, this study firstly shows the connection between economic and environmental systems, and subsequently the use of cooperative bargaining theory (Nash and Kalai-Smorodinsky bargaining solutions) as a tool to understand the interactions between agents and predict the potential results from the negotiation process, with the intention to give support to the decision-making procedure.

This work is organized as follows:

- i) Section 2 describes the roots of environmental degradation and its connection with the four situations in which the market system fails to achieve efficiency: public goods, externalities, open-access common property resources, and market power. The contributions of Arthur Pigou (1932) and Ronald Coase (1960) to deal with the problem of pollution are also exposed there;
- ii) Section 3 introduces the role of environmental policies and their instruments, as command-and-control and market-based mechanisms. The concept of emissions trading and some experience in using this instrument are related in supplementary subsections, as well as the introduction of the bubble policy concept, that allow industry management to figure out the possibility to clean up air pollution at a least cost way;
- iii) Finally, Section 4 details a theoretical approach to emissions trading in the context of the bubble policy, using the concepts of cooperative bargaining theory, more precisely Nash (1950) and Kalai-Smorodinsky (1975) bargaining solutions, to demonstrate how firms could interact in order to achieve the cost-efficient outcome, that is, the “Coase solution”.

Such analysis has found two interesting responses. In the first case, firms are bargaining only about the compensation price per unit of emissions reductions. It is much unexpected that Nash or Kalai-Smorodinsky solutions would be exactly similar with the cost-efficient Coase solution. In order to achieve that result, firms would be more successful playing an iterative game, proposed by Schlicht (1996). This author suggested a mechanism of bilateral bargaining based on the assumption that through a repetitive interaction parties are able to reach an efficient outcome.

The second case shows that firms could bargain not only about the price per unit, but also about the allocation of the surplus between agents, i.e., the compensation price for the complete amount of emission reduction. In the event of this, the results are symmetric and the Nash and Kalai-Smorodinsky bargaining solution coincide. Besides, the outcome of this type of game is by definition always efficient, because the Coase solution will be attained all the time.

For the sake of conclusion, it will be done a recommendation about which case and which bargaining solution would be more suitable for firms to achieve the cost efficient outcome.

## **2. ENVIRONMENTAL PROBLEMS**

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### **2.1 The roots of environmental degradation**

There are too many explanations for environmental degradation and excessive exploitation of natural resources: continuing growth of human population, high levels of consumption of energy and natural resources, ignorance of long-term effects, social and cultural values that demand high priority on immediate material consumption. As Booth (1995) has emphasized, the causes of environmental problems, and the failure of environmental regulation, are deeply embedded in the processes that generate economic wealth and growth, stressing the statement that economic system fails to give proper value to the environment.

Four situations in which the price/market system fails to achieve efficiency are recognized by economics. They are public goods, externalities, open-access common property resources, and market power<sup>1</sup>. Collectively, they are known as the sources of market failure. Market failure occurs when freely functioning markets fail to deliver an efficient or optimal allocation of resources, therefore, economic and social welfare may not be maximized, leading to a loss of efficiency. Resources are allocated in an efficient manner if it is not possible to rearrange them in a condition that can improve one person's welfare without reducing the welfare of another. This is known as the Pareto efficiency or Pareto optimality.

If it is found a way to make some people better off without making anybody else worse off, it is a Pareto improvement. If an allocation allows for a Pareto improvement, it is called Pareto inefficient; if an allocation is such that no Pareto improvements are possible, it is called Pareto efficient or Pareto optimal. In short, an economic situation is Pareto efficient if there is no way to make some group of people better off without making some other group worse off. The concept of Pareto efficiency<sup>2</sup> can be used to evaluate different ways of resources allocation (Varian, 2003).

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<sup>1</sup> Market power is also showed in situations of monopoly, monopsony, oligopoly, etc, but is not directing relevant as a root of environmental degradation and it will not be considered in this work.

<sup>2</sup> Pareto efficiency is named after the economist and sociologist Vilfredo Pareto (1848-1923) who was the first to examine the implications of this idea.



Pearson (2000) asserts that the combination of public goods, externalities and inadequate user restrictions on common property resources amounts to a powerful explanation of environmental degradation and abusive use of natural resources. This author also pointed out the potential solutions: collective action for the provision of public goods; internalization of externalities either through the extension of property rights, private negotiation of restrictions on externalities, or public restrictions; and limitations on excessive use of common property resources.

These interrelated sources of the inefficiency in the allocation of environmental resources are shortly explained in the following subsections.

### **2.1.1 Public goods**

A pure public good has two characteristics: non-rivalry in consumption and non-excludability. It means that nobody can be excluded from using the goods or service and the consumption by one person does not detract from another's consumption. If a consumer can not be excluded from using the goods or service, he/she will have no incentive to purchase it, and the potential producer, with no probability for revenue, will have no incentive to bear the costs of production, consequently little or none of the goods or service will be produced.

Public goods provide a very important example of market failure. The production of public goods results in positive externalities which are not remunerated. Because no private organization can reap all the benefits of a public good which they have produced, there will be insufficient incentives to produce it voluntarily. Consumers can take advantage of public goods without contributing sufficiently to their creation. This is called the free-rider problem, or occasionally, the "easy rider problem" (because consumer's contributions will be small but non-zero). Free riding is an economic problem when it leads to the non-production or under-production of a public good, and thus to Pareto inefficiency, or when it leads to the excessive use of a common property resources.

Pollution and degradation of the environment could be considered as a "public bad": a person has limited ability to exclude his/her consumption and consumption by one person does not reduce the amount consumed by others. Note that public bad has the

same characteristics of public goods, but while the market fails to produce sufficient public goods, it produces abundant quantity of public bad.

One of the most common ways of looking at goods in economics, shown in the table below (Table 1), is the classic division based on whether there is competition involved in obtaining a given good and whether it is possible to exclude a person from consumption of a given good.

**Table 1: Classic characterization of goods**

		Exclusion from consumption (excludability)	
		YES	NO
Competition in consumption (rivalry)	YES	<b>Private good</b> (food, clothing, cars)	<b>Common good</b> (natural environment)
	NO	<b>Club good</b> (clubs, private schools)	<b>Public good</b> (national security)

An important variation of the conception of public goods is the “common goods”, which are placed somewhere between pure public and private goods. Common goods maintain the characteristic of non-excludability, but at certain level of consumption the use by one consumer interferes with the use by another one and, consequently, they lose the peculiar quality of non-rivalry. Typical examples of common goods, where more users eventually reduce the benefits enjoyed by previous users, include education, police and fire protection, health care, local roadways, over fishing, amenity losses from overcrowding public area, and local environmental quality such as trash collection, clean water, public sanitation, and so forth.

In short, the use of environmental for waste disposal services directly interferes with the beneficial use of that media by others and consequently the medium is “congested” or “overused”. The challenge for public policy is to allocate the now scarce resource in an efficient direction among competing users. Actually, common goods shade into the problem of open-access common property resources, considered in the next subsection.

### **2.1.2 Open-access common property resources**

A common property resource is defined as a natural or human made resource system, where the size or characteristics of which makes it costly, but not impossible, to exclude potential beneficiaries from obtaining benefits from its use. Unlike pure public goods, common property resources face problems of congestion or overuse. A common property resource typically consists of a core resource providing a limited quantity of extraction. While the core resource is to be protected or limited in order to allow for its continuous exploitation, its excessive consumption can cause the exhaustion of the resources.

A clear discernment can be made among a resource that pertains to everyone and a resource that pertains to no one. The right of occupation of a resource that pertains to no one (or to everyone, according to individual points of view) is based on the fact that most things become exhausted by indiscriminate use and that appropriation consequently is the condition for their utility to human being.

In fact, the users of a common good resource have no (or very little) incentive for the conservation of that good. This situation is known as social traps (Platt, 1973), in which people, organizations, or societies drawn into certain patterns of behaviour with promises of immediate rewards and then confronted with unpleasant long-run consequences. The “tragedy of commons” (Hardin, 1968) is a good example of social trap used to study overexploitation of natural resources. In that work, Hardin used overgrazing of communally held pasture as a metaphor for increased pollution of shared air, water and land resources. Unless restricted by regulation, air and water resources exhibit free access for waste disposal purposes.

The strong tendency to overuse or overexploitation of open-access common property resources is clearly linked to market failure. If an individual exploits a resource to the point where him/her private marginal costs<sup>3</sup> equal him/her private marginal revenue, he/she is generating an external cost borne by other users in the form of degraded soil, lower fish catch, etc. The social cost of exploiting the resource exceeds the individual private cost, and the productivity of the resource is impaired. In this

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<sup>3</sup> Marginal refers to the effects of small changes. For example, if the total cost of production of a good increased from \$10.000 to \$10.010 when the production increased from a rate of 500 to 501, the marginal cost of the 501<sup>st</sup> unit is \$10 (Freeman, 2003). Marginal cost is defined as the change in total costs resulting from increasing output by one unit. Marginal costs relate to variable costs only. Changes in fixed costs in the short run affect total costs, but not marginal costs.

direction, open-access common property resources are firmly connected to common public goods.

The two prevalent responses to the problem of open-access common property resources are to privatize through private property rights or to have an external agency, most likely government, enforcing restrictions on access.

### **2.1.3 Externalities**

The concept of externalities is closely related to public goods. Externalities are the third party effects arising from production and consumption of goods and services for which no appropriate compensation is paid. Externalities occur in nearly every market and industry and can cause market failure if the price mechanism does not take into account the full social costs and benefits of production and consumption. Externalities occur outside of the market, they affect economic agents not directly involved in the production and/or consumption of a particular good or service.

Externalities create a divergence between the private and social costs of production. Social cost is the total of all the costs associated with an economic activity. It embraces all the costs of production of the output of a particular good or service. It includes both costs borne by the economic agent and also all costs borne by society at large. It includes the costs reflected in the organization's production function (private costs) and the costs external to the firm's private costs (external costs).

If social costs are larger than private costs, then a negative externality appears. Environmental pollution is an example of a social cost that is rarely borne completely by the polluter thereby creating a negative externality. On the other hand, if private costs are greater than social costs, then a positive externality exists. An example is when a supplier of educational services indirectly benefits society as a whole but only received payment for the direct benefit received by the recipient of the education: the benefit to society of an educated population is a positive externality. In either case, a market failure exists, because resources will be allocated inefficiently.

The inefficiency associated with unregulated environmental externalities arises because the agents responsible for the externality have no incentives to restrict it, as the benefits of such an action (damages avoided) would accrue to others. For

instance, in competitive conditions, a firm that alone incurred substantial pollution abatement cost<sup>4</sup> might be driven out of business. Usually, governments intervene to improve social welfare when the price-market system fails to allocate resources efficiently.

The relation between externalities and public goods becomes clear: public goods are non-excludable; with a positive externality, the agent producing the externality can not appropriate and charge it for his beneficial effects. On the other hand, with a negative externality, the victim is the unwilling recipient of the effect and can not be directly excluded. The producer does not bear the costs, but shift it to the victim. The lack of excludability is central to both the public goods and externality problems. Besides, for common public goods, the cost imposed by one user on another can itself be considered as externality.

## **2.2 Pollution as externality**

In a physical view, pollution is defined as the discharge of harmful substances, resulting by human production activities, in the form of gases (air pollution), chemicals (water pollution), trash, nuclear waste (land/soil contamination) and others (noise). Besides a serious side-effect in natural disasters, pollution also causes a variety of illness and health risks for humans, like cancer, allergies, immune diseases, etc.

Turner, Pearce and Bateman (1994) affirm that the economic definition of pollution is *“dependent upon both some physical effect of waste on the environment and a human reaction to that physical effect, i.e. a loss of welfare due to the imposition of an external cost”*. Clearly, pollution is a negative externality, because the social costs of its consumption or production are larger than the private costs. The evident solution to correct this market failure is to “internalize the externality”, i.e. make the polluter pay the cost of the pollution.

Environmental protection involves substantial economic costs and damages are only a part of the social costs associated with pollution. The other cost is abating pollution

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<sup>4</sup> A cost borne by many businesses for the removal and/or reduction of an undesirable item that they have created. Abatement costs are generally incurred when corporations are required to reduce possible nuisances or negative by-products created during production. Examples of abatement costs would be the pollution reduction costs of paper mills and noise reduction costs of manufacturing plants.

to a lower level (abatement costs). Such costs include the costs of the labour, capital, and energy needed to reduce the emissions of pollution associated with particular levels of production or consumption. Generally, these costs are analyzed as “opportunity costs”.

Opportunity costs are the amount that is sacrificed when choosing one activity over the next best alternative. For instance, if one country wants to invest more money to reduce harmful gases emissions and consume more clean air (good 1), it has to give up some investments in public health, education and others (good 2). Giving up the opportunity to consume good 2 is the true economic cost of more good 1 consumption. The opportunity cost of pollution abatement is the output of conventional economic goods and services foregone, while the benefits are, of course, environmental damages avoided.

Pollution abatement and environmental protection should be pursued to the point at which marginal benefits equal marginal costs (Pearson, 2000). However, difficulties arise to transform protection measures into ambient environmental quality, and environmental quality into physical environmental damages and damages avoided. Moreover, the concept of environmental value becomes obscure when intrinsic values are introduced. The valuation challenge arises from the lack of markets and prices for many environmental services. Varian (2003) argues that the crucial characteristic of externalities is that there are goods which people care about which are not sold on markets and this lack of markets for externalities that causes problems. For example, there are no markets for noise made by cars, or pollution, or clean air.

The contributions of Arthur Pigou (1920) and Ronald Coase (1960) become essential to deal with externality theory and struggle the problem of pollution, although they leads to quite different policy conclusions: whereas Pigou attributes environmental pollution to divergence between social marginal cost and private marginal cost and his analysis suggests a policy of government taxes and subsidies to correct externalities, Coase emphasizes that if property rights are well defined, costless bargaining between polluters and victims can lead to efficient outcomes without direct government involvement.

### **2.2.1 The Pigouvian prescription**

The pioneer work of Arthur Pigou (1932) related environmental pollution as divergence between social marginal cost and private marginal cost and recommended taxes on activities generating negative externalities, and subsidies on activities generating positive externalities, as means of internalizing externalities and bringing the choice of the firm in line with what it would have been had it faced the true social cost (benefit) of production.

A Pigouvian tax may be levied on producers who pollute the environment to encourage them to reduce pollution and to provide revenue which may be used to counterweight the negative effects of the pollution. Suppose a steel company which was charged by the government for the damage done by its pollution. By doing so it converts the external cost into an internal cost (internalizes the externality). In deciding how much steel to produce and what price to sell it at, the company will now include the cost of its pollution (paid as an emission fee) along with other costs. In deciding how much pollution control equipment to buy, the company balances the cost of control against its benefits, and buys the optimal amount. So a system of emission fees can produce both an efficient amount of steel and an efficient amount of pollution control.

According to Varian (2003), one of the problems with Pigouvian taxes is that is essential to know the optimal level of pollution in order to impose the tax. But if the optimal level of pollution is known, then it is possible to make the firms know it and they could produce exactly that amount and not have to mess with this taxation scheme at all. Another weakness is that a Pigouvian tax relies on partial market analysis: the polluting activity is regulated to the socially optimal level, but the victims are not yet compensated. Instead, the government has an additional tax income. For these problems, the remaining questions are: is there an omniscient state with the ability to set taxes at the appropriate rate to equalize marginal private and social costs? How can the tax income be allocated in a way that does not distort the allocation again?

The market structure and type of regulation will also influence the responses of the firms. If for example, producers' prices are managed on the basis of retention price formula and if a firm's capacity of utilization exceeds the target level then the firm

has no deterrence to incur costs in creating and operating as abatement plant. Even for a profit-maximizing firm in a competitive market, the level of pollution abatement will depend on the nature of institutional mechanisms for monitoring and enforcing pollution control measures. Hence these problems make difficult the task of deciding the level of tax and evaluating the effect of the tax on pollution abatement in an industry.

### **2.2.2 The Coase theorem**

According to Ronald Coase<sup>5</sup> (1960) many disputes over common resources derive from the fact that no one owns them; or everyone owns them, as in the case of public property. However, these disputes could be resolved if the unclaimed resources were divided up as private property. Assigning property rights greatly enhances the ability to resolve disputes over the use and abuse of resources. Property rights may be defined in terms of who holds rights – whether persons (individuals, business firms and other units with the legal identity of persons), organizations, governments, or loosely defined latent groups (Olson, 1965). In other words, the definition of property rights refers to whether the generator of the externality has the legal right to generate it or the victim of the externality has the legal right to be free from exposure to the externality (Kahn, 1997).

Property rights are important for the well-functioning of a market. Without them, even the most ordinary market transactions are difficult. Property rights make strong difference in whether a market will allocate goods and bads efficiently. Coase (1960) ascribes the negative externality to lack of well-defined property rights on environmental resources and high transaction costs in finding solutions via bargaining among polluters. This author showed that in the absence of transaction costs, the social optimum could be reached (e.g. the optimal level of pollution, the optimal amount of trees cut, of land protected, of reforestation, of environmental protection, etc.) regardless if property rights are initially allocated to those which cause the pollution (polluters) or to those suffering from the pollution (victims). This result is known as the *Coase theorem*, which could be formally expressed as follows: given well-defined property rights, low bargaining costs, perfect information, perfect

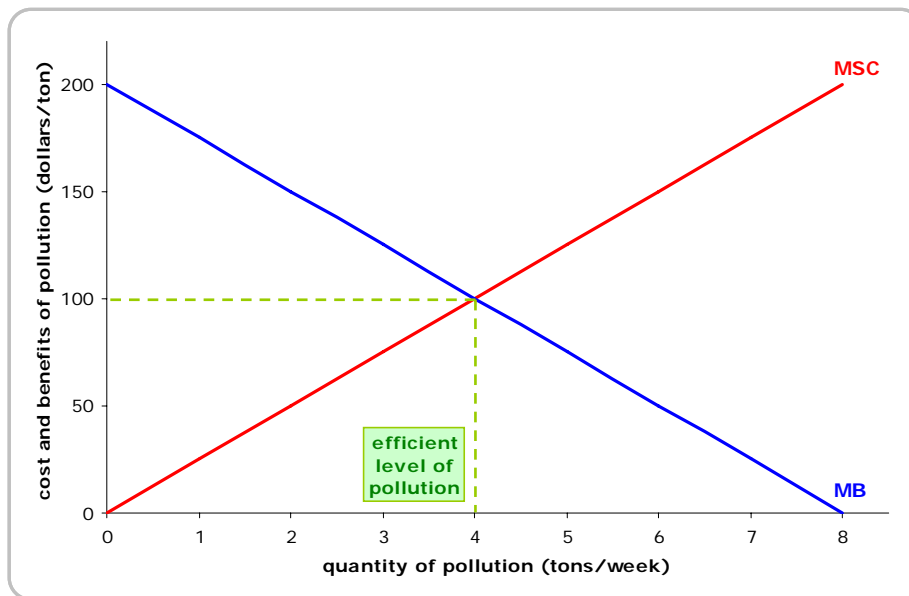
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<sup>5</sup> Ronald Coase is an emeritus professor at the University of Chicago Law School. His famous paper “The Problem of Social Cost” has been given a variety of interpretations. Coase received the 1991 Nobel Prize in Economics for this work.



competition, and the absence of transaction costs and income effects, affected parties to an externality will agree on an allocation of resources that is both Pareto optimal and independent of any prior assignment of property rights (Coase, 1960).

In order to reinforce Coase's argument, consider the following situation: a chemical firm produces some amount of chemicals, and also produces a certain amount of pollution (externalities), which it discharges into a river. A fishery is located downstream and is unfavourably affected by chemical firm's pollution. It is clear that fishery's costs of producing a given amount of fish depend on the amount of pollution produced by the chemical firm, because pollution increases the cost of providing fish and decreases the cost of chemicals production. In other arrangement, increasing the amount of pollution will decrease the cost of producing chemicals, whereas reducing pollution will increase the cost of chemicals production (consequently, reducing the cost of providing fish).



**Figure 1: Coase solution**

Pollution of a river imposes a marginal social cost (MSC) on the fishery and provides a marginal benefit (MB) to the chemical firm. The efficient amount of pollution is the quantity that makes marginal benefit equals to marginal social cost – say 4 tons per week, as shown above (Figure 1). If the property rights are given to the chemical firm and allow it to pollute the river, the fishery will pay \$400 a week ( $\$100/\text{ton} \times 4 \text{ tons/week}$ ) to the firm for the assurance that pollution will not exceed 4 tons per

week. On the other hand, if the fishery has the property rights over the river, the polluter may compensate the fishery and will pay \$400 for pollution rights to discharge 4 tons a week. The point behind this example is to show that a negotiation process will develop, regardless of the direction of the definition of property rights that leads to the optimal level of pollution. This topic will be recovered in section 5.

Contrary to Pigou, who suggested an intervention of government to correct externalities, Coase proposed that when property rights are well defined, the efficient result is reached without direct government implication. Nevertheless, it is important to emphasize that the Coase solution does not completely exclude the role of government, whom has the attribution to establish or clarify property rights and provide enforcement mechanisms.

Anyhow, the Coase bargaining solution bears potential propositions and demand careful elaboration. In order to reach the optimum result and efficiency, some conditions are vital: it must be possible to define property rights precisely; this property right must be enforceable, and transferable. One group or another has to be able to negotiate this right, if desired; parties to the transaction must be well defined; those owning the property rights must be able to capture all values associated with the resource they own; transaction costs must be minimal. It is clearly conceived that transaction costs refer to any use of resources required to negotiate and enforce agreements, including the cost of information needed to formulate a bargaining strategy, the time spent haggling, and the cost of preventing cheating by the parties to the bargain (Cooter, 1987).

The difficulty of applying the Coase theorem lies in meeting the many premises aforementioned. Hereunder, it is reviewed some of hindrances in the core aspects of the theorem:

- a) Transaction costs:** by definition, transaction costs are the real economic costs of aggregating the collective interests of the groups (polluters and victims), the costs of negotiating and the costs of enforcing the agreement. They are those costs that are borne by the victim and the generator of the externality in negotiating an agreed upon level of the externality, with compensation to one party or the other as part of this agreement (Kahn, 1997). Often, polluters and victims are plentiful and scattered, and the transactions

costs become prohibitive (Pearce and Turner, 1990). In the example of chemical firm and fishery, they both can get together to discuss who is going to make an adjustment and at what level of compensation. However, if the externality in question is carbon dioxide emissions in a country, there will be hundreds of millions of generators of the externality (everybody who burns fossil fuels, for example) and hundreds of millions of victims of the pollution. Under these conditions, transaction costs will be very significant, and if these costs exceed the benefits, then the agreement may not happen (Pearce and Turner, 1990).

**b) Free-riders:** one way to reduce transactions costs is to designate an agent who acts in behalf of a large number of people (Pearce and Turner, 1990). Suppose that an environmental organization (Sierra Club, Greenpeace, etc) act as agent for its members to negotiate in their behalf. Nonetheless, not everybody who desires lower carbon dioxide levels contributes to the environmental organization for this goal. If the organization is successful in reducing carbon dioxide emissions, all people benefit, not just those who paid for that: individual victims may act as free-rider and do not pay for their share in the assumption that other victims will do that. It means that, even if the group could agree to a plan of action, a free-rider problem appears. Namely, no one is forced to pay for the solution. Any single individual could abstain from his contribution, hoping that everyone else will pay and he will benefit from their solution anyway (Varian, 2003). Consequently, the optimal amount of a public good may not be generated because of the free-rider problem (Varian, 2003).

**c) Perfect competition:** It describes a hypothetical market form in which no producer or consumer has the market power to influence prices in the market (Regan, 1972). This means that the market features a large number of competitors, homogenous goods, free entry and exit to a market, and perfect information. Under perfect competition, private and social costs will be equal which would lead to a completely efficient outcome, but without it the incentive of firms to be more efficient diminishes allowing for a greater problem with externalities. Perfect information is required if firms are to be aware of bargaining possibilities with others. In short, in a world of perfect

competition, perfect information, and zero transaction costs, the allocation of resources in the economy will be efficient and will be unaffected by legal rules regarding the initial impact of costs resulting from externalities (Regan, 1972).

**d) Income effect:** The change in demand due to the change in purchasing power is called income effect (Varian, 2003); considering that a different allocation of property rights changes the society's overall supply and demand, the income effect may occur. Also, most people desire a higher price for selling than buying a right, hence the income that either party makes from this relationship will differ, and depending on who gets the property right. At the same time, polluters may have the incentive to threaten with pollution when no such activity is contemplated, in order to extort payment from victims (Schlicht, 1996). The example of externality problem given by Varian (2003), presented as a negotiation between a smoker and a non-smoker, is useful to illustrate the extortion problem: consider that the smoker has the right to smoke; the non-smoker offers him an amount of money reducing or stopping smoking. The non-smoker accepts and an efficient solution is achieved. Presume that other smokers will come along in order to extort a bribe just for not smoking. The non-smokers may be induced to frequently bribe each of them in front of the threat of smoking. Visualized from this angle, under certain conditions, the Coase mechanism may be used as a form of extortion, obstructing any possibility of a market or bargaining solution (Schlicht, 1996).

It must be taken into account that the creation of a market solution in the Coase Theorem internalizes the externality, but does not necessarily bring pollution to a zero level, because the Pareto-relevant externality is eliminated. An externality is defined to be Pareto-relevant "when the extent of the activity may be modified in such a way that the externally affected party A can be made better off without the acting party B being made worse off. That is to say, 'gains from trade' characterize the Pareto-relevant externality, trade that takes the form of some change in the activity of B as his part of the bargain" (Buchanan and Stubblebine, 1962, P. 374). Where there are external costs and the affected party is not concerned (no reduction in welfare) then the externality is irrelevant. Only if there is a loss of utility is there a potentially relevant externality. However, a Pareto-relevant externality requires there

to be gains from trade. A Pareto-relevant externality is one whose removal leads to a Pareto improvement.

For all above-mentioned difficulties, the conditions under which the allocation of private property rights may restore social efficiency restrict the applicability of property rights in practice. On the other hand, a Coase bargaining assert emphatically that an economy may be able to move toward or achieve Pareto-efficient resource allocation without pervasive government regulation and also offer an innovative solution to the problem of externalities, especially in an international context, where there is no supranational environmental agency with the power and authority to regulate externalities and correct market failures (Pearson, 2000).

## **3. ENVIRONMENTAL POLICIES**

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### **3.1 The role of environmental policies**

Environmental policy aims at correcting market and regulatory failures to improve environmental quality. Ideally, it should be designed to maximize the net benefits to society by achieving the optimal level of environmental quality. In a rational and ideal model of environmental policies goals are clear and work efficiently, effects of options are understood and predictable, and the final choices maximize previously fixed goals. However, the definition of this optimal level is laborious mainly due to difficulties in evaluating environmental costs and benefits in environmental terms, also because sometimes goals are unclear or in conflict, information is missing or unreliable, and results are often different from what was planned.

The successful integration of environmental policies with sectoral and other economic policies is indispensable to assuring that environmental policy goals are reached at the least cost and that the effects of other policy measures on the environment are addressed. Environmental policy comprehends a statement of intentions and principles in relation to overall environmental performance which provides a framework for action and for the setting of environmental objectives and targets, using particular instruments to accomplish them, within a specific term. It comprises from long-term and global to short-term and local actions. The official rules or regulations have to be adopted, implemented, enforced and monitored by some environmental authority (mainly governmental agency).

The first step to introduce an efficient policy instrument is to make a series of questions concerning the nature of environmental problems, and evaluate their causes and their consequences. Some questions are very difficult to answer accurately, especially because their solutions are rooted in scientific knowledge. At least, these questions can promote a public discussion and bring information related to social, economic and biological implications.

Kraft (2004) developed a comprehensive and very useful scheme which considers the nature and cause of problems, what might be done about them and what kind of

policy tools are most appropriate. Table 2 shows a condensed view of such framework.

**Table 2: Activity, tasks and questions**

<i>Activity</i>	<i>Tasks</i>	<i>Examples of questions that might be asked</i>
Identify the problems	Determine which environmental and resource problems are of concern	What are the causes of the problem and its consequences? How does the problem affect human health or environmental quality?
Measure the problems or examine advanced arguments about them	Estimate the magnitude of the problems in terms of risks posed to human and environmental health; examine implications for the economy, society, or culture; or assess the problems in other ways	How severe is the problem and how does it compare with other environmental risks or other societal problems? What forecasts are available for estimating the magnitude of the problem in the future? How much consensus or conflict exists among scientists or other experts?
Interpret and evaluate the data and arguments	Determine the meaning of the data assess, the logic and persuasiveness of the arguments, and evaluate the acceptability of the risks	What conclusions may be drawn from the data or the arguments? Are the risks socially acceptable or must they be lowered? Do we understand the causes of the problem well enough to determine a course of action? What opportunities exist to intervene to resolve the problem?
Determine the policy implications	Determine whether government intervention is needed and what policy options might be considered. If policies and programs already exist, evaluate how well they are working and the policy changes that might be needed	Can the problem be handled privately, or is government action warranted? Is federal action necessary, or is the problem best handled at state and local levels? What kinds of policy action are more suitable? How do the options compare in terms of costs, likely effectiveness, social and political feasibility, ethical considerations, and other relevant criteria?

Frequently, policymakers tend to design solutions that they think would be more appropriate to solve all problems. However, it must be considered that a fixed tool is efficient in some cases, but it is innocuous in others. In this situation, the questions are: what alternatives exist and what are the pros and cons to use them? What instrument is better addressed to solve the problem?

A relevant pace to evaluate and anticipate the performance of environmental policies is to make an economic analysis. Usually, three forms are utilized to fulfil such task: economic impact analysis, cost-benefit and cost-effectiveness analysis (Fiorino, 1995).

Impact analysis has been most importantly used to predict the economic effects of government actions. Its purpose is to predict the several kinds of effects of environmental agencies actions on companies, industries, or economy as a whole. Some effects impact direct on firms; others impact on consumers or economic sectors. Impact analysis assumes a relatively simple cause-and-effect model: if action X is took, the consequence Y could be predicted.

Whilst impact analysis examine the cost side of the situation, the cost-benefits analysis try to describe and value the benefits that accrue to society as the result of a policy. At first, the cost-benefits analysis identifies the expected effects on society and ranks them as cost or benefits. The second step is to determine values, usually in form of currency (dollars), to each of these categories. Then, it is discounted costs and benefits to account for the effects of time, to make them comparable. Finally, it is necessary to calculate the ratio of the costs to the benefits and choose the combination of policies that maximizes net benefits. The inclusion of all gains and losses to society in cost-benefit analysis distinguishes it from cost-effectiveness analysis, which is a more limited view of costs and benefits.

Last but not least, the cost-effectiveness analysis seeks to find the best alternative that maximizes results for a given application of resources. The costs of alternatives are measured by their requisite estimated dollar expenditures. Effectiveness is defined by the degree of goal attainment, and may also (but not necessarily) be measured in dollars. Either the net effectiveness (effectiveness minus costs) or the cost effectiveness ratios of alternatives are compared. The most cost-effective method chosen may involve one or more alternatives. It is less comprehensive than a full cost-benefit analysis, but wider conceptually than economic impact analysis.

The ideal economist's version of public-policy is "that one which will typically be efficient (maximizing net benefits) and cost-effectiveness (achieving a goal with the least costly method). However, efficiency and cost-effectiveness are by no means the only possible criteria for judging environmental policies" (Hahn, 1992). Other



considerations might include overall effectiveness, ease of implementation, equity, information requirements, monitoring and enforcement capability, political feasibility, and clarity to the general public.

## **3.2 Environmental policies instruments**

### **3.2.1 Typology of instruments**

The policy tools are planned to internalize the external cost of pollution, making the polluter pay the bill and the same time minimize the cost of a given level of abatement under given conditions. A large amount of instruments have been used by regulators to induce producers and consumers to accept the responsibility for a level of activity that coincides with the level that maximizes social welfare. Frequently, a single instrument does not proceed solo. Combinations of different types of tools usually work better alongside to attain a desired environmental outcome, considering that some instruments have an effect in the long-run, while others in the short-run.

In principle, these environmental instruments are distributed in four main groups<sup>6</sup>, which are briefly explained below. Two of them, regulatory and economic incentives, are detailed exposed and compared in the subsection 4.2.2.

- a) **Information and education:** they work best when an absence of information about how best to diminish environmental impacts is a significant obstruction to people changing their behaviour. In other words, information and education provide people with knowledge they need to understand and evaluate hazards and to take suitable action to prevent or reduce those hazards. They include development of new technologies to provide alternative ways of production, causing less damage to environment and reducing costs. Examples are research and development, training programs, media campaigns (warnings on cigarette packages), technical assistance (instructions of using chemical products), etc. Information and education instruments are less intrusive than other tools and they are fitting for consumers with risky life-style who needs additional information about their behaviour of consumption.

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<sup>6</sup> The group distribution of policy instruments is based on Fiorino (1995); however he just considered three groups: information, direct regulation and market incentives.

- b) Voluntary:** they are appropriate when people already have some incentive to change their behaviour and work best in small than in large groups. Also, voluntary initiatives rely on market forces and altruism to determine the optimal level of control. These instruments do not need to be negotiated, enacted and implemented by state authorities, as mandatory instruments. The government's role with voluntary groups may be facilitate their planning and decision-making processes and to assist them with technical information. While these programs are worthwhile and vital to limiting pollution, they are small contributors and often unreliable. Examples are voluntary agreements, voluntary environmental standards, recycling programs, etc.
- c) Regulatory or Command-and-Control:** They are usually used when a general improvement in environmental performance is desired, but it is impossible to assign exactly what changes in behaviour would be appropriate to achieve that. These tools may increase the cost of certain actions through provision of sanctions and incentives, and give a direct and clear response to problems, setting visible standards. They fit better for industrial sources of pollution, but they are intrusive and frequently inflexible. The constraints imposed by regulatory approach generally take the form of limits on inputs or outputs to the consumption or production process. Examples that constitute restrictions on inputs would include requiring sulphur-removing scrubbers on the smokestacks of coal burning utilities, requiring catalytic converters on automobiles, and banning the use of leaded gasoline. Regulations that take the form of restrictions on outputs include emissions limitations on the exhaust of automobiles, prohibitions against the dumping of toxic substances, and prohibitions against littering.
- d) Economic incentives or Market-based instruments:** economic incentives are based on a different philosophy than command-and-control regulations. Rather than defining certain behaviours as legal or illegal and specifying penalties, economic incentives simply make individual self interest coincide with the social interest. Economic instruments generally allow greater flexibility of response than regulatory instruments, because they help to reduce the costs of raising environmental performance. These tools induce firms to respond in different ways, depending on the costs of controls, the

nature of the product, the degree of economic competitiveness in the regulated industry, inter alia. Examples are pollution taxes, marketable pollution permits (emissions trading), deposit-refund system, market barrier reductions, elimination of government subsidies, etc.

### **3.2.2 Command-and-control ‘versus’ market-based instruments**

Past experiences in environmental policies have demonstrated that countries must choose an enabling legal and administrative system and an enforcement mechanism in order to achieve their environmental goals. Electing the appropriate policy tools is sometimes choosing between directly setting effluent and emissions standards for individual pollution sources and the use of effluent/emissions charges or taxes. The first is known as the regulatory instruments or “Command and Control” (CAC) and the second as the economic incentives or “Market-Based Instruments” (MBI).

The distinction between CAC and MBI is not always pronounced. An effluent standard enforced by fines has some of the attributes of an incentive tax system. In fact, most policies have at least some elements of both approaches, but they could be defined as CAC or MBI based on their dominant features. In all cases, clarification of property rights is a required step to achieve efficient outcomes. Well defined property rights will encourage the holders of the asset to be more aware of the consequences of their activities, and more likely to take them into account in management decisions.

The mix of policy instruments varies from country to country depending on its goals, stage of development, institutional capabilities and political preferences, but there has been a gradual change in favour of MBI. The justifications are various: MBI minimize total abatement costs by equating the marginal abatement costs (the cost of reducing pollution by one more unit) across polluters and encouraging a broader array of abatement options; MBI encourage more research and development into abatement technologies and alternatives to the activities that generate the pollution; the presumed superiority of MBI in achieving environmental goals at lesser cost compared with CAC instruments; the requirement of enormous volume of information to design and enforce the CAC system; delay of implementation of CAC instruments due to exigency of very detailed and complex regulations, among others.

On the other side, some economists advocate policies based on CAC approach, despite their inability to equate marginal abatement costs across polluter. Kahn (1997) argues that there are three sets of circumstances that may call for the use of CAC: when monitoring costs are high; when the optimal level of emissions is at or near zero; and during random events or emergencies that change the relationship between emissions and damages.

Harrington and Morgenstern (2004) evaluate CAC and MBI approaches in order to observe the advantages and disadvantages as well as to compare and decide which is more efficient in different situations (Table 3). They concluded that in the majority of the cases MBI appear to produce cost savings in pollution abatement, as well as innovations that reduce the overall cost. However, the results about MBI efficiency are tempered by evidence that polluting firms prefer a CAC instrument because of it is perceived to have a lower costs to them. The authors also concluded that a great number of policies are a blend of CAC and MBI, beginning as a CAC policy and then having MBI elements added or substituted.

**Table 3: Command-and-Control versus Market-based Instruments**

<i>STATEMENTS</i>	<i>RATIONALE</i>	<i>EXAMPLES</i>
MBI are more efficient than CAC instruments, because they result in a lower unit cost of abatement	MBI are more cost effective at achieving a given emissions reductions, but to get from cost-effectiveness to efficiency requires additional assumptions, including that the system has a perfect competition. Also, CAC instrument can be as efficient if the emissions standard for each plant is chosen so that the marginal costs of abatement equal the marginal social costs of pollutant damage.	In fact, MBI is generally more efficient. The USA program of marketable permits to lower SO <sub>2</sub> emissions realized that costs are only about one-half what was expected back in 1990 and about one-quarter of the estimated cost of various CAC standards
The real advantages of MBI are only realized over time, because they provide a continuous incentive to reduce emissions, thus promoting new technology, and leading to a maximum flexibility in emissions reductions	The effects of CAC on technology are potentially complicated. On one hand, costly regulations provide an incentive to find cheaper ways of compliance. On the other hand, the requirement to install a specific technology conceivably discourages research, since discovering new ways to reduce emissions can lead to more stringent regulations	MBI provides greater incentives than CAC for continuing innovation over time in many cases, but not all. The Swedish NO <sub>x</sub> tax induced experimentation in boiler operations that led to substantial reductions in emissions. Because NO <sub>x</sub> emissions from boilers are peculiar, it was unknown in advance what would work

		in each boiler. Achieving these reductions from CAC would therefore have been impossible
CAC policies achieve their objectives quicker and with greater certainty than MBI policies	Although CAC approach is not the least costly, it has been accepted as the way to accelerate compliance. It seems that MBI, particularly emissions fees, would not achieve the same objectives	CAC approach obtained relative effectiveness in the USA effort to remove the solvent TCE (in that case, MBI rules did not attract significant industry participation). On the other hand MBI policy were very efficient in the Dutch water case, where the influence of effluent fees on organic waste-load reductions was prompt and large
Regulated firms are more likely to oppose MBI regulations than CAC because they fear they will face higher costs, despite the greater efficiency of MBI	In spite of MBI have lower social cost overall, firms pay higher costs under MBI than CAC. Under CAC the polluting firm pays to abate pollution, while in many MBI the firm pays the cost of abatement plus a fee for the remaining pollution it discharges. The firm is better off only if the abatement cost is lower by an amount at least as great as the fee payment	In almost all cases, governments eliminate the burden of MBI by returning fees of the firms. In France, revenues collected through NO <sub>x</sub> discharge fees subsidized the firms' abatement investments, while in Sweden the fees were returned to the firms on the basis of the energy they produced
CAC policies have higher administrative costs	Administrative costs are determined by the amount of interaction between the regulator and regulated source. The complexity of setting and enforcing specific requirements is higher than implementing fee-based MBI policies	The CAC program in the USA imposed high administrative costs on EPA than the MBI program; on the other hand, the SO <sub>2</sub> reduction program in Germany does not show evidence of higher administrative costs than a comparable MBI program

Considering that MBI are preferable on one count, and CAC instruments are preferable on other, the choice between the two appears to be very difficult. However, there is an instrument that combines the desirable properties of both approaches. It is known as the marketable pollution permit, also referred to as "emissions trading", whose characteristics and modus operandi are exposed in the section 4.3.

### **3.3 The emissions trading concept**

The idea of using transferable discharge permits to allocate the pollution control burden among firms or individuals was developed in the late 1960s in works by Crocker (1966) and Dales (1968). In the theoretical version of emissions trading system, rights to emit pollutants or use natural resources would be distributed or sold to stakeholders. Market negotiations between potential permit buyers and sellers would occur and result in the reallocation of these permits across the stakeholders.

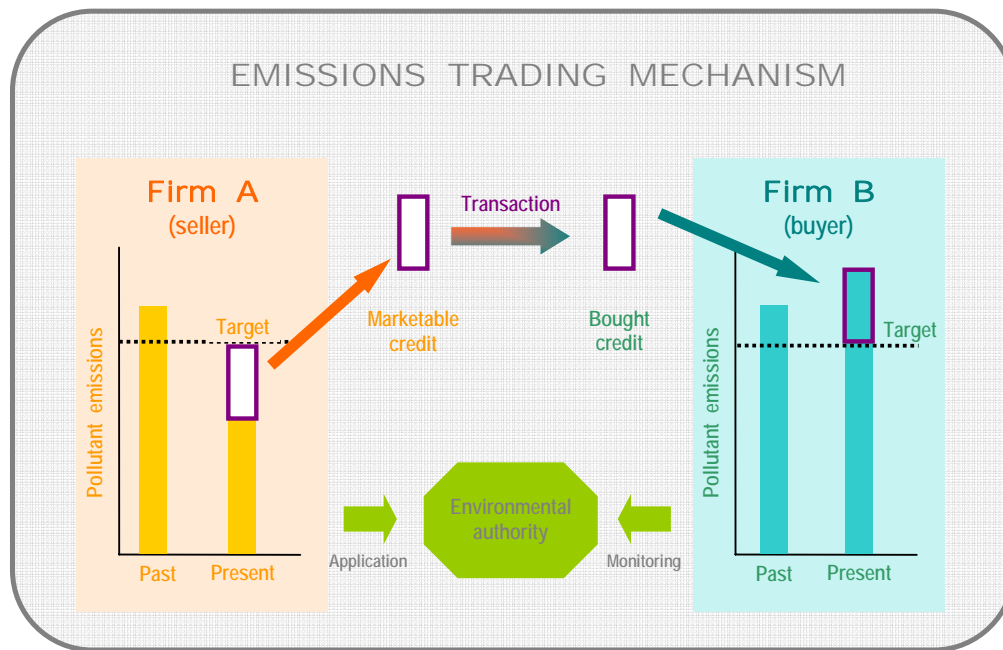
The first emissions trading program was implemented in the United States, when the U.S. Environmental Protection Agency (EPA) developed the “Clean Air Act”, in the 1970s, for air pollution regulation. In the 1980s occurred an expansion in the use of this mechanism and some programs were created (to remove lead from refined gasoline, to controlling chlorofluorocarbons, etc). By the 1990s the number and scope of emissions trading programs was expanding rapidly, including the program to control SO<sub>2</sub> and NO<sub>x</sub> emissions and, more recently, the greenhouse gases emissions (some experience with emissions trading is reported in subsection 3.5).

For the sake of simplicity, the emissions trading mechanism is illustrated using the following example<sup>7</sup>: consider two firms, A and B, both of which emit significant quantities of a given pollutant. Their emissions damage air quality and the authorities decide that emissions should be reduced by a given amount, say by 10 percent. At first glance, the solution seems simple: both A and B cut their emissions as requested. But in the real world, this may impose very different charges on the two firms. For instance, firm A may be able to reduce its emissions by 10 percent or even more at relatively low cost. On the other hand, firm B may find this a difficult and costly process. It is this potential difference in reduction cost between A and B that creates a market opportunity. It is here that market comes into play and it works as shown in Figure 2: firm A can reduce emissions at a relatively low cost and can then make additional reductions. For firm B, the cost of reductions is high, and a manner to avoid some of the disbursement would be greatly welcomed. Hence, firm A agrees

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<sup>7</sup> SOURCE: “An emerging market for the environment: a guide to emissions trading”. UNEP, UCCEE, and UNCTAD, 2002.

to make those further reductions and firm B pays for this surplus, at a price that is above the cost to A, but below what it would cost to B.



**Figure 2: Emissions Trading Mechanism**

Formally, a scheme of emissions trading begins when the regulatory authority (government) determines the target level of pollution, i.e. the definition of the maximum quantity of pollutants to be discharged over some fixed period of time; the following step is to stipulate the allocation of pollution across polluters. So far, this is exactly the same as a CAC policy that specifies the permitted amounts of pollution for each polluter. However, the major difference between CAC scheme and a system of emissions trading is that once the initial allocation of pollution is made, polluters are free to negotiate their rights to pollute (buy additional permits or sell their excess). In essence, the government has created limited property rights, providing the creation for a private market, similar to a Coasian approach (Pearson, 2000). But unlike Coasian markets, the transactions are generally among polluters themselves, and not between polluters and victims (although, in certain conditions, victims could also buy pollution permits and refrain from using them, thus reducing pollution).

The permits could be distributed to polluters based on historic pollution levels (grandfathering), auctioned to the highest bidder, distributed freely or by lottery, or allocated by some other scheme or combination of schemes. Initially, "this ability to

negotiate the rights to pollute may seem to be trivial, but it is this feature that equates the marginal abatement cost across polluters” (Kahn, 1997). As long as the permits are marketable, polluter’s attempts to minimize their total pollution costs (the cost of abatement for pollution that is eliminated plus the cost of permits for pollution that is still emitted) will result in marginal costs being equated across all polluters and the minimization of the total abatement costs of achieving the target level of pollution.

In other words, as a market for permits emerged, a market clearing price would also emerge. This price would indicate to polluters the opportunity cost of waste emissions. Cost minimization behaviour would result and marginal abatement costs would be equalized. Polluters with low costs of abatement will find it relatively easy to abate pollution rather than buy more permits. On the other hand, polluters with higher costs of abatement will buy up permits rather than abating emissions. Since polluters have different costs of abatement, the market will form with low cost polluters selling permits to high cost polluters. (Pearce and Turner, 1990).

In summary, emissions trading are able to achieve a desired level of abatement at least cost by equalizing marginal abatement cost among various pollution sources. That is a great advantage compared to other policy instruments. The emissions trading accomplish efficient allocation of abatement effort without detailed knowledge by regulators of individual polluters’ marginal abatement cost functions. And, similar to the Coase Theorem, the ultimate allocation of abatement effort among polluters under certain circumstances is independent of the initial allocation of the permits. Finally, if the permits’ market is competitive, the marginal abatement costs for all polluters will be equated when the market for permits is in equilibrium.

Although the method for the initial allocation of emissions trading is unimportant from an efficiency point of view, it is disputable because there are significant equity considerations: if permits are auctioned, this creates a substantial initial cost for polluters (and revenue for the government), but if initial distribution of permits is based on grandfathering (a mechanism that does not reflect marginal abatement costs of different sources) there will have to be a series of transfers (purchases and sales) of permits to attain the least cost solution (Baumol and Oates, 1988).



Some advantages concerning the implementation of an emissions trading scheme were discussed by Baumol and Oates (1988): (1) marketable permits reduce the uncertainty and adjustment costs involved in attaining legally required levels of environmental quality. The agency will issue permits only up to the maximum pollution standard. With environmental charges/taxes for instance, the environmental quality target may not be met if they are set too low; (2) marketable permits are not affected by economic growth and price inflation as pollution charges/taxes are. Inflation will erode the real value of charges and expanding production will increase total pollution emissions. The charge/tax would have to be continually increased or else the standards will not be complied with. In the case of permits, market forces sort them selves out and with an increase in production or inflation, the response will be an increase in the price of permits, not pollution; (3) in instances where geographical distribution of pollution is important, the reduction of pollution at a less polluter point should not allow a one-to-one increase in pollution at a more polluted area. One cannot discriminate between polluters at different points with pollution charges but one can with permits.

At any rate, the motivating principle behind the creation of emission markets is the Coase Theorem: in the absence of transaction costs, the involved parties can bargain to a mutually beneficial efficient outcome. However, transaction costs are almost never zero and the disadvantages regarding to tradable emissions are basically related to them. Stavins (1995) has identified three potential sources of transaction costs in emissions trading markets: “search and information”; “bargaining and decision”; and “monitoring and enforcement”. The first source may be the most obvious. Due to the public good nature of some information, it can be underprovided by markets. Brokers step in, provide information about firms’ pollution-control options and potential trading partners, and thus reduce transaction costs, while absorbing some as fees. The second source, bargaining and decision, is potentially as important. There are real resource costs to a firm involved in entering into negotiations, including time and/or fees for brokerage, legal, and insurance services. Bargaining to a mutually beneficial outcome could be costly, maybe so costly that exchange would not be occur at all. The third source can also be significant, but these costs are typically borne by the responsible governmental authority and not by trading partners, and hence do not fall within our notion of transaction costs incurred by firms.

Reducing transaction costs is a crucial component of enabling people to use markets to manage and optimize pollution. An important part of reducing transaction costs is the definition and enforcement of property rights. Again, it is important to stress that Coase solution does not fully eliminate the role of government, whom must establish or clarify property rights and provide enforcement mechanisms.

Another shortcoming in a scheme of emissions trading is still relating to the role of government: to make such program more politically acceptable to industry and to minimize the economic impact of pollution control requirements, the government could issue more permits than it is necessary for the existing rates of emission. The excess surplus results in a low initial price of permits and weak incentives to reduce emissions or to develop new technology for emissions control. At the same time, the allocation of valuable quantitative right to emit pollutants, invites lobbying and possible corruption.

In despite of some weaknesses, including the fact that a cost-efficient reduction does not lead to a complete internalization of externalities (the remaining emissions are still an external effect), many authors advocate in favour of emissions trading. They argue that when designed appropriately, emissions trading allow flexibility for emitters without resigning the environmental objective of reducing emissions. Polluters can reduce their emissions entirely through their own efforts: getting permits free or buying them auctioned by the government or unused by another source. Fundamentally, emissions trading are led by the desire to minimize costs and maximize profits.

### **3.3.1 Types of emissions trading policies**

Emission Reduction Credits (ERC) can be defined as the currency used in trading among emission points. The ERCs are created when a source reduces emissions below either the level of actual emissions or the level required by the control authority. The reductions must be real, surplus to permit requirements, quantifiable, permanent and enforceable. Defined in terms of a specific amount of a particular pollutant, the certified ERC can be used to accomplish emissions standards at other discharge point controlled by the creating source or it can be sold to other sources.

While the ERC is the currency used in emissions trading, the offset, bubble, banking, and netting policies establish how this currency can be used. These policies form an “incentive system” designed to encourage firms to reduce emissions and to use those reductions to meet their own financial objectives: it began with the offset policy, a tool for reducing emissions from existing sources in non-attainment areas to make ‘room’ for construction of new facilities. The bubble policy expands on the trading concept introduced in the offset policy by providing incentives to reduce the cost of pollution control at existing facilities. The banking policy allows plants to obtain a credit for emission reductions that go beyond current cleanup requirements. Plants may sell the credits to others, presumably at a profit, or may use them later either as offsets for new capacity or as trade offs under a bubble (Costle, 1980). A short description about each of these policy types is given below:

- a) Bubble policy** – it was the first principle of emissions trading. By placing an imaginary "bubble" around the factory and setting a standard for this entire source to comply with, industry can adjust the emissions of each individual ‘smokestack’ (some can emit more than others) to what is economically feasible as long as the factory as a whole can comply. In essence, sources are free to choose the mix of control among the discharge points as long as the overall emission reduction requirements are satisfied. More details about bubble policy will be given in Section 4.
  
- b) Offset policy** – applied to compensate the additional emissions from a new source. Also, all of the existing sources in the area that are controlled by the owner of the new source need to be in compliance with emission standards. Lastly, the owner would need to urge existing sources to reduce enough emissions so that the new source would be an overall benefit to the area. The requirement to offset is mandatory for the new or expanding source, but the decision by the existing source to reduce is voluntary. In summary, the offset rules provide an incentive for new sources to reduce emissions from existing sources in the region and to seek offsets from other firms. The policy also encourages technological innovation to find means of creating offsets and probably encourages older and dirty facilities to shut down sooner than they otherwise would in order to sell offsets.

- c) **Banking policy** – it is a way of reserving emission reduction credits. If a source retires and a new source is not introduced immediately, it can "bank" the emissions that are reduced by removing this source. In summary, it allows firms to store certified emission reduction credits for subsequent use in the offset, bubble or netting programs or for sale to others.
  
- d) **Netting policy** – it allows sources to modify or expand their existing facilities in some cases without going through the full new source review process that normally applies to new facilities. To do this, sources have to show that the plantwide emissions from the modified facility will not increase much over current levels.

### 3.3.2 Experiences with emissions trading

As the emissions trading programs were first used in the USA, that country has gained more experience in applying this form of environmental regulation; consequently most of the examples of this mechanism are from the USA. Below is given a brief description of some applications<sup>8</sup>, included the experience of other nations and the proposed emissions trading scheme for greenhouse gases.

- ✓ **Clean Air Act (1975- )** – The Clean Air Act (CAA) is a federal law, covering the whole of the USA, implemented by the US Environment Protection Agency (EPA). The EPA sets a limit on the maximum allowable concentration of a pollutant in the air anywhere in the country. If a region exceeds one or more of the limits, the state must develop a State Implementation Plan (SIP), which must be approved by the EPA, to reduce emissions of the pollutants that the concentrations will be reduced to acceptable levels. The 1990 CAA amendments proposed emissions trading, added provisions for addressing five main areas: air-quality standards, motor vehicle emissions and alternative fuels, toxic air pollutants, acid rain, and stratospheric ozone depletion. In many ways, this law set out to strengthen and improve existing regulations. Through emissions trading options, overall emission control costs are lowered

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<sup>8</sup> SOURCES: U.S Environmental Protection Agency (EPA): <http://www.epa.gov>; UNEP, UCCEE and UNCTAD (2002). *An emerging market for the environment: a guide to emissions trading*. Denmark, United Nations Publication; FARRELL, Alexander E. (February 2005). *Review of Market-based Incentives for Consideration of Applications in California*. University of California, Berkeley for the California Energy Commission, PIER Energy-Related Environmental Research. CEC-500-2005-12.

by encouraging the largest reductions to occur at facilities that can reduce pollution at the lowest cost.

- ✓ **Acid rain (1993- )** – In order to achieve reductions of emissions which contribute to acid rain, the CAA incorporated another quite different version of the tradable permits. Under this approach, allowances to emit sulphur oxides have been allocated to older plants and the number of allowances is restricted to assure a reduction of 10 million tons in emissions from 1980 levels by the year of 2010. Each allowance is defined for a specific calendar year, but unused allowances can be carried forward into the next year and they are also transferable among sources. In the end of the period, utilities which emit more than authorized must pay a penalty and are required to forfeit an equivalent number of tons in the following year. The Acid Rain Program has been a success in several ways: (1) substantial emission reductions have occurred. Emissions of regulated sources have declined substantially since their peak in the early 1980s. In part this is due to the availability of low-sulphur coal across much of the country. However, this process was sped up and extended by the Acid Rain Program, as emission reductions continued to occur in spite of increasing coal use. From 1990-2002, SO<sub>2</sub> emissions declined by about one-third, while coal-fired generation increased by more than 20%; (2) the program has greatly reduced the cost of SO<sub>2</sub> control compared to command-and-control policies. In the first five years, emissions trading reduced compliance costs by about one-third to half, estimates of the savings range from \$350 million to \$1,400 million. Allowance prices have ranged from \$66/ton to about \$200/ton (nominal). However, most of these savings are not due to trading of allowances per se, but from the flexibility in compliance that allowed firms to find their own least-cost approach; (3) the SO<sub>2</sub> market has been a success, although this market is not overseen by financial regulators, prices in this market are relatively reliable. There are up to several dozen trades each day, resulting in from 20,000 to 100,000 allowances trading hands each week. Several different organizations monitor the market closely, some of which publish regular (daily, or monthly) reports. All vintages of allowances are priced the same, because there are no restrictions on banking, which helps smooth the operation of the market.

- ✓ **RECLAIM (1994- )** – The Regional Clean Air Incentives Market (RECLAIM) was established in California for NO<sub>x</sub> and SO<sub>2</sub> emissions by large point sources (i.e. emitting more than 4 tons per year). Under RECLAIM each of the participating industrial polluters receives annually a free allocation of Reclaim Trading Credits (RTCs) for NO<sub>x</sub> and SO<sub>2</sub>, which is based on the peak year for each facility between 1989 and 1992. New sources must purchase sufficient RTCs from existing sources to cover their emissions. Existing participant continue to receive allowances if they cease to operate. When RECLAIM was first implemented in 1994, the cap was generous, allowing for an increase in emissions over historical levels for many sources, but it declined steadily each year, aiming at an overall reduction of about 75% by 2003. For the first several years, the RECLAIM market functioned quite well, with readily available allowances at low prices. However, emissions in 1993–1998 did not decline nearly as fast as the cap, due to a failure of many (but not all) participants to install emission control equipment. Although the state regulatory agency warned participants, many firms were unwilling to take appropriate actions because of a failure to consider future emission allowance markets and its belief that the government would bail them out in case of serious problems. The result was a breakdown of the market and in response a temporary abandonment of the MBI approach by the state government. By early 2000 it had become clear to even the most short-sighted that emissions would exceed allocations, which was a problem, because RECLAIM had no banking provision, and prices for NO<sub>x</sub> allowances rose to over \$40,000/ton. Electricity companies, which were making record profits at the time, could afford these prices, but other companies in the RECLAIM market could not. Thus, the RECLAIM cap was broken, and several firms were significantly out of compliance and paid record fines. Facing significant political pressure, the state regulatory agency decided essentially to go back to a CAC approach for electric power plants by requiring them to submit compliance plans. In addition, state regulators separated power companies from the rest of the RECLAIM market and subjected them to a high tax for emissions not covered by allowances. For other participants, RECLAIM proceeds as before and allowance prices have moderated. Several key lessons emerge from the RECLAIM experience. First, because they force firms to gather more

information and make more decisions, MBI may be more difficult for firms to understand and manage than CAC programs, even if they have lower costs. Second, in some cases the optimal strategy may be non-compliance, placing more emphasis on the design of penalties. Third, emission markets are no different from others; they are volatile (especially when it is not possible to store the commodity, like electricity).

- ✓ **Danish CO<sub>2</sub> Programme** – The first emission trading program to address climate change was a emissions trading programme for CO<sub>2</sub> emissions adopted by Denmark in 1999 to achieve a national greenhouse gases<sup>9</sup> (GHG) emissions reduction target of 5% in 2000 (relative to 1990) and 20% by 2005. The Danish program covers the domestic electricity sector, which is made up of eight firms, although two account for more than 90% of all emissions. Allocations were made on a modified historical basis and are not serialized. Banking is limited and there is some uncertainty about the validity of allowances beyond 2003. This program includes a tax of about \$5.5/ton for emissions that are not covered by an allowance, which means the integrity of the cap is not guaranteed. It is possible to use verified emissions reductions (VERs) as well as credits created through provisions of the Kyoto Protocol (discussed below). In the first two years of the program, about two dozen trades were made in the approximate range of \$2-\$4/ton. This has resulted in over half a million allowances changing hands. Some of these trades have been exchanged of Danish allowances for VER credits, and one trade of Danish allowances for U.K. allowances (discussed below). However, the Danish system will soon be superseded by a European Union (EU) system. The Danish experience illustrates that emission trading systems can be used in conjunction with other policies, in this case differentiated by sector. It also illustrates that smaller systems can be integrated into larger programs. And it has the distinction of being the first programme for GHG.
  
- ✓ **United Kingdom Climate Change Levy and Emissions Trading Scheme** – The first economy-wide GHG control policy was announced in November 2000 by the United Kingdom, and it contained a combination of MBI, including taxes, subsidies, and ERCs. The U.K. Emission Trading System

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<sup>9</sup> Carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF<sub>6</sub>).

(ETS) is an ERC program open to reductions in all GHG (measured in CO<sub>2</sub>-equivalent, or CO<sub>2</sub>e). To join the program, firms must enter into a Climate Change Levy Agreement (CCLA) in which they voluntarily accept an emissions cap in return for an 80% reduction in their Climate Change Levy until 2013. Companies that adopt such a target also earn the right to use ETS credits to meet their CCLA targets and sell allowances generated by exceeding their target. By the end of 2002, over three dozen trade organizations had designed model CCLAs for their members and over six thousand companies had signed CCLAs. CCLA firms that do not achieve the promised reductions are taxed on the excess at about \$44/ton of CO<sub>2</sub>e, measured as CO<sub>2</sub>. The last component, Direct Entry, is a \$310M subsidy that the U.K. government made available through an auction for voluntary actions by eligible firms to reduce GHG emissions in 2002-2006 from 1998-2000 baselines. Electricity and heat production were not eligible for this program, except for combined heat and power, which was allowed in. The rules for the ETS include standards for certifying ERCs through third-party verifiers. This auction was held via the Internet over two days in March 2002, and resulted in 34 organizations (of 38 bidders) winning subsidies at the level of about \$22/ton-CO<sub>2</sub> e. Over half of the emissions will be non-CO<sub>2</sub>e GHG. In addition to these two methods, organizations can join the ETS through more traditional means, by earning ERCs from a specific project that meets all the necessary monitoring and verification requirements of the ETS and simply by buying or selling credits. By the end of 2002, over 400 companies had opened accounts on the UK registry and about one million credits had been exchanged in several hundred individual transactions. Prices on this market are in the range of \$5-\$10/ton-CO<sub>2</sub>e, measured as CO<sub>2</sub>.

- ✓ **EU Greenhouse Gas Emissions Trading** - On July 2, 2003 the European Parliament approved a directive on emissions trading that will create a market in carbon dioxide emissions across the EU beginning January 2005. As described in the EU Green Paper, emissions trading will establish limits on carbon dioxide emissions from energy intensive sectors. Sources that reduce emissions to a level below their limit can sell this surplus or bank it for future use. The EU mechanism will be the first multinational emissions trading scheme in the world. One key feature is the right of member states to auction a



portion of the allowances. The rest of the allowances will be granted to existing sources without charge.

✓ **Emissions trading for greenhouse gases under the Kyoto Protocol)**

– The central objective of the Kyoto Protocol is the “stabilization of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system” (UNFCCC). The Kyoto Protocol, which entered in force on February 16<sup>th</sup> 2005, is designed to limit emissions of GHG in the industrialized countries that ratified the Protocol (Annex B Parties) for the 2008-2012 time periods. The Protocol establishes four international mechanisms that allow for flexibility in achieving GHG emission reductions: Bubble Policy, Joint Implementation (JI), Clean Development Mechanism (CDM), and International Emissions Trading (IET). The principle supporting these mechanisms is found in the UNFCCC, which called for cost-efficient policies to solve a global problem. During the first commitment period (2008-2012) the Bubble Policy will only be implemented by the EU Member States in achieving an overall reduction of 8%. At the European level, Member States have already agreed on differentiated targets within the EU "bubble" to achieve the shared reduction commitment. The remaining three flexibility mechanisms outlined in the Kyoto Protocol require further elaboration and negotiations concerning their actual implementation; The Clean Development Mechanism allows Parties without emissions limitations commitments to earn credits for implementing emission reduction and specified types of sink enhancement projects. The rules establish an international process for reviewing the baseline and the emission reduction or sink enhancement achieved by each CDM project. Implementation of CDM projects can begin immediately. Credits awarded for CDM projects, known as certified emission reductions (CERs), can be used by Annex B Parties toward compliance with their national commitments; Joint Implementation allows Annex B Parties to award credits for emission reduction and sink enhancement projects. Since these actions help the party meet its national commitment, any JI credits, known as emission reduction units (ERUs), awarded are subtracted from its available AAUs or RMUs to avoid double counting. The rules allow countries not eligible to participate in International Emissions Trading to host JI projects. Parties eligible for IET may host JI

projects as well and may prefer this mechanism under some circumstances even though the transaction costs are likely to be higher; International Emissions Trading (as well as the bubble policy) rely not on the transfer of reduction "credits" but rather on the trading of emission "rights" or allowances. In such a scenario, transfers between countries would be based on a "purchase" of emission rights from those countries whose emissions are below their national quotas. The main risk associated with IET is enforcement of compliance. There is no international regulatory authority with the power to impose penalties on Parties that fail to meet their emissions limitation commitments, and the track record for voluntary compliance by sovereign nations with their commitments under international environmental agreements is relatively poor. Each ton of excess emissions by an Annex B party will result in the loss of 1.3 AAUs for the next commitment period. To help compensate for this relatively weak enforcement regime, each Annex B Party is required to hold a specified quantity of AAUs and other units (the commitment period reserve) at all times. This limits the extent to which trading can contribute to non-compliance. The ways the mechanisms can be used by an individual source will depend upon the domestic policies adopted.

### **3.3.3 Bubble policy as a special case**

On December 1979, the U.S. EPA Administrator, Douglas Costle<sup>10</sup>, announced the "bubble policy" as a new concept to allow industry management to figure out the best possibility to clean up air pollution at a least cost way. The bubble policy allows polluters to treat entire plant as if they exist under a large bubble, because the focus of regulation is not on the emissions of individual smokestacks or pieces of equipment within the plant, but rather on the total amount of pollution coming out of the bubble. Polluters are free, within certain limits, to change processes and equipment within the bubble plant so long as the total amount of pollution coming out of the bubble does not increase (Costle, 1980).

The bubble's purposes are to provide greater flexibility to sources to effectively manage their pollutant emissions, and to meet pollutant effluent limitations at the least cost (Deland, 1979). First, polluters who expand their plant capacity by

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<sup>10</sup> Douglas Michael Costle was Administrator of the US Environmental Protection Agency from March 1977 until January 1981, under President Jimmy Carter administration.

modifying existing components may apply less expensive technology. While in the absence of the bubble concept polluters might be required to apply the most expensive and advanced pollution control technology, the bubble concept allows them to apply less effective control technology to a modified component as long as offsetting reductions occur within a plant. Thus, polluters gain flexibility to reduce emissions within a plant where control is least expensive. Second, the bubble concept allow polluters to avoid the substantial procedural, informational, and substantive burdens required for the issuance of a permit for a proposed modification of a component (Glass, 1980).

In summary, the bubble policy was designed to encourage plants to propose their own emission standards, extending them in places where it is low costly, and relaxing or even eliminating them where pollution control costs are high. By treating an entire industrial plant as a single source for regulatory purposes, this concept allows polluters to lower their costs and to find more efficient ways of production, through industrial innovation (Glass, 1980). Costle (1980) cites the possible cost saving which “may help move some industries from a posture of belligerence to one of cooperation as they work to choose among possible solutions”.

This concept would be especially attractive for chemical plants, steel mills, coating lines and petroleum refineries. Bubble policy allows firms in the same area to negotiate emissions of the same pollutant. In fact, it should be most useful to industries with many processes emitting similar pollutants for which the marginal costs of control are different. Emissions trade-offs between more than one firm is permitted as long as the air quality is unaffected. This type of trade, however, requires the firm to make a more detailed showing of equivalence than would be required for a single plant trade.

According to Glass (1980), the bubble concept is justified as applied to both the prevention of significant deterioration provisions and new source performance standards in clean air regions, since the current air quality in clean air regions do not cause adverse health effects. But the bubble concept should not be allowed to apply to the non-attainment area<sup>11</sup> provisions and new source performance standards in dirty air regions, because inhabitants of these areas currently suffer adverse health

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<sup>11</sup> The U.S EPA defines a "non-attainment area" as a locality where air pollution levels persistently exceed the national ambient air quality standards or that contributes to ambient air quality in a nearby area that fails to meet standards. Non-attainment areas are given a classification based on the severity of the violation and the type of air quality standard they exceed.

effects from air pollution, unlike inhabitants of clean air regions. Thus, pollution reductions forgone by allowing “bubble offsets” have serious health effects. Cost saving created by the bubble concept in dirty air regions must be weighed against the greater health damage in those areas.

## **4. A game-theoretic approach to emissions trading**

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### **4.1 Introduction into cooperative bargaining**

As displayed in the subsection 3.2.2, an ideal situation to achieve a Coasian bargaining solution is where the number of agents are small (presuming low transaction cost), there is perfect information among agents (they know own and other's payoff functions), and the property rights is well assigned. In such scenario, the best alternative to the firms linked by a production of externality is to merge (as an imaginary bubble) in order to internalize the externality or, in more realistic assumption, bring the pollution to a socially optimal amount.

In order to predict in what circumstances firms could interact strategically within a bubble, formulate hypotheses about their behaviour and predict a final result, the most adequate instrument is modelling a cooperative game. A cooperative game is one in which players are able to make enforceable contracts. Hence, it is not defined as games in which players actually do cooperate, but as games in which any cooperation is enforceable by an outside party (e.g., government.). According to Nash (1953, p. 128), "the word cooperative is used because the two individuals are supposed to be able to discuss the situation and agree on a rational joint plan of action, an agreement that should be assumed to be enforceable".

When agreements are binding, players can negotiate or bargain outcomes that are mutually beneficial. Typical situations of bargaining are characterized by "a situation in which individuals (players) have the possibility of concluding a mutually beneficial agreement, there is a conflict of interests about which agreement to conclude, and no agreement may be imposed on any individual without his approval" (Osborne and Rubinstein, 1990, p. 1). Many social, political and economic problems fit this definition: a buyer and a seller trying to transact a good for money, a firm and a union sitting at the negotiation table to sign a labour contract, etc.

The upshots of negotiation depend on agent's attitudes towards their bargaining items and their expectations from the negotiation. Evidently the result of a bargaining process is the agreements that are reached in the negotiation. If negotiations break down and no full agreement is reached, the 'status quo' outcome then results (also called 'disagreement outcome'). In most situations when the

demands of two agents conflict, concessions from players are expected. The final outcome then consists of the combination of those demands that each agent chooses to retain.

A possible result in a bargaining model is a situation that at least one player, and probably both, can improve from the point of view of its private gains. However, if one player insists too much on getting a bigger share, it runs the risk of a negotiation failure. A bargaining process is hence the joint discovery of the point beyond which each player will no longer retreat. In spite of each agent desire to maximize its gains from the negotiation, every agent must be better off by cooperating than by acting alone (Osborne, 2004). It means that all the agents would prefer to share the resources than drive the negotiations to breakdown. If the negotiated outcome is optimal for all the players then it is a Pareto efficient outcome.

According to Carmichael (2005), bargaining is probable to be an attribute of any transaction where the object of the trade is unique in some sense but its desirability is limited. Uniqueness gives players a degree of monopoly or bargaining power and this is what makes a breakdown in negotiations so costly. Monopoly power consents players to influence the terms of the trade, it elevates them to the status of price makers rather than price takers. If both sides of a trading relationship have monopoly power then they need to negotiate the terms of the trade. In a simple sales transaction between a buyer and a seller, the buyer prefers a lower price and the seller a higher price; if neither is a price taker, they will beat down the price.

In summary, the objective of bargaining theory is to find theoretical predictions of what agreement, if any, will be achieved by the bargainers. Much of the modern theory of bargaining in economics has its origin in two papers written by John Nash (1950, 1953). This author has introduced an axiomatic method which permitted a unique feasible outcome to be selected as the solution of a given bargaining problem. He formulated four axioms which have to be satisfied by the solution, and established the existence of a unique solution satisfying all the axioms. Another prominent bargaining solution was presented by Kalai and Smorodinsky (1975). These authors proposed to retain three of the four Nash's axioms and drop one of them; instead, they proposed an individual monotonicity axiom.

Serrano (2005) considered that while the Nash solution pays attention to local arguments, the Kalai-Smorodinsky solution is mostly driven by 'global' considerations, such as the highest utility each bargainer can obtain in the problem. Both concepts, Nash and Kalai-Smorodinsky, are central in this work and will be recovered in appropriate time.

It is worthwhile to cite that, although the two major axiomatic bargaining solutions are Nash's and Kalai-Smorodinsky's, many authors have developed diverse solutions, including a strategic bargaining solution, as Raiffa (1982), Rubinstein (1985), Osborne and Rubinstein (1990), Binmore, Osborne and Rubinstein (1992), among others.

## **4.2 Bubble policy as a bargaining game**

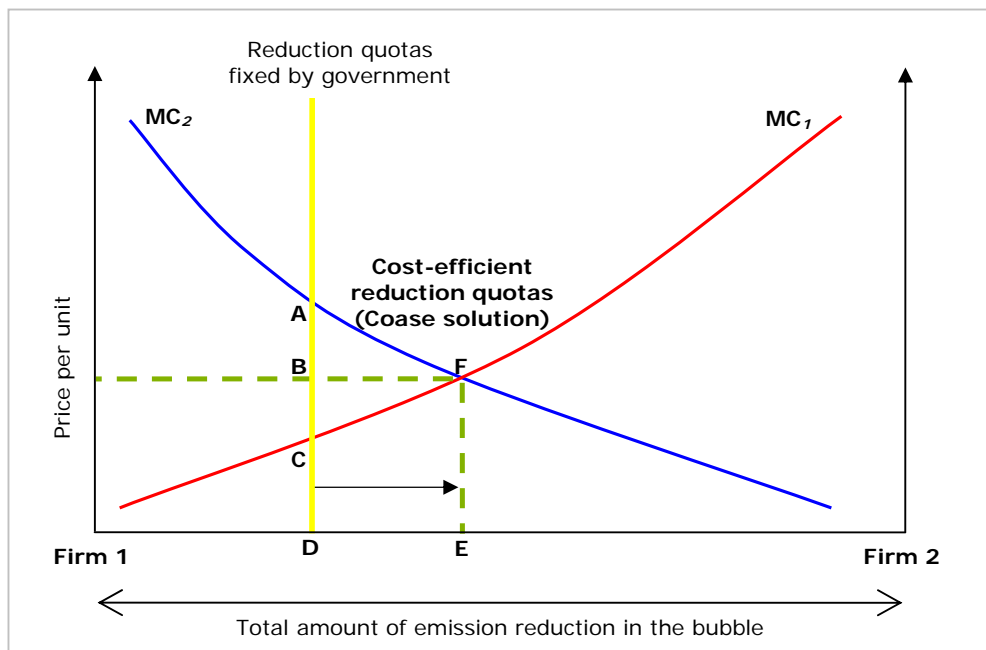
### **4.2.1 Structure of the game**

A bargaining problem is characterized as a situation in which two (or more) individuals or organizations have to agree on the choice of one specific alternative from a given set of alternatives to them, while have conflicting interests over this set of alternatives. Furthermore, the bargaining problem determines one alternative which will be the natural outcome of the bargaining problem if these agents do not agree on which option to choose from the set of alternatives available (disagreement/threat outcome). In order to begin to analyze the bargaining problem, the players are assumed as highly rational, they are identical in negotiating skills, and they have full knowledge of preferences of each other (Nash, 1950, 1953; Osborne and Rubinstein, 1990).

Consider two adjoining firms, say Firm 1 and Firm 2, which may be different in many terms (size of the plant, for example) and hence they are differently affected in absolute reduction amount. Firm 1 is a small polluter, while Firm 2 is a large one. They also have different marginal costs of emissions reductions and these costs increase with each avoided unit of emissions. Suppose now that government has established targets for air pollution control by setting an ambient air quality standard for such pollutant. The reduction target for the overall bubble is 10%. The crucial point is: if firms do not bargain, both of them have to reduce 10%.

As Firm 2's cost of reduction is more expensive than Firm 1's costs, it would buy emissions credits from Firm 1, since its costs are cheaper. Hence Firm 1's additional costs of reductions would be covered by selling the surplus emissions to Firm 2. It is indisputable that both firms want to maximize their profits from the negotiation and probably none of them will agree to anything less than what they could get by not reaching any agreement (Osborne and Rubinstein, 1994). The question is: how can firms achieve the most efficient bargaining solution?

A situation completely equivalent to the Coase Theorem demand that for an efficient bargaining solution the marginal costs (MC) of both firms have to be equal ( $MC_1 = MC_2$ ). Figure 3 characterizes this situation, where the point **F** determines the Coase efficient solution, and the area **ACF** is the total surplus of both firms (maximum gains). The benefits for Firm 1 are given by the area **BCF**, because the additional income (paid by Firm 2) is **BDEF** and the additional costs are **CDEF**. The benefits of Firm 2 are given by **ABF**, because there are avoided costs of **ADEF** and compensation payments to Firm 1 of **BDEF**.



**Figure 3: efficient bargaining solution**

The preferences of Firm 1 and Firm 2 shown in Figure 3 are also represented by payoff functions in equations (1) and (2), respectively:



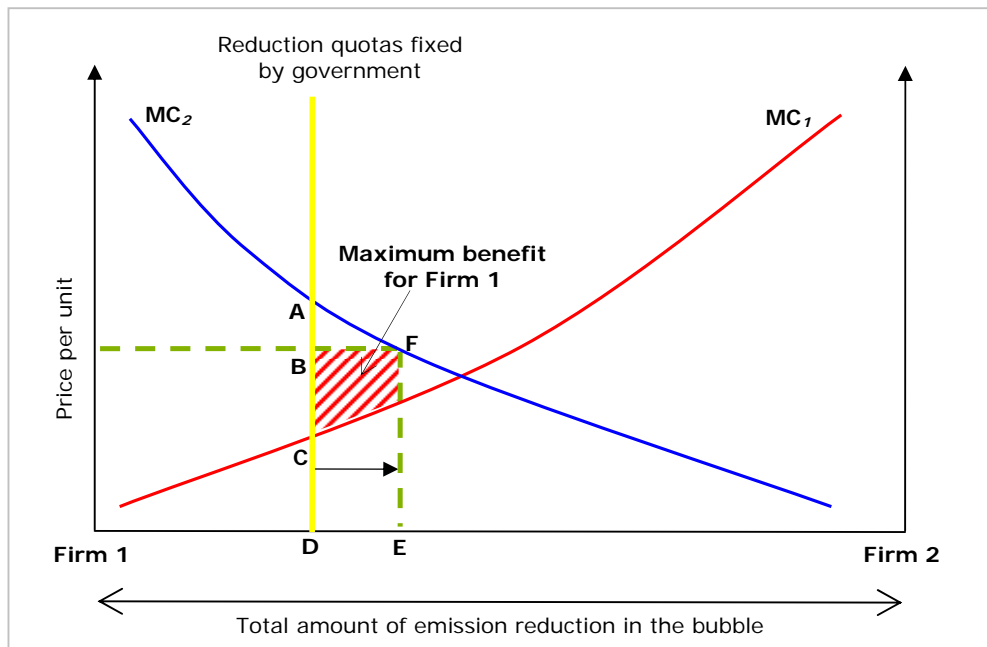
$$\Pi_{F_1} = p \cdot x - [C_{F_1}(x_{F_1} + x) - C_{F_1}(x_{F_1})] \quad (1)$$

$$\Pi_{F_2} = [C_{F_2}(x_{F_2}) - C_{F_2}(x_{F_2} - x)] - p \cdot x \quad (2)$$

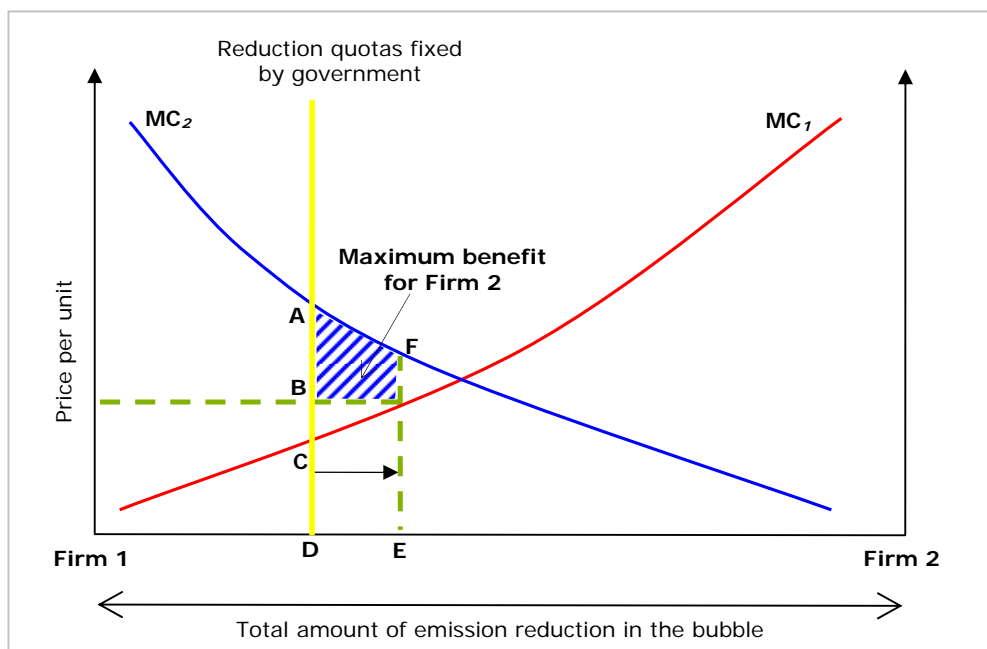
Where  $\mathbf{x}$  is each unit of emission reduction,  $\mathbf{p}$  is the price per unit of emission reduction paid by Firm 2,  $\mathbf{C}$  is the total costs of reductions, and  $\mathbf{F}$  represents the firms 1 ( $F_1$ ) and 2 ( $F_2$ ). It is completely clear that Firm 1 prefers a higher price and Firm 2 a lower price of emissions reductions, as a way to maximize their profits.

As shown early, one precondition of the Coase theorem is perfect competition that would lead to a completely efficient outcome. However, in this game there are only two agents, in which Firm 1 is a single seller and Firm 2 a single buyer, i.e. a bilateral monopoly. A bilateral monopoly is characterized by one firm or individual, a monopolist, on the supply side and one firm or individual, a monopsonist, on the demand side. In addition, bilateral monopoly is a two person game whose sum (surplus) is positive if the players reach an agreement on its division, otherwise zero. It is always in the immediate interest of either player to come to some agreement rather than none, provided that the share of the surplus allocated to it is higher than zero - the amount achieved in case of no agreement (Friedman, 1987).

In a bilateral monopoly, both players have monopoly power and neither is a price taker. According to the monopoly Cournot model, each firm chooses its output so as to maximize its profits given its beliefs about the other firm's choice (Varian, 2003). If Firm 1 maximizes its benefits and Firm 2 acts as a price taker, Firm 1 may charge a higher price and reduce fewer emissions than in the efficient solution (Figure 4), nevertheless, Firm 2 has also power to determine the price. Then, if Firm 2 maximizes benefits and Firm 1 acts like a price taker, the price may be too low and the additionally reduction emissions would be also lower than in the efficient solution (Figure 5). Hence, under these conditions the Coase solution is efficient, but unlikely to be the outcome of this bargaining process.



**Figure 4: Bargaining when Firm 1 is monopolist**

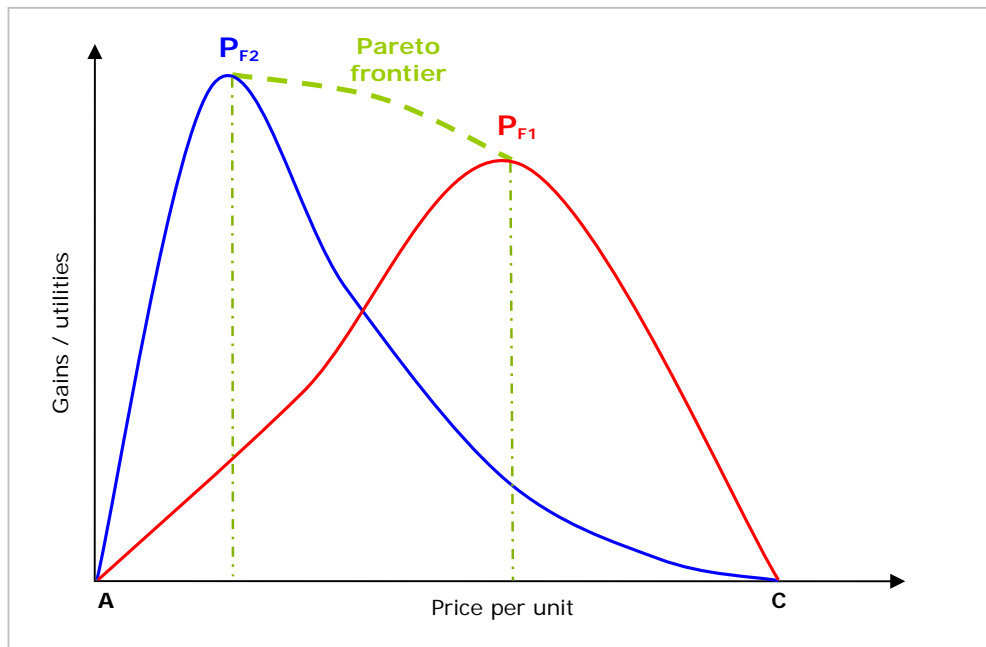


**Figure 5: Bargaining when Firm 2 is monopolist**

As already mentioned, Firm 1 prefers a higher price and Firm 2 a lower price of emissions reductions. The agreed price will be the result of negotiation between them and any agreement will depend on their relative bargaining power.

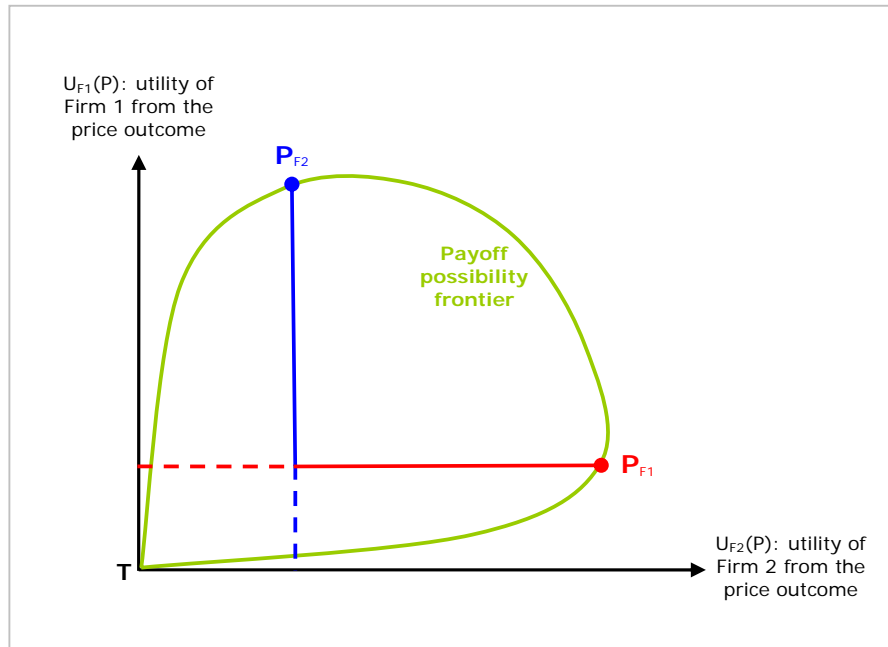
Figures 4 and 5 above also show the lower and upper limits of the bargaining zone, which is a price range ( $A < R < C$ ) where all prices lead to a Pareto efficient solution (Figure 6). This area is known as “Pareto frontier”. By definition, the Pareto frontier is the set of all of the possible outcomes that are Pareto optimal. A member of the Pareto frontier is definitely an efficient agreement.

In Figure 6, the upper limit of the Pareto frontier is determined by  $P_{F2}$  and the lower limit is defined by  $P_{F1}$ . Note that  $P_{F1}$  (the price that maximizes Firm 1’s profits) is a possible starting price demand for Firm 1 and  $P_{F2}$  (the price that maximize Firm 2’s gains) is a possible initial price offer for Firm 2.



**Figure 6: The Pareto frontier**

In another perspective, Figure 7 illustrates some of these rationality attributes in relation to this bargaining problem. The Firm 2’s utility,  $U_{F2}(p)$ , for alternative price outcomes,  $p$ , is measured along the horizontal axis and the Firm 1’s utility,  $U_{F1}(p)$ , is measure along the vertical axis. The curve between  $P_{F1}$  and  $P_{F2}$  ( $P_{F1}P_{F2}$ ) is the payoff possibility frontier (Pareto frontier).



**Figure 7: Another view of the Pareto frontier**

Along  $\mathbf{P}_{F1}\mathbf{P}_{F2}$  all profits are shared between Firm 1 and Firm 2. As the Firm 1's share of profits is a negative function of the Firm 2's share, the Pareto frontier maps the maximum possible value of  $\mathbf{U}_{F1}(\mathbf{P})$  as a function of  $\mathbf{U}_{F2}(\mathbf{P})$ . It means that movements down and along  $\mathbf{P}_{F1}\mathbf{P}_{F2}$  indicates a lower price outcome as the Firm 2's utility is rising and the Firm 1's utility is falling. Outcomes that lie below  $\mathbf{P}_{F1}\mathbf{P}_{F2}$  leave some profits unclaimed. Such outcomes is not Pareto efficient, since at least one player could do better without making the other player worse off by securing a price outcome along  $\mathbf{P}_{F1}\mathbf{P}_{F2}$ . Price outcomes above  $\mathbf{P}_{F1}\mathbf{P}_{F2}$  are not available (the Firm 2's profits are not high enough).

Still in Figure 7, the point  $\mathbf{T}$  represents the threat outcomes of Firm 1 and Firm 2, their corresponding utilities in the case of no agreement. On the one hand, Firm 1 will be unlikely to agree to any price less than it could earn if no agreement is made and it does not sell any unit of emission reduction. On the other hand, Firm 2 will also be improbable to agree to any price higher than the price which leaves it with the minimal level of profits that it could make by buying any emissions credits. It follows that  $\mathbf{T}_{F1}$  and  $\mathbf{T}_{F2}$  are the threat outcomes of the Firm 1 and Firm 2, respectively, their

best alternative outcomes or their fallback positions, in the event of no agreement. Namely, threat point  $T = (T_{F1}, T_{F2})$ .

Nash (1950) defines a bargaining problem to be the set of utility pairs that can be derived from possible agreements, together with a pair of utilities which is designated to be the disagreement/threat point. In order to narrow the range of possible outcomes, four axioms (including that of Pareto efficiency) are proposed by this author, which represent reasonable restrictions on possible agreements. These axioms and the Nash bargaining solution, as well as the Kalai-Smorodinsky solution, are presented in the coming subsection.

#### **4.2.2 Applying solution concepts**

Varian (2003) asserts that “the challenge in modelling bargaining is to find some other dimensions on which the players can negotiate”. One solution, the Nash bargaining solution, which most authors identify with a normative approach to bargaining, takes an axiomatic approach by specifying certain properties that a reasonable bargaining solution should have and then proving that there is only one outcome that satisfies these axioms. A solution, according to Nash (1950, p. 155), “means a determination of the amount of satisfaction each individual should expect to get from the situation, or, rather, a determination of how much it should be worth to each of these individuals to have this opportunity to bargain”. The desirable properties (axioms) that a bargaining solution should have are the following (Harsanyi, 1987; Binmore and Dasgupta, 1987; Osborne and Rubinstein, 1990. Osborne, 2004; Carmichael, 2005; Serrano, 2005):

- a) Pareto efficiency** – the outcome should be efficient, in the sense that no other agreement yields both players higher payoffs, hence to obtain an efficient solution, it is necessary to pick a point of the Pareto frontier. Efficiency is the basic ingredient of a normative approach to bargaining and negotiations should yield an efficient outcome in which all gains from cooperation are exploited.
- b) Symmetry or Anonymity** – this axiom implies that when the player’s utility functions and their threat utilities are the same they receive equal shares. That is, in a bargaining solution in which each of the threats made by

one bargainer can be countered by the other with exactly the same threat, both should be equally treated by the solution. In other words, in a symmetric game the two players have exactly the same strategic possibilities and have exactly the same bargaining power. Therefore, neither player will have any reason to accept an agreement yielding him a lower payoff than his opponent's. This axiom is sometimes called "equal treatment of equals" and it ensures that the solution yields 'fair' outcomes.

**c) Independence of equivalent utility representations** – the solution should not change if either player's utility function is altered in a linear way. This means that the solution is independent of the units in which utility is measured. For instance, if the bargain is over money and one player's utility for money doubles this should not change the monetary outcomes but whatever the player gets he will simply value it twice as much. In other words, if utility functions are rescaled but they represent the same preferences, the solution should be rescaled in the same fashion. No fundamental change in the recommended agreement will happen following a renormalization of utility functions; the utility will simply rescale utilities accordingly. Note that this axiom ensures that the outcome of bargaining will be independent of interpersonal comparisons of the two player's utilities.

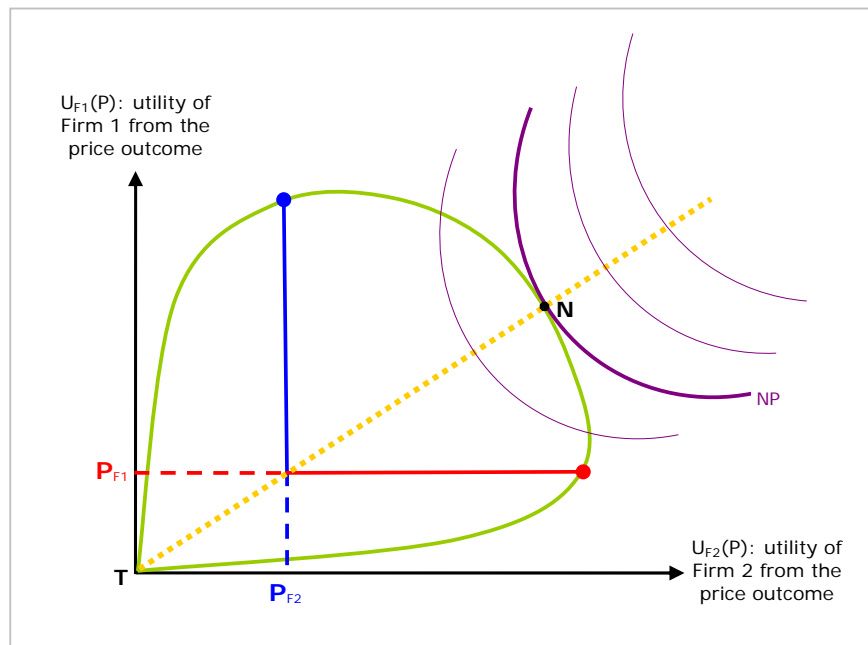
**d) Independence of irrelevant alternatives** – suppose a solution picks a point from a given normalized bargaining problem. Consider now a new normalized problem, subset of the original, but containing the point selected earlier by the solution. Then, the solution must still assign the same point. That is, the solution should be independent of irrelevant alternatives: if the number or range of possible outcomes is restricted but this does not affect the threat point and the previous solution is still available, the outcome should not change.

With these four axioms, Nash (1950) proves that there is a unique solution to bargaining problems that satisfies all properties: it is the one that assigns to each normalized bargaining problem the point that maximizes the product of utilities of the two bargainers. The Nash bargaining solution is the outcome which maximizes the product of the player's gains from any agreement. This product is known as the Nash product.

For instance, suppose that a point  $\mu$  represents a given price that confers to Firm 1 and Firm 2 a price  $\mathbf{P}_\mu$ . Firm 1's utility from  $\mathbf{P}_\mu$  is  $\mathbf{U}_{F1}(\mathbf{P}_\mu)$  and the Firm 2's utility is  $\mathbf{U}_{F2}(\mathbf{P}_\mu)$ . Firm 1's gains from a price agreement  $\mathbf{P}_\mu$  is the utility increment measured by the vertical distance  $\mathbf{U}_{F1}(\mathbf{P}_\mu) - \mathbf{T}_{F1}$ . The Firm 2's gains from the agreement at  $\mu$  is the utility increment represented by the horizontal distance  $\mathbf{U}_{F2}(\mathbf{P}_\mu) - \mathbf{T}_{F2}$ . Multiplying these two utility increments together results the Nash Product (NP), that is:

$$NP = [U_{F_1}(p_\mu) - T_{F_1}] \cdot [U_{F_2}(p_\mu) - T_{F_2}] \quad (3)$$

Nash bargaining solution is obtained by maximizing that product, where  $\mathbf{T}$  is the threat point, which gives the value for the  $\mathbf{T}_{F1}$  and  $\mathbf{T}_{F2}$  if the negotiating fails. Geometrically, Nash solution corresponds to the point where the hyperbola NP reaches its largest value in the boundary of the Pareto border (point N in Figure 8).



**Figure 8: Nash bargaining solution**

Apart from the first three of Nash's axioms being quite uncontroversial (Harsanyi, 1987; Osborne and Rubinstein, 1990; Carmichael, 2005; Serrano, 2005), the fourth one (independence of irrelevant alternatives, known as IIA) raised some criticisms. The best known variation of Nash bargaining solution was contributed by Kalai and Smorodinsky (1975). These authors proposed to preserve these first three of Nash's

axioms, but drop IIA. Instead, they introduced an individual “monotonicity axiom”. The principal criticism made by Kalai and Smorodinsky (1975) about IIA is that it makes the result ignore the relative size of the sacrifices made by the parties in order to achieve an agreement. The solution proposed by these authors consists of equalizing the players' sacrifice proportional to the maximum gain they could expect in the available set of options, as well as warrants that an expansion of the set of options that is advantageous to one party never hurts this party in the conclusive selection.

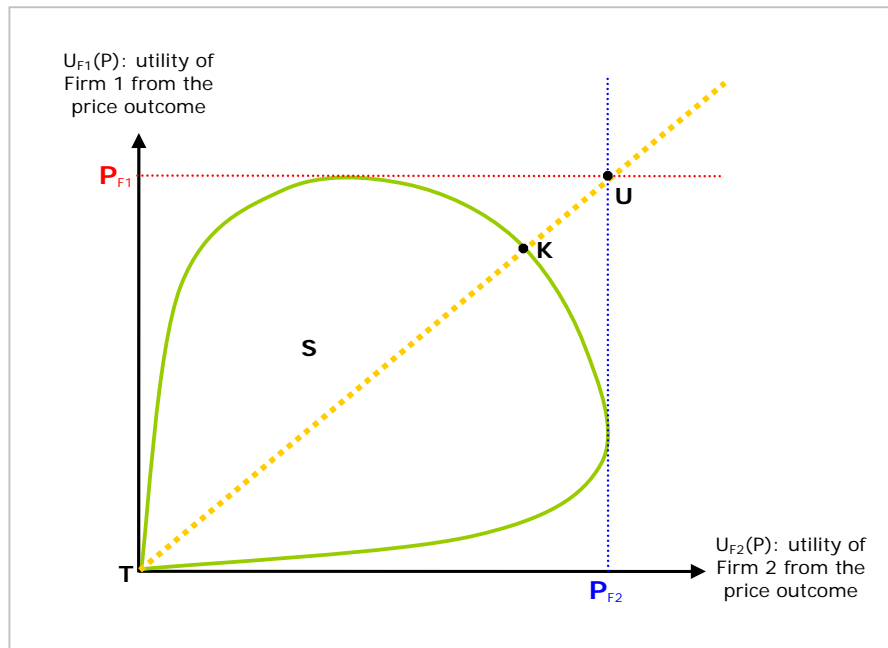
Kalai and Smorodinsky (1975, p. 515) affirm that a monotonicity axiom “states that if, for every utility level that player 1 may demand, the maximum feasible utility level that player 2 can simultaneously reach is increased, then the utility level assigned to player 2 according to the solution should also be increased”. The Kalai-Smorodinsky (hereafter KS) solution is characterized by equal proportional concessions of both parties in a conflict from their respective maximally feasible utility levels. As stated by Elster (1989, p. 64), in KS bargaining solution “the utilities gains should be proportional to the maximum feasible gains which the parties could achieve”.

The important elements in a KS bargaining problem are the threat point, the bargaining set, and the utopia point. The utopia point is the outcome that would satisfy each player's maximum claim. Since each player names their “ideal” utility level, the utopia point will generally not be in the bargaining set (hence, the utopia point is typically not feasible). For instance, if the negotiators from Firm 1 ask to Firm 2 how much it would like to pay for each unit of emissions reductions, the last will probably answer that it would like to get the emissions credit for free, zero costs. This is an unfeasible price for Firm 1 sells their emissions credits (it wants the highest price as possible), but it would be the ideal price for Firm 2 buys them. These claims are not coherent with one another, and so the utopia point lies outside the space of outcomes that may actually result from the negotiation.

Considering this, there is a unique solution to bargaining that satisfies the Nash's requirements (except IIA) and monotonicity axiom: it is the one that assigns to each normalized bargaining problem the intersection point of the Pareto frontier and the straight line segment  $0,0$  (threat or disagreement point) and the utopia point. That



is, the KS bargaining solution, shown in Figure 9, where **S** is the bargaining set, **U** is the utopia point and **K** is the KS bargaining solution.



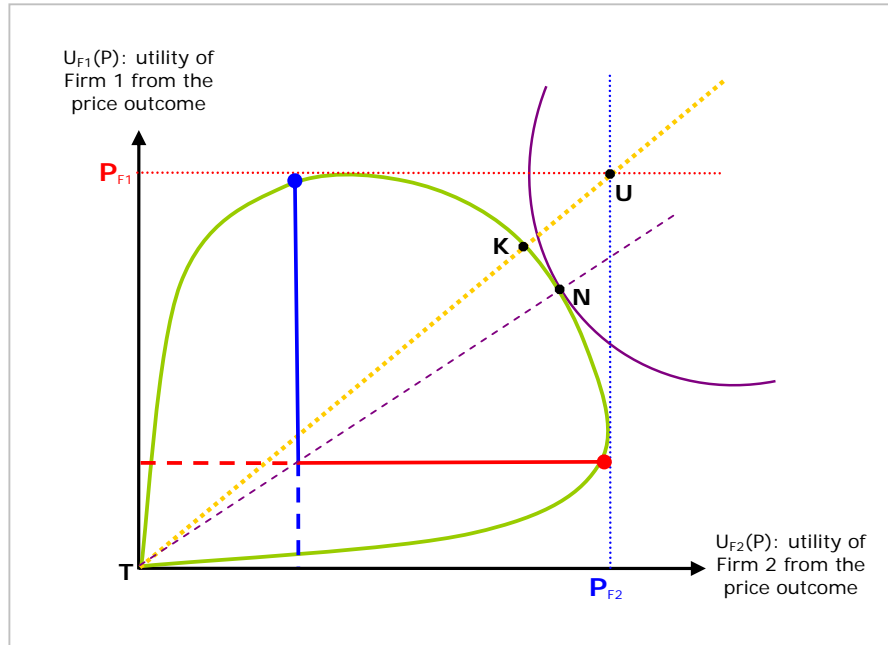
**Figure 9: Kalai-Smorodinsky bargaining solution**

If the bargaining set is changed in such a way that the welfare of both firms can be improved, then neither firm should lose from such alteration. Another manner to consider this is when the Pareto frontier expands outside, the bargaining solution to the new problem should be Pareto superior<sup>12</sup> to the old one (Elster, 1989).

As already exposed, the crucial divergence between Nash and KS bargaining solutions is the application of “independence of irrelevant alternatives” for the first, and the “monotonicity axiom” for the latest one. In order to reinforce these arguments, suppose that Firm 1 prefers a price  $x$  to sell their emissions credits and Firm 2 prefers to buy these credits for price  $y$ . As a result of negotiation, both firms agree with an alternative price  $z$ . However, when they are formalizing the transaction, for any reason, the Firm 1’s most preferred outcome (price  $x$ ) is no longer feasible. The bargaining space has just shrunk. The independence of irrelevant alternatives axiom stipulates that since they have already decided not to choose price  $x$ , the fact that it is no more possible should not give to firms any reason to change

<sup>12</sup> Pareto Superiority: a move from one distribution point to another is said to be *superior* when at least one party is better off and no one else is worse off. This includes moves that benefit all parties; the essential concern is that no one is worse off after the move compared to welfare before the move. (Varian, 2003).

their decision. Hence the Nash bargaining solution indicates that firms sustain price  $z$ . The KS bargaining solution, on the other hand, proposes that because Firm 1 changed its preference, they both should re-evaluate their decision and find another solution. In Figure 10, the Nash and KS bargaining solutions are superimposed in order to show these differences.



**Figure 10: Comparing bargaining solutions**

In the context of negotiations between Firm 1 and Firm 2, both concepts, Nash and Kalai-Smorodinsky, picks one of the prices within the Pareto frontier and shows a solution. The question is: which of these normative bargaining solution concepts are more close to the Coase cost efficient solution  $F$  (shown in Figure 3)?

Actually, it is very unlikely that both bargaining solutions, Nash or Kalai-Smorodinsky, would be strictly equivalent with the cost efficient reduction quotas  $F$ , especially because the game proposed up till now refers to a two-firms bargaining once about the price per emission unit, i.e. the allocation of pollution depends on the negotiated price. However, all possible bargaining outcomes which are not identical with the efficient solution where marginal costs are equalized (Coase solution) give room for further welfare improvement. This inference leads to Schlicht (1996, 1997) and his “Coase mechanism”, that is a mechanism of bilateral bargaining based on the



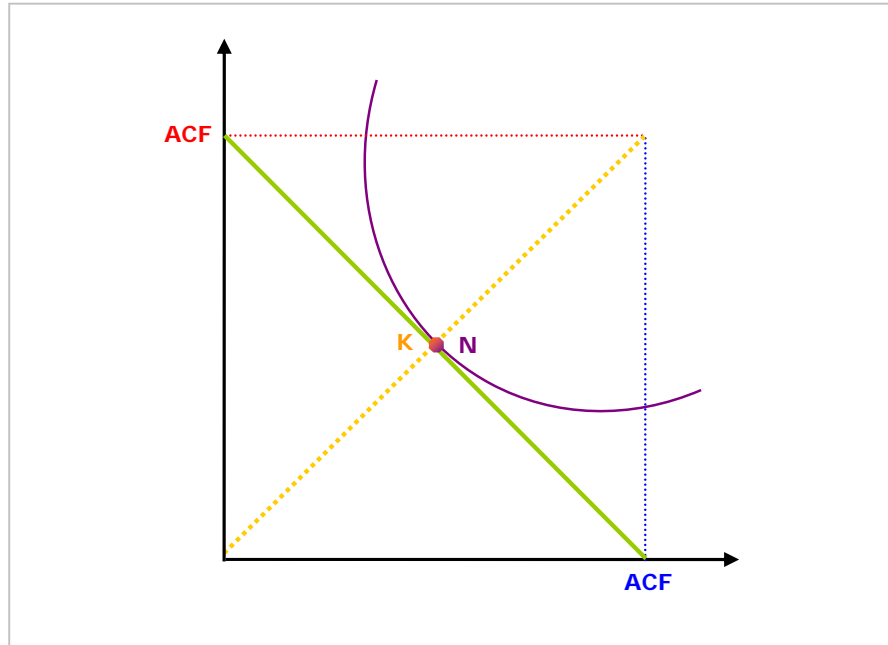
firms to start another round of negotiation that would shift the yellow line closer to the efficient point (Coase solution), and so on. The diagrams in Figure 11 show the same result in different views: after any cycle of bargaining, the Pareto border would be shrunk and the efficient solution would become reachable.

It seems plausible to affirm that there are no erroneous results (both, Nash and KS, are proper and applicable), even though none of them would achieve the efficient point through one-shot game. Instead, as asserted by Schlicht (1996), the iterative bargaining would surely achieve the Coase efficient outcome. It is important to prevent that, in this context the income effects demand careful attention (subsection 3.2.2, d). Although, in order to avoid that, Schlicht (1996) suggested that well-defined property rights (especially zoning laws and regulations) prevents from excessive transaction costs, as well as averts possible inefficiencies resulting from iterative bargaining.

Turning to Figure 3 is also possible to apprehend that firms can bargain not only about the compensation price per emission unit, as shown up to now, but also about the allocation of the surplus between agents, comprehended in the area **DE**.

Suppose that marginal cost functions from both firms are common knowledge, that is, both firms know the total surplus (area **ACF** in figure 3) when the Coase solution is implemented. As firms know the efficient solution **E**, they would bargain only about how the total gains **ACF** should be split up between them. In this case, the bargaining result is completely irrelevant since the physical allocation of emissions units is always efficient (**ACF** is continually reached); just the distribution of pollution rights is affected by bargaining.

It is important to reinforce that, contrary to the bargaining process shown in subsection 5.2.2, both firms then bargain not about the transfer volume of pollution rights (since its allocation depends on the negotiated price) or the compensation price per emissions unit, but only about the compensation price for the complete amount **E**. When considering this type of game, the results are symmetric and the Nash and Kalai-Smorodinsky bargaining solutions coincide, as depicted in Figure 12.



**Figure 12: Bargaining solution (allocation of surplus between firms)**

However, this model of game demands strong information requirements, seeing that the marginal costs of both firms have to be common knowledge, which are extremely difficult to meet in reality. Actually, each firm has the possibility to alternate the amount of transferred emission rights, i.e. the transfer volume is endogenous outcome of the bargaining process. As conclusion, a realistic game is more related to the iterative process previously described.

## 5. CONCLUDING REMARKS

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It was shown that only the prices (and hence traded volume of pollution rights) comprised in the Pareto frontier lead to an efficient situation in terms of individual benefits and can be a result of a bargaining game. Two solution concepts, Nash and Kalai-Smorodinsky, have picked one of these prices, but neither of these two bargaining results achieved the cost efficient price (the Coase solution).

Given that all possible bargaining results (Nash, Kalai-Smorodinsky) which are not identical with the Coase solution are subject of further welfare improvement, it could be implemented a mechanism of bilateral bargaining based on the assumption that through a repetitive interaction parties are able to reach an efficient outcome (see Schlicht, 1996). It is assumed that one of these solutions is set up, and then a certain amount of emissions rights is passed on to the other firm which pays a price per unit. The efficient solution was not reached and the difference between marginal costs is smaller, but still positive. There is no impediment to firms start another round of negotiation until the Coase solution point.

Another situation is when firms bargain not about the compensation price per unit of emission reduction, instead they bargain about the compensation price for the complete amount (the area **DE** in figure 3), i.e. the allocation of the surplus between firms. By definition, this solution is always efficient, although it requires precise information about the marginal costs of both firms.

Before starting the negotiation, firms have the possibility to choose which type of game they want to play among two valid alternatives: 1) an iterative bargaining game, where they have to negotiate the price per unit of emissions reduction; or 2) bargaining about the compensation price for the complete amount of emissions reduction. In both cases, due the nature of the game, whatever bargaining solution (Nash or Kalai-Smorodinsky) is picked up the final result would be adequate, as long as firms are aware about the shortcomings and demands of each alternative.

## 6. REFERENCES

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- Anbar, D. and Kalai, E. (1978). "A one-shot bargaining problem". International Journal of Game Theory, **7**(1): 13-18.
- Axelrod, R. and Dion, D. (1988). "The Further Evolution of Cooperation". Science, **242**(4884): 1385-1390.
- Axelrod, R. and Hamilton, W.D. (1981). "The Evolution of Cooperation". Science, **211**(4489): 1390-1396.
- Baumol, W.J. and Oates, W.E. (1988). **The Theory of Environmental Policy**, Prentice-Hall, 2<sup>nd</sup> Ed., Cambridge University Press, Cambridge. 299 p.
- Binmore, K.G. and Dasgupta, P. (1987). **The Economics of Bargain**, Oxford, England: Blackwell Publishers. 260 p.
- Binmore, K.G, Rubinstein A. and Wolinsky A. (1986): "The Nash Bargaining Solution in Economic Modelling," Rand Journal of Economics, **17**, 176–188.
- Bernholz, P. (1997). "Property rights, contracts, cyclical social preferences and the Coase Theorem: a synthesis". European Journal of Political Economy **13**(1997a): 419-442.
- Booth, D. E. (1995). "Economic growth and the limits of environmental regulation: A social economic analysis." Review of Social Economy **53**(4): 553-573.
- Buchanan, J.M. and Stubblebine, W.C. (1962). "Externality". Economica **29**(116): 371-384.
- Carmichael, F. (2005). **A guide to Game Theory**. Harlow, England: Pearson Education Limited. 304 p.
- Coase, R.H. (1960). "The Problem of Social Cost". Journal of Law & Economics **3**(OCT): 1-44.
- Coase, R.H. (1937). "The Nature of the Firm". Economica **4**: 386-405.
- Cooter, R.D. (1987). "Coase Theorem" in **The New Palgrave Dictionary of Economics**, J. Eatwell, M. Milgate and P. Newman (eds.), McMillan, London.
- Costanza, R. (1987). "Social Traps and Environmental-Policy". Bioscience **37**(6): 407-412.
- Costle, D.M. (1980). "New Ways to Regulate - Bubble Policy". Journal of the Air Pollution Control Association **30**(1): 10-11.
- Crawford, V.P. (1991). "Thomas Schelling and the Analysis of Strategic Behavior", 265-294 in Richard Zeckhauser, Editor, **Strategy and Choice**, Cambridge: MIT Press.

- Crocker, T.D. (1966). "The structuring of atmospheric pollution control systems". In H. Wolozin (Ed.), The Economics of air pollution (61-68). New York: W.W. Norton & Co.
- Dales, J. H. (1968). **Pollution, Property and Prices**. Toronto, University of Toronto Press. 117 p.
- Deardorff, A. V. (1996). "International externalities in the use of pollution policies". International Review of Law and Economics **16**(1): 53-59.
- Deland, M.R. (1979). "Bubble Concept". Environmental Science & TECHNOLOGY **13**(3): 277-277.'
- Elster, J. (1989). **The cement of Society**. Cambridge, UK: Cambridge University Press. 320 p.
- Farrell, Alexander E. (February 2005). **Review of Market-based Incentives for Consideration of Applications in California**. University of California, Berkeley for the California Energy Commission, PIER Energy-Related Environmental Research. CEC-500-2005-12.
- Fiorino, D.J. (1995). **Making Environmental Policy**. Berkeley, USA: University of California Press. 269 p.
- Friedman, J.W. (1991). **Game Theory with Applications to Economics**. New York, USA: Oxford University Press. 2<sup>nd</sup> Edition. 352 p.
- Friedman, J.W. (1987). "Bilateral monopoly" in **The New Palgrave Dictionary of Economics**, J. Eatwell, M. Milgate and P. Newman (eds.), McMillan, London.
- Fullerton, D. (2001). "A framework to compare environmental policies". Southern Economic Journal **68**(2): 224-248.
- Gibbons, R. (1992). **A primer in Game Theory**. Harlow, England: Pearson Education Limited. 267 p.
- Glass, A.W. (1980). "The EPA's Bubble Concept after Alabama-Power." Stanford Law Review **32**(5): 943-975.
- Hahn, R. W. and Hester, G.L. (1989). "Marketable Permits - Lessons for Theory and Practice." Ecology Law Quarterly **16**(2): 361-406.
- Hahn, R.W. (1993). "Comparing Environmental Markets with Standards." Canadian Journal of Economics-Revue Canadienne D Economique **26**(2): 346-354.
- Hahn, R.W. (2000). "The impact of economics on environmental policy". Journal of Environmental Economics and Management **39**, 375-399.
- Hahn, R.W. and Stavins, R.N. (1992). "Economic Incentives for Environmental-Protection - Integrating Theory and Practice." American Economic Review **82**(2): 464-468.



- Hamaide, B. (2003). "Economic and Political cooperation in various climate policy scenarios". Climate Policy **3**(2): 171-177.
- Hardin, G. (1968). "The tragedy of the commons". Science. 162:1243-1248.
- Harrington, W. and Morgenstern, R.D. (2004). "Economics Incentives versus Command and Control: what's the best approach for solving environmental problems? Resources. Fall/Winter 2004 (152).
- Harsanyi, J.C. (1987). "Bargaining" in **The New Palgrave Dictionary of Economics**, J. Eatwell, M. Milgate and P. Newman (eds.), McMillan, London.
- Kahn, J.R. (1997). **The Economic Approach to Environmental and Natural Resources**. Orlando, FL, USA: Dryden Press Series in Economics. 2<sup>nd</sup> Edition. 536 p.
- Kalai, E. and Smorodinsky, M. (1975). "Other solutions to Nash's bargaining problem". Econometrica, 43, 513-518.
- Kimura, K. (1993). "Perception of Pollution as a Social Dilemma". Journal of Mathematical Sociology **18**(1): 81-91.
- Kraft, M.E. (2004). **Environmental Policy and Politics**. New York, USA: Pearson Longman. 3<sup>rd</sup> Edition. 310 p.
- Kreps, D.M. (1990). **Game Theory and Economic Modelling**. New York, USA: Oxford University Press. 208 p.
- Lewin, P. (1982). "Pollution Externalities - Social Cost and Strict Liability". Cato Journal **2**(1): 205-229.
- Liroff, R.A. (1986). **Reforming Air Pollution Regulations: The Toil and Trouble of EPA's Bubble**. Washington, USA: Conservation Foundation. 186 p.
- Moulin, H. (1984). "Implementing the Kalai-Smorodinsky Bargaining Solution." Journal of Economic Theory **33**(1): 32-45.
- Mukerjee, S. and Biswas, P. (1993). "Source Resolution and Risk Apportionment to Augment the Bubble Policy - Application to a Steel Plant Bubble". Environmental Management **17**(4): 531-543.
- Nash, J. (1950). "The Bargaining Problem". Econometrica, 18:155-162.
- Nash, J. (1953). "Two-person cooperative games". Econometrica, 21:128-140.
- Noll, R.G. (1982). "Implementing Marketable Emissions Permits". American Economic Review **72**(2): 120-124.
- Olsen, M. (1965). **The Logic of Collective Action: Public Goods and the Theory of Groups**. Cambridge, USA: Harvard University Press.

- Osborne, M.J. (2004). **An introduction to Game Theory**. New York, USA: Oxford University Press. 533 p.
- Osborne, M.J. and Rubinstein, A. (1990) **Bargaining and Markets**. San Diego, USA: Academic Press. 232 p.
- Osborne, M.J. and Rubinstein, A. (1994) **A course in Game Theory**. London, England: The MIT Press. 368 p.
- Pearce, D.W. and Turner, R.K. (1990) **Economics of Natural Resources and the Environment**. Baltimore, USA: The John Hopkins University Press. 392 p.
- Pearson, C.S. (2000). **Economics and the global environment**. New York, USA: Cambridge University Press. 583 p.
- Pigou, A.C. (1932). **The Economics of Welfare**. London: Macmillan and Co. Library of Economics and Liberty
- Platt, J. (1973). "Social Traps". American Psychologist **28**(8): 641-651.
- Regan, D. H. (1972). "Problem of Social Cost Revisited." Journal of Law & Economics **15**(2): 427-437.
- Requate, T. (2005). "Dynamic incentives by environmental policy instruments - a survey". Ecological Economics **54**(2-3): 175-195.
- Schelling, T. C. (1961). "Experimental Games and Bargaining Theory". World Politics **14**(1): 47-68.
- Schlicht, E. (1996). "Exploiting the Coase mechanism: The extortion problem." Kyklos **49**(3): 319-330.
- Schlicht, E. (1997). "The Coase mechanism and the iteration argument: Reply." Kyklos **50**(4): 581-585.
- Serrano, R. (2005). "Bargaining" in **The New Palgrave Dictionary of Economics**, (2<sup>nd</sup> edition), S. Durlauf and L. Blume (eds.), McMillan, London, forthcoming.
- Stavins, R.N. (1995). "Transaction Costs and Tradeable Permits." Journal of Environmental Economics and Management **29**(2): 133-148.
- Sun, M. (1984). "High Court Upholds EPA's Bubble Concept." Science **225**(4658): 150-150.
- Taboas, A. (1984). "Environmental Bubble Policy". Environment International **10**(4): 273-273.
- Turner, R.K., Pearce, D.W. and Bateman, I.J. (1993). **Environmental Economics: An Elementary Introduction**. Baltimore, USA: The John Hopkins University Press. 324 p.

UNEP, UCCEE and UNCTAD (2002). **An emerging market for the environment: a guide to emissions trading**. Denmark, United Nations Publication.

Varian, H.R. (2003) **Intermediate Microeconomics: a modern approach**, 6<sup>th</sup> Edition. New York, USA. W.W. Norton & Company. 728 p.

Vig, N.J. and Kraft, M.E. (2003). **Environmental Policy: New Directions for the Twenty-First Century**. Washington, DC, USA: CQ Press. 5<sup>th</sup> Edition. 436 p.

Von Neumann, J. and Morgenstern, O. (1944). **Theory of Games and Economic Behavior**. Princeton, USA: Princeton University Press.