Chapter 1

Introduction

This is the way the world ends,
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Not with a bang, but a whimper. - T.S. Eliot.

1.1 Introduction

In this dissertation I seek to explore the interlinkages between environmental regulation and market structure. Thus my study is located at the intersection of two of the most active and interesting sub-disciplines of economics, environmental economics and industrial organization.

In the recent decades environmental economics has attracted a lot of attention, from economists as well as scientists. This interest stems from a greater understanding of the role played by the environment in the economic process.
The economy and the environment are intrinsically linked to each other in different ways. The environment's first role is a supplier of resources, both energy and material. The second role is a sink for the waste products arising out of production and consumption. Sometimes wastes are transformed by the environment itself, either biologically, or chemically. Such transformation has a gradually increasing cost for the society that values clean environment, and, beyond a point it is too costly and it may not be possible to sustain a reasonably clean environment by natural processes. For some inputs, however, such transformation is not possible at all. These inputs, often called cumulative pollutants, include metals like lead and cadmium and man-made chemicals like DDT, which continue to accumulate in the environment. The environment also performs an important role as a supplier of educational and spiritual values. For example, while the existence of the Himalaya may give pleasure to people all over the world, for people in the neighboring countries the Himalaya is, in addition, a source of spiritual value.

Clearly, there are many, and sometimes conflicting, demands on the environment. However, it is only recently that the realization has begun to sink in that the environment is a scarce resource. Earlier the environment was often treated as a free good, leading to indiscriminate exploitation, causing severe and sometimes irreparable environmental damage.

Let me briefly describe some of the main environmental problems facing
us, viz. air\textsuperscript{1} and water pollution,\textsuperscript{2} toxic emissions\textsuperscript{3} and ecosystem health.\textsuperscript{4}

Air pollution, specially in urban areas, can lead to sickness, irritation and decreased human performance. It also damages materials leading to increased maintenance costs. One of the more dramatic manifestations of the problem can be found in the phenomenon of acid rain, whereby rainfall contains acidic gases like sulphur dioxide, nitrogen dioxide, ammonia etc.

\textsuperscript{1}Air pollution is primarily caused by the combustion of fossil fuels, as well farming, which lead to the emission of sulphur dioxide, carbon dioxide, nitrogen oxides, particulates etc into the atmosphere. This problem is particularly severe in the urban areas. In India, for example, in 60 out of 62 cities, the air pollution levels are much higher than the WHO guidelines (see Panicker, 2003).

\textsuperscript{2}Water pollution refers to the deposition of organic and sometimes chemical wastes, including pathogenic human wastes, into waterways or lakes. Even when wastes are not directly dumped into water, much of the wastes that are dumped in land, and emitted into the air often find their way into surface and ground water. In India, for example, the availability of freshwater has gone down from 6000 million cubic meters in 1947, to 2300 million cubic meters in 1997. In fact, by 2047 per capita water availability has been projected to decline by 67\% (see Panicker, 2003).

\textsuperscript{3}Toxic chemicals in the environment include pesticides, which find their way into the food chain and lead, which finds its way into the atmosphere because of its presence in automobile fuels (though its use in automobile fuel is being banned by an increasing number of countries).

\textsuperscript{4}Ecosystems all across the world are being destroyed for commercial purposes e.g. wetlands are being cleared in the name of land reclamation for agriculture and housing. Another serious problem is that of rain forest destruction. Such destruction is due to the pressure of agriculture, poor property rights, commercial exploitation for timber etc. The Ivory Coast, for example, is losing rain forest at the rate of 300000 hectares every year. In fact, Ehui et al. (1989) report that of the original 16 million hectares of rainforest, only 3.4 million remain. Globally, Repetto (1988) reports that the rain forest area is being depleted at the rate of 1.8 per cent per annum.
Adverse effects of acid rain include an acidic geology and effects on aquatic systems and forests, causing direct harm to the leaves and needles of some trees. In the United Kingdom a major cause for concern has been the damage to the bio-diversity of vulnerable mountain areas where some of the most natural and undisturbed sites for nature conservation occurs (see Fry and Cooke, 1987).

Water pollution is such a serious problem that the World bank (1992) estimated that about 1 billion people, about a fifth of the world's population, is without access to safe drinking water. This is an extremely serious situation given that basic health (as measured by life expectancy and child mortality) is very closely linked to the availability of safe drinking water.

Next turning to toxic emissions, pesticides have been found to disturb food chains, especially in birds. In fact, pesticides have been found in ground water as well. This is a particularly serious problem in underdeveloped countries where a significant number of people are still dependent on untreated ground water. Lead pollution also has serious consequences, including mental retardation, especially in poor urban children.

Worsening ecosystem health has led to several species becoming endangered and even extinct. In the case of rainforests, apart from the fact that they represent a repository of bio-diversity, such destruction has serious consequences in terms of increased emission of carbon dioxide into the atmosphere, increased soil erosion, loss of plants of medicinal value, etc. Equally importantly, rain forests, which are mainly situated in the less developed countries are a source of livelihood for a large section of the population, and their destruction may well spell eventual economic doom for many of these
people.

While all these linkages are equally vital, the increasing focus on environment has, perhaps, more to do with some of the more dramatic manifestations of environmental degradation e.g. global warming, ozone layer depletion etc. All these events have potentially disastrous consequences for the world. It has been predicted that global warming could lead to a rise in the sea level between 0.6-3.5 m, leading to the inundation of many low lying coastal areas. Local effects include some regions getting much drier, while other regions getting much wetter leading to concomitant changes in the eco-system. The depletion of the ozone layer is fraught with similar grave consequences. Apart from a growing number of skin cancer cases, exposure to UV rays can also cause damage to crops and the marine eco-system.

All these phenomena have driven home the message that the environment is a scarce resource and that environmental degradation poses a serious threat to the present and future generations and have serious socio-economic

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5Global warming refers to the phenomenon whereby an acceleration of the greenhouse effect (caused by carbon dioxide and other gases trapping long-wave infra-red radiation into the atmosphere) leads to an increased warming of the earth. Jamieson (1988), for example, predicts a rise in global temperature between 1.5 to 4.5 centigrade over this century (assuming that the carbon dioxide level is going to double).

6The ozone layer in our atmosphere perform a vital function by absorbing the UV rays of the sunlight. In the recent decades, however, increased emission of chlorofluorocarbons (CFCs) has lead to holes in the ozone layer (over the arctic and the antarctic so far), allowing free entry of UV rays. There has also been a steady depletion in the ozone level over the years, raising the possibility that such holes could become more wide spread.


8In fact, India is among the 25 countries most vulnerable to a rise in the sea level (see Panicker, 2003).
implications, especially for the underdeveloped countries. Given that much of economics deals with the allocation of scarce resources, it is only natural that people turn to economics for a better understanding of environmental problems.

1.2 Environmental Economics and Industrial Organization

The multidimensional and multidisciplinary characteristics of environmental phenomena has sparked interest among economists from various sub-disciplines of economics, as well as led to growing interactions between scientists and economists. While I realize that the purely scientific aspects of the problem are also of great importance and interest, as a student of economics, however, in my discussion I shall concentrate on the economics of the problem.

There has been a growing interest in environmental economics, in particular environmental policy, both at the theoretical and at the applied level. Thus from the 1990's onwards there has been a wide range of extensions of the basic policy framework developed earlier (mainly in the 1960's and 1970's). The earlier literature is mainly concerned with issues of externalities, common property resources, economics of natural resources etc.\footnote{This literature has been summarized in several books including Baumol and Oates (1975), Pearce and Turner (1990), Siebert (1987) etc.} The later extensions are an outcome of the evolution of the field, as environmental problems came under more detailed scientific scrutiny and as environmental
economics interacted with other branches of economic theory, in particular industrial organization and international economics. These extensions have not only helped us to understand complicated issues like those of transboundary pollution, international environmental cooperation, climate changes etc., but they have also allowed us to tackle new issues like uncertainty, non-point sources of pollution, the role of innovation and technical progress, the role of firms as the main source of pollution, effects of market structure etc.

The essential issue discussed in the traditional literature is that of market failure. If there were markets in environmental products which worked perfectly, then one would expect that the environment would be exploited at the socially optimal level. Since that is clearly not the case, markets in environmental products are either absent, or fail to perform adequately. Thus the fundamental problem is to understand why there may be market failure. Traditionally economists have focussed on issues like incomplete markets, externalities, non-exclusion, non-rival consumption and asymmetric information.10

Much of this early literature developed independently of the developments in the emerging field of industrial organization. From the 1980's onwards economists started using game theoretic tools to gain a better understanding of the ways that firms interact in the market place.11 This development has deepened our understanding as to how firms compete among themselves using various tools like price, advertisement, choice of location, quality, R&D etc. and the welfare implications of such competition. From a purely the-

10 The issue of market failure has been discussed in somewhat greater detail in chapter 2 (to follow).
11 Tirole (1988) provides a magisterial survey of the field.
Theoretical standpoint industrial organization made an important contribution in understanding the foundations of standard economic models like that of perfect competition, limit-pricing etc. The development of industrial organization theory also has important practical implications for industrial policy, in particular in clarifying the role of competition in enhancing efficiency and kind of policy tools best suited to achieve this end.

Given that oligopolistic firms are often the principal actors in producing, selling and sometimes exporting dirty products, as well as in environmental R&D, many economists came to realize that one's understanding of environmental economics will be incomplete without a thorough understanding of the ways firms in dirty industries interact. Thus it is natural that from the 1990's onwards there was a growing and fruitful interaction between the two fields of environmental economics and industrial economics, with industrial organization frameworks and methodologies being increasingly adopted by environmental economists.

Traditionally environmental policy, even when it concentrates on firms as the primary economic agents, is based on the polarized assumption of either perfect competition or monopoly. The assumption of competitive product markets (see Baumol and Oates, 1988) is the most common one in the anal-

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12 This literature seeks to demonstrate that perfect competition can be achieved as a limiting case of oligopolistic markets as the number of firms becomes very large.

13 In fact even management scientists have started to pay greater attention to the relationships between firms and the environment, in particular the impact of environmental problems and environmental regulations on managements strategies and vice versa. In the last few years this has been a growing research area that deals with management tools like environmental information systems, environmental reporting strategies, eco-auditing etc.
ysis of environmental policy, though there are some notable exceptions that assume that the product market is monopolistic (e.g. Buchanan, 1969). One interesting implication of using a monopolistic framework stems from the output distortion in case of a monopoly firm. Buchanan (1969) showed that as a result, setting effluent fees to equal the marginal external damages of pollution (as in the case of competitive markets) will not lead to optimality and may even reduce social welfare. This is because the effluent fees will reduce the already sub-optimal level of monopoly output even further. Thus any gain in welfare due to reduced pollution may be outweighed by the welfare loss due to reduced output. This implies that complete internalization of the external damages caused by the monopolist may not be desirable, but rather that optimal policy requires an emission tax that is less than marginal damages.

Until recently much less attention has been given to the analysis of environmental policy under an oligopolistic market structure. This is surprising since this assumption could be regarded as the more realistic one for modern industrial societies (see for example Ebert, 1992 and Conrad and Wang, 1993). The basic implications of the departure from the competitive market assumption is that more externalities enter the analysis, with these new externalities significantly affecting the effectiveness of the environmental policy instruments. While these may lead to great complexities in the analysis (Baumol and Oates, 1988) that is a small price to pay for greater realism and a deeper understanding of the problems.

While this is still an extremely active research area, let me mention just
a few of the insights coming out of this literature. First, since there are additional externalities present, in such an oligopolistic setup one needs to use other policy tools, in addition to the usual ones, if one is to achieve the first best outcome. For example, in a monopoly setup, in addition to a Pigouvian tax, one requires a production subsidy and a lumpsum tax in order to implement the first best outcome. Second, the result that under a monopoly framework there is over-internalization of pollution externalities so that the optimal tax could be less than marginal damages, carry over to the oligopolistic framework, as long as the market structure is exogenous. However, if the market structure is endogenous, then, in some cases, the optimal tax could be greater than the marginal damage. Third, there are interesting implications for the emission trading permit program. For example, it has been shown that if the product market is competitive then an emissions trading program could reduce welfare. Fourth, a larger emission tax may increase industry profits and concentration, rather than reduce them. Fifth, an oligopolistic framework has also been very fruitful in analyzing environmental R&D by firms. For example, the literature has made good progress in identifying the optimal policy mix between emission tax and subsidy on environmental R&D under different market conditions, etc.

\textsuperscript{14}In the literature survey (chapter 2) I provide a more detailed discussion of these results.
1.3 An Overview of the Issues Addressed in this Dissertation

In my study I want to analyze some issues regarding the linkage between environmental policy, market structure and the various inefficiencies associated with environmental policies.

I plan to examine this linkage using a model of joint venture formation in a dirty product, where the decision regarding whether to form a joint venture or not is endogenous to the model. My choice of this particular framework is motivated by the growing importance of joint ventures in recent years, especially in the less developed countries (LDCs). Since the 1980's many LDCs have been following a policy of domestic liberalization. One of the main goals behind such policies is to attract foreign multinational companies (MNCs) to invest in the domestic economy. So as a vehicle for such foreign participation, joint ventures are of great importance to policy makers in LDCs. On the other hand, in the recent debates over the move towards greater liberalization in the Uruguay Round of the GATT, the single European market and particularly the NAFTA, some environmentalists raised concerns that globalization may damage the environment.\textsuperscript{15} Thus it seems natural to examine the interaction between environmental policy and joint venture formation.

I consider an industry producing a dirty product comprising two firms that can either form a joint venture, or compete over quantity. The first task is to develop a simple theory of joint venture formation based on synergy

\textsuperscript{15}See the debate between Bhagwati and Daly (1993), as well as the contribution by Low (1992).
and moral hazard. In joint ventures involving foreign MNCs and a LDC firm it has often been observed that the MNC has a better access to technology, management knowhow, capital etc., while the domestic firm has better access to labor, marketing channels as well as a better knowledge of local politics, bureaucratic procedures etc. Thus in a joint venture framework there will be a synergy between the partner firms in the sense that the MNC firm can supply the inputs that it is efficient in, while the domestic firm can supply the inputs that it is efficient in. Similar synergies are reported in case of joint ventures between domestic firms as well. Another important issue in joint ventures is that of moral hazard, in the sense that the level of inputs is not verifiable. Thus it is not possible to write a contract that specifies the amount of inputs to be supplied since both the partner firms will have an incentive to free-ride on the other.

Thus joint venture formation has two advantages over Cournot competition. First, there is the gain due to synergy, and second, by forming a joint venture the firms can avoid the dissipation of rents. However, the moral hazard problem implies that joint venture formation involves some costs as well. Depending on the relative magnitudes of these various advantages and disadvantages there can be either joint venture formation, or Cournot competition.

Production leads to pollution, the level of pollution being monotonically related to the level of output. Since the industry is polluting, the government uses several policy measures (setting an emission standard, emission tax etc.) so as to control the pollution. All these policy measures create a pollution abatement cost, which the firms have to bear. I assume that the stricter the
governmental policy, higher is the abatement cost.

To begin with, in chapter 3, I consider a basic model when the firms are symmetric, there is no environmental R&D and there is no export by the firms.\(^{16}\) I then examine how government regulation and an exogenously given market structure affects the level of pollution. The next question is whether changes in environmental policy can trigger regime switches from joint venture to Cournot competition and vice versa. I then examine the effects of a change in environmental regulation on the level of pollution and output when the market structure is endogenous. I also seek to understand the mechanics behind the regime switch by decomposing the incentive for joint venture formation into its constituent effects. Finally, I perform some welfare analysis where I examine if the first best outcome can be implemented through an appropriate choice of policy instruments.

In the next three chapters I extend my analysis in several directions. The objective here is twofold. First, these extensions allow me to perform a robustness check of the basic results. Second, they allow me to bring into the analysis several elements that are of interest by themselves, e.g. environmental R&D, exports etc.

In the next chapter, i.e. chapter 4, I relax the assumption that the firms are symmetric. I thus assume that the MNC is more efficient compared to the domestic firm. It may be argued that for many international joint ventures this formulation is, in fact, more realistic. The questions analyzed in this chapter are substantially the same as that in the earlier chapter.

In chapter 5, I extend my analysis to allow for the case where the firms

\(^{16}\text{All these assumptions will be relaxed in the subsequent chapters.}\)
can undertake R&D aimed at reducing the emission level. This extension is empirically important because there is some evidence to suggest that firms often respond to environmental changes through R&D, rather than by reducing inputs. For example, in a business survey of the first 200 Fortune 500 companies, Zanetti and Abate (1993) find that big corporations tend to respond to environmental policy measures primarily through technological and organizational innovations, secondarily through re-localizing of plants, and only in a small number of cases by switching inputs.

The basic model is a modification of that used in chapters 3 and 4. Since in this chapter the focus is on R&D, I abstract from the production aspects by assuming that the firms are capacity constrained. Moreover, the cost structure of both the firms are taken to be symmetric. I assume that pollution control takes the form of end-of-pipe treatment i.e. given the technological relation between output and pollution, emission or industrial refuge is treated by the firms before it is released into nature. The purpose of the environmental R&D is therefore to produce more sophisticated technology for the end of pipe treatment of industrial emission.

I first consider the case where there is no spill-over in R&D. In this setup I examine the impact of a change in emission taxes, as well as R&D subsidy by the government on the level of environmental R&D and pollution, both when the market structure is exogenous, as well as when it is endogenous. I then examine if the results obtained so far are robust if spill-over effects are introduced into the analysis. These are followed by the usual decomposition analysis and an examination of some welfare issues.

The next chapter, i.e. chapter 6, is motivated by the ongoing debate on
the strategic aspect of 'ecological dumping' and the widespread apprehension that stringent environmental regulation may damage the competitiveness of the domestic industry. The moves towards trade liberalization (in the Uruguay Round of the GATT, in the Single European Market, and especially in the NAFTA) and the deepening of the existing trade treaties (such as the Maastricht Treaty) have increased the economic interdependence of the countries. Industrial lobbies apprehend that stricter environmental policies and standards would affect the competitiveness of their product in the international markets. Environmentalists are concerned that this would cause migration of the pollution intensive industries to "pollution havens". Moreover, it was feared that an increase in trade would lead to an expansion in consumption and production. This in its turn would cause increased pollution and a greater extraction of scarce natural resources. It was also argued that in the absence of trade policy instruments, national governments would seek to distort their environmental policies as a surrogate for trade policies to gain competitiveness in the international markets. Thus governments could impose a regime of liberal environmental regulation (so called eco-dumping) for fear that tough environmental regulations may damage the competitiveness of their domestic industries and hence reduce their exports. In this debate, however, it is taken for granted that stricter environmental regulations lead to lower exports. I re-examine this assumption in a framework where the market structure is itself endogenous.

In this chapter I extend my analysis to allow for trade by the domestic firms. The basic model is very similar to that used in the earlier chapters. The firms are symmetric, there is no R&D and moreover, the firms can sell
either in the domestic, or in the world market. In the domestic market they face a downward sloping demand function, while in the world market, prices are assumed to be exogenously given. The domestic country is small in the sense that it faces a perfectly elastic demand in the international market. Domestic firms however have some market power in the home country market. There are trade barriers so that foreign firms cannot compete in the domestic market.

I then examine the effects of a change in environmental regulation on the level of pollution, as well as exports, both when the market structure is exogenous, as well as when it is endogenous. I also perform the usual decomposition analysis.

As the discussion so far shows, my study aims to extend the standard environmental policy framework in two respects. First, I move away from the polarized assumption of either perfect competition or monopoly, assuming an oligopolistic market structure instead. Second, I have assumed that the market structure is endogenous, rather than exogenous. While there have been some studies that use an oligopolistic framework to examine this interaction, these mostly assume that the market structure is exogenously given. While an exogenously given market structure may be a reasonable assumption for some markets, in particular if the product is an established one and/or the economy is regulated, such an assumption may be unsuitable for relatively new products, especially if the industry is an unregulated one. Thus an examination of a framework where the market structure is

\footnote{Such a framework is in fact not so common before the 1990's.}

\footnote{The literature survey (chapter 2) provide a detailed description of these studies.}
endogenous is of some interest.

While a detailed description of the results must wait, it may not be out of place to present one particular theme that seems to recur throughout these chapters. I demonstrate that environmental policy may have some non-obvious effects on these variables, like the level of pollution, industry output, the level of environmental R&D, exports etc. For example one of the major results in both chapters 3 and 4 is that an increase in environmental regulation may lead to an increase in the level of pollution. Similarly, in chapter 5, I find that an increase in subsidy on environmental R&D may lead to a decrease in environmental R&D and an increase in the level of pollution. These results arise because in my framework whether a joint venture forms or not is endogenous to the model. Hence changes in environmental policy can cause regime switches from joint venture to Cournot competition, and vice versa. Such regime switches can lead to drastic changes in the levels of various variables and hence the results follow.

Finally, in chapter 7, I provide a re-examination of what I call the Porter hypothesis. The traditional approach to environmental policy consists of comparing the beneficial effects of environmental regulation with the cost that must be borne to secure these benefits. It is out of this cost-benefit approach that the standard trade-off discussed in virtually every environmental economics text book emerges. However, Porter and van der Linde (1995) deny the validity of this approach to the analysis of environmental regulation, claiming it to be an artifact of what they see as a "static mind set" of having neglected innovation. Thus in their view there is no trade off, as it has been observed in many cases that enforcement of environmen-
tal standards not only reduce environmental damage, but also lead to cost efficient product quality.

There appears to be two alternative (perhaps equally valid) ways of formalizing the Porter hypothesis. The first way would be to say that initially firms operate at a point below their production possibility frontier. As a result of environmental regulations firms are forced to move closer to their production possibility frontier, so that the firms production decision becomes more environmentally friendly and less inefficient. This is the interpretation adopted, for example, by Murthy and Kumar (2001) in their paper. The second approach would be to say that firms, given the constraints facing them, are operating on their production possibility frontier. As a result of environmental regulations, however, adopting a new environmentally friendlier technology becomes more attractive. This is the approach adopted by Palmer, Oates and Portney (1995). I follow Palmer, Oates and Portney (1995) in adopting the second approach for my work.

In this chapter I analyze this question in a theoretical framework. I examine conditions under which the Porter hypothesis may, or may not go through. I also examine the consequences of R&D subsidy, as well as stricter environmental regulation on the level of pollution in my framework.

### 1.4 Organization of Chapters

Let me now describe the organization of chapters in the dissertation.

The *Introduction*, i.e. chapter 1, provides a backdrop for my analysis, and also provide an overview of my work in this dissertation. In chapter 2, entitled
Literature Survey, I provide a detailed discussion of the relevant literature. In the next chapter, entitled Environmental Policy and Market Structure, I introduce the basic model where firms are symmetric, and there is neither R&D, nor exports. In chapter 4, entitled The Case of a More Efficient MNC, I consider the case where the firms are asymmetric. In the next chapter, entitled Environmental Policy and R&D, I extend the analysis by allowing for environmental R&D. An extension to the open economy case is taken up in chapter 6, entitled Environmental Policy and Exports. In chapter 7, entitled Revisiting the Porter Hypothesis, I re-examine the theoretical underpinnings of the Porter hypothesis. Finally, chapter 8 concludes.