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**Innovation, Regulation and Environmental Management
in the Chilean and Canadian Pulp and Paper Industries**

by

Brent Herbert-Copley

A thesis submitted to
the Faculty of Graduate Studies
in partial fulfilment of
the requirements of the degree of

Doctor of Philosophy

Department of Political Science

Carleton University
Ottawa, Ontario
18 December 1998

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**INNOVATION, REGULATION AND ENVIRONMENTAL MANAGEMENT IN THE
CHILEAN AND CANADIAN PULP AND PAPER INDUSTRIES**

submitted by

Brent Herbert-Copley, B.A. Hons., M.A.

in partial fulfilment of the requirements
for the degree of Doctor of Philosophy

Chair, Department of Political Science

Thesis Supervisor

External Examiner

Carleton University
December 18, 1998

Abstract

Policy instruments to control industrial pollution are all based — implicitly or explicitly — on an assumption that public policy can alter the extent and direction of technological change, whether by promoting the diffusion of existing technologies, by encouraging the development of new technological solutions, or by inducing firms to undertake incremental improvements to existing technologies. But while there is widespread expectation that regulations can provide a stimulus to innovation, the empirical evidence is scarce.

In light of this situation, this thesis undertakes a comparative study of the links between environmental regulation and innovation in the pulp and paper industries in Canada and Chile. Comparison of the two cases allows us to examine the situation of firms in regulated and less-regulated environments, and also to examine the ways in which other, non-regulatory factors affect corporate environmental behaviour.

The thesis develops a conceptual model of firm-level environmental behaviour, emphasizing the ways in which behaviour is shaped by the structural features of the industry, the nature of regulatory and other pressures facing firms, and the historically-shaped “habits and practices” of firms themselves. It then applies this model to the two cases, focusing on three main issues:

- the nature of environmental strategies and investments pursued by firms in response to environmental pressures;
- the way in which non-regulatory factors (ownership, export orientation, internal characteristics) mediate the impact of environmental regulations; and,

- the extent to which regulations work to spur a process of innovation in the industry and its supplier networks.

Based on empirical analysis of firms in Canada and Chile, the thesis concludes that regulations are effective in promoting the diffusion of existing technologies for pollution abatement and control – and to some degree in stimulating incremental improvements in performance. But the extent to which they stimulate more far-reaching innovations is limited: especially in a mature, supplier-dominated industry like pulp and paper, the ability of policy-makers to stimulate innovation as a result of environmental regulations is extremely limited. In fact, the key relationships seem to go the opposite way: strengthening the innovative capabilities of industry and the domestic supply base is important to ensure strong environmental performance.

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The original idea for this thesis grew from a series of research projects sponsored in the early 1990s by my employer, the International Development Research Centre (IDRC),

dealing with industrial restructuring in Latin American industry. From that time forward, IDRC has been supportive of my own research efforts, and provided me with a study leave to carry out some of the field work and analysis contained in this thesis. As always with work at IDRC, I have benefitted from interaction with researchers in a variety of countries, whose own work has stimulated my interests and enriched my analysis.

Finally, I am indebted to my wife, Mary, and my sons Drew and Taylor, who have patiently accepted the extra burdens placed on family life by this project, and have remained a constant source of encouragement. As in everything, it is they who are the true inspiration for this thesis.

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List of Acronyms

adt	air-dried tonnes
AOX	adsorbable oxygenated halides
ATCP	Asociación Técnica de la Celulosa y el Papel [Technical Association for Pulp and Paper] (Chile)
BOD	biochemical oxygen demand (also expressed as BOD ₅ or BOD ₇ to designate time-period of measurement, in days)
BTU	British thermal units
CAC	"command-and-control"
CAD	Canadian dollars
CEPA	Canadian Environmental Protection Act
CFCs	chlorofluorocarbons
COD	chemical oxygen demand
CONAMA	Consejo Nacional del Medio Ambiente [National Council for the Environment] (Chile)
CONICYT	Consejo Nacional de Ciencia y Tecnología [National Council for Science and Technology] (Chile)
COREMAs	Consejos Regionales del Medio Ambiente [Regional Councils for the Environment] (Chile)
CORFO	Corporación de Fomento de la Producción [Development Corporation] (Chile)
CORMA	Corporación de la Madera [Forest Industry Association] (Chile)
CPPA	Canadian Pulp and Paper Association
CTMP	chemi-thermo-mechanical pulping
DGTMMYMM	Dirección General del Territorio Marítimo y Marina Mercante [Directorate for Maritime Territory and Merchant Marine] (Chile)
ECF	elemental chlorine free
EIA	environmental impact assessment
EPA	Environmental Protection Agency (United States)
gal	gallons
IFC	International Finance Corporation
INFOR	Instituto Forestal [Forestry Institute] (Chile)
INN	Instituto Nacional de Normalización [National Standards Institute] (Chile)
INTEC	Instituto Nacional de Investigaciones Tecnológicas [National Institute for Technological Research] (Chile)
ISO	International Standards Organization
kg	kilogram
MBI	market-based instruments
NGO	non-governmental organization
OECD	Organization for Economic Cooperation and Development
PACE	pollution abatement and control expenditures
Paprican	Pulp and Paper Research Institute of Canada
PCBs	polychlorinated biphenols
PPMP	Pulp and Paper Modernization Program (Canada)

R&D	research and development
RMP	refiner mechanical pulping
SGW	stone groundwood
SIC	Standard Industrial Classification
SOFOFA	Sociedad de Fomento Fabríl [Association of Manufacturers] (Chile)
SSS	Superintendencia de Servicios Sanitarios [Superintendent of Sanitary Services] (Chile)
TCF	total chlorine free
TFP	total factor productivity
TMP	thermo-mechanical pulping
TRS	total reduced sulphur
UNCTAD	United Nations Conference on Trade and Development
UNCTC	United Nations Center on Transnational Corporations
UK	United Kingdom
US	United States
USD	United States dollars
VOCs	volatile organic compounds

Chapter I: Introduction

1. Background and Problem Statement

Over the past decade, increasing environmental concerns have resulted in pressures to strengthen regulations governing industrial pollution in both industrialized and developing countries. Governments have responded with increasingly stringent pollution standards, tightened environmental impact assessment requirements for new investments, improved monitoring and enforcement capabilities, and, in some cases, experiments with market-based alternatives to direct regulation such as deposit-refund schemes, pollution charges, and tradeable emissions permits. Pressures to strengthen environmental policies have gained force in part because of the trend toward trade-related environmental measures: "side agreements" on environmental standards in regional trade agreements such as NAFTA, product labeling and certification programs in many industrialized countries, and the prospect of the inclusion of environmental issues in future multilateral trade negotiations. In developing countries, donor agencies have increasingly placed environmental conditions on lending, in particular by insisting on environmental impact assessments for new projects.

As a result, developing countries in particular are under considerable pressure to strengthen legal frameworks for control of industrial pollution. But the likely impacts of such changes remains unclear, due to our limited understanding of the way in which environmental policies affect the environmental and competitive performance of firms. This is particularly true in terms of the linkages between environmental regulations and innovation.

Policy instruments to control industrial pollution are all based — implicitly or explicitly — on an assumption that public policy can alter the extent and direction of technological change in industry in one or more of the following three ways:

- by promoting the **diffusion of existing technologies** for the reduction and/or control of pollution within the targeted industry;
- by encouraging the **development of new technological solutions**, either by regulated firms or by outside technology suppliers; or,
- by inducing regulated firms to make more limited, **incremental innovations** in their products or production processes in order to improve the firms' environmental performance.¹

In recent years, a number of influential observers have argued that environmental regulations can play a significant role in promoting innovation, resulting not only in environmental improvements but also enhanced competitiveness of regulated firms and industries (Porter, 1991; Porter and van der Linde, 1995). Based on this kind of analysis, some authors have gone so far as to call for the development of an “innovation-driven environmental policy”, in which the enhancement of technological change becomes “the central mission of environmental policy” (Banks and Heaton, 1995, 43). The prospect of this kind of “win-win” relationship between environmental

¹ Environmental policy may also provide incentives to shift the overall structure of industrial production to less-polluting activities. This thesis is concerned with efforts to reduce pollution **within** a given industrial branch (which may include significant product innovations) rather than with shifts in the distribution of output **among** branches. Even in the case of policy measures geared at inducing shifts in the structure of production, however, technological change still plays a central role.

protection and innovation is particularly salient given increasing recognition of the importance of innovation and learning as key determinants of competitiveness at both the firm and national levels (Dosi et al, 1988; OECD, 1992; Ernst, Mytelka and Ganiatsos, 1998; Edquist, 1997). If regulations promote more innovative behaviour on the part of targeted firms and industries, then there may be scope to achieve simultaneous improvements in the economic and environmental performance of industrial firms in developing countries.

In fact, however, the link between environmental regulation and innovation is far from clear-cut. Two sets of doubts can be raised, both of which argue for a measure of caution in framing environmental policies on the expectation of producing a significant stimulus to innovation.

In the first place, much of the existing literature on regulation asserts that the innovative stimulus provided by environmental regulations is limited, and is primarily oriented toward "end-of-pipe" pollution control measures rather than more far-reaching internal process changes. Empirical analysis of the links between regulation, environmental management and innovation has so far been limited. The existing literature is largely theoretical in nature, and as will be pointed out in the next chapter, suffers from a number of weaknesses which make it difficult to draw reliable policy conclusions. Nonetheless, there are significant doubts about the extent to which regulation can be counted on to promote the kinds of far-reaching product and process innovations needed in order to ensure significant improvements in environmental performance in many industrial branches.

Second, increasing number of observers suggest that regulatory pressures are **not** the

only — or even the most important — determinants of firms' environmental performance. Particularly in developing countries with relatively weak regulatory frameworks, the environmental behaviour of firms may be strongly influenced by the market orientation of these firms (the extent to which they export to more environmentally-demanding Northern markets) and/or by ownership of firms (with multinational corporations basing their environmental management decisions on company-wide standards and practices rather than tailoring environmental practices to domestic environmental regulations). To the extent that improvements in environmental performance are motivated by these kinds of firm-specific factors and not simply by compliance with regulations, then the links between environmental regulation and innovation are more complex.

Understanding these relationships is important to policy-makers in industrialized and developing countries, in order to assess the optimal design, timing, and balance of policies — not only regulatory policies, but complementary industrial and innovation policy measures as well. Those responsible for environmental policies need to understand the extent to which their actions may have dynamic benefits in spurring innovation, and also the extent to which non-regulatory factors can promote environmental improvements even in the absence of strict environmental regulations — or at least can alter the nature of environmental strategies pursued by firms.

In response to this gap, this thesis carries out a comparative analysis of the environmental performance of pulp and paper firms in Canada and Chile. The pulp and paper industry has been chosen because it is one of the most polluting of all industrial branches, whether measured in terms of toxicity indices or average levels of pollution abatement costs. Because of this, pulp producers have faced increasing pressures not

only from formal government regulations, but also as a result of consumer pressures and market restrictions like eco-labelling programs.

The two countries provide an interesting basis for comparison. Canada is a leading pulp and paper producer with a well-established industry and a relatively stringent framework of environmental policies. Of particular note are new regulations at the federal and provincial level which entered into force at the beginning of this decade, and resulted in tighter standards for liquid effluents, and less scope for exceptions.

Aggregate data suggest that the industry as a whole has adapted to new regulations by investing heavily in pollution reduction/control, with effluent levels falling dramatically; this thesis represents one of the first opportunities to go beyond these aggregate data and assess the impact of the regulations on individual firms. Chile, meanwhile, is a smaller but rapidly-growing pulp and paper producer, with a significant and increasing share of production destined for export markets. Domestic regulations are weaker than in Canada, but environmental pressures in key export markets are seen as a critical factor. A number of new, export-oriented pulp mills have been constructed in recent years, and secondary evidence suggests these are relatively up-to-date by international standards in terms of their environmental design and performance.

2. Research Design

The thesis argues that the links between environmental regulation and innovation need to be understood on the basis of a framework in which the internal characteristics of the firm and the industry, the competitive environment in which firms operate, and the nature of the regulatory process all influence the strategies of firms. The overall objective of the thesis is to examine the way in which environmental regulations affect

the process of innovation in a specific industrial branch like pulp and paper, and the way this impact is mediated by other, non-regulatory influences on corporate environmental behaviour.

In order to address this general issue, the thesis examines three more specific research questions:

- What kinds of strategies do firms adopt in response to environmental pressures, and what kinds of investments do they undertake in order to improve their environmental performance?
- How is the impact of regulations mediated by other factors? What are the principal factors which influence firms' investments in improved environmental performance? What explains the varying strategies they pursue, and their relative success in meeting environmental targets?
- To what extent do environmental regulations spur a process of innovation, stimulating firms to develop and/or adopt novel means of meeting environmental targets, and encouraging them to make ongoing improvements to existing plant and equipment?

The thesis examines the nature of regulatory and non-regulatory factors affecting the industry in the two case-study countries, and the broad patterns of response by firms and suppliers. In each country, the thesis explores the balance between end-of-pipe pollution control technologies and broader process changes, and between major investments and incremental "housekeeping" measures. In the case of Canada a primary issue of concern is the factors which have induced some firms to go beyond

regulatory requirements by investing in broader process changes as well as “end-of-pipe” controls. In Chile, a key question is whether environment-related measures have been limited to new, export-oriented firms, or have also extended to older mills and those producing for domestic and regional markets. The thesis then examines the extent to which efforts to improve environmental performance have led to the development of new technologies and/or the strengthening of innovative capabilities of firms or suppliers, and the ways in which other, complementary policies have helped to promote or retard innovation. Particular emphasis is placed on the way in which structural features of the pulp and paper industry (price-based competition; low levels of innovation; dominance of outside technology suppliers) affect the scope for innovation in response to environmental pressures.

in order to address these issues, the thesis develops a conceptual model of firm-level environmental behaviour, and applies it to study firm- and mill-level variations in environmental behaviour in the two countries. The model permits analysis of the way in which firms’ patterns of response vary depending on:

- actual and anticipated levels of regulatory burden;
- ownership;
- export orientation;
- age and scale of mills; and,
- the internal resources and capabilities of firms to effect change (levels of R&D spending; commitment to corporate environmental management; linkages to

outside sources of technology and expertise).

Throughout the analysis, emphasis is placed on the way in which current patterns of response are shaped by past habits and practices of the firm.

Three approaches are used to isolate the impact of regulations from other factors. First, the performance of Canadian firms and mills prior to and following the entry into force of new regulations in the early 1990s is assessed, to provide a “before/after” comparison. Second, matched sets of firms in Canada and Chile are compared in order to provide a “with/without” comparison between more- and less-regulated environments. Third, analysis also examines the extent to which more stringent regulations in some Canadian provinces have affected environmental behaviour of firms.

The thesis is based primarily on surveys of senior company officials in the two countries. In the case of Chile, a series face-to-face interviews and site visits to individual mills was conducted in the spring of 1996. Interviews were conducted with representatives of six of the seven major pulp and paper firms in the country, and focused on six mills which together account for over 50 percent of pulp production in the country, and 90 percent of newsprint production. Interviews were conducted using a standardized interview guide, and concentrated on three issues: the nature of environmental improvements carried out at respondent mills between 1990 and 1996 (or, in the case of newer mills, environmental measures included in the original project design); motives for environment-related investments, and overall corporate attitudes toward environmental management and environmental regulation; and, sources of technology for environmental improvements, and the impact of recent changes on the innovative capabilities of firms and the industry as a whole. The results of this survey were

supplemented by interviews with outside observers (industry associations, consulting companies, NGOs, suppliers, regulatory officials, representatives of other government departments), and review of available secondary information.

Given the much larger number of pulp and paper firms in Canada, research on the Canadian industry relied on a mail survey of senior officials (Vice-President Environment or equivalent) rather than face-to-face interviews. The survey instrument covered the same three issues as that used in Chile, but with a more explicit focus on the ways in which firms had responded recent changes in environmental regulations (notably changes to the Canadian Environmental Protection Act and the Fisheries Act introduced in 1992). Questionnaires were mailed to the head offices of all pulp and paper mills subject to these acts, and consisted of a series of questions dealing with corporate environmental policies and attitudes toward regulation (completed on a corporate basis) followed by a one-page summary of recent investments at respondent mills (completed on a mill-by-mill basis). Questionnaires were administered in the fall of 1997, and elicited responses from 34 firms (48% of the total sample) representing 56 mills (again, 48% of the sample).

As in the Chilean case, survey data was supplemented by review of available secondary documents, and by interviews with outside observers (industry association representatives; representatives of supplier firms, engineering companies, and research bodies; and representatives of government agencies). In addition, follow-up interviews were carried out with representatives of a small number of respondent firms in order to probe the survey results in more detail and gain insights into the patterns of response at individual firms and mills. Finally, interview data was integrated with other data on effluent levels at respondent mills — both prior to the entry in force of the new

regulations and after. For the former data, estimates of mills' environmental performance circa 1988, prepared as part of a 1990 background study of the likely economic impact of the proposed changes to federal regulations, were used (McCubbin et al, 1990); for the latter data, Environment Canada compliance data for 1996 were used. In this way, the thesis was able to assess the way in which differing firm- and mill-level characteristics are linked not only to levels and patterns of environmental investment, but also to absolute levels of environmental performance, and to relative changes in environmental performance since the entry into force of new regulations.

Significance and Limitations of the Research

The significance of this thesis derives from a number of factors. In the first place, it fills a gap in existing policy analysis in both countries. Despite the rapid growth of the pulp and paper industry in Chile, there has been relatively little analysis of the environmental performance of the industry, and none which deals in detail with the differing environmental management strategies of firms and the reasons for variance among firms. A number of studies have analyzed the environmental consequences of Chile's export boom, including forest product exports (Gomez-Lobo, 1992; Meller, O'Ryan and Solimano, 1996; Scholz et al, 1994) but in no case is there detailed analysis of the situation of individual firms, nor do the studies focus on the links between environmental performance and innovation. Available studies of innovation and competitiveness in the Chilean pulp and paper industry have almost completely ignored the environmental variable as a factor in the decision-making of firms (Bercovich and Katz, 1997; CEPAL, 1995). Understanding the links between regulation, environmental management and innovation in Chilean pulp and paper firms is particularly critical at present, given

pressures on the Chilean government to sustain the pace of export-oriented industrialization while at the same time continuing recent efforts to strengthen environmental policy.

In Canada, this thesis represents one of the first attempts to understand the impact of recent regulations on the environmental performance of firms and on the process of innovation in the industry. Aggregate data from both industry and government sources indicate that the industry as a whole has adapted quickly to the tightened regulatory requirements of the 1990s: overall effluent levels have fallen dramatically, and practically all mills have complied with the requirements of the new regulations. But there is as yet no detailed analysis of the ways in which patterns of response have varied across firms, or the broader impact of regulations on innovation and technical change in the industry. This is particularly important given that the 1992 regulations represented a watershed in regulatory policy and practice in Canada, involving not only more strict regulatory limits, but also tightened timetables for compliance and reduced scope for exceptions. Understanding this experience thus has broader implications for overall industrial environmental policy in the country, even beyond the pulp and paper industry. While a number of existing studies examine the impact of earlier regulatory experiences in the industry (Sinclair, 1991) or the process of development of the 1992 regulations (Stanbury, 1993), this thesis is the first analysis of the impact of the 1992 regulations on individual firms in the industry.

At a more general level, the thesis should help to advance understanding of the factors governing environmental management decisions by firms, and the impact of environmental regulation on innovation. As noted above, empirical analysis of these relationships remains rare, and our understanding continues to be based in large

measure on theoretical arguments. Not only does this thesis provide additional empirical data on a key industrial sector, it introduces two elements of analysis missing from most existing studies. First, it is one of the few studies which undertakes comparative analysis of firm-level behaviour in jurisdictions characterized by differing levels of regulatory stringency. By studying roughly-similar firms (in terms of size, age and product lines) in Chile and Canada, the thesis goes beyond the kind of insights available in single-country studies of regulatory impacts. While this kind of “with/without” analysis is subject to a number of constraints (see below), it provides a useful complement to more straightforward “before/after” analysis of individual country experiences. By comparing firm-level experiences in the two countries in approximately the same period (circa 1990-96), the analysis is able to minimize the impact of cyclical shifts in the industry as a whole, which can be a problem in longitudinal studies of individual groups of firms.

Second, access to good primary and secondary source data on Canadian firms has permitted additional analysis not usually possible in studies of regulatory impacts. Existing studies tend to focus on a single parameter to assess the environmental performance of firms (either pollution abatement expenditures or, where available, data on effluent levels). In the case of this thesis, survey data on environmental expenditures have been matched with additional mill-level data on effluent levels, and on relative changes in effluent levels since the entry into force of new regulations. Thus, the thesis is able to assess the way in which firm- and mill-level characteristics affect levels and patterns of environmental investment by firms, absolute levels of environmental performance, and relative changes in environmental performance compared to pre-regulatory levels. In addition, data on anticipated costs of compliance have allowed a

more sophisticated analysis of the regulatory burden facing individual firms than is the case in most existing studies, which generally either assume uniform regulatory pressures on firms across the industry, or use other variables — such as age of mills — as proxies for relative regulatory burden. This kind of aggregate analysis, meanwhile, is enriched in this thesis by case-studies of individual firms and mills, as a means of probing relationships in more detail.

Finally, the thesis develops a conceptual model to understand the interactions between environmental regulation, innovation, and the overall competitive situation of firms. In doing so, it integrates strands from a number of bodies of literature. In particular, the thesis draws on evolutionary analysis of the process of innovation and technical change, to develop a model emphasizing the historically-bounded nature of firms' decisions, and the importance of interactions between the firm and outside actors (parent/partner firms; competitors; equipment suppliers; regulatory agencies). The model also integrates political economy considerations absent from most analyses of environmental regulations, depicting firms as strategic actors who do not simply respond to environmental pressures, but also help to shape the nature of those pressures. While this model is still crude, it provides an approach to understanding the key relationships which goes beyond the simplified models of firm-level behaviour characteristic of much of the literature.

At the same time, there are a number of limitations on the research which should be mentioned. First, the research deals with only one aspect of the overall environmental challenge facing pulp and paper production. It concentrates on mill-level pollution reduction and control measures, with particular focus on measures to reduce or improve the quality of liquid effluents, and does not deal with upstream forest management

issues, nor with downstream product disposal and recycling. While these concerns are central to the longer-term sustainability of paper production, they are beyond the scope of this project. Second, the level of detail available in the two countries is uneven, and as a result comparative analysis is more limited than originally hoped. In particular, comprehensive data on levels of environment-related spending and on environmental performance (effluent levels) are not available for Chilean mills, and research has instead relied upon more qualitative assessment of corporate attitudes and behaviour. In part, this reflects the small number of pulp and paper firms in Chile (which makes aggregate analysis of data difficult). Future analysis would be enriched by being able to make more explicit comparisons of environmental performance of firms in the two countries. Nonetheless, firms in Chile were for the most part willing to discuss the nature of their environmental activities, and the analysis generated sufficient insights to permit useful comparison across the two countries. Finally, while brief case-studies of individual firms' experiences are included in this thesis, time and resources did not permit more detailed study of individual mills. As will be discussed in the final chapter, one promising direction for future research is more in-depth case-study to assess the ways in which the overall innovative behaviour of firms affects their response to environmental pressures.

3. Outline of the Thesis

The next chapter reviews the literature on environmental regulation and innovation. It outlines the "conventional wisdom" emerging from theoretical analyses, and contrasts this with the picture emerging from more recent empirical analysis. This is followed by a consideration of some of the weaknesses of the existing literature, in particular its

limited conception of both the regulatory process and the nature of innovation in regulated firms, and its relative neglect of non-regulatory factors (ownership, market orientation) influencing the motivations of firms to engage in environment-related investments. Based on this review of the literature, the chapter proceeds to develop a conceptual framework to analyze the strategic behaviour of firms in response to environmental pressures, and the extent to which decisions by firms contribute to the strengthening of innovative capabilities within individual firms or in the industry more broadly. Firms' decisions with regard to environment-related investments are conceptualized as a product of three sets of factors: the internal resources and capabilities available to the firm ("means"); the market and regulatory incentives for environmental investments ("motive"); and the range of technically- and economically-feasible alternatives open to the firm in order to improve its environmental performance ("opportunities"). The chapter concludes by outlining the main research hypotheses to be examined in the remainder of the thesis.

Chapter 3 deals with the third element in the explanatory framework introduced in Chapter 2: the range of opportunities available to firms to improve their environmental performance. It outlines the main environmental challenges facing pulp and paper producers, and the ways in which these have come to dominate the overall process of technological change in the industry over the past two decades. At the same time, it argues, firms' responses to environmental challenges have been and continue to be shaped by some of the basic structural conditions of the industry –notably its scale-intensity, the prevalence of price-based competition, and the dominance of outside technology suppliers. The chapter concludes by examining the main technological options open to firms to reduce mill-level pollution, emphasizing the way in which the

costs and benefits of particular options are influenced by the conditions of individual mills.

Chapters 4 through 7 present the results of empirical research, dealing first with the Canadian experience, and then with the Chilean industry. Chapters 4 and 6 provide an introduction to each case, by outlining the other elements in the explanatory framework outlined above — the “means” available to firms to respond to environmental challenges, and the “motives” which shape their choices. In each case, the chapter provides a brief overview of the historical evolution of the pulp and paper industry, focusing in particular on the sources and directions of technological change in the industry and the technical resources available both in-house and within support institutions and supplier industries. This is followed in each case by a discussion of the evolution of environmental regulations facing the pulp and paper industry. The chapters discuss the ways in which the industry has intervened to help shape the nature of these regulations, and the nature of non-regulatory factors (especially market factors) shaping firms’ decisions.

Chapters 5 and 7 present the main empirical findings of research. Chapter 5 outlines the results of a mail survey of Canadian firms carried out in the fall of 1997, as well as follow-up interviews conducted in mid-1998. Chapter 7 summarizes the survey carried out in early 1996 in Chile, covering six of the seven principal pulp and paper firms in the country. In each case, the chapter concentrates on three main issues: the nature of environmental investments at pulp and paper mills between 1990 and 1996; the motives of firms for undertaking environmental improvements; and, the extent to which environmental challenges have resulted in development and diffusion of new technologies within the industry, and/or have strengthened overall technological

capabilities in respondent firms and outside technology suppliers. Chapter 7 also presents a brief comparative analysis of the situation of match pairs of Canadian and Chilean mills, in order to contrast performance in more- and less-regulated environments.

Chapter 8 summarizes the results of the preceding chapters and draws some general lessons for environmental and industrial policy, as well as for future research. It focuses in particular on strategies for reform of environmental policies facing the sector, outlining the differing policy instruments and approaches appropriate to the two country contexts. It also discusses the link between environmental and industrial policy, and the ways in which complementary industrial policies may help spur innovative outcomes in response to environmental pressures.

Chapter 2: Environmental Regulation and Innovation — Literature Review and Conceptual Framework

I. Introduction

The potential role of environmental regulations in promoting innovation has long been recognized. In a 1975 study, for example, Allen Kneese and Charles Schultze (1975, p. 82) argued that “Over the long run, perhaps the most important single criterion on which to judge environmental policies is the extent to which they spur new technology toward the efficient conservation of environmental quality.”

Despite this recognition, there is surprisingly little research examining the nature of this link between regulation and technological innovation in specific countries and sectors. Research on the technological implications of environmental regulation has been overshadowed by concerns for the static efficiency of particular policy instruments, and (to a slightly lesser degree) the political and administrative feasibility of applying such instruments (Kemp, 1995, 24). The literature which does exist is largely theoretical in nature, with a body of empirical evidence on the link between regulation and innovation only beginning to emerge over the past decade. And as was pointed out in the previous chapter, existing analysis suffers from a number of limitations which reduce its usefulness as a guide to understanding the specific cases of concern in this thesis.

This chapter begins by reviewing the literature on environmental regulation and innovation. It outlines the “conventional wisdom” emerging from theoretical analysis, and then contrasts this with the picture emerging from more recent empirical studies. Section III then proceeds to review some of the shortcomings of existing studies, and in

doing so outlines three broad concerns which need to be considered in conceptualizing the links between regulation and innovation:

- the nature of innovation in regulated firms. Here, the emphasis is on innovation as a process of learning and capability accumulation, in which incremental improvements in performance are considered alongside major technological advances and incorporation of new technology and equipment. Firms' responses to changes in policy or market incentives are conditioned by their past habits and practices, as well as by the nature of linkages between firms and other actors (parent and partner firms, competitors, R&D institutions, outside equipment suppliers).
- the nature of the regulatory process. Firm-level responses are influenced not only by the choice of policy instrument, but also by the ways in which specific instruments are developed and applied. Moreover, firms do not simply react to a set of exogenously-defined regulatory pressures, but instead individually and collectively influence the nature, timing and enforcement of regulations. As a result, it is critical to understand the political economy of regulation, and the ways in which power relationships among firms and between firms and regulators shape regulatory requirements and responses.
- non-regulatory influences on firms' behaviour. While much of the existing literature glosses over distinctions among firms, in fact there is considerable heterogeneity in firms' responses to a given set of regulatory pressures. Three factors are of particular importance in explaining inter-firm differences: the internal resources and innovative capabilities of the firm; the market orientation

of the firm (particularly levels of exports to environmentally-demanding markets); and, the influence of parent or partner firms — particularly in the case of foreign-owned subsidiaries or joint ventures.

Based on these considerations, Section IV then outlines a conceptual framework for the study. The emphasis is on understanding the strategic behaviour of firms in response to environmental pressures, and the extent to which decisions by firms contribute to the strengthening of innovative capabilities within individual firms or in the industry more broadly. Firms are viewed as historically-bounded agents, and their decisions with regard to environment-related investments are conceptualized as a product of three sets of factors: the internal resources and capabilities available to the firm (“means”); the market and regulatory incentives for environmental investments (“motive”); and the range of technically- and economically-feasible alternatives open to the firm in order to improve its environmental performance (“opportunities”). The chapter concludes by outlining a series of hypotheses which will be used to guide the analysis in subsequent chapters.

The insights which can be generated by this kind of complex framework are of necessity somewhat tentative and qualitative, particularly in comparison with the more restrictive — but statistically rigorous — models characteristic of much of the literature. But as the next section of this chapter argues, the limitations on our current understanding of the way regulation affects innovation are due in large measure to the dominance of theoretical arguments over empirical evidence, and to the methodological simplifications demanded by “rigorous” analysis of empirical data. In this context, the analysis in this thesis is best viewed as a complement to existing theoretical and empirical studies. It is intended to describe the complexity of the relationship between regulation and

innovation, to provide some initial empirical evidence regarding particular aspects of this relationship, and to point the way to additional analysis which is beyond the scope of the thesis itself.

II. Environmental Regulation and Innovation: A Brief Literature Review

This section of the chapter begins by setting out the “conventional wisdom” regarding the links between environmental regulation and innovation, as it emerges from mainstream environmental economics theory. It then discusses some of the limitations of this theoretical analysis, and the relative paucity of empirical analysis to back up — or challenge — theoretical positions. This is followed by a brief overview of existing empirical studies, focusing both on case-study evidence and on aggregate analysis. Not only are empirical studies infrequent, but those which do exist present a number of conceptual and methodological weaknesses which reduce their utility as a guide to understanding the ways in which regulations affect innovation.

a) Theoretical Analysis

The central theme of most theoretical literature on regulation and innovation is the impact of alternate policy **instruments**. In particular the literature has focused on the choice between traditional command and control (CAC) measures like effluent limits or restrictions on the use of polluting products and technologies, and market-based instruments (MBIs) like pollution charges, deposit-refund schemes, and tradeable permits.¹ Analysis of the impact of differing degrees of regulatory **stringency** are more

¹ Writers such as Hahn (1993) choose to refer to CAC regulations as “quantity-based” measures, and MBIs as “price-based” measures, recognizing that even quantitative limits on pollution do at least indirectly change the “market” for pollution and pollution control technologies.

rare. The “MBI vs CAC” issue is not of direct concern for this thesis, since policy instruments in use in the pulp and paper industry in Canada and Chile are entirely of the command-and-control variety, other than some tax incentives for investments in new machinery and equipment. Nonetheless, it is worth summarizing the literature on alternative policy instruments since it sets out the “conventional wisdom” regarding the impact of regulations on innovation.²

The essence of this conventional wisdom is two-fold. **First**, at least in comparison to MBIs, command and control regulations provide a relatively weak stimulus to innovation. **Second**, to the extent that regulations do spur the development of new technologies, these are likely to be end-of-pipe control technologies, rather than less-polluting process technologies. End-of-pipe solutions are viewed as inferior both on environmental grounds (they tend to displace environmental effects rather than eliminating them — as, for example, with effluent treatment technologies which reduce liquid effluents, but create new challenges in terms of disposal of potentially toxic solid wastes), and in terms of their economic effects (they represent an additional cost to firms, but do not permit cost savings or improved competitiveness through reduced waste, input substitution, or re-design of products). Regulations may in fact retard the process of innovation, since they are likely to redirect R&D resources toward “compliance-oriented”

² See Kemp (1995, 24-55) for an excellent review and critique of the theoretical literature on the impact of alternative policy instruments on innovation. For statements of the mainstream preference for MBIs over CAC regulation, see Environment Canada (1992); or OECD (1992). Teitenberg (1997) argues that in addition to the distinction between MBIs and CAC regulations, attention also needs to be placed on “information-based” policies, which attempt to control pollution by ensuring better public information about the extent of pollution problems (e.g., product certification programs, pollutant release inventories, labelling). This thesis does not pay direct attention to these types of measures, although there is some discussion of public participation in environmental assessment proceedings, and to the impact of labelling practices in foreign countries as an influence on the environmental behaviour of exporting firms.

activities, and away from more “productive” product and process innovations.

The theoretical basis for such claims is relatively straightforward, provided a number of simplifying assumptions are made regarding the availability of information, the speed of adjustment, and the nature of pollution problems themselves. Regulations provide an incentive to innovate (or to adopt new technologies) only up to the point at which a particular standard has been met; beyond that point there is no incentive to action by the regulated firm unless the standards themselves are revised upward. By contrast, market-based incentives provide a continuing incentive to innovation by firms, since any reduction in pollution should in theory result in increased revenues or reduced costs to the firm.

Moreover, regulations constrain firms’ choices in terms of the nature and timing of environmental expenditures (in comparison to market-based incentives which provide discretion to firms in terms of the type of environmental measures to be undertaken and the speed of adjustment) and as a result are likely to bias firms toward end-of-pipe control technologies. This is particularly true of so-called “technology-based” standards, which mandate use of a particular control technology (catalytic converters for automobiles, for example). Even in the case of “performance-based” standards which specify quantitative limits on levels of pollution, however, the same result may hold. Levels of performance-based standards are typically set on the basis of “best-available” control technologies: given relatively short time-frames for compliance and the lengthy period needed to develop alternative process technology, firms may have little choice but to adopt such control technologies in order to meet mandated levels of performance. In addition, as Kemp (1995, 69) points out, process-integrated technologies generally imply greater sunk costs, since their use requires the replacement of existing production

facilities — as opposed to control technologies which can be installed without major changes in production processes. Given relatively short timetables for compliance with performance standards, this may swing cost-benefit calculations in favour of end-of-pipe solutions, despite longer term competitive advantages of process-integrated technologies.

In fact, however, the assumptions on which these conclusions are based can be challenged on a number of fronts. The notion that MBIs will promote the development and adoption of more efficient technical solutions depends critically on assumptions regarding the availability of information to firms on the nature of environmental problems and the likely impacts of alternative control methods, which may not hold in practice. The preference for MBIs frequently rests on shaky assumptions regarding the administrative feasibility of alternative policy instruments: while MBIs may require less enforcement effort than CAC regulations, they require significant amounts of up-front information and effort to ensure that taxes/charges are set an appropriate level (see O'Connor, 1995). As a result, complex market-based control schemes may be beyond the grasp of regulatory agencies (particularly in developing countries) where there are significant information asymmetries between firms and regulators. And even if we accept these kinds of simplifying assumptions, the preference for MBIs may not hold in cases where the speed of pollution reductions is critical, where location matters,³ or where there are thresholds which pollutants cannot be allowed to exceed. In these cases, command-and-control regulations may in fact produce more effective pollution reduction than market-based alternatives.

³ Teitenberg (1995, 110) argues that the case in favour of economic instruments is less clear where the location of emissions matters, since firms will have incentives to reduce pollution where it is most efficient to do so, rather than where pollution problems are most acute.

b) Empirical Studies

Beyond these theoretical shortcomings, the fact remains that there is still relatively little empirical evidence to back or challenge claims regarding the impact of regulations on innovation. Given the relatively limited use of market-based incentives to date, there are few empirical studies of the technological impact of MBIs either on their own⁴ or in comparison with command-and-control regulations. One exception is a study by Jaffe and Stavins (1994), who use a general equilibrium model to analyze the impact of energy taxes, technology adoption subsidies and technology standards (changes to building codes) on diffusion of new thermal insulation practices in the US residential housing industry. Their analysis suggests that technology standards have a weaker influence on the adoption of new technology than economic instruments. However, the findings are tentative, and do not necessarily apply to the kind of performance-based standards generally found in the pulp and paper industry.

Leaving aside comparisons between MBIs and command-and-control regulations, what evidence is there regarding the impact of regulations on the development and adoption of new technologies?

i) Case-Study Evidence

In the first place, there is a relatively large body of case-study evidence regarding the “technology-forcing” nature of environmental regulations. Of particular note is work by

⁴ Kemp (1995, 234) notes that “there is no reported case of a technological innovation that has been developed in response to a pollution tax or tradeable permit, but this may be due to the limited use of these instruments and the low level of the tax or high number of pollution rights”. Cramer (1990), in an early review of existing empirical evidence, argues that the primary impact of MBIs appears to have been to stimulate end-of-pipe changes — exactly the charge leveled against standards in most of the theoretical literature.

Michael Porter and collaborators (Porter, 1991; Porter and van de Linde, 1995), who present a number of cases in which regulatory pressures have helped spur the development of new technological solutions which go beyond end-of-pipe controls, and which improve the competitiveness of innovating firms. Porter argues that well-designed regulations can promote innovations which more than offset the costs to firms of improved environmental performance, thus erasing the conflict between private costs and social benefits which has long been the central tenet of regulatory theory (Porter and van de Linde, 1995, 98).

Unfortunately, this kind of evidence does not easily permit generalization, nor do Porter and his colleagues attempt to isolate regulatory factors from other influences on corporate behaviour. There has also been widespread criticism of some of Porter's analysis, particularly the assumption that there are likely to be widespread and generalized opportunities for firms to profit from reducing pollution.⁵ While there are typically a number of opportunities for firms to save on input costs – or avoid disposal costs – by cleaning up their production process, such opportunities are likely to vary across industrial branches. Nor is it certain that opportunities for cost-savings will be sufficiently large for firms to justify the capital costs involved, or the learning costs associated with pursuing innovation. A further limitation of the analysis is the focus on successful, innovative firms: while this provides interesting insights into the way in which environmental pressures have affected particular firms, it is difficult to generalize from these firms to other firms in the industry.

A somewhat different – but complementary – effort to understand the links between

⁵ For a critique of the "Porter hypothesis", see Palmer, Oates and Portney, 1995; Palmer and Simpson, 1993; or Walley and Whitehead, 1994.

regulation and the development and diffusion of new technologies is provided by Ashford et al (1985), who review the evidence from studies carried out in the 1970s and early 1980s in the United States. Like Porter, they find evidence of significant technological effort in response to regulatory pressures. However, they conclude that the most frequent responses have been incremental improvements to existing processes or products, or diffusion of existing technologies (end-of-pipe control technologies and input substitutions requiring little additional technological effort). More far-reaching technological changes did occur in a minority of cases, but only as a result of extremely stringent regulations which effectively banned polluting substances (PCBs, CFCs, leaded gasoline and batteries).

Unfortunately, the kind of analysis presented by Ashford and colleagues is of limited benefit in explaining firm-specific patterns of response to regulation in a given industry like pulp and paper. They focus on examining sectoral technological responses of broad industry groups to specific regulatory challenges. Differences in responses by individual firms — and the factors that explain these — are not accorded serious attention. Nor is there an analysis of the way in which the varying patterns of response (diffusion of existing technologies; incremental innovations; radical innovations) have affected the technological capabilities of firms; it is possible, for example, that a strategy of incremental innovation may over the long-run lead to significant improvements in the technological prowess of firms, leaving the industry relatively well-placed to respond to future environmental and competitive challenges. Moreover, the focus on comparisons among a set of disparate regulatory experiences means that judgements regarding the relative stringency of different regulations are extremely subjective, nor is it easy to disentangle the impact of regulatory stringency from differences in the competitive

circumstances of target industries and the state of development of compliance technologies.

Other case-study evidence suggests that the impact of regulations on innovation has been more limited. Rothwell (1992) reviews a number of European and OECD studies conducted in the 1970s and early 1980s, and concludes that the impact of regulation has been limited at best: regulation was generally not the most important factor influencing innovation outcomes, and overall has had negative impacts on “business-oriented” (i.e., non-compliance-oriented) innovations. A similarly negative picture of the impact of US regulations is painted by Heaton, Repetto and Sobin (1991), who argue that existing regulatory policy “exhibits systematic biases against new technology and in favour of the status quo” (Heaton, Repetto and Sobin, 1991, 23). Of course — as Porter and his supporters have been at pains to point out — the failures of existing regulatory policies do not mean that better-crafted regulations could not perhaps induce innovation. Nor do they suggest that innovation is likely to emerge in the absence of regulation altogether — as the dismal environmental experience of former Soviet republics in Central and Eastern Europe attests.

ii) Aggregate Analysis

At best, then, case-study evidence is uncertain: while there are examples of innovation in response to regulatory pressures, it is unclear how widespread this kind of response is (both among sectors and within firms in a sector) or under what conditions innovative responses to regulatory pressures are more likely to emerge. Aggregate analysis of the links between regulation and technological change is also rare, and does not provide a solid basis of evidence.

To begin with, there have been a number of studies of the impact of environmental regulations on industry-wide productivity, all proceeding from the hypothesis (outlined above) that regulations steer firms away from “productive” investments in favour of “unproductive” compliance-oriented activities. Olewiler (1994, 95-100) reviews the results of a number of Canadian and US studies of this type; existing studies, she concludes, suggest that environmental regulations have a small negative impact on the growth of total factor productivity in all sectors studied (although the extent of the impact varies across sectors).

This kind of analysis, however, suffers from a number of important limitations. Total factor productivity indices are a notoriously crude measure of technological innovation (see, for example, the critique by Lall, 1994). In the case of environment-related innovations, TFP measures do not capture broader cost savings (lower health-care costs, lower-clean up costs) which are not reflected in measures of total output. Nor do they account for impacts of regulation on industries supplying environmental goods and technologies — a factor likely to be particularly important in industries like pulp and paper where key elements of overall technology come from outside the industry. Even leaving aside these qualifications, the fact remains that observed reductions in productivity are quite small, and in no case does the stringency of environmental regulations appear as a major determinant of sectoral productivity performance. In fact, the expectation that regulations will depress aggregate productivity may be increasingly called into question in the future. Drawing a line between “compliance-oriented” and “production-oriented” investments has always been difficult, and is likely to become even more so as the focus of regulations — and of environmental investments by firms — shifts away from pollution control technology and toward more integrated pollution

prevention approaches. Most aggregate productivity analyses use data from the 1960s, 1970s and early 1980s, prior to the period in which regulators and firms began to shift emphasis (Olewiler, 1994, 95). As will be pointed out below, it is critical to understand the specific nature of regulatory policies and practices — and the state of development of pollution control technology in the industry — in order to adequately assess the links between regulation and innovation.

Studies of other aggregate indicators of technological innovation (R&D expenditures, patents) are also rare, but two recent studies provide some evidence. Lanjouw and Mody (1996) use international patent data to analyze the impact of regulatory stringency on development of new technologies. Their conclusion is that increases in the stringency of domestic environmental regulations are linked to the development of new pollution control technology: incidence of environment-related patenting (lagged to reflect the time needed for innovators to respond to regulatory pressures) is correlated with measures of regulatory stringency. This result is particularly interesting since it suggests that regulations may lead not only to the application of existing “best practice” technology, but also to the development of new technologies. On the other hand, the results are constrained by two factors. First, like many other aggregate analyses, the study uses abatement cost data as a measure of regulatory stringency. Abatement costs, however, are in many ways a poor proxy for regulatory stringency, since they reflect not only the extent of environmental burdens on an industry, but also its efficiency in meeting this burden (see Jaffe and Palmer, 1994, 25-26).⁶ Second, the patent data

⁶ One indication of some of the problems with use of abatement cost data is found in a 1995 study of the link between regulation and plant-level productivity (Gray and Shadbegian, 1995). The authors find a significant relationship between plant-level abatement costs (used as a proxy for regulatory burden) and inter-plant variations in productivity. But they find no similar relationship between abatement costs and rates of productivity **growth**, nor between abatement

set used by Lanjouw and Mody is limited to pollution **control** technologies; their analysis thus does not capture efforts to develop cleaner process technologies, nor more incremental technological improvements which are unlikely to be reflected in patent statistics. As a result, the analysis does nothing to counter one of the most frequent criticisms of CAC regulations — that they spur the development and adoption of end-of-pipe technologies, but do not induce firms to search for more cost-effective solutions through internal process changes.

Jaffe and Palmer (1994) undertake a similar analysis, but with several important differences: they use US rather than international data, and focus on cross-sectoral as opposed to cross-country comparisons; they analyze not only patent statistics, but also R&D expenditures; and, rather than focusing on pollution control technologies alone, they analyze **overall** levels of patenting and R&D in regulated industries. Their analysis finds no statistical relationship between levels of patenting and abatement costs, but does find a statistically-significant relationship between R&D expenditures and abatement costs. The results provide some support to the findings of Lanjouw and Mody that regulations promote the development of new pollution control technology, and in this case suggest that overall levels of R&D — rather than just development of end-of-pipe technologies — may be affected by regulatory pressures on a particular industry.

Once again, however, the analysis is limited by a number of factors. Like earlier analyses of productivity impacts, use of sectoral R&D statistics means that Palmer and

costs and productivity variations within a plant over time. Moreover, other measures of regulatory burden (compliance status, extent of enforcement action, emissions levels) are not significantly related with productivity. This suggests that abatement costs may in-fact be more closely related to underlying differences in the productive efficiency of plants than to levels of regulatory burden. It also casts doubt on some of the findings of other studies with regard to the negative impact of regulation on productivity growth.

Jaffe's analysis does not capture the impact of regulations on outside technology suppliers. In many cases, it is reasonable to assume that the most important impact of regulations will be to spur development of new technologies by firms outside the regulated industry. The same is true of patent statistics, and one reason for the apparent contradiction between Jaffe and Palmer's findings regarding patents and those of Lanjouw and Mody may be the difficulty of assigning patents to particular industry classifications in the former analysis. Moreover, like Lanjouw and Mody, the analysis rests on a weak proxy for regulatory stringency (sectoral pollution abatement expenditures) and does not capture the impact of incremental improvements to existing technologies which are not patented and may not be based on formal R&D spending.

III. Missing Elements

Overall, the limited empirical evidence which is available suggests a somewhat more nuanced picture of the links between regulation and innovation than that portrayed by the theoretical "conventional wisdom". There is as yet insufficient empirical evidence to advance any firm conclusions with regard to the relative effectiveness of market-based versus command-and-control measures in stimulating innovation, despite the theoretical case in favour of the former (see Dewees, 1993, 38). On the other hand, there is evidence that regulations have promoted development of new technological solutions, as evidenced by case-study data (Ashford et al, 1985; Kemp, 1995; Porter and van de Linde, 1995), cross-country patent studies (Lanjouw and Mody, 1996), and cross-sectoral data on R&D expenditures by US firms (Jaffe and Palmer, 1994). But there are serious limitations on existing studies which make generalization difficult, and the extent to which regulations have promoted process innovations as well as end-of-pipe

improvements is still very much open to question.

All of this suggests the need for additional empirical study on the links between environmental regulation and innovation. Future study, moreover, should attempt to respond to the weaknesses of existing literature, paying particular attention to the following issues: the process of innovation and technical change in target industries; the nature of the regulatory process; and, the interaction between regulatory and non-regulatory factors in determining firm-level behaviour. The following paragraphs discuss these three issues, and in the process begin to outline some of the elements of an explanatory model of firm-level environmental behaviour. Section IV then returns to these issues in order to present a more explicit version of the model.

a) The Innovation Process

To begin with, most of the studies referred to above are based on a very simplified model of the innovation process (viewing innovation as a discrete act undertaken by firms in response to some set of market or regulatory forces) and on a limited range of indicators of innovative effort (primarily formal R&D spending, patenting, and diffusion of specific pollution abatement and control technologies). This is at odds with much of the recent scholarship on innovation, particularly from what has come to be called the "evolutionary" school of thought (for overviews of this literature, see Dosi et al, 1988; or Bell and Pavitt, 1993).

This literature puts forward a much more complex model of technological innovation. Three points are of importance for the current thesis.

In the first place, **innovation is a learning process**. Radical innovations and major

investment programs are of course important. But in large measure the process of technological innovation involves the gradual accumulation by firms of various types of technological capabilities — from basic production capabilities through more sophisticated investment, marketing and process change capabilities (Ernst, Mytelka and Ganiatsos, 1998; Lall, 1994). As a result, the true nature and extent of innovation is unlikely to be captured in formal R&D, patent or investment statistics.

For the purposes of the current analysis, this highlights the need to pay attention to the ways in which firms learn, and to all three channels of technological change outlined at the beginning of Chapter 1: the development of new technologies (“innovation”), the adoption of existing technologies (“diffusion”), and the incremental improvement of existing technologies (“incremental technical change”). Unfortunately, many analyses fail to adequately distinguish among these three channels, and focus largely or solely on development and diffusion of major new innovations. Particularly in the case of aggregate analyses, incremental technical change tends to be ignored. Case-study analysis is better-placed to capture incremental improvements, but even in these cases there has been a tendency to dismiss such efforts as second- or third-best responses to environmental challenges. In fact, however, even imitative strategies and adoption of proven technologies may demand significant levels of adaptation, and hence the development of innovative capabilities within the firm.

To date, there have been few efforts to examine the ways in which dealing with environmental challenges contributes to the overall innovative **capabilities** of the firm, as opposed to simply generating particular innovative **outcomes**. But Rothwell (1992) has argued that the “learning benefits” associated with environmental improvements

may in fact be significant:

In some instances, overcoming the problems involved in regulatory compliance enhanced firms' problem-solving capabilities and their creative potential. Thus, while the costs and uncertainties associated with regulatory compliance might have had immediate adverse impacts on firms' innovatory activities [because of diversion of R&D resources to compliance-oriented activities], the firms might have enjoyed learning benefits that actually increased their innovatory potential in the longer term (Rothwell, 1992, 455).

Capturing such impacts demands detailed examination of the process of responding to environmental challenges within individual firms, rather than aggregate analysis alone.

Second, the evolutionary perspective emphasizes that **innovation is highly interactive**.

Rather than viewing firms as independent, integrated actors, evolutionary theorists have stressed the importance of close interaction and feedback both within the firm (between production and design departments, for example) and between the firm and other economic actors, notably customers and suppliers (see, for example, Lundvall, 1988).

This means that efforts to understand the impact of environmental regulation on innovation must pay attention to the interactions within firms (e.g., between environmental management, R&D and production departments), as well as the ways in which regulatory factors affect firms' interactions with local equipment suppliers and R&D institutes.

Of particular importance is the interaction between firms and outside technology suppliers. In many industrial branches (including pulp and paper) key advances in process technology emerge not from within the industry itself, but from outside equipment suppliers and consulting engineering companies (Chapter 3 provides a detailed analysis of the process of technological change in the pulp and paper industry,

emphasizing the highly supplier-dominated nature of the industry). This is even more important for pollution control technologies, which rarely emerge from within the regulated industry, and instead usually come from independent environmental technology companies.

As noted earlier, however, many empirical studies of the links between regulation and technological change fail to account for the impacts of regulations on outside technology suppliers. The same is true of theoretical studies. In his 1995 review of theoretical models of innovation and pollution control, Kemp (1995, 44) notes that only one — the analysis by Milliman and Price (1989) — takes into consideration innovation by outside technology suppliers. As Kemp notes, doing so can alter the conventional wisdom emerging from theoretical analysis: while most modeling exercises suggest that command and control regulations provide less innovative stimulus than market-based instruments like emissions taxes and tradeable permits, the opposite result may hold if the model considers that the innovation is supplied by the outside firm, and allows for a regulatory authority that responds correctly to changes in marginal conditions by increasing the stringency of regulations.

Finally, the evolutionary school of thought emphasizes that **history matters**. Past decisions by firms radically affect the options open to them in the present, and thus the way in which they react to changes in market conditions or incentives. As a result, the study of innovation must pay attention to the way in which the historical evolution of sectors and firms set the parameters of firm-level behaviour at any given point in time (Chudnovsky et al, 1994). There is a significant degree of path dependency, both at the level of the firm and in terms of broader technological systems (see Kemp and Soete,

1992, 445, for an application to environmental issues). Mytelka (1995) uses the term “policy dynamics” to denote the ways in which the historically-determined habits and practices of firms interact with formal policy instruments to influence firm-level behaviour. These habits and practices are not simply static attributes of the firm, but derive from the evolving nature of competition in the industry, and from past policies (regulatory policies, tariff protection, R&D incentives) at work in the industry.

In addition to consideration of the historical evolution of particular firms, therefore, it is also important to stress the ways in which overall patterns of technology supply in an industry may evolve, and may enhance or constrain the choices open to firms. Analysis of regulation has long recognized that one adverse consequence of technology-based standards may be to “lock in” particular control technologies, reducing the incentives to firms to go beyond existing levels of environmental performance. But while regulatory factors may be one potential source of “lock-in”, they are by no means the only one, as evolutionary analyses by Arthur (1990) and others have emphasized. One possible explanation for the tendency of regulated firms to invest in end-of-pipe pollution control technologies rather than in-plant process changes is the greater certainty provided by the former, particularly at a point where alternative process technology is relatively new and unproven. As alternative process technologies become more mature and proven, firms may become more willing to risk such investments — regardless of the regulatory regime facing them.

Overall, the evolutionary framework stresses the complexity of the innovation process and the importance of firm-level factors, which in turn argues against highly aggregate analysis of firms' behaviour. Unfortunately, there have been relatively few attempts to apply this kind of a conceptual framework to the analysis of environmental issues; for

exceptions, see Kemp (1995); Kemp and Soete (1990 and 1992); Warhurst (1992); or Bell (1990).

b) The Regulatory Process

Just as the process of innovation is more complex than is depicted in much of the literature, so too is the regulatory process. Most existing studies dramatically simplify the regulatory process in order to facilitate their analysis. Reliable measures of regulatory stringency are difficult to construct, and most quantitative analyses have chosen to rely upon abatement cost data, which is problematic at best. The focus of academic discourse on choice of policy instruments (MBIs versus standards) has tended to deflect attention away from other aspects of regulatory design and implementation. As David Wallace (1995, 22) argues, "we need a more sophisticated viewpoint than simply 'economic instruments good; standards bad', or vice versa". This is particularly true given that most regulatory regimes are "mixed" systems (Skea, 1994), applying a combination of different types of policy instruments (tax instruments plus process standards, for example).⁷

In fact, the extent of innovative stimulus provided by regulatory standards depends on a number of factors related both to the design of regulations and their implementation.

In terms of standards design, regulators are faced with a number of choices, each of which has varying impacts on regulated firms. Generally speaking, as noted earlier,

⁷ One of the few empirical analyses of MBIs in developing countries — a study by Vincent (1993) on effluent control in Malaysian palm oil processing — finds generally positive impacts on adoption of improved technologies, but is unable to separate the impact of market-based instruments (effluent fees and R&D subsidies) from more traditional performance standards applied simultaneously.

performance-based standards are preferred to technology-based standards. Similarly, it is generally agreed that industry-specific standards are superior to generic standards (since the former are able to take into account the specific conditions of the industry and the state of development of compliance technology). It is also reasonable to expect that multi-media standards (i.e., comprehensive sets of standards governing liquid effluents, airborne pollutants, and solid waste) provide a more effective stimulus to innovation than single-media approaches, since the former promote internal process changes aimed at reducing contaminants at source rather than simply treatment technologies which may displace problems from one media to another.

In terms of implementation, a number of factors are important. First, and perhaps least controversially, levels of enforcement and monitoring are as important as the letter of regulations in determining the true regulatory burden faced by firms. This makes comparisons across jurisdictions (or even among industries in a given jurisdiction) difficult (Doering et al, 1992, 19).

Second, firms' decisions are likely to be based not simply on current levels of regulatory burden, but also on expectations of future regulatory changes (see Fleet and Abraham, 1994). The way in which regulatory expectations frame firm-level responses, however, is by no means clear. On the one hand, expectations of future tightening of regulations may prompt firms to adopt far-reaching technological improvements, particularly in industries where capital investment costs are high (see Warhurst, 1992, re the behaviour of multinational mining firms in developing countries, where this is advanced as one possible explanation of the tendency of firms to apply state-of-the-art environmental management techniques in their developing country operations). On the other hand, firms may be reluctant to innovate -- or at least to engage in innovative

activities beyond simple regulatory compliance – if they feel that any gains will simply provoke a subsequent tightening of regulatory standards (McCain, 1978). In a recent article, Heyes and Liston-Heyes (1997, 503) argue that much depends on the nature of technology supply in the regulated industry: regulatory “ratchetting” will depress R&D spending by the regulated industry, but is likely to encourage research by outside technology suppliers. Porter and van de Linde (1995, 113) argue that the ideal situation is one in which regulatory limits are revised on a regular basis — thus avoiding the tendency for regulations to freeze existing patterns of technological development, but providing firms with a measure of stability and predictability in terms of current and future regulatory limits.

Third, in a large number of cases regulations are based on negotiated rather than legislated compliance. While formal regulations may specify levels of effluent to be achieved or types of technologies to be applied, in practice regulatory officials will negotiate a timetable for compliance by the firm, based on judgements as to the economic feasibility of compliance and the costs to society (particularly job losses) if the firm were shut down or forced to scale back production. This interaction between regulator and regulated is made all the more difficult by the frequent information asymmetries between the parties; particularly in gauging the economic feasibility of compliance, regulators often have little choice but to rely on claims by company officials (for a discussion of some of these factors in the case of the Canadian pulp and paper industry, see Sinclair, 1991).

These kinds of interactions between firms and regulators are not necessarily negative. Indeed, in a study of environmental regulations and innovation in six OECD countries, Wallace (1995) argues that the “quality of dialogue” between regulator and industry is

one of two critical determinants of the ability of regulations to spur innovation (the other being the political independence of the regulatory body from industry). He argues that the extent of dialogue, the competence of regulatory officials and the willingness of firms to part with information all affect the extent to which regulations can work to spur innovation: "Through engaging in a process of high-quality dialogue, certain regulatory regimes have achieved a sensitivity toward industry which allows innovative solutions to emerge" (Wallace, 1995, 229). By permitting firms time and flexibility to adapt, negotiated compliance approaches may help overcome the barriers to introducing more far-reaching internal process changes, as opposed to just end-of-pipe solutions (Luken, 1997, 72; for a review of the advantages and disadvantages of negotiated versus 'specified' compliance approaches, see Yakowitz and Hanmer, 1993, 301-303).

On the other hand, much depends on the political independence, resources and competence of regulatory officials. Close relations can also lead to "capture" by the regulated industry, with regulatory outcomes reflecting short-term interests of industry and unlikely to be framed in a manner which encourages innovation.⁸ Moreover, while industry can in general be expected to oppose stricter regulations, positions may vary among firms in the regulated industry depending on their competitive situation. There may even be an element of pre-emptive standard-setting in the environmental management decisions of leading firms. In cases where compliance technologies are developed within the regulated industry, leading firms may welcome standards as an opportunity to expand the market for their own technology. Even where this is not the case, early decisions by a firm to apply up-to-date technologies may provide it with a

⁸ See Helm (1993). For an earlier discussion of this possibility of regulatory capture — not specifically related to environmental issues — see Mahon (1977).

substantial competitive edge over competitors. Skea (1994, 426) also argues that dominant firms may be able to use regulations to restrict entry, thus reinforcing their technological capabilities and competitive advantage; over the longer term, he contends, this may have negative impacts on the introduction of more innovative technological solutions.

Clearly, it is an over-simplification to see firms as simply reacting to a set of stable and exogenously-determined regulatory pressures: both in the initial framing of regulations and in negotiating specific conditions of compliance, firms (and industry associations) can play a much more active role. Regulation is not so much a discrete act as a process -- and one in which firms both react to and help to shape the nature of regulatory requirements.

Unfortunately, few analyses have attempted to deal with these kinds of political economy considerations. Milliman and Price (1989) develop a theoretical model to analyze the returns to regulated firms and outside technology suppliers under a range of policy instruments, and their resulting incentives to promote or obstruct adjustments in regulatory stringency. Kemp (1995) integrates political economy concerns into his model as well, arguing that opposition from polluting firms is likely to result in government setting tax rates at too low a level in order to promote innovation. Beyond this, however, most theoretical and aggregate analyses fail to adequately consider the finer points of regulatory design, or the political economy considerations affecting regulatory outcomes.

c) Non-Regulatory Influences on Environmental Behaviour

A key implication of the above analysis is a recognition of the **differential** impact of environmental regulations on individual firms. Much of the existing theoretical and empirical literature on the relationship between regulation and innovation has glossed over differences among firms, relying instead on simplified models of the firm and/or highly aggregate data. In fact, however, the environmental performance of firms may vary widely under a given set of regulatory constraints. One indication of this comes from a series of recent World Bank studies on the determinants of industrial pollution. Based on plant-level data from several Asian and Latin American countries, these studies find that despite relatively lax environmental regulations, plant-level environmental performance varies widely, even within industrial branches (Hartman et al, 1995; Hettige et al, 1996; Dasgupta et al, 1998).

To a certain degree, this is not surprising — studies of productivity trends have similarly found a wide range of variation around industry averages, reflecting gaps between more- and less-productive firms. But it reinforces the need to consider the way in which regulatory and non-regulatory factors interact to shape the incentives facing firms and the nature of their responses. Three non-regulatory factors are of particular importance to the current research: the innovative resources and capabilities of the firm; its market orientation; and the link between the firm and (foreign-owned) parent or partner firms.

i) Resources and Capabilities

The ability of firms to innovate or adopt new technologies — and thus to improve their overall environmental performance — depends critically on a number of firm-specific

variables, relating in particular to the kinds of resources and capabilities firms can mobilize to respond to environmental and competitive pressures. These include the size and financial resources of the company in question, the extent of in-house technological resources, the age and scale of existing plant, the type of process technology in use, and the nature of links between the firm and outside sources of equipment and technology.

The World Bank studies mentioned above, for example, find that environmental performance is positively correlated with scale, indicating that there are significant economies of scale in pollution prevention which make clean-up more costly for smaller firms. Hettige et al (1996, 1999) also find a positive correlation between pollution intensity and the overall productive efficiency of plants, and hypothesize that this reflects both the greater availability of resources for financing clean-up, and the superior implementation capability of management in efficient plants; similar results are reported by Hartman et al (1995) in their study of pulp and paper mills. On the other hand, the studies are less categorical with regard to the impact of age of plants. Hettige et al (1996, 1991) find that the impact of age varies widely among studies, while Dasgupta et al (1998) find no correlation between environmental performance and age of machinery and equipment once other factors are controlled for. In part, this reflects the difficulty of using date of construction as a proxy for vintage of technology, since many plants have undergone extensive modernization since construction. It may also reflect differences in the efficiency with which new machinery is operated in individual plants: poor maintenance and inefficiencies in other aspects of plant management could more than offset the environmental improvements resulting from investments in new machinery and equipment.

Beyond analysis of the impact of size and age of plants on pollution levels and abatement expenditures, there is relatively little analysis of other aspects of the overall resources and capabilities of firms. Two aspects deserve particular attention: the overall R&D and innovation capabilities of the firm (R&D expenditures, extent of product and process innovations), and the commitment to superior environmental management on the part of the firm (formal environmental policies and practices, extent of past environmental actions). Both of these are likely to influence the level and type of actions taken by firms in response to external environmental pressures. Unlike size and age of plants, these factors are not simply static attributes of the firm, but also reflect its historically shaped habits and practices, and the kinds of relationships established between the firm and outside actors (parent/partner firms; competitors; R&D institutions; equipment suppliers and consulting firms). Of particular interest for this thesis is the extent to which the overall “innovativeness” of firms in non-environmental areas affects the nature of their response to environmental pressures. While it is reasonable to expect that more innovative firms will be more likely to innovate in the environmental field as well, there is as yet relatively little evidence to test such a claim.

Beyond these differences in the **ability** of firms to effectively respond to regulatory pressures, there may also be critical differences among firms in their **willingness** to pursue environmental improvements — with or without regulatory pressures. As noted at the outset of this chapter, two such variables have received attention in recent years: market orientation (particularly the extent to which firms’ output is destined for environmentally-demanding markets) and ownership. Both factors may constitute important determinants of firm-level environmental management practices, and may

alter the linkages between regulatory factors and innovation.⁹

ii) Market Factors

The influence of market factors is relatively straightforward: firms will be more likely to develop/adopt cleaner technologies if their output is sold in markets where there is a premium for products with superior environmental characteristics. This premium may result from direct consumer preference for "green" products; from eco-labeling schemes like those used by many European countries, which act as a direct constraint on the import of less environmentally-friendly products; or from differences in environmental standards between countries, which may exert a less direct influence by affecting purchasing decisions by industrial clients.¹⁰ In practice, this means that firms producing goods for export to industrialized country markets will have greater incentive to make improvements in environmental performance than will firms selling on less demanding Southern markets.

There is at least some empirical evidence that this is in fact the case. Lanjouw and Mody's study of international patent statistics, mentioned in the last section, finds that a

⁹ The World Bank studies mentioned above also point to a third factor affecting the willingness of firms to engage in environmental investments in the absence of formal regulatory pressures. All three of the studies argue that informal regulatory pressures and community pressure — as measured by the visibility of plants and their proximity to major population centres — exert a significant influence on firms' environmental performance (Hartman et al, 1995; Hettige et al, 1996; Dasgupta et al, 1998). I return to this issue in the discussion of environmental regulations in Chile and Canada in later chapters.

¹⁰ This final point requires some explanation. In the case of the pulp and paper industry, pulp shipments are directed exclusively toward paper producing firms, rather than being sold on consumer markets. In a case where (for instance) a US paper manufacturer is purchasing pulp from a Canadian mill, the nature of purchasing decisions may be dramatically affected by US effluent standards. If US standards have forced the firm to phase out the use of chlorine in its own pulp production, the firm will presumably be less likely to import chlorine-bleached pulp from its Canadian supplier, preferring to standardize product inputs.

disproportionate share of vehicular patents in the United States were granted to Japanese and German inventors. They argue that this is “a case of regulation in one country spurring innovation in other countries, with more impressive outcomes than in the regulating country itself” (Lanjouw and Mody, 1996, 561). A study in Argentina of the pulp and paper, iron and steel and leather sectors concluded that “external signals play a key role in defining environmental management practices in export-oriented firms, particularly those whose production is destined for industrialized country markets” (Chudnovsky and Chidiak, 1995, 15; see also Chudnovsky et al, 1996). Similarly, research on industrial environmental issues in South Africa concludes that “international environmental pressures are having a positive impact on the environmental performance of South African exporters” -- although the authors go on to note that this usually goes hand-in-hand with local pressures in the form of regulations or community activism (Bethlehem and Goldblatt, 1997, 90-91).¹¹ On the other hand, some recent analysis presents contradictory evidence. A World Bank study of determinants of environmental performance in Mexican industry, for example, finds no evidence that level of exports to OECD countries is linked to superior environmental performance (Dasgupta et al, 1998); similar studies of Asian industry find no clear link between export orientation and pollution intensity (Hettige et al, 1996, 1901).

There are at least two possible explanations for this seemingly contradictory evidence.

The first is simply that all industrialized country markets are not equivalent in terms of

¹¹ It is also important to bear in mind that while export market pressures act as a stimulus to environmental improvements by **individual** exporting firms, this in no way means that the **overall** impact of export-orientation on the environment is positive: much depends on the way in which export-orientation alters the entire structure of production and trade in the direction of more- or less-environmentally-damaging activities. These kinds of considerations are beyond the scope of this thesis, but clearly are at the heart of the trade and environment debate.

their environmental requirements: hence more disaggregated analysis would be required to understand the ways in which export market pressures affect the propensity of firms to pursue environmental improvements even in the absence of regulatory pressures. Another possible explanation, however — and one which will be investigated further in this thesis — is that export market pressures only exert an influence on certain aspects of firms' environmental behaviour.

Kemp and Soete (1990, 253) argue that consumer preferences are only likely to be felt with regard to product innovations, not changes in process technology:

New products sold in the consumers' market have to meet the needs of consumers, which, in the case of ecological products, depend on whether consumers are environment-minded and prepared to pay for it ... Diffusion of process innovations, on the other hand, ... depends in the first instance on the company's objectives and values, where cost efficiency occupies a far more prominent position (Kemp and Soete, 1990, 253).

This is perhaps an overstatement of the differing motives for pursuit of product versus process innovations. Product characteristics frequently reflect underlying differences in process technology. Environmental groups have actively worked to ensure that consumer choices reflect the range of environmental impacts of paper production (including not only manufacturing processes, but also forest management practices); eco-labels in some industrialized countries similarly apply variants of "life-cycle" analysis; and intermediate pulp purchasers (notably European paper manufacturers) routinely demand detailed environmental information from supplier mills. Even so, however, it may well be that external market demand does not exert an influence on the entire range of process technology choices facing firms, but rather only those which are easily captured in product characteristics (for example, in the case of pulp and paper products, changes in bleaching sequences which are in turn reflected in chlorine content

of pulp). If this is the case, then it can be expected that export market pressures will be more likely to spur internal process changes linked to product characteristics, but less likely to exert an influence on external treatment technologies or on other process changes which have a less visible impact on final products. I return to this point in the discussion of patterns of firm-level environmental management in Canada and Chile in chapters 5 and 7.

A final set of market factors affecting firms' decisions with respect to environmental technologies is the extent and nature of competition among firms – that is, the market structure of the polluting industry. Again, the relationship here is unclear: as Kemp and Soete (1990, 254) argue, "more research on the relationship between market structure and pollution control is needed". While firms in relatively non-competitive markets may have little incentive to adopt pollution abatement technologies (and high levels of bargaining power vis-a-vis regulatory officials), a highly competitive environment might lead firms to concentrate on cost reductions to the detriment of investments in environmental performance. Additional cross-country and cross-sectoral research is needed to explore this issue; one critical weakness in the World Bank studies on determinants of industrial pollution mentioned earlier is a failure to take into account differences in market structures across sectors and countries. Given the focus of this thesis on a single industry and only two countries, it is not possible to probe this issue in great detail. However, some attention will be given to the ways in which the competitive position of individual firms (e.g., are they relatively high-cost or low-cost producers?) affects the nature of their environmental management strategies and investments. Attention will also be paid to the way in which changing market conditions in the industry as a whole (notably cyclical shifts in pulp prices) affect environment-related decisions by

firms.

iii) Ownership

While market-related influences are relatively clear-cut, a more complicated question concerns the impact of ownership on environmental management decisions, particularly the distinction between foreign- and domestically-owned firms. Foreign ownership may affect firms' ability to respond to regulatory pressures in a number of ways, through impacts on financial resources, channels of information, and access to technology. Foreign-owned firms may also face a different set of incentives to engage in environment-related innovation, since they are affected by both host- and home-country pressures.

The conventional wisdom with regard to the links between foreign investment and environmental performance has been that multinational firms tailor their environmental management practices to the nature of regulatory and consumer pressure in host markets. This is one of the tenets of the so-called "pollution-haven" thesis, which argues that firms in highly-polluting industries have shifted production to developing country markets where the costs of environmental management are lower. Recent studies, relying primarily on cross-sectional data and econometric analysis, however, have cast doubt on such claims (see, for example, Low, 1992; for reviews of this literature, see Olewiler, 1994; Olokesusi, 1994; or Anderson, 1997). In a sense, this is not surprising. Even in the most highly-polluting industries, pollution abatement costs are only one factor affecting investment decisions, and inter-country differences in compliance costs can easily be outweighed by other factors. As a 1991 UNCTAD report noted,

... in the United States, estimated cost increases attributed to environmental control in those [pollution-intensive] industries varied between only 1.9 and 2.9 percent. It is not surprising, therefore, that there is no evidence of any significant “pollution haven” effect in the Third World even though average pollution control cost levels in developing countries were about 50 to 60 percent below United States levels (UNCTAD, 1991, 20).

Technological changes prompted by tighter environmental standards in industrialized countries may work to offset even the small initial cost advantages of countries with less stringent regulations, thus forestalling any significant relocation of production (Anderson, 1997, 322). This does not mean that environmental standards will not influence locational decisions -- particularly when combined with other cost advantages resulting from differences in labour standards and tax codes. But it does suggest that variations in the stringency of environmental regulations **alone** may be unlikely to induce relocation of industries.

Even if inter-country differences in compliance costs are not sufficient to significantly shape locational decisions, they may still affect the kinds of environmental management practices (and control technologies) employed in different jurisdictions. As early as the the beginning of the 1980s, some observers -- while questioning the likelihood of environment-related industrial relocation -- were beginning to point to the existence of “double standards” in the environment and workplace health and safety practices of multinational corporations (see the discussion in UNCTC, 1985, 46).

Other research, however, has suggested that the opposite may be true at least in some industries. Warhurst (1992), in a study of environmental management in the mining industry, argues that multinational mining companies tend to employ the latest (and hence cleanest) versions of process technologies in their operations in developing

countries, rather than "dumping" older technologies. This results not from any altruism on their part, but rather from a recognition of the costs of transferring out-dated technology -- the extra costs implied in managing several vintages of technology across their operations, in particular -- and from a sensitivity to both home-country environmental pressures and the possibility of future shifts in regulatory standards in the host country.¹² While this result is still preliminary -- and may be due to the extremely high capital costs and lack of mobility of investments in the mining industry -- it at very least raises an interesting set of questions to be tested in other environmentally-sensitive industries.

Other analysts echo these kinds of findings, arguing that the advantages of corporate-wide uniformity in environmental standards outweighs any potential cost advantages from lax environmental and workplace health and safety procedures:

One theme that clearly emerges is the obvious practical need for reasonable consistency throughout the corporation. Given that much of the technical expertise and regulatory pressure are generally located in the country that houses the headquarters of the multinational corporation, it is natural that the organizational framework and standards there will guide most of the overseas operations. For example, it would be clearly impractical to design separate training curricula, personnel evaluation systems, audit and inspection protocols, risk reduction initiatives, and standard environmental procedures for operations in distinct plants or countries. By the same token, it would be impractical to have different corporate engineering standards, accounting practices, capital budgeting procedures, and other aspects that are usually standard throughout large corporations. In addition, considering the large investments in designing such programs even for the single home country, the opportunity to share the results throughout the worldwide corporate network certainly appeals to corporate-level environmental managers (Hadlock, 1994, 163-4).

¹² This is consistent with the results of a 1991 survey of environmental management in transnational corporations; in that survey, 62 percent of respondents indicated that home-country legislation affected company-wide environmental policies and programs, while only 18 percent of respondents pointed to the impact of host-country legislation (UNCTAD, 1993, 38).

Even where corporate procedures do not demand such consistency, managers of overseas operations may still upgrade environmental management practices -- either because they incorrectly assume it is mandatory, or because of a desire to be recognized for excellence within the corporation (Hadlock, 1994, 164).

These kinds of arguments are not entirely convincing. While there may well be reasons to expect that corporate environmental procedures "should" be applied across a company's operations, this may not be the case in practice -- as high-profile environmental accidents in the chemical and mining industries have illustrated. At the very least, however, it seems reasonable to expect that home-country market pressures and regulations may be an important factor in explaining firms' behaviour in host markets. Other things being equal, the costs of compliance with environmental regulation may be lower (and the benefits higher) for foreign-owned firms than for domestic firms, due to previous investments in compliance in other jurisdictions, the cost advantages of standardization, and sensitivity to public opinion in its home market.

Unfortunately, there is relatively little solid empirical evidence to gauge the validity of such claims -- and at least some room for doubt. More recent work on the mining industry by Warhurst and colleagues (1995), for example, has downplayed the importance of ownership as a predictor of environmental behaviour -- suggesting instead that the primary influence on environmental performance is the overall productive efficiency and capacity to innovate of leading firms, not ownership. A survey of multinational corporations by the United Nations found that while home-country legislation was a key factor influencing company-wide environmental policies and programmes, there were often few mechanisms to promote standardization across subsidiaries: only about half of respondent firms had formal arrangements for allocating

environmental management responsibilities between headquarters and controlled affiliates overseas — and only fifteen percent had such arrangements with non-controlled joint-venture affiliates (UNCTAD, 1993, 60-61). And a 1992 study of five US-based multinationals concluded that regulatory factors (both home-country and host-country) still represent a significant impact on corporate environment management:

... our study identified few actions in support of sustainable development that were not required by regulations, needed within the company to achieve or ensure regulatory compliance, anticipated as becoming the subject of regulation or increased public concern, or requested by host-country governments as part of an agreement to do business. When voluntary actions supporting sustainable development were identified, the majority were taken on an ad hoc basis at the initiative of a local manager (Rappaport and Flaherty, 1992, 155-6).

The World Bank studies mentioned earlier also suggest the need for caution. Analysis of Asian and Mexican firms suggest that neither foreign ownership nor foreign financing are linked with superior environmental performance (Hettige et al, 1996; Hartman et al, 1995; Dasgupta et al, 1998).¹³

Further analysis is needed to probe the reasons for this apparently contradictory evidence. It may be that initial improvements by foreign-owned firms are quickly matched by their local counterparts, particularly where environmental improvements yield cost or market advantages. As with export orientation, it may also be that foreign ownership only influences certain aspects of corporate environmental behaviour; foreign-owned firms may be more likely to adopt sophisticated environmental

¹³ The study by Hettige et al (1996) does find one significant impact of ownership: publicly-owned firms, they claim, are significantly more polluting than their privately-owned counterparts. Given the absence of public ownership in the pulp and paper industry in either of the countries under study in this thesis, this issue is not addressed here. Clearly, however, it is an interesting question, and further research is needed to test this finding, and to explore the reasons for (possible) differences in environmental performance among public- and privately-owned firms.

management procedures developed by head offices, whereas differences in the physical characteristics of foreign- and locally-owned plants (e.g., application of pollution control technologies) may be less significant. Empirical analysis in later chapters (particularly regarding the Chilean case) will explore this issue in more detail.

IV. Toward a Conceptual Framework

Overall, the preceding discussion underlines the complexity of the relationships between environmental regulation and innovation. It also suggests the limitations of highly aggregative analysis, and the importance of distinctions among firms in terms of their characteristics, history and competitive environment. The paragraphs which follow map out a loose conceptual framework within which to analyze the way in which regulatory factors affect innovation within firms. Neither this framework nor the empirical analysis in later chapters is able to deal with **all** of the complexities outlined above, but an effort is made to integrate some of the key factors missing in many existing studies.

To begin with, firms are strategic actors. Faced with heightened regulatory pressures, they do not simply make a choice between complying and not complying. Rather, there are a series of options open to firms in terms of the nature and timing of compliance, and their ability to influence the nature of regulatory pressures themselves. Firms may choose to improve their environmental performance, whether by engaging in incremental improvements (better "housekeeping"), purchase of new equipment, or by developing new technological solutions themselves -- or some combination of the three. Equally, however, they may choose to act individually or collectively to alter the regulatory pressures facing them -- by influencing the framing of regulations, or by negotiating with regulatory authorities regarding timetables for action. They may also

choose to scale back their operations and/or shift to other lines of production, or to simply ignore regulations, either preferring to pay any penalties levelled against them, or counting on weak monitoring and enforcement capabilities to permit them to escape penalty.

In practice, firms are likely to combine elements of a number of the above options.

Three broad types of strategy can be identified, each of which involves different modes of interaction with regulatory officials, different levels and types of environment-related investments, and different corporate environmental management policies (for a slightly different typology of corporate environmental management strategies, see UNCTAD, 1993, 168; or Lopez, 1996, 15):

- **defensive** strategies are oriented largely to avoiding or minimizing regulatory pressures on firms. This may involve attempts to forestall regulations, to secure exceptions for particular facilities, or to extend timetables for compliance. Environmental improvements are likely to be pursued only to the extent that they are part of broader modernization programs. Research expenditures for environmental purposes are likely to be non-existent, and adoption of new pollution prevention and control technologies will lag behind competitor firms.
- **compliance-oriented** strategies, as the name implies, focus largely on ensuring compliance with the existing regulatory or market-place demands. Levels of environment-related investments may be significant, but will be extremely lumpy, responding largely to short-term regulatory pressures rather than being organized as a longer-term environmental strategy. Innovative efforts will focus on the adoption of “best practice” control technology and on minor improvements

to existing machinery, or what one study has referred to as an “adopt and adapt” strategy. In-house research is likely to be limited, and there will be little incentive to pursue far-reaching process changes.

- **offensive** strategies are oriented toward anticipating future environmental pressures on the firm (whether regulatory or market-related) and acting to meet them. Investments are likely to combine in-plant measures and external treatment, and will be designed build in flexibility to adapt to future environmental demands. Larger modernization programs will be seen as an opportunity to make step-jumps in environmental performance. At the extreme, firms may seek to profit from increasing environmental pressures, through high levels of in-house research and attempts to differentiate products on the basis of environmental characteristics. Firms are likely to have well-developed corporate environmental management policies, and to exhibit levels of environmental performance well-beyond competitor firms and the requirements of existing regulations.

A firm's choice of strategy in turn influences its environmental performance (effluent levels, degree of compliance with regulatory requirements) as well as the scope for innovation by the firm. At the same time, however, innovation is not necessarily limited to firms which pursue more ambitious environmental investments. Thus, for example, the extent of diffusion of new process technologies may give some indication of the impact of regulations; but it may also be that a firm which opts for a more incremental approach (minor improvements to the efficiency of existing equipment, for example) could profit more in terms of longer-run technological learning than one which chooses

to import new machinery.

A firm's choice of strategy is determined by the interplay of a number of variables, of which regulatory pressures are only one factor. As Figure 2.1 shows, the choices made by firms can be understood in terms of the interactions among three sets of factors:

- a set of incentives facing the firm ("motive");
- a set of capabilities and resources available to the firm ("means"); and,
- the range of options open to the firm in question ("opportunity").

It is worthwhile explaining each of these sets of factors in a bit more detail.

At the simplest level, firms' decisions with regard to environment-related innovation will be based on an assessment of the costs and benefits of improved environmental control technologies. Firms' perceptions of these costs and benefits are shaped by a number of factors, which constitute the key incentives to environment-related innovation.

Depending on the circumstances of the firm in question, these incentives may include some or all of the following:

- regulatory pressures (both the letter of regulations, but also firms' expectations about the effectiveness of monitoring and enforcement, and about future trends in regulatory limits).

Figure 2.1: A Simple Model of Firm-Level Environmental Behaviour

- market demand, in particular that resulting from consumer preferences and regulatory requirements in key export markets.
- patterns of inter-firm competition, notably the extent to which competition among firms is based on environmental considerations and/or overall innovativeness, and the competitive situation of the firm with regard to its principal rivals.
- pressures from parent or partner firms, particularly in cases where the firm is wholly or partially foreign-owned, and where parent/partner firms have invested in environmental improvements to their operations in other jurisdictions and/or are sensitive to home-country environmental pressures.

These incentives for environmental improvements are mediated by two additional sets of factors. **First**, the ability of a firm to respond to the incentives outlined above will depend on the kinds of resources and capabilities which it can marshal to pursue environment-related innovations. Key factors will include:

- size and financial resources of firm
- extent of in-house R&D, production engineering and quality control resources
- extent of financial or technical alliances with leading firms (either equity or non-equity links), as well as the firms' links with outside R&D institutions and equipment suppliers
- environmental management policies, practices and capabilities (nature of corporate environmental policies; extent of in-house environmental engineering capabilities; audit and certification practices)

Second, firms' decisions depend critically upon the range of technological solutions available to the firm at a given point in time. Once again, a number of factors impinge upon the opportunities open to firms:

- the nature of regulations affecting the industry — particularly whether regulators tend to rely on performance- or technology-based standards. More generally, the degree of flexibility in implementation of regulations will be an important factor in determining the breadth of alternatives open to a firm.
- the physical characteristics of the plant in question: types of products in question and type of process technology in use, as well as the age and scale of existing plant and equipment, and by whether we are dealing with new, greenfield investment or conversion of existing plant.
- the nature of technology supply in the industry. As will be discussed in the next chapter, the pulp and paper industry is largely supplier-dominated: major improvements in production technology derive from a relatively small number of suppliers, based almost entirely in advanced industrial countries with relatively stringent environmental regulations. These kinds of structural factors are a major influence on environmental investments, particularly for greenfield mills — although they do not explain firms' efforts to make incremental improvements in environmental performance after start-up, nor are they sufficient to understand the conditions under which firms accumulate the technological capabilities to successfully manage major investment programs.
- the extent of the firms' previous experience in working with outside technology

suppliers, or managing in-house research and development and investment programs — which will condition what firm management perceives as “feasible” options for improving environmental performance.

In presenting these main “blocks” of variables, the framework attempts to integrate two elements missing from much of the existing literature. First, the framework characterizes the firm as a historically-bounded agent. The “means” and “opportunities” available to the firm are not simply static attributes of the firm or sector, but rather are conditioned by past habits and practices — hence the strong feedback loops between the current strategy of the firm and its (future) resources, capabilities and opportunities. Firms’ previous experiences in pursuing innovation or attempting to improve environmental management affect the stock of in-house resources and capabilities available to them, but also expose them to interaction with outside actors (equipment suppliers, consulting firms, independent research institutions). The nature of this interaction will in turn affect the likelihood that a firm will choose to interact with external technology suppliers — or, alternatively, pursue in-house research — in the future. In this way, a firms’ historically-shaped resources, capabilities and opportunities act as a filter between the external incentives facing the firm and its choice of strategy, privileging some courses of action and constraining others.

These relationships are further illustrated in Figure 2.2. Past decisions by the firm affect current behaviour by directly influencing the internal resources and opportunities available to the firm, and by indirectly shaping its interactions with parent/partner firms and outside technology suppliers. There is also a feedback loop between the firms’ strategy and the regulatory pressures facing it, emphasizing the fact that individual and

Figure 2.2: Linkages and Feedback in the Model

collective action by firms can alter the regulatory environment itself.

In addition to emphasizing the importance of history, the framework stresses the need to understand the sectoral context within which firms operate, and the links between the firm and a variety of outside agents. Again, Figure 2.2 presents a graphic representation of the most important relationships.

Firms are influenced both by the characteristics of the sector (patterns of inter-firm competition and technology supply) and by demand conditions facing the industry (regulatory factors and market demand). These factors wield an influence not only on the firm, but also on parent/partner firms and outside technology suppliers. Firms' motives for environmental improvements are thus determined by regulatory and market-related incentives, but also by the influence of parent/partner firms and by the nature of competition with rival firms. Parent/partner firms also contribute to the "means" available to firms — through R&D resources and the experience gained with environmental investments in other jurisdictions. Opportunities for environmental improvement, meanwhile, are shaped by the specific regulatory pressures facing the firm, as well as by linkages with external technology suppliers — which in turn are influenced by the overall pattern of innovation and technology supply in the sector.

V. Conclusions

The model outlined above is still relatively crude. It does not reflect the specific patterns of competition between rival firms in the industry, nor does it distinguish between various categories of technology suppliers (equipment suppliers, consulting engineering firms, public sector R&D institutions). But it does provide a basis for conceptualizing the key

relationships which goes beyond overly simplistic models of the firm and mono-causal explanations of behaviour.

The remaining chapters of this thesis deal in detail with various elements of the model, beginning with a discussion in the next chapter of the sectoral characteristics of the pulp and paper industry, and the way that these help to condition both the motives of firms, and the range of options open to them to improve their environmental performance. The concluding chapter of the thesis returns more explicitly to this model, and its relevance as a tool to understand the links between regulation and innovation in the pulp and paper industry.

Based on the model outlined above and the discussion in the previous sections, it is possible to outline a series of working hypotheses to guide the research. These hypotheses will be further refined in subsequent chapters dealing with the specifics of the Canadian and Chilean cases.

1. In the first place, the extent to which environmental pressures (regulatory or otherwise) induce a process of innovation will be affected by the structural conditions of the industry itself — the “sector characteristics” set out in the bottom section of Figure 2.2. The next chapter deals in more detail with the nature of the pulp and paper industry. As will be argued, a slow rate of change in core process technology in the industry, combined with the dominance of outside technology suppliers, is likely to limit the “opportunities” for innovation by firms in response to environmental pressures. Similarly, the prevalence of price-based competition for key pulp and paper products is likely to constrain inter-firm rivalry based on environmental characteristics of production, except in certain product markets (e.g., some specialty paper products). Hence, inter-

firm competition on environmental grounds is not likely to be a primary “motive” for environmental investments. As a result of these factors, the overall strategy of the industry in response to environmental pressures is likely to focus on diffusion of existing “best practice” technologies and incremental improvements to existing facilities — what we have labeled a “compliance oriented” or “adopt and adapt” strategy. Depending on the degree of regulatory burden, the extent of market-related environmental pressures, and the relative power of the industry vis-a-vis regulators, “defensive” strategies may also be followed in some cases, with firms working to block the development and enforcement of stricter regulations. Pursuit of “offensive” strategies is likely to be rare.

2. Within these broad patterns, responses of individual firms to environmental pressures are likely to vary widely. The following working hypotheses about firm- and mill-level variations can be advanced:

a) in the case of greenfield mills constructed within the last decade, the primary influence on design is likely to come from external technology suppliers. As will be pointed out in the next chapter, patterns of technology supply in the industry are highly concentrated, with a key role played by equipment suppliers and engineering companies based in industrialized countries. As a result of this situation, there is likely to be little variation in pollution abatement and control technologies among greenfield mills — either within countries or between Canadian and Chilean firms. There may, however, be differences in the extent of ongoing improvements and adaptation after start-up, reflecting differences in market and/or regulatory pressures.

b) in the case of existing mills, levels of environment-related investments will be linked to the actual and/or anticipated regulatory burden facing the mill. Regulatory pressures,

however, are likely to steer firms largely toward end-of-pipe controls, with less impact upon the development and adoption of process technologies or upon incremental improvements to existing facilities.

c) levels of environment-related spending at existing mills will also be correlated with the market orientation of mills, and in particular the extent to which production is directed toward environmentally-demanding export markets. Unlike regulatory pressures, market-related pressures are likely to promote the development and adoption of new product and process technology, and ongoing efforts to improve environmental performance beyond regulatory requirements.

d) foreign-owned firms in both countries will be more likely to engage in environmental improvements than their locally-owned counterparts, due to the greater internal resources available to them, the desire to standardize procedures across corporate operations, and the pressures of home-country public opinion. Other things being equal, wholly or partially foreign-owned firms will be characterized by higher levels of environmental spending, more aggressive environmental strategies, and higher levels of environmental performance than local firms.

e) the internal resources, habits and capabilities of firms will affect their ability to realize improvements in environmental performance, as well as their willingness to engage in more ambitious environmental activities. Levels of environmental performance are likely to be positively correlated with:

- size of firms and mills (reflecting economies of scale in pollution control at the mill level, and the greater internal technical and financial resources of large, multi-plant firms);

- the degree of “innovativeness” of the firm, as evidenced by levels of corporate R&D, links with external research institutions, and history of innovative behaviour; and,
- the extent of corporate commitment to environmental management.

These factors may not be reflected in levels of environment-related investment (which in fact may be **lower** than in competitor firms, due to economies of scale and/or the impact of environmental investments made prior to the period under study). But they should result in higher levels of environmental performance, and (at least in the case of the latter two factors) a greater propensity to innovate in response to environmental pressures.

Chapter 3: Competition, the Environment and Innovation in the International Pulp and Paper Industry

I. Introduction

As noted in the last chapter, regulatory and market pressures are mediated in the first instance by the range of technically- and economically-feasible options open to firms in order to improve their environmental performance. These depend in large measure on the structural characteristics of the industry in question. In order to analyze firms' responses to environmental regulation, therefore, it is first necessary to understand the nature of the industry in which they operate. As one recent analysis of the pulp and paper industry argues, "the industry's internal capacity and tendency toward technological and organization innovation must be considered before the effects of external influences can be well understood and interventions appraised" (Smith, 1997, 38). This chapter outlines some of the key characteristics of the international pulp and paper industry, while later chapters deal in more detail with the Canadian and Chilean industries.

This chapter is organized in three main sections. The next section describes the main environmental challenges facing pulp and paper production, and the way these differ among mills depending on type of pulp technology and choice of bleaching methods. Section III then discusses the central role of environmental considerations in pulp and paper research and development and in the competitive strategies of firms, and outlines some of the structural features of the industry which affect firms' responses to environmental challenges. The final section of the chapter analyses the main technical options to improve the environmental performance of pulp and paper production, and

the way that firm-level characteristics and practices affect the range of options open to individual firms.

The overall messages of the chapter are two-fold. In the first place, environmental concerns have become a potent force shaping the nature of innovation in the industry. But the environmental dimension cannot be understood in isolation from some of the other structural characteristics of pulp and paper production -- notably the scale- and capital-intensity of production; the volatile nature of demand for paper products; the prevalence of price-based competition among firms; and the dominance of outside sources of technology and technical expertise. It is the interaction of environmental concerns with these other factors which has shaped current patterns of innovation and technology adoption in the industry. Second, while in theory there is a considerable variety of technologies available to reduce contamination, in practice the range of technically and economically feasible options open to any given firm is considerably more narrow. Firms' options are constrained by the capital costs of pollution prevention and control technologies, the manner in which they affect production costs and product characteristics, and the technical requirements of different pollution prevention and control options.

II. Environmental Impacts of Pulp and Paper Production

Paper production involves the separation of fibre from raw materials (primarily wood, but also straw, bagasse, bamboo and other materials) and its subsequent refinement into a range of paper products. The industry is generally separated into pulp production on the one hand, and paper and paperboard on the other.

Pulp production is divided into integrated pulp (i.e., pulp which is not marketed outside the mill, but instead is used directly in production of paper products) and market pulp (i.e., pulp which is sold to non-integrated paper producers, either domestically or internationally). Market pulp currently accounts for approximately 20 percent of world pulp capacity. The paper sub-sector, meanwhile, is differentiated in terms of end-uses. Different end-uses demand different levels of quality in pulp inputs (high for printing and writing papers, low for building papers and board). There are also important differences in terms of the scale and complexity of production, and the extent of segmentation of product markets. Newsprint, for example, is essentially an industrial commodity, whereas some printing and writing and specialty papers are produced on much smaller scale for specialized niche markets.

As noted in Chapter 1, pulp and paper is generally regarded as one of the most environmentally sensitive of all manufacturing sectors – whether this is measured in terms of toxicity indices (i.e., quantity of toxic materials generated per unit of output) or average pollution abatement costs (i.e., average industry spending on environmental initiatives, as a percentage of total capital investment or value-added). Toxicity indices compiled by the World Bank, for example, place pulp and paper fifth of out 28 three-digit SIC manufacturing branches, with only leather, industrial chemicals, plastic products and printing and graphics registering higher levels of toxicity.¹ Similarly, data on pollution abatement and control expenditures by US industry rank pulp and paper fifth

¹ Toxicity indices are based on US Environmental Protection Agency databases of emissions by US industry, converted by World Bank staff into compound indicators of toxicity – in this case a linear estimate of toxicity to humans and terrestrial life. Pulp and paper scores somewhat lower using an exponential measure of toxicity, but even so ranks ninth among the 28 branches covered. Data are drawn from Martin et al (1991), as reported in Gomez-Lobo (1992), pp. 95-96.

among industrial branches in terms of expenditures per unit of output, with only petroleum refining, industrial chemicals, ferrous metals and products, and non-ferrous metals and products registering higher levels.² While comparable data are not available for countries other than the US, the picture is not likely to vary significantly across countries.³

Over the past several years, there have been a number of comprehensive studies of the environmental implications of pulp and paper production (Paper Task Force, 1995; IIED, 1996; or Smith, 1997).⁴ All three of the reports emphasize the need to consider the entire “paper cycle” – including not only manufacturing, but also upstream resource management issues, transportation, and downstream disposal and recycling – in assessing the overall environmental impacts of the industry. While the focus of this thesis is specifically on mill-level pollution, it is worthwhile discussing briefly the broader environmental profile of pulp and paper production.

There are three broad sets of environmental concerns in pulp and paper production.

In the first place, there are significant pressures on forest products firms to improve **forest management** practices to permit more sustainable harvesting of timber. These

² Pollution abatement and control expenditure (PACE) data are drawn from Jaffe and Palmer (1994), p. 10. These figures relate to operating costs only (as opposed to capital and operating costs).

³ Canadian data for 1993 show pulp and paper ranked second of eleven industrial branches in terms of pollution abatement and control expenditures as a percentage of total capital investment, with only the electricity and gas industry registering higher levels of spending. See Gagnon, 1996, p. 14.

⁴ Summaries of the three reports, along with a roundtable discussion of their principal findings, are reproduced in a recent issue of the Journal of Industrial Ecology; see Lifset (1998).

kinds of “upstream” environmental impacts have become a progressively more important issue for the pulp and paper industry in recent years. They are felt not only by firms cutting virgin timber, but also for those (like the major Chilean firms) relying on plantations, where there is pressure to use degraded or wasteland rather than forested land. The nature of environmental pressures has also become more diverse, stressing not merely adequate reforestation, but also conservation of biodiversity, protection of habitat of endangered species, and safeguarding of traditional ways of life of indigenous peoples .

A second set of concerns surrounds the overall **resource- and material-intensity** of paper production. The primary input into pulp and paper production, of course, is wood fibre. There have been significant efforts to reduce wood usage not only by improved forestry practices, but also by changes in process technology (higher pulp yields), increased use of “whole tree chips” (without de-barking) in pulping, and reductions in wastage at the paper-making stage. The most important development in this area, however, has been the increasing emphasis on recycling of paper products. This has resulted in changes in patterns of input use, as well as shifts in product mix as recycled products capture increasing market shares in some segments of the paper market. The greater reliance on recycling has also led to changes in the overall economics of paper-making, with shifts not only in raw material inputs, but also energy and chemical use, and plant location⁵. In addition to wood fibre, paper production also demands significant

⁵ In addition to reducing overall demand for new wood pulp, recycling tends to change the economics of industrial location, promoting growth of paper production close to the major population centres which are the primary source of recycled fibre. This in turn could put exporting countries like Canada, the Nordics and Latin Americans at a competitive disadvantage, as transportation costs for both raw materials and final products would be much higher than for plants located close to major markets.

inputs of energy. Concern for energy efficiency has been less significant than other environmental concerns, in large part because of reliance on self-generated energy in chemical pulp production – although this may be changing as recycling rates increase and as alternatives to chemical pulping (discussed below) take over an increasing share of the market.⁶

Third, and most important for this thesis, pulp and paper manufacturing is characterized by significant levels of **pollution**, with contaminants released in liquid effluents, airborne emissions and solid wastes. Pulp manufacture is in a sense inherently polluting, as it involves the deliberate removal of a portion of the wood (the lignin which binds fibres together) in order to secure the fibres necessary for paper-making. While pollution levels vary among process technologies, direct contamination is of four main types:

- organic material in liquid effluents. Levels of organic matter are generally measured in terms of **biochemical oxygen demand (BOD)** or **chemical oxygen demand (COD)**, which reflect the impact of biodegradable wastes on dissolved oxygen levels in water – and thus indirectly on the ability of a body of water to support aquatic life. Also important are levels of **total suspended solids (TSS)**.
- toxic compounds in liquid effluents, resulting primarily from chlorine used in order to improve the colour of pulp. During the late 1980s and early 1990s, effluent

⁶ See Ruth and Harrington (1998) for a discussion of future energy and fibre demand in US pulp and paper production. Energy demand varies crucially among pulping technologies, but there are a variety of technical options to improve energy efficiency in all processes (Caule et al, 1995; Simonsen et al, 1993). A complete accounting of energy demand in paper production, of course, would include both purchased and self-generated energy – as well as the energy used in transportation of inputs and finished products.

control measures have shifted from a concern with overall BOD levels toward concern with toxins resulting from the bleaching process. Levels of contamination are generally measured by levels of overall **organochlorines (adsorbable organic halides, or AOX)**, by the presence of specific toxins like **dioxin and furans**, or in terms of the extent of use of **elemental chlorine**.

- airborne emissions. Air pollution is a less significant problem in pulp and paper production than water pollution, but it is nonetheless important, particularly for chemical (Kraft) pulp. Most of the emphasis is placed upon sulphur compounds, normally measured in terms of **total reduced sulphur (TRS)** emissions⁷, which are responsible for the characteristic odour associated with Kraft mills. In addition, however, pulp production results in a variety of particulates, nitrogen oxides, and volatile organic compounds (VOCs). Power generation (either within the plant or from external sources) also contributes to carbon dioxide and sulphur dioxide pollution.
- disposal of **solid wastes**. The increased use of end-of-pipe treatment technologies has increased the quantity of solid wastes generated from pulp manufacture, as has the gradual move toward greater “closure” of mills and reduced volume of liquid effluents. Traditionally solid wastes from pulp mills have not been treated as dangerous, and landfilling has been the most common disposal method. With increased quantities of wastes and heightened concern over toxic compounds generated during pulp production, there is now pressure

⁷ TRS is a shorthand for four separate gases produced during Kraft pulp production (hydrogen sulfide, methyl mercaptan, dimethyl sulfide, and dimethyl disulfide). See Smook (1982), p. 366

to examine alternatives, from incineration to the re-use of some wastes in other end-uses.

The environmental impact of individual pulp and paper mills, of course, varies considerably. Two factors are of particular importance in understanding inter-mill differences, particularly with regard to quantity and toxicity of liquid effluents: first, the type of core process technology employed; and, second, whether or not pulp is bleached to improve its colour.

a) Environmental Impact of Alternative Pulping Technologies.

Different process options for pulp production are associated with different pulp characteristics, raw material requirements and end-product uses. They also have varying environmental impacts. The most important distinction is between chemical pulps, mechanical pulps, and secondary or recycled-fibre pulps.

i) chemical pulping. Chemical pulping is the dominant technology in the industry, accounting for approximately 42 percent of all pulp capacity (including non-wood pulp and recycled fibre) as of the mid-1990s (IIED, 1996, 104). In chemical pulping, wood chips are “cooked” in a chemical solution at high temperatures in order to remove the lignin. The result is a high-quality, long-fibre pulp, suitable for uses demanding greater resistance and purity. The alkaline sulphate or Kraft variant is most common, and largely due to its superior strength (“Kraft” is the German word for strong) has become the industry standard; the older acid sulphite process is now much less common.⁸

⁸ There are also a number of specialty “dissolving” and “alpha cellulose” pulps which are produced using variants of chemical pulping technology, and destined for production of cellophane, rayon, and related products used outside the paper industry.

One of the key advantages of the Kraft process over earlier sulphite pulping came with the development in the 1950s of recovery boilers which allow mills to recover and re-use spent cooking chemicals, while at the same time generating energy through the combustion of wood-based organic matter. Up to 98 percent of pulping chemicals can be recovered, and modern Kraft mills are typically energy self-sufficient and in many cases sell surplus energy (IIED, 1996, 105). While Kraft pulping is thus far less polluting than earlier chemical pulping methods, it still generates significant quantities of organic and chemical wastes – in part because of relatively low yields (40-60 percent of wood input by dry weight). Its characteristic brown colour also means that pulp is frequently bleached to suit the demands of particular paper products. The capital costs of recovery systems contribute to high levels of scale-intensity, with 1,000 tons/day generally seen as the minimum efficient scale for new Kraft mills (Smith, 1997, 116).

ii) mechanical pulping. Mechanical pulping methods are the oldest process, and involve the grinding of wood in water to produce pulp. Mechanical processes are in turn divided into stone groundwood (SGW) and refiner (RMP) pulp; while the former grinds whole logs against a revolving grindstone, the latter grinds wood chips between revolving discs, and thus can use sawmill waste in addition to whole logs. Mechanical pulping produces a higher pulp yield than chemical pulping (85-95 percent of wood input by dry weight) but of short fibres with higher residual lignin content than in chemical pulping. This means that mechanical pulps are weaker than Kraft pulp, and while lighter in colour, do not maintain their colour as well (the residual lignin discolours with time and exposure to sunlight). As a result, mechanical pulps are typically used for papers requiring lower resistance and less demanding standards in terms of colour (tissue, cardboard, newsprint).

Thermomechanical (TMP) or chemo-thermomechanical (CTMP) pulping is a more recent variant of mechanical pulping, first introduced in the late 1960s. Wood chips are softened with steam pre-treatment (with or without addition of chemicals) before pulping. This produces a higher-quality fibre than traditional mechanical pulping, but maintains some of mechanical pulping's advantage in terms of higher yields. TMP/CTMP has gained market share rapidly since its introduction, as producers have moved either to phase out older mechanical pulp lines and/or decrease the percentage of Kraft pulp in paper (see the discussion in Wheeler and Martin, 1992). There are also a group of "semi-chemical" processes which combine mechanical and chemical methods; these account for a small percentage of installed capacity world-wide, primarily for hardwoods.

Mechanical pulps (including TMP/CTMP) have some distinct environmental advantages over chemical pulps, due to their higher yields and lower chemical use. They also generate a lighter -coloured pulp, and hence do not generally require the use of chlorine for bleaching (although pulp may be "brightened" using other chemicals such as peroxides or hydrosulphites. On the other hand, they are much more energy-intensive than Kraft pulping. Scale economies are less pronounced because of the absence of recovery systems, allowing mechanical mills to operate efficiently at lower rates of output than is possible for Kraft pulping.

Table 3.1 outlines the main characteristics of different mechanical and chemical pulping methods. As can be seen, differences in pollution- and resource-intensity are only one of the factors governing choice of process routes, with pulp characteristics, capital and labour costs, technological complexity and scale also impinging on investment decisions. It should also be remembered that due to differences in pulp strength and

other characteristics, the various process routes are not perfect substitutes, but instead tend to be used for different end-products. Partly as a result, output prices also differ among different types and grades of pulp: low yields and high capital costs translate into high unit costs of Kraft production in comparison with mechanical methods, but this is offset by the higher price commanded by Kraft pulp on international markets. Section IV of this chapter returns to the question of technological choices facing firms in their efforts to reduce mill-level contamination.

Table 3.1: Comparison of Mechanical and Chemical Pulping Methods						
	Stone Ground- wood	Refiner Ground- wood	Thermo- Mechanical	Chemi- Thermo- Mechanical	Sulphite	Kraft
Yield on dry wood (%)	96-97	94-95	92-93	90-92	50-75	40-50
Energy Requirements	energy intensive	energy intensive	energy intensive	energy intensive	energy intensive	nearly energy self- sufficient
Pulp Strength	lowest _____ increasing to _____ highest					
Technological Complexity	lowest _____ increasing to _____ highest					
Capital Cost	lowest _____ increasing to _____ highest					
Labour Requirement	high	low	low	low	variable	variable
Water Pollution Potential	low	low	low to medium	medium	high	high
Air Pollution Potential	nil	nil	slight	low	high	high
Source: Beak Consultants, "Environmental Considerations in the Pulp and Paper Industry", 1980; reprinted in Wheeler and Martin, 1992, p. 217.						

iii) recycled fibre. A third main set of pulping technologies are those used for production of pulp from recycled wood fibre. Use of recycled fibre has increased

markedly over the past two decades, and now accounts for perhaps a third of total pulp capacity world-wide (IIED, 1996, 104). The utilization of various types of fibre is measured in terms of the "fibre furnish" of paper products: while the proportion of recycled fibre has increased for all classes of paper products, it is most pronounced in newsprint and cardboard/boxboard uses. Recycling leads to a shortening of fibres, which reduces the potential use of recycled fibre in some paper products requiring superior strength and/or appearance. Even here, however, adaptations in paper-making technology are leading to progressively greater use of recycled fibre.

The environmental impact of recycled fibre pulping depends in particular upon whether there is need for removal of inks, adhesives and other impurities. "De-inking" involves the use of chemicals to assist in separating inks from the paper fibre, with the ink then removed by flotation or washing. When de-inking is not required, secondary fibre pulping is relatively simple and requires little or no use of chemicals; the environmental impact of such operations is much lower than other pulp mills, and similar to the impact of paper converting mills without in-house pulp capacity. Like mechanical pulping, secondary fibre pulping (whether de-inked or not) is economically viable at relatively small scales of production, but requires purchase of outside energy.

In addition to these three dominant forms of pulp production, recent years have also seen the development of a number of alternative pulping technologies which, while still at a relatively early stage of development, hold out the promise of significant environmental benefits. These include solvent-based pulping in which organic solvents like ethanol and methanol are used to remove the lignin from wood fibre. Solvent-based methods produce pulp of similar quality to Kraft methods, but at lower scale and with

higher yields and less need for bleaching. They also result in the recovery of a number of marketable wood-based chemicals – although the extra revenue deriving from these products may be offset by the need to purchase outside energy. Also of interest is the use of biotechnological pulping agents; these are not yet at a stage where they offer a potential alternative to traditional bleaching technologies, but there has been some commercial application of enzymes such as xylanase as a delignification agent in combination with chemical pulping methods (see the discussion of alternative pulping methods in Smith, 1997, 118-120).

b) The Bleaching Debate

The second main factor which influences the extent of pollution from pulp production is the nature of bleaching processes used to improve the colour of pulp. All pulping methods generate organic material in liquid effluents (plus some toxic compounds found in the extractives of wood itself) with the extent of pollution depending primarily on wood yield. As noted above, however, increasing attention has been placed on toxic compounds in bleach plant effluent, particularly since the discovery in the late 1980s of potentially carcinogenic dioxins and furans in the effluent from bleached Kraft pulp mills.

The extent of bleaching is a function of product end-use and type of process technology. Given their inherently greater brightness, mechanical pulps are not generally bleached for use in newsprint or similar products – although they may be “brightened” with chemicals other than chlorine for use in tissue and similar products where colour is a key factor in consumer demand. For chemical pulp, however, the dark colour of raw pulp means that bleaching is common for many end-uses. Hence, the bleaching issue is primarily of concern to chemical pulp producers. Traditional end-of-pipe controls

reduce but do not eliminate organochlorines, and as a result much of the emphasis is on internal process changes to reduce or eliminate the use of chlorine in bleaching.

Currently, the main point of contention is between **elemental chlorine free (ECF)** pulp on the one hand and **total chlorine free (TCF)** pulp on the other. In ECF pulp production, chlorine dioxide is used in place of chlorine gas, resulting in lower levels of organochlorines and reduced airborne emissions; in TCF pulp production, alternative bleaching compounds (mostly ozone or peroxide) are used in place of chlorine. Pressures to move toward TCF production have been spearheaded by Scandinavian producers, who pioneered chlorine-free production and have attempted to use this new technology to command a price premium on international markets. While production is slowly moving toward ECF pulp as the industry standard, the North American industry has for the most part resisted the further shift to TCF production, both by lobbying regarding environmental regulations, and by investing in research regarding the specific components of chlorine which result in damage to aquatic life.

There is now a vigorous debate regarding the environmental benefits of ECF vs TCF (see, for example, Smith, 1997, 120-132; and IIED, 1996, 114-117). The environmental impact of alternative bleaching techniques depends not only on the choice between ECF and TCF methods, but also on a range of additional measures which can be combined with either method to reduce emissions and improve overall environmental performance. Thus, “enhanced” ECF production adds oxygen delignification and extended cooking in the pre-bleaching stage to remove excess lignin and hence reduce chlorine dioxide use; “ozone” ECF substitutes ozone in the first phase of chlorine dioxide bleaching sequence, but does not totally eliminate chlorine dioxide use; and, experimentation has been

undertaken with a “closed” ECF process in which bleach plant effluent is recycled and chlorides removed.

Table 3.2: Environmental Indicators of Alternative Bleached Kraft Pulp Technologies						
	Traditional pulping and bleaching	Traditional ECF	Enhanced ECF	Low-effluent ozone ECF	Low-effluent TCF	Enhanced ECF with chloride removal
Bleach plant effluent flow (gal/adt)	12,000	12,000	6,500	2,300	1,700	2,300
Total energy consumption (million BTU/adt)	12.9	15.5	10.2	9.6	9.6	10.5
Purchased energy consumption (million BTU/adt)	12.9	15.5	8.2	6.5	6.5	7.4
Biochemical oxygen demand (kg/adt)	15	15	9	4	3	2
Chemical oxygen demand (kg/adt)	65	65	22	11	9	11
Colour (kg/adt)	100	100	67	3	4	2
AOX (kg/adt)	2	1.5	0.8	0.1	<0.01	0.1
Chloroform air emissions (pounds/adt)	0.118	0.011	0.002	not available	0	not available
Source: Blum, Denison and Ruston (1998), p. 41. Values are for parameters measured at the bleach plant; actual releases to the environment will be affected by the extent and nature of “end-of-pipe” pollution control technologies.						

As Table 3.2 illustrates, the environmental impact of alternative bleaching techniques varies considerably, but enhancements to ECF bleaching can allow it to meet most of the parameters of TCF, with the exception of AOX levels. Performance parameters for ECF production may be even higher for new, state-of-the-art facilities: the 1500 adt/day Alberta-Pacific mill in Northern Alberta, which entered production in the early 1990s, for

example, has reported TSS levels as low as 1-1.2 kg/adt, BOD of 0.2-0.3 kg/adt, and AOX levels of only 0.02 kg/adt (Caule, Clayton and Simonsen, 1995, 61) – although the higher performance may in this case be the result of use of hardwood (which has a lower lignin content than the more common softwood) as a fibre source. The North American industry has argued that below a certain level, AOX is not a reliable indicator of toxicity, and that ECF production combined with secondary treatment of effluents is sufficient to eliminate the most dangerous organochlorines. Moreover, recent research has suggested that remaining toxins in pulp and paper effluent may in fact result not from chlorine, but rather from organic compounds in wood itself (IIED, 1996, 117)

Based on this kind of evidence, at least one recent report argues that “in terms of environmental impact of effluent, there is no significant difference between the two systems [ECF and TCF]” (IIED, 1996, 115). While TCF production continues to account for a significant share of output in some European countries, the North American industry has continued to resist the switch, and at present there is no market premium for TCF over ECF pulp. R&D attention, meanwhile, has begun to switch from elimination of chlorine in bleaching toward full process closure or “zero-effluent” strategies, in which all liquid effluents are recovered and recycled. While process closure is now commercially viable for mechanical pulps, initial attempts at closure of bleached Kraft mills created problems in terms of product quality and corrosion of machinery because of the presence of chlorides in recirculated effluents – and as a result a perception that full closure would only be possible for TCF pulp. More recent research and pilot plant work, however, has demonstrated that closure of ECF mills may

be a realistic alternative, and the industry is investing heavily in research to this end.⁹

III. Structural Influences on Innovation and Environmental Performance

As awareness of the full range of environmental impacts of pulp production has grown — spurred on by increasingly stringent regulations in European and to a lesser degree North American countries — environmental concerns have come to play a major role in the competitive strategies of pulp and paper firms, and in the overall direction of technological change in the industry. In her recent study of the US pulp and paper industry, Maureen Smith of the University of California at Los Angeles argues that:

... for the first time in the industry's history, its internal decision-making and its future are being substantially driven by a network of diverse and often conflicting environmental forces, ranging from federal pollution control mandates and international environmental accords to consumer education campaigns and grassroots mobilization around particular facilities, companies, forests, and products. Profit and competitiveness remain the industry's goals, but the major parameters are now environmental (Smith, 1997, 16).

In all major producing countries, environment-related spending has come to account for an increasing share of both total capital investment and R&D expenditures. The economics of the industry are now in large measure determined by rates of sustainable timber harvest, waste paper recovery rates, and the capital costs of meeting environmental regulations. Many of the most important directions in corporate R&D (development of fast-growing species; low-effluent processes; development of new value-added paper products) are explicitly or implicitly motivated by environmental concerns. Environment-related programs at the Pulp and Paper Research Institute of

⁹ See the next chapter for a discussion of Canadian research in this area; for discussions of options for closure, see Rubenstein (1994), 133-143; or Caule, Clayton and Simonsen (1995), 48-86.

Canada (Paprican), a collaborative industry-funded research body, accounted for approximately 50 percent of total spending in the mid-1990s – although the total has since decreased in the face of unfavourable price trends and the absence of new short-term regulatory pressures (see the discussion in Chapter 4).

On the other hand, care must be taken in analyzing the place of environmental issues in the overall competitive situation of the industry. In the first place, it is frequently difficult to separate environment-related investments from those motivated by concerns for costs, competitiveness and productivity. Many of the most important improvements in the environmental performance of the industry (recovery boilers in Kraft pulp production; oxygen delignification to remove excess lignin prior to bleaching) have been motivated largely or entirely by their economic rather than environmental benefits.

Moreover, firms' responses to environmental challenges are also shaped by some of the broad structural characteristics of the industry. Four of these are of particular relevance to the current discussion, in that they have major implications for the nature of innovation in the industry, and on the returns to firms from development or adoption of new pollution-prevention or -control technologies:

- the scale- and capital-intensity of pulp and paper production;
- the volatile nature of demand in the industry;
- the predominance of price-based competition among pulp and paper firms; and,
- the dominance of outside actors as key sources of technology and technical know-how.

a) Capital- and Scale-Intensity

Like many other resource-processing industries, pulp and paper production is heavily scale- and capital-intensive, particularly at the stage of pulp production. The average size of new pulp and paper plants has increased over the past decades, as has the capital investment required for start-up. Swedish data, for example, indicate that between 1960 and 1993 average capacity increased by 4.9 percent annually for pulp mills, and 5.6 percent annually for paper and board mills (IIED, 1996, 23). While figures vary from country to country, on the average pulp and paper is one and one-half to two times as capital-intensive as averages for all manufacturing industries (IIED, 1996, 23). As a result, there are significant barriers to entry of new producers in the industry.¹⁰ Economies of scale, of course vary widely by type of product -- they are highest for semi-commodities like market pulp and newsprint, and much lower for some segments of paper manufacture. Even within pulp production, minimum efficient scale varies widely depending on the type of process technology in use.

As a result of barriers to entry, ownership tends to be relatively concentrated -- although less so than in some other capital-intensive manufacturing branches (IIED, 1996, 22). The extent of concentration varies widely: in Sweden the three largest firms account for some 75 percent of output, whereas in Canada ownership is more dispersed, and the average size of firms is much smaller than in competitor countries. In almost all countries, however, the mid- to late-1990s have seen a trend toward greater levels of concentration, with a number of high-profile mergers among leading firms anxious to

¹⁰ Canadian data from the 1970s ranked pulp and paper 16th of 71 3-digit industries in terms of overall barriers to entry; significantly, pulp and paper ranked third overall in terms of capital costs of entry, but much lower in terms of some of the other barriers (advertising costs, R&D-intensity). See the discussion in De Silva (1988, 12).

trim costs and increase shareholder value in a tight pulp market.

The largest firms in the industry also tend to be highly integrated vertically, with operations from forestry through to pulp production -- and, increasingly, recycled paper production. The trend here, however, is mixed. On the one hand, there has been a gradual shift toward integrated paper plants, with market pulp production growing more slowly. On the other hand, forest products firms have in a number of cases been divesting themselves of non-core operations in an attempt to reduce costs in order to compete with new, lower-cost producers. Moreover, there is relatively little backward integration from pulp and paper production into the production of pulp and paper **equipment**: for the most part, firms are dependent on outside suppliers for major investment programs (see Section IIIc below). One partial exception are the leading Swedish and Finnish forest products companies, which in many cases launched successful equipment manufacturing arms. Even here, however, most firms have since divested themselves of such businesses, which are now run by independent firms -- albeit with strong non-equity links to paper producers (see the discussion of the Finnish forest industry "cluster" in Ojainmaa, 1994, 80-83).

Capital- and scale-intensity in turn have an impact on environmental strategies in the industry. Given the high capital costs of pulp and paper production, producers are generally concerned to avoid costly retrofitting or replacement of existing mills until capital equipment has been fully depreciated (Smith, 1997, 41-42). This biases investments toward relatively discrete actions at existing mills (end-of-pipe controls, stand-alone process improvements) but also means that new mills are generally designed to exceed existing environmental standards and provide firms with a "comfort

zone” to adapt to regulatory changes. There is also a significant relationship between scale of production and environmental measures: the capital costs of environmental improvements are a particular burden for smaller mills, who in turn generally finance environmental measures by additions to scale.

b) Volatile Demand Patterns

The overriding feature of demand for pulp and paper products is its cyclical nature. Demand for paper products is very sensitive to fluctuations in overall levels of economic activity. Price movements reflect this fact -- although international prices do not simply mirror levels of aggregate demand, but also depend on the strategies of leading firms and some of the structural features of the industry. Given the relatively large scale and capital-intensity of production, capacity does not adjust smoothly to meet shifts in demand, but instead is characterized by large, “lumpy” additions to capacity -- resulting in fairly abrupt changes in international prices.

Prices over the past decade illustrate this instability. While demand was buoyant through most of the 1980s, slower growth of world economic output and major additions to installed capacity led to a period of declining prices between 1989 and late 1993. Prices then recovered and climbed to record levels, largely because of efforts of major producers to keep inventories low and limit new additions to capacity. The price of benchmark Northern bleached sulphate Kraft (NBSK) pulp more than doubled between late 1993 and the end of 1995, from \$425 USD to record prices of just over \$1,000 USD per tonne; the price of newsprint also increased over the same period, although at a slightly more restrained rate. Prices have since fallen sharply once again, and have remained low since early 1996. The recent downturn in international prices reflects

the entry into production of a number of new market pulp mills in Latin America, the Southern United States and Asia (notably Indonesia), as well as additions to capacity by existing mills in Europe and North America as firms attempt to finance environmental improvements. Prices for other commodity paper products like newsprint have followed a similar pattern, although specialty paper products generally face more stable prices.

Figure 3.1 presents the US price index for pulp and paper products.¹¹ The volatility of pulp (and to a lesser degree paper) products is readily evident, with price swings being particularly abrupt over the past decade.

Longer-term demand trends are conditioned by two factors. The first of these is the increasing demand for paper products from developing countries. Paper consumption tends to increase with levels of per capita income. Not surprisingly, then, the vast majority of pulp consumption is concentrated in the industrialized countries. Developing countries accounted for 25 percent of world consumption in 1993, up from approximately 15 percent in 1980 – a figure expected to increase to 31 percent by 2010 (IIED, 1996, 84, 93). The other factor governing overall demand trends is the growing use of recycled fibre in paper production. Recycling rates have risen much faster than predicted even a few years ago, spurred on by consumer pressure and a number of government-sponsored incentive schemes. Global waste paper recovery rates (waste paper consumption as a percentage of total paper and paperboard consumption) reached almost 40 percent in 1994 (up from 33 percent in 1988), with rates in Japan and a number of European countries standing at above 50 percent (IIED, 1996, 180). Recycling rates are likely to continue to increase over the next decade, but there are technical limits on the extent of recycling¹², and given practical issues in collection and recovery it appears unlikely that the global recovery rate will rise above 60 percent

¹¹ Indices reflect prices in current dollars, which explains the overall upward trend in pulp and paper prices.

¹² One analysis (Oxford Analytica, 1994,15) suggests an upper limit of 65 percent recycling, due to the permanent loss of paper to libraries and other archives, the presence of paper in unrecoverable waste (toilet and sanitary paper; paper mixed in complex waste), and the need to include a portion of new primary fibres in recycled products in order to compensate for the progressive shortening of fibres caused by recycling. Technological changes may, however, eventually offset each of these limits.

(IIED, 1996, 199).

Recent analyses suggest continued growth in demand over the coming decades, but with growth rates slowing over time. Pulpwood supply is probably sufficient to meet projected demand (IIED, 1996, 99), with the result that long-run average pulp and paper prices will remain stable or decline over time. However, demand is extremely susceptible to changes in overall economic conditions (such as the recent slow-down of growth in the Asian economies) and as a result pulp and paper prices will remain extremely volatile.

This volatility in turn affects the manner in which firms respond to environmental challenges. During periods of strong market demand, firms are more likely to invest in environmental improvements, and to consider new investments more generally. When prices are low, on the other hand, the focus of firms shifts to issues of costs, competitiveness and product quality. Prolonged periods of low prices may also lead firms to scale back R&D and other technical activities in an effort to reduce overall production costs.

c) Price-Based Competition

Closely linked to the cyclical nature of paper demand is the prevalence of price-based competition among firms. As noted above, pulp and newsprint are relatively standardized products, and as a result competition among leading firms has typically been on the basis of price -- although other factors such as reliability of supply are also an important consideration. Tariff and non-tariff barriers are relatively low (the last GATT round resulted in an agreement to phase out all barriers on pulp and paper

products in North America, Europe, Japan and Korea) and hence price advantages largely reflect differences in firms' costs of production¹³.

Efforts to reduce production costs have traditionally been oriented in two directions. In the first place, firms have focused on increasing scale in order to decrease unit costs – a typical "industrial commodity" strategy. This remains a potent factor in the strategies of most leading firms, and the entry of Southern producers with natural cost advantages has increased the pressure on Northern forest products firms to trim costs. Second, firms have attempted to exploit natural advantages in the production of wood fibre. It is this factor which explains the rapid growth of developing country production and exports over the past decade – as well as the continued competitiveness of Canadian producers, despite the smaller average size and greater age of plants in comparison with competitors in the US and Europe.

While price-based competition remains the rule, the nature of competition in the industry is also changing somewhat. Product differentiation in paper products is increasingly important, with some firms successfully exploiting narrower market segments where product quality, not price, is the prime criterion. Environmental concerns are also increasing the pressures on firms to decrease effluents and boost their use of recycled fibres. This has buttressed the rise of differentiated paper products, with "green" paper products able to command a premium in industrialized country markets. As the recent experience with TCF pulp has demonstrated, however, there are significant limits to the ability of pulp and paper producers to command a market premium based on superior

¹³ There are, of course, still a number of subsidies granted by producing countries – from investment tax credits to cogeneration arrangements (in which mills can sell electricity to utilities at one price, and repurchase it from the utility at a lower price). See Industry, Science and Technology Canada, 1992 for a discussion of Canadian and US subsidies to pulp and paper production.

environmental performance, particularly for commodity products like market pulp and newsprint.

The limited ability to pass on environmental costs to consumers means that firms are relatively conservative in their environmental investments. Nathan Rosenberg and colleagues have argued that one reason for the relatively slow pace of incorporation of new technologies in the forest products industries is precisely the need to control costs: uncertainties surrounding the performance of new technologies are always significant, and “seemingly superior technologies may be adopted slowly at first because they do not decisively reduce costs” (Rosenberg et al, 1994, 240). Smith makes a similar point about the barriers to adoption of alternative pulping and bleaching technologies in the US pulp and paper industry, arguing that the mature nature of the pulp and paper industry militates against radical changes in technology:

... new entrants and innovators, unlike those in a fluid early stage of technological development and industrial growth, do not have the luxury of competing in a new product niche with other young companies on the basis of quality, but rather are pitched against large integrated manufacturers of standardized commodities in a price competitive market. Although they may bring significant advantages in terms of reduced pollution control costs and reduced raw material costs, they also bring uncertainty and risk, which are very poor companions to entry costs that usually begin at \$50 - \$100 million and can easily climb into the hundreds of millions. (Smith, 1997, 42).

Production costs are a key consideration for all firms, but particularly for older, smaller mills, which not only have to shoulder the capital costs of environmental improvements, but also face competition from newer, larger mills with lower unit costs of production. At these mills, the need to control costs is likely to push firms toward relatively minor process optimization measures, with more ambitious plans introduced only in the context of major modernization programs. Where regulations demand more far-

reaching changes, smaller firms are likely to combine environmental measures with increases in overall scale of output – both as a means of narrowing the price gap with newer, larger mills, and also because strong price-based competition means that pollution abatement costs can only be financed by increasing output.

d) Dominance of Outside Technology Suppliers

Innovation strategies in the industry tend to be fairly conservative. The pulp and paper industry is a relatively mature sector, and is not characterized by rapid changes in technology. Levels of total factor productivity growth are low compared to most other manufacturing sectors. The industry tends to be characterized by gradual, incremental improvements rather than by abrupt advances. Indeed, the last truly revolutionary advance in pulping technology – thermomechanical pulping – was first introduced in the late 1960s.

The slow pace of incorporation of new technologies is linked to the characteristics of the industry discussed above. Smook (1982, 176) argues that the spread of new innovations has been slowed by high capital cost of pulp and paper plants and low profit margins (which have discouraged fast write-offs and risky ventures) and by the long "shakedown" period needed to bring new, unproven technology up to rated levels of operating efficiency. Moreover, capital spending in the industry is fairly lumpy, with large year-to-year fluctuations. This reflects not only the increasing scale and capital-intensity of production, but also the tendency of firms to finance modernization programs and new additions to capacity from current earnings. As a result, capital spending mirrors (and accentuates) the boom and bust cycles of pulp prices. Depending on their timing with respect to business cycles, environmental regulations may steer firms toward

discrete, compliance-oriented investments rather than more far-reaching changes to process technology — even when there are likely to be long-term economic returns from a more aggressive stance.

Levels of corporate R&D are also relatively modest — ranging between 0.8 and 1.1 percent of sales for major producers like Finland, Sweden and the United States, and a far-lower 0.3 percent of sales for Canada (see the next chapter for a discussion of the weak R&D performance of Canadian pulp and paper firms). This reflects not simply the conservative nature of firms, but also the dominance of outside machinery and equipment suppliers. The industry is a "supplier-dominated" one, to use the terminology developed by Pavitt (1984). While some of the larger firms in the industry have made significant advances in forestry practices, effluent control and the like, the main source of technological advance in core process technology rests with outside firms (Rosenberg et al, 1994, 234), and particularly with technology embodied in new capital equipment. Thus, for example, a study of the Finnish pulp and paper industry concludes that

Typically, the significance of intramural R&D as a source of technology is minor in the pulp and paper industry, while technologies embodied in investments have a dominant role. In addition to incremental process and product innovations, the pulp and paper industry's own innovation activity has been directed towards increases in cost efficiency of existing production technologies (Ojainmaa, 1994, 80).

Similar patterns are found in Canada, where the majority of in-house R&D by pulp and paper firms is oriented toward adaptation of process technology purchased from outside suppliers, rather than development of new technologies per se (Science Council, 1992).

The pulp and paper equipment manufacturing sub-sector consists of a large number

and variety of firms, ranging from large equipment manufacturers capable of supplying complete systems, to smaller, more specialized firms producing particular types of equipment. It is concentrated in a relatively small number of industrialized countries, with the United States and the Nordic countries playing leading roles; Canada is not a major producer, in contrast to its relatively strong position in production of logging equipment.

Given the low overall rate of innovation in core process technology, there is usually a range of suppliers for any given piece of plant and equipment. There are, however, some exceptions. Supply of some more recent pollution control technology is quite concentrated: a 1992 OECD study, for example, notes that manufacture of oxygen delignification equipment (one of the principal options for reducing chlorine bleaching in Kraft pulp mills) is dominated by three companies, two Swedish and one American (OECD, 1992, 16).

As a result of the dominance of Scandinavian and US producers, equipment tends to be manufactured to meet environmental standards in those jurisdictions. Moreover, design and engineering work for new plants is dominated by a small number of consulting firms based in industrialized countries, who tend to apply standardized plant layouts and equipment configurations. One result of this is that there are relatively few options to use "dirty" technology in new pulp and paper plants. The OECD study mentioned earlier, for example, notes that oxygen delignification equipment is now integrated into "virtually all new [Kraft] pulp mills being exported throughout the world" (OECD, 1992, 17). Spread of new pollution-reduction techniques to existing plants has of course been slower, but even here there is a certain standardization of process technology given the

dominance of Northern equipment suppliers.

One important trend in the industry has been the growth of strategic alliances between major forest products firms and equipment suppliers. This is particularly true of the Swedish and Finnish industries, where research partnerships to develop new technologies are common (see Ojainmaa, 1994, 73-74). This places pulp and paper firms in countries with a weak equipment and machinery base (like both Canada and Chile) at a competitive disadvantage in the development and application of new technologies (see the next chapter for details).

IV. Main Technological Options for Pollution Prevention and Control

The discussion in the previous section suggests that radical innovations in pollution prevention and control are likely to be rare in the pulp and paper industry, with incremental improvements and adoption of existing control technologies likely to be the norm. Within this general sectoral picture, individual firms' choices with regard to environment-related investments are likely to be affected by a variety of factors: the physical characteristics of the firm (greenfield vs. existing mill; large- vs. smaller scale); the timing of investments with regard to business cycles and pulp prices; and, the nature of linkages between the firm and outside technology suppliers. They will also be affected by the overall financial strategy of the firm with regard to its mills.

This section looks in more detail at the range of choices facing firms, by examining the principal technological options open to pulp and paper firms to reduce levels of air and water contamination from their operations. Most of the focus is on pulp production, as this is the most polluting stage of paper production, with somewhat less emphasis on

paper production.¹⁴

As noted in the last chapter, much of the debate regarding environmental investments by manufacturing firms tends to focus on the choice between “end-of-pipe” controls and internal process changes -- with mainstream environmental economics theory (and some empirical evidence) suggesting that command and control regulations will bias firms toward end-of-pipe measures rather than potentially more effective but riskier internal process changes. In fact, however, the choices facing firms are more complex. It is possible to outline four broad categories of technological options available to firms, ranging from the most complex, systemic changes to the simplest and most discrete:

- major process change;
- minor process change;
- process optimization; and
- “end-of-pipe” treatment.

The following paragraphs provide a brief description of each category, and the conditions under which firms are likely to pursue each category. As Table 3.3 outlines, the categories differ markedly in terms of sources of technology, impact on production costs, and impact on product characteristics -- and hence the conditions under which

¹⁴ Reducing environmental impacts at the paper-making stage is essentially a matter of controlling water usage, minimizing waste and re-using rejects or “broke”, and improving energy efficiency.

they are likely to be technically and economically feasible for particular firms.¹⁵

Three caveats must be raised regarding the choices open to firms to deal with industrial pollution. First, there is no single "pollution problem" in pulp production: instead, there are a series of linked problems, with complex interactions between them. Thus, for example, recent efforts to reduce chlorinated organic compounds generated in Kraft pulping via extended cooking and oxygen delignification operate by **reducing** pulp yields, and also may increase energy requirements (Webb, 1992, 68). It is thus important to understand the ways in which improvements in one facet of a mill's environmental performance affect other aspects -- as well as how they affect production costs. Second, the economic effects of efforts to improve environmental performance are complex: some operating costs will decrease as a result of more efficient use of inputs (energy, chemicals), but others may increase, and capital costs vary widely depending on the kinds of improvements in question. In many cases, environmental improvements are embodied in new, more efficient plant and equipment, with the result that it is extremely difficult to disentangle environment-related investments from those geared to improving production efficiency. This is particularly true in the case of greenfield investments and major modernization programs, where improved pollution control technologies tend to be "bundled" into overall technology packages. Finally, it must be remembered that the various options for reducing pollution are not necessarily direct substitutes for one another. In many cases, they are in fact complements, and most firms employ a mix of different strategies to reach pollution targets.

¹⁵ Not included in this typology are shifts in product design; except in relatively simple cases, these typically imply process changes as well (at least in pulp and paper production) and thus are subsumed under the other categories.

Table 3.3: Technological Options for Pollution Prevention and Control

	Source of Technical Knowledge	Impact on Production Costs	Impact on Product Characteristics	Examples
Major Process Change	External. Key role of consulting firms in providing technology packages. Significant learning required to ensure efficient operation.	Extremely high capital costs, partially offset by possibility of major improvements in efficiency, resource use. In some cases may result in by-products with commercial value (e.g., chemical by-products from solvent pulping).	Often significant changes in pulp quality, end-uses.	<ul style="list-style-type: none"> - changes in pulp process technology (e.g., shift from groundwood to TMP/CTMP; recycled fibre pulping; solvent-based methods) - alternative bleaching processes (biotechnology-based bleaching) - process closure and "zero-effluent" strategies
Minor Process Change	Usually external. Significant learning required to ensure efficient operation. In some cases changes may be designed and managed by in-house staff.	Mixed. Some input costs may decrease, but generally significant capital costs.	Some, due to increases in use of recycled fibre, changes to bleach sequences.	<ul style="list-style-type: none"> - improved chipping and fibre handling techniques - improvements in pre-bleaching stage to reduce residual lignin (oxygen delignification, extended cooking), improved pulp washing prior to bleaching - changes to bleaching sequences to reduce chlorine use - increased use of recycled fibre in paper-making - cogeneration of energy
Process Optimization	Largely internal, except for some specialized equipment.	Generally decrease, due to limited capital costs, improved yields, decreases in energy and other inputs.	Nil	<ul style="list-style-type: none"> - house-keeping measures to separate waste streams and partially "close" process loops - improvements in cleaning, screening to reduce waste, increase fibre recovery - spill control - automated process control - improvements in energy efficiency
"End-of-Pipe" Treatment	External; generally standardized, "off-the-shelf" technologies. Some internal effort needed to ensure optimization.	Generally increase, due to capital outlays required, plus increased maintenance costs, decreased energy efficiency	Nil	<ul style="list-style-type: none"> - primary and secondary treatment of liquid effluents - scrubbers and/or electrostatic precipitators to limit airborne emissions; stripping of gases to limit odours - improved handling and disposal of solid wastes

a) Major Process Change

At one extreme are major, radical changes in process technology. Such changes tend to be systemic rather than discrete (i.e., they involve changes in several facets of plant design and layout, rather than just a single operation or piece of equipment). They imply major new technological knowledge, and typically (although not always) depend on outside sources of technological expertise. They involve significant capital costs, as well as indirect "learning" costs associated with the mastery of new technology.

As a result of these factors, this type of major process change is generally only feasible in new, greenfield investments, or in the context of major modernization programs.

Major process changes are unlikely to be pursued solely in order to comply with environmental regulations; instead, they are usually also motivated by the search for greater operating efficiency and/or the pursuit of new market opportunities (higher value-added products; commercialization of new process technology).

The main type of major process change in recent years has been the growing prominence of TMP and CTMP production. As noted above, the factors governing choices among pulp-making processes are complex, but one of the key advantages of TMP/CTMP compared with Kraft pulp is its significantly lower environmental impact.¹⁶ Other examples would include application of completely new pulping technologies (such as the solvent-based Alcell technology developed by Repap of Montreal), or non-

¹⁶ As noted earlier, due to differing product characteristics TMP/CTMP does not generally substitute **directly** for Kraft pulp. Instead, TMP/CTMP has tended to substitute for older mechanical pulping processes, permitting the production of a higher quality pulp. This in turn has allowed paper producers to reduce the percentage of Kraft pulp in newsprint and other paper products, and thus **indirectly** substitute for Kraft pulp. See Wheeler and Martin (1992) for a more complete discussion of the factors governing the rise of TMP).

traditional bleaching technologies such as the use of bio-engineered enzymes.

Also included in this category would be attempts at "closure" of mills, in which waste streams are re-used and recycled in order to attain zero-effluent (or near-zero) production. Although in a sense a form of process optimization, total plant closure strategies involve significantly complex and systemic changes to be considered as major process change. They generally imply significant capital costs (improved recovery boilers, non-corroding pipes, etc). The impact on operating costs is mixed: while there are savings on some inputs, maintenance and energy costs tend to be higher. Recent estimates suggest that even in the case of new, greenfield mills, low-effluent Kraft pulp production would be significantly more expensive per unit of output than conventional processes (Mannisto et al, 1995).

b) Minor Process Change

The dividing line between major and minor process changes is a blurry one. In general, minor process changes tend to be more discrete than those described above, although they may imply changes to more than one facet of mill operation. They still involve significant capital costs, but are both economically and technically feasible as renovations to existing mills. Impact on overall production costs is mixed: capital costs will be significant, but may be partially offset by savings on some operating costs. External sources of technology are likely to be important in this category, but in-house capabilities are also likely to be salient as firms try to integrate new equipment into existing production routines.

Examples include changes to bleaching sequences to reduce chlorine use (oxygen

delignification; extended cooking before the bleaching stage; substitution of chlorine dioxide for chlorine); cogeneration technologies which permit savings in total energy costs; efforts to improve wood yields through improved chipping technologies, higher-yield digesters and the like; or shifts in input use (increased use of recycled pulp).

These kinds of minor process changes may be prompted either by efficiency considerations or by specific environmental concerns. Given the prospect of longer-term cost-savings and/or changes in product characteristics, process changes are likely to be favoured in cases where regulations provide firms with a long time-horizon to implement changes, or where there are specific regulatory or market barriers which cannot be met through end-of-pipe changes (e.g., restrictions on import of chlorine-bleached paper products; limits on AOX levels). On the other hand, however, process changes demand considerable time and effort on the part of firms to ensure efficient operation, and their short-run effects on effluent levels may be uncertain; hence, they are unlikely to be favoured by firms facing short-run targets on “traditional” pollutants like TSS and BOD. Learning costs may be less significant for larger firms with a number of mills, who can presumably apply the lessons learned in one mill to their other operations, thus reducing the level of risk posed by process changes.

c) Process Optimization

A third type of technological response involves optimization of existing process technologies. As with the other categories, there is a range of options within this category -- from relatively simple housekeeping measures (fixing leaks, separating waste streams for recovery) to more complicated automated process control technologies. Also included in this category would be improvements in environmental

management practices (waste auditing, etc.).

Capital costs are likely to vary widely, but in almost all cases will be more than offset by savings in operating costs. While some degree of external technological input will be involved (particularly for the more complicated options), in-house knowledge of plant operation will be a crucial input. Learning costs will be limited, and there will be relatively little impact on product characteristics.

Process optimization measures are unlikely to be sufficient to comply with regulatory requirements, particularly in the short run. Nor do they generate the kinds of changes in product characteristics necessary to ensure access to environmentally more demanding markets. As a result, pursuit of process optimization measures is likely to be related not so much to external environmental pressures on the firm (regulatory or market-based), but rather to the internal characteristics of firms and mills. Established mills -- particularly those facing significant cost pressures due to age and scale of equipment -- are likely to place considerable emphasis on these kinds of process optimization activities. More generally, the more innovative firms in the industry are likely to pursue these kinds of optimization activities alongside broader process changes, as a means of ensuring continual improvements in operating parameters.

d) End-of-Pipe Treatment

The final category of technological response is the installation of "end-of-pipe" equipment to reduce or recover contaminants: scrubbers and electrostatic precipitators for airborne emissions; primary, secondary and tertiary treatment facilities for liquid effluents; and facilities for handling and disposal of solid wastes.

Such technologies are sourced almost exclusively from external sources, generally as off-the-shelf equipment with limited customization. Little in-house technological input is required, and learning costs are negligible – although there is need for ongoing effort to optimize effluent treatment systems. End-of-pipe solutions generally imply increases in both capital and operating costs (energy costs in particular are likely to increase). They are applied specifically in order to meet environmental goals, with no positive spill-overs on the economic performance of firms, and no impact on product characteristics. In fact, end-of-pipe technologies generally increase operating costs because of decreased energy efficiency and increased maintenance costs.

The principal advantage of end-of-pipe solutions from the perspective of the firm is the certainty they provide regarding short-run reductions in environmental impact. This is offset, however, by their high costs and neutral or negative impact on operating costs. End-of-pipe technologies are a low-risk but high-cost solution, and are thus likely to be favoured as a means of meeting specific, short-run environmental targets – notably those imposed by environmental regulations, or by specific restrictions on access to key markets (eco-labelling schemes which stipulate effluent targets or use of particular control technologies). The exception is in the case of greenfield mills, where most new mills incorporate industry-standard control technologies regardless of short-run regulatory or market pressures.

V. Conclusions

A major conclusion of the above analysis is that some of the structural features of the international pulp and paper industry (scale- and capital-intensity; low levels of R&D and slow rates of change in core process technology; price-based competition and limited

scope for product differentiation) dramatically affect the opportunities for innovation in response to environmental pressures. In particular, these features of the industry militate against radical advances in technology, and instead favour incremental improvements to existing equipment and/or the application of proven pollution abatement and control technologies.

Capital-intensity and lengthy depreciation periods also mean that firms are extremely sensitive to shifts in regulatory and/or market requirements, basing investment decisions on anticipated **future** requirements rather than current conditions alone. Combined with the dominance of outside technology suppliers -- and the relatively concentrated nature of the market for pulp and paper equipment and consulting services -- this should result in considerable standardization in the characteristics of new pulp and paper mills across countries, regardless of regulatory regimes.

In the case of greenfield investments, therefore, mills are likely to be designed to meet European or North American standards, and to incorporate the most recent generations of pollution abatement and control technologies. There may be some latitude with regard to internal process options (bleaching sequences) and control technologies (primary vs. secondary treatment) depending on the market orientation of the mill and the specific regulatory requirements facing it. But even here long depreciation periods and the cost advantages of standardization will limit the extent of customization to local circumstances.

For existing mills, on the other hand, the scope for variations in pollution abatement and control technologies will be considerable. Choices will depend in part on the specific market and regulatory pressures facing the firm. But much will also depend on the

competitive position of the firm with regard to its rivals, as well as on the internal resources of the firm and its overall attitude toward innovation. Even in the case of new mills, the willingness of the firm to pursue improvements in environmental performance after start-up will be determined in large measure by its historically-determined habits and practices of innovation. These habits in turn are strongly influenced by the overall policy environment facing the industry, and by the historical development of the industry.

The following chapter examines these relationships by discussing the historical development of the pulp and paper industry in Canada, the evolution of public policies, and the specific environmental pressures facing Canadian firms. This in turn sets the stage for presentation of the results of research on firm-level strategies and behaviour in Chapters 5. Chapters 6 and 7 then present a similar analysis of the Chilean case, along with comparative analysis of Canadian and Chilean mills.

Chapter 4: The Pulp and Paper Industry in Canada

I. Introduction

Having discussed the environmental impact of pulp and paper manufacturing and the options open to firms in their efforts to control pollution from mill operations (the “opportunities” for environmental action, to use the terminology developed in Chapter 2), this chapter shifts focus to examine the principal influences on corporate environmental management decisions by Canadian pulp and paper firms, and the resources and capabilities of the Canadian industry to respond to environmental challenges. In this way, it provides an overview of the other two elements of the conceptual framework presented in Chapter 2: the “motives” for firms to undertake environmental improvements, and the “means” available to them to effect change. Chapter 6 presents a similar overview of the Chilean industry.

Section II provides a brief overview of the structure and evolution of the Canadian industry, and the range of trade and industrial policy measures influencing the operations of firms. Particular emphasis is placed on understanding the level and direction of innovative effort in the industry, which constitutes a key determinant of the ability of firms to respond to environmental pressures. As noted in the last chapter, the industry is less innovative than competitors in other industrialized countries, due to low levels of intramural R&D and a weak domestic equipment manufacturing sector. On the other hand, firms count on strong collaborative R&D programs and a well-developed consulting engineering sector, both of which are critical in firms' efforts to adapt to environmental pressures.

Section III then proceeds to examine the principal factors influencing environmental investments by the industry. Domestic regulations (federal and provincial) appear to be the main source of pressure. The early 1990s saw a significant tightening of regulatory limits, and Canadian regulations now meet or exceed those in competitor countries. Market pressures and the influence of foreign parent/partner firms appear to be less significant — although market-related factors may be a key influence on market pulp producers, who in many cases export a sizeable share of production to European markets. Uncertainty about future regulatory limits in the US may also have increased pressure for environmental measures at Canadian firms, given the dominance of the US market as a destination for Canadian products. Whatever the balance of motives, the Canadian industry has responded in the late early 1990s with a significant program of environment-related investment. Average effluent levels have fallen dramatically, and the vast majority of mills are now in compliance with existing regulations.

Section IV summarizes the main conclusions of the analysis, and sets out the main issues for examination in the more detailed firm- and mill-level analysis to be presented in Chapter 5.

II. Industrial Structure, Policies and Performance

a) Structure and Evolution of the Industry

The pulp and paper industry has a long history in Canada, and continues to play a significant economic role in the country. The forest products industry accounts for approximately 7.3 percent of total Canadian employment, and 12.0 percent of manufacturing value added — with about 40 percent of this latter figure resulting from

pulp and paper production.¹ Net exports of pulp and paper products in 1997 totaled \$16.4 billion, second only to the energy sector in its contribution to Canada's merchandise trade balance. Canada remains the world's largest exporter of market pulp and of newsprint, accounting for approximately 30 percent of world pulp exports and 50 percent of newsprint exports.

Table 4.1 shows the growth of production and exports by principal product group since 1980. As can be seen, the industry is dominated by market pulp and newsprint production. Other paper products account for a smaller percentage of output, but the production of paper products (notably printing and writing papers) has been increasing in recent years, as leading firms in the industry have attempted to diversify away from semi-processed commodities toward higher value-added products (see discussion below). The industry is highly export-oriented, with exports accounting for 80-85 percent of all shipments in recent years.

While export ratios are high for all products, destination of exports differs markedly. Newsprint and other paper products are shipped overwhelmingly to US destinations, whereas Western European markets are of particular importance as a destination for market pulp exports. As will be pointed out in Section III of this chapter, this means that the kinds of market-related environmental pressures faced by Canadian firms differ depending on products.

¹ Unless otherwise noted, figures in this and subsequent paragraphs are taken from the Canadian Pulp and Paper Association (CPPA), Reference Tables, various years.

Table 4.1: Canada -- Production and Export by Product (000 tonnes)							
	Pulp			Newsprint		Other Paper and Board	
	Production	Market Pulp Shipments	Market Pulp Exports	Production	Export	Production	Export
1980	19,715	6,709	5,992	8,625	7,642	2,418	980
1981	19,098	6,223	5,494	8,950	7,871	2,309	879
1982	16,699	5,381	4,757	8,097	7,109	2,315	972
1983	19,219	6,584	5,807	8,414	7,405	2,651	1,197
1984	20,179	6,389	5,527	8,917	7,863	2,871	1,335
1985	20,242	6,527	5,717	8,890	7,883	3,159	1,554
1986	21,556	7,316	6,466	9,202	8,118	3,486	1,765
1987	22,865	7,838	6,876	9,630	8,559	3,714	1,983
1988	23,535	7,933	6,983	9,840	8,542	4,107	2,270
1989	23,422	7,893	7,030	9,640	8,466	4,285	2,521
1990	22,605	6,999	6,275	9,068	7,999	4,651	2,947
1991	23,096	7,747	7,018	8,855	7,602	4,719	3,111
1992	22,653	7,845	7,134	8,753	7,924	4,769	3,204
1993	22,896	8,132	7,386	9,131	8,004	5,295	3,588
1994	24,649	9,668	8,831	9,299	8,325	5,556	3,874
1995	25,402	9,687	8,803	9,226	8,051	6,043	4,217
1996	24,352	9,633	8,819	9,025	7,739	5,795	4,099
1997	24,850	10,118	9,249	9,204	8,252	6,082	4,424
Source: Canadian Pulp and Paper Association, <u>Reference Tables</u> (1998).							

The industry has grown in large measure due to an abundant supply of high-quality, low-cost wood fibre. This advantage in fibre supply continues to be a main source of competitive advantage in the industry: while a number of lower-cost wood-producing regions (Southern US, Brazil, Indonesia) have arisen in the past two decades, the quality-cost ratio of Canadian softwood pulp is still very high, and remains the principal foundation of the industry.

On the other hand, overall productivity rates have been relatively stagnant since the 1960s, reflecting relatively low rates of new investment and continued pressure on input and labour costs (Statistics Canada, 1996). The longer-term competitiveness of the industry is constrained by several factors. The first of these is the limited production of value-added paper products. While printing and writing paper production and exports have increased significantly over the past two decades, the industry is still dominated by commodity exports which are vulnerable to competition from new paper-producing regions with lower fibre costs. In addition, the greater average age and smaller average scale of Canadian pulp and paper **mills** vis-a-vis competitor countries has long been a source of concern. Given the general trend in pulp and paper production to greater scale of new mills, new entrants generally enjoy a significant advantage in scale economies compared to established Canadian mills. Finally, competitiveness has also been limited by the smaller average size of Canadian pulp and paper **firms** compared to rivals. Despite Canada's leading position as a pulp and paper producer, until recently few Canadian firms have ranked among the largest in the industry world-wide — although has changed somewhat in recent years due to a number of high-profile mergers and acquisitions.

Competitive pressures have been particularly significant for newsprint producers, who in addition to smaller average mill size have also been affected by changes in patterns of input supply: increases in the recycled content in newsprint puts Canadian producers at a competitive disadvantage vis-a-vis American producers, who are generally located closer to major urban markets which constitute the principal source of recycled fibre. Partly as a result of this, newsprint production and exports have stagnated over the past two decades. Market pulp and other paper products, on the other hand, have been

more dynamic. Table 4.2 shows the evolution of Canada's competitive position in the three principal product groups. As can be seen, share of pulp exports has remained largely steady at 30-35 percent over the past three decades, but newsprint exports as a share of world exports have fallen significantly in the same period. While still much smaller in volume terms, Canada's share of printing and writing paper exports has almost doubled (Globerman et al, 1998, S30).

Table 4.2: Canada's Share of World Exports, by Volume (percent)			
	1965-1974	1975-1984	1985-1994
Wood Pulp	31.0	34.2	32.3
Newsprint	70.0	64.6	55.7
Printing and Writing Paper	7.2	8.6	13.3
Source: Globerman et al (1998), S30.			

Overall capacity in the industry grew relatively slowly during the 1970s and early 1980s, as a number of producers closed older, less productive mills in the face of increased competitive pressures. Capacity has grown somewhat more rapidly since the mid-1980s, at least for pulp and printing and writing papers; newsprint capacity has continued to stagnate in the face of strong competitive pressures. Even during the most recent period, however, new investment has been oriented primarily to upgrading and expansion of existing plants, rather than to new, greenfield investments. Only a very small number of new mills have been built over the past decade. Expansion of existing mills has been given added impetus by environmental pressures which have increased capital costs for pollution abatement and control: typically, firms have financed new investments by adding capacity. One indication of the extent of investment in modernization and expansion has been the rapid increase in TMP and

CTMP production, as newsprint and other mills have phased out groundwood and sulphite pulp production. While Kraft pulp remains dominant, TMP and CTMP have come to represent an increasing share of overall Canadian pulp production over the past two decades.

Levels of foreign investment in the industry are significant, coming primarily from US forest products firms — and more recently from Japanese investors. Aside from New Zealand based Fletcher Challenge (3 mills) and Sweden's Stora (1 mill) all foreign investment in the industry originates from the US or Japan. Approximately one-quarter of total output is accounted for by foreign-controlled firms.

b) Trade and Industrial Policy

The strong export orientation of Canadian pulp and paper firms has meant that domestic import protection has been relatively unimportant as an influence on the industry. Recent years in particular have seen the elimination of barriers on forest products as a result of GATT/WTO negotiations and bilateral/regional trade agreements.

More significant have been a series of government measures designed to promote investment and modernization in the industry. A study of subsidies to pulp and paper producers in Canada and the US (ISTC, 1992a) found that overall levels of subsidy in the two jurisdictions during the 1980s were roughly similar. However, the form of subsidies was significantly different, with Canadian support overwhelmingly in the form of grants and direct financing, as opposed to US subsidies which tended to take less transparent forms (tax-exempt bonds; high-leverage financing; and cogeneration schemes in which firms sold electricity generated within mills to utilities at a high rate,

and repurchased it at from the utility at a lower rate). Overall Canadian subsidies amounted to about 5.4 percent of investment on average, with more than half of the amount (over \$500 million in constant 1989 dollars over the course of the 1980s) coming in the form of grants.

Canadian government (federal and to a lesser degree provincial) grant programs have been designed primarily to assist firms overcome some of the structural hurdles facing them — notably the age/size problems noted in the previous section. To a lesser degree, they have also been focused on improving environmental performance and stimulating the growth of higher value-added products.

The best-known of the programs was the Pulp and Paper Modernization Program (PPMP), a joint federal-provincial program which operated between 1979 and the mid-1980s (and until 1991 in Newfoundland) and offered capital subsidies to firms for modernization, rationalization of production, pollution abatement, energy efficiency and development of higher value-added products. The program was successful in stimulating investment, including investments in improved environmental performance in some mills. However, one analysis (de Sliva, 1988) argues that the overall impact of the program was limited, for a number of reasons:

- it came into effect just as profitability in the industry was increasing due to improvements in pulp prices and closure of many older, unprofitable mills; as a result, the justification for the program was questionable, in that firms in fact faced little difficulty in attracting capital for new investments;
- it was not incremental — much of the investment subsidized under the program would have occurred even in the absence of subsidies;

- subsidies did **not** go primarily to older mills; and,
- Canadian content rules provided a boon to domestic suppliers, but increased prices and hence limited the impact of the program on the overall competitive position of the industry.

In addition, the impact of the program was limited by the fact that British Columbia and the Prairie provinces refused to participate in the program.

At the same time, it is also true that the PPMP helped lay the foundations for compliance with environmental regulations introduced in the early 1990s — at least among mills in Eastern Canada which faced the greatest competitive and environmental threats due to their age and size. It is unlikely that adjustment to the new regulations would have been so widespread and rapid (see section IV of this chapter) without the upgrading investments carried out under the PPMP in the 1980s. Firms have also benefitted from a number of additional fiscal incentives not directed exclusively at the pulp and paper industry — notably accelerated capital cost allowances on pollution abatement investments, and rebates of federal sales tax on pollution abatement equipment.

During the 1990s, critiques of earlier programs combined with a much tighter fiscal situation have resulted in significant changes in the nature of government support to the industry. Capital subsidies have been largely phased out, and much of the emphasis has now turned to R&D support. The federal government Forest Industries R&D and Innovation Program was launched in 1990 as a vehicle for shared-cost financing of mission-oriented, pre-commercial R&D involving forest products companies, equipment

suppliers and research institutes. Originally focused on individual research projects, the program has recently shifted to emphasize larger umbrella programs on particular topics. Two such Memoranda of Understanding have now been signed — one with the Pulp and Paper Research Institute of Canada for a program on closed-cycle technologies; and one led by MacMillan Bloedel on high value-added paper products.

c) Level and Direction of Innovative Effort

Despite programs such as the ones outlined above, most observers agree that the level of innovation in the Canadian pulp and paper industry is low compared to that in many competitor countries. There are a number of indications of this situation (Globerman et al, 1998, S33-37; see also Science Council, 1992):

- levels of intramural R&D spending by Canadian firms are low by international standards, averaging only 0.4 percent of sales compared to 1.1 percent in the United States, 0.5-1.0 in Finland, and 0.6-1.4 in Sweden;²
- Canadians hold only a small share of total patents registered in the paper products and paper-making fields, either in Canada or in the US;
- employment of R&D personnel in Canadian firms is lower than for comparable US and Scandinavian firms;

² Levels of intramural R&D spending are lower in pulp and paper than in almost all other Canadian industrial branches. On the other hand, the relative weakness of Canadian pulp and paper R&D spending to competitor countries does not appear to be any more significant than the R&D gap facing Canada in other industries. Statistics Canada data for 1993 show that overall business expenditures on R&D (all industries) was only 0.8 percent of Canadian GDP, compared to 1.9 percent in the United States and Japan, and 2.1 percent in Sweden. See Statistics Canada (1996c).

- rates of adoption of new technologies (e.g, advanced manufacturing technologies) appear to have been slower than in competitor countries, or in other industries in Canada.

The ability of the Canadian pulp and paper industry to innovate in response to environmental pressures is also limited by the relative weakness of the domestic equipment manufacturing industry. This industry is relatively small in comparison to the United States and Scandinavian countries, and is dominated by branch offices of foreign-controlled firms. Partly as a result of this, there has been little development of the strong supplier-user linkages witnessed in countries like Finland. The pulp and paper equipment industry grew significantly during the 1980s, but remains small in global terms (approximately 50 firms and \$250 million CAD in sales in 1990). Most of the growth during the 1980s came as a result of increased exports from a small number of specialized suppliers (ISTC, 1992b, 8) — there is no evidence that linkages with Canadian pulp and paper firms have improved over the period, and there are no inter-corporate holdings or alliances for technology development between equipment suppliers and pulp and paper firms.

Globerman and colleagues (1998, S35) argue that Canadian forest product firms “have simply built their competitive success on access to high-quality fibre and an engineering focus on being cost-efficient in the production of ‘commodity’ products”. Levels of innovation are low, and innovative effort is geared largely to improving product quality and costs, rather than promoting product innovation and differentiation. As a result, they argue, Canadian producers are poorly placed to face the challenge of moving to higher value-added products as new entrants erode some of the typical cost advantages of Canadian pulp production. To the extent that this characterization is true, it can also

be expected to have significant impacts on the manner in which firms adapt to environmental pressures — with a focus on incremental improvements and adaption of control technologies rather than more far-reaching process changes. The weakness of the domestic equipment manufacturing base can be expected to further erode the potential for development and introduction of process changes.

At the same time, however, the Canadian industry does have strengths on which to draw in its efforts to adapt to environmental pressures. While the domestic manufacturing base is weak, the service sector (consulting engineering companies, monitoring services) is much better developed. Canadian consulting engineering companies are strong, and in a number of cases are among the world leaders in pulp and paper mill design and engineering — including in the environmental field.

Even more importantly, a well-developed structure of collaborative research provides a strong basis for adaptation. The principal institution in this regard is the Pulp and Paper Research Institute of Canada, a collaborative research body linked to the Canadian Pulp and Paper Association. The Institute, which has a current budget of approximately \$40 million annually, is funded primarily by contributions from member companies (about 75 percent of total revenue, with contributions levied on a per-tonne of output basis).

Smaller contributions come from contract research, interest income and a direct contribution from Industry Canada, and indirect support is provided by the Quebec government in the form of 40 percent refundable tax credit for expenditures on research consortia like Paprican.

Paprican is generally seen as an example of a successful industry-led research consortia. Its success is due in part to the highly export-oriented nature of the Canadian

industry, which means that member companies view foreign producers as their principal rivals; this, plus the relatively standardized nature of pulp and paper technology, mean that the scope for collaboration in pre-competitive research is relatively large (Potworowski, 1994, A-13). Paprican accounts for a significant share of total R&D activity in the industry, with active programs in the areas of product quality and value, cost-competitiveness issues, and environmental performance. The Institute also carries out contract research and provides technical services to its members. There are currently 42 member companies, who collectively represent some 90 percent of total pulp and paper capacity in the country.

The Institute has played a key role in research in the environmental field. At its height in the early 1990s, environment-related research accounted for approximately half of the total research budget. This has since declined dramatically, and now represents under 20 percent of the total — reflecting the fact that major regulatory hurdles have now been cleared by the industry and that lower pulp prices since 1996 have placed increased pressure on firms to cut costs and improve quality to compete in a tight international market. The role of the Institute was particularly important in the industry's adjustment to the dioxin "scare" of the late 1980s: Institute research played a major role in identifying toxins in pulp mill effluents and developing strategies for their removal. Equally important to the industry, it helped to stave off federal AOX regulations, and in essence bought time for the industry to adjust to dioxin/furan regulations. At present, the major focus of Paprican research in the environmental field is on process closure for bleached Kraft pulp plants.

Despite the important role of Paprican, it appears likely that the primary direction of innovation in the Canadian industry in response to environmental pressures will be

continued application of imported abatement and control technologies, coupled with incremental improvements in the efficiency of existing operations — what one report refers to as an “adopt and adapt” strategy (Science Council, 1992, 17). More ambitious programs like Paprican’s work on closed-cycle technologies are promising, but have not yet resulted in commercial applications, and have not been a factor in adjustment by industry to recent regulatory pressures. There have been some more major technical breakthroughs in the industry — notably pioneering work on closed-cycle processes for TMP production by Millar Western and others, and Repap’s work on solvent-based pulping processes³ — but these are exceptions to the general pattern of innovation in the industry. I return to this issue in the discussion in Chapter 5.

III. Environmental Pressures and Policies

This section of the chapter discusses the principal influences on the environmental behaviour of the Canadian pulp and paper industry as of the mid-1990s, and general trends in environmental performance for the industry as a whole. It sets the stage for the more detailed analysis of individual firms in Chapter 5.

The paragraphs which follow argue that the principal influence on environmental behaviour for the industry as a whole in recent years has been regulatory pressure, with market pressure and other factors (e.g., ownership) playing a less important role. The

³ Repap’s Alcell process for solvent-based pulping represented a major technical breakthrough for the industry with significant environmental implications (Science Council 1992, 17), but to date has had no commercial application. The process was ready for application in one mill in the mid-1990s, but plans were shelved due to the fall in world pulp prices. The process shows promise for hardwood pulping, although there is some loss of pulp strength. More importantly, the competitiveness of the process depends on ability to sell recovered lignin for manufacture of other products: these are high value-added but low-volume applications, which raises doubts about the viability of the process on a widespread scale.

situation, however, varies considerably among firms and product lines, with a number of bleached Kraft pulp producers in particular exposed to strong environmental demands in European export markets.

a) Market and Ownership Factors

As noted in Section II of this chapter, the Canadian pulp and paper industry is highly export-oriented, with over 80 percent of total shipments destined for export markets. As a result, producers are extremely susceptible to shifts in environmental demands in key export markets. This is backed up by the findings of a survey of 76 Canadian forest product firms carried out by the Conference Board of Canada in 1992 (Krajewski, 1992, 39-56). Sixty-five percent of exporting firms in the sample reported that foreign environmental measures affected their ability to access export markets. Of the foreign-market environmental measures mentioned as a barrier to market access, the most important were regulations concerning waste paper recycling (23 percent), bans on harvesting of old-growth forests (21 percent), and chlorine bleaching/AOX regulations (14 percent).

It is important, however, not to overstate the impact of export-market environmental pressures. Pulp and paper exports are concentrated in the United States, which accounts for approximately 60 percent of total exports, and 50 percent of total shipments. By contrast, European markets take in approximately 16 percent of total exports, or 13 percent of total shipments. Environmental demands are generally highest in European markets, due to strong consumer demand and a number of well-established eco-labelling programs. In contrast, environmental standards in the US during the 1990s have not been significantly more demanding than Canadian standards,

and in many respects are less demanding – the exception being regulations on waste paper recycling, where US standards for recycled content have placed Canadian firms at a competitive disadvantage due to the greater reliance of Canadian newsprint producers on virgin fibre, and the greater proximity of US producers to major urban centres which are the source for recycled fibre.

In terms of regulations on pulp mill effluents, the main constraints are likely to arise in European markets, where pressures to phase out chlorine use have been strongest. Overall, then, foreign-market effluent standards are likely to exert an influence on only a minor share of Canadian pulp and paper exports.

There are, however, two caveats to this conclusion. First, it is likely that the key constraint regarding US market access has not been **actual** regulations, but expectations of future regulatory limits. For several years, the United States Environmental Protection Agency (EPA) has been involved in discussions regarding new pulp and paper effluent guidelines as part of its overall “cluster rules” initiative on industrial environmental standards. There was considerable uncertainty about the outcome of this process over the course of the mid-1990s, in particular concern within the Canadian industry that regulations would stipulate stringent limits on AOX levels which would be difficult for Canadian producers to meet without converting bleached Kraft pulp operations to TCF production. In the end, the new guidelines announced by the EPA in November 1997 include BOD, TSS and AOX limits comparable to (or less stringent than) those in most Canadian jurisdictions (McCubbin, 1997, 193; see the data presented in Table 4.3 below). More stringent limits on AOX were included only as part of a voluntary incentives program. Nonetheless, there is no doubt that uncertainty about

future US limits may have exerted an important influence on Canadian producers, since Canadian regulations required them to make critical investment decisions at a time when US regulations were still under discussion.

Second, it must be remembered that export destinations vary considerably among products. Newsprint exports are concentrated in the US and Asian markets: shipments to Western Europe account for less than 10 percent of total exports and have been falling over time. By contrast, Western Europe accounts for approximately 30 percent of market pulp exports. Thus, environmental standards in European markets — notably restrictions on chlorine-based bleaching — are likely to exert considerable influence on investments by Canadian bleached Kraft pulp producers, but will be less of a factor for newsprint and other paper producers without bleaching operations.

Foreign ownership appears unlikely to be a significant influence on the environmental management decisions of Canadian firms. As noted above, there is significant foreign investment in the industry, with perhaps one-quarter of total sales accounted for by foreign-controlled mills. Moreover, a number of mills involve minority participation by foreign joint venture partners. But foreign investment is overwhelmingly from US and (to a lesser degree) Asian companies, where it is reasonable to assume that environmental pressures are not significantly higher than for Canadian-owned firms. Aside from limited investments by the Swedish firm Stora, European producers do not have equity stakes in Canadian companies. New Zealand-based Fletcher Challenge is active in the Canadian market, with three mills in Western Canada.

Thus, differences in regulatory pressures between home-country and Canadian markets are not likely to be a factor for most foreign investors in the industry. To the extent that

foreign ownership is correlated with superior environmental performance, this is likely to result from the larger size and financial resources of foreign-owned firms, and their ability to draw on experiences with regulatory compliance in a number of jurisdictions. This is not expected to be a major factor determining firm-level behaviour, but will be explored further in Chapter 5.

b) Regulatory Policies

The early 1990s witnessed a series of significant changes in environmental regulations facing the pulp and paper industry in Canada, with the result that regulatory pressures now represent a key constraint on the activities of Canadian pulp and paper firms.

Prior to the 1990s, effluent regulations had been relatively weak and ineffective. The principal legislation at the federal level was a set of 1971 amendments to the Fisheries Act. Whereas earlier standards had been set on a mill-by-mill basis based on assessments of the assimilative capacity of the receiving body of water, the 1971 amendments set standards for total suspended solids (TSS), biochemical oxygen demand (BOD), and acute lethality⁴ based on the type of process technology employed at individual mills. Standards were set on a Canada-wide basis, and were meant to apply to all direct-discharge mills – although older mills were to be provided with time to adapt to the requirements of the legislation, by negotiating with authorities regarding timetables for compliance.

⁴ The “acute lethality” parameter is peculiar to Canada as a measure of toxicity. It involves a test in which rainbow trout fingerling are exposed to effluent, and survival rates over a 96-hour period are measured. The test is still used in the latest 1992 regulations, although there has been criticism that its relevance as a measure of the toxicity of effluents is limited (Stanbury, 1993, Chapter 1, pp. 8-9).

In practice, the Act suffered from a number of weaknesses (see Sinclair, 1991; Bonsor, 1990; and Stanbury, 1993 for reviews). In the first place, standards were in fact not uniform across the country. Regulation of industrial pollution in Canada is shared between federal and provincial governments, and overlapping mandates have been a source of confusion and concern. Most provinces issue permits for mill operations: provincial standards are typically set on a mill-by-mill basis, and in many case regulate additional parameters (pH, colour, and more recently AOX) beyond those covered by federal regulations. Moreover, enforcement of regulations was — and continues to be — primarily the responsibility of provincial officials. Thus, actual regulatory limits facing mills varied widely across the country: data compiled by Sinclair (1991, 88-89) showed that of 122 direct discharge mills in operation in 1985, approximately 45 percent were subject to provincial limits more stringent than federal requirements, 31 percent faced less stringent requirements, and 16 percent faced provincial limits equal to those required under federal law (in the remaining 7 percent, information was not available).

Even more critically, in practice regulations were only applied to mills constructed after 1971 (or which expanded production by more than 10 percent after 1971); for older mills, regulations were used only as guidelines, and company officials negotiated timetables for compliance with regulatory authorities. Given the imbalance in technical and economic knowledge about mill operations between company and regulatory officials — and the potential economic impact of mill closings on what are frequently remote, single-industry communities — regulatory officials tended to be sensitive to claims about the negative economic consequences of regulations on older mills (Sinclair, 1991, 98-99). As a result, most older mills were exempted from the regulations: Bonsor (1990, 169) claims that as of 1990 only 10 percent of all pulp and

paper mills in the country were subject to the regulations. Data for 1985 indicate that a large number of mills fell below federal guidelines for environmental performance: 79 percent met BOD limits, 61 percent were in compliance with TSS limits, and only 32 percent met acute lethality standards (Sinclair, 1991, 90). Prosecutions of violators were relatively rare, and fines levied were insufficient to act as a deterrent (Bonsor, 1990, 170; see also Nemetz, 1986).

By the late 1980s, pressures had mounted for changes in regulatory policy vis-a-vis the industry. In part, changes were motivated by the evident failure of existing regulations and accompanying investment subsidies to promote environmental improvements across the industry. A 1988 study commissioned by the federal environment department (Sinclair, 1988) noted the failure of the "guidelines" approach to promoting improvements at older mills. Meanwhile, widespread media attention in 1987 and 1988 following the discovery of significant concentrations of potentially carcinogenic dioxins in Kraft pulp mill effluents in Ontario raised the pressures on both government and industry to take action.

The main result was a series of amendments to the Fisheries Act and the Canadian Environmental Protection Act (CEPA), which came into effect in July 1992 – as well as a number of changes to provincial regulations announced at about the same time (or in some cases somewhat earlier).⁵ The 1992 regulations introduced new, more stringent

⁵ The relevant provincial regulations are as follows. Alberta: Environmental Protection and Enhancement Act, June 1992 (Alberta has not issued specific regulations specifying characteristics of pulp mill effluents; instead, these are established on a mill-by-mill basis and regulated through licences to operate. British Columbia: Environmental Protection Act, 1994; and Pulp Mill and Pulp and Paper Mill Liquid Effluent Control Regulations (December 1990). Ontario: Environmental Protection Act, 1990. Control orders for all bleached Kraft mills were issued in 1989, setting limits on BOD, TSS and AOX; limits were revised and extended to all pulp and paper mills in November 1993. Quebec: Regulations Respecting Pulp and Paper Mills,

regulations on BOD and TSS, based on performance standards which could be reached with the installation of up-to-date primary and secondary treatment facilities. They also maintained acute lethality standards, and added new regulations governing dioxin and furan emissions. Even more importantly, the regulations were designed to apply to all mills (not just new ones) and to dramatically restrict the scope for exemptions from regulation. In the case of dioxin and furan limits (which applied only to mills using chlorine bleaching), mills in operation prior to 1990 were given until January 1994 to ensure compliance; all mills also had to immediately cease using woodchips contaminated with pentachlorophenol, and to reformulate defoamers to remove dioxins and furans - thus removing the two major sources of dioxin/furan emissions.⁶ In the case of BOD and TSS limits, mills which needed time to install treatment facilities or alter production processes could apply for an "authorization" to delay compliance until December 31, 1993, and a further "extension" of the time limit to December 31, 1995 under "exceptional circumstances". In practice, extensions were widely used – of the 157 mills subject to the new BOD/TSS limits, 97 were granted extensions to the end of 1995 (Environment Canada, 1998). Even so, the timetable for compliance with regulations was extremely tight by earlier standards, and there was no scope for exception beyond the December 1995 deadline.

October 1992, issued under the Environmental Quality Act. Remaining provinces have not set limits independent of federal regulations. For an overview, see Simons Consulting Group, 1994, Appendix 1.

⁶ The somewhat tighter timetable for compliance with dioxin and furan regulations (in comparison with limits on "traditional" pollutants) reflected the fact that many pulp mills had already undertaken early action to reduce chlorine use, reformulate defoamers and cut use of contaminated woodchips. At the time of promulgation of the new regulations, approximately 60 percent of affected mills were in compliance with the dioxin/furan limits, compared to perhaps one-quarter of mills which complied with new BOD/TSS limits.

Regulations also included requirements for firms to undertake aquatic Environmental Effects Monitoring (EEM) studies at all mills. EEM provisions were meant to provide greater mill-specific information in order to assess the needs for future adjustments to regulations or development of site-specific control measures. In practice, EEM provisions have been resented by industry as an extra cost to their operations, particularly because of overlap with provincial monitoring requirements; one study suggests that costs of monitoring are higher in Canada than in most competitor countries (Simons Consulting Group, 1994, 63). More recently, perception of the EEM measures appears to have improved, presumably because of better federal-provincial cooperation, and increased familiarity with the monitoring procedures and requirements.

Development of the regulations involved a series of background studies, regulatory impact analyses, and public consultations between 1990 and 1992. Industry sources clearly had an impact on this process in several respects: they successfully pushed for time extensions for compliance with the regulations; they intervened to revise estimates of capital costs for compliance with the new regulations; and, perhaps most significantly, they worked to offset pressures for the imposition of a federal standard on AOX. Overall, however, the position of industry with regard to the regulations was relatively weak and defensive: pressure to extend deadlines, for example, was as much the result of special pleading by individual mills as it was the result of an orchestrated strategy by the industry. One study (Stanbury, 1993, 3:18-20) argues that the relatively limited influence of industry on the regulations was the result of two factors. First, there was the weakness of the industry association (CPPA) as a lobbyist, particularly in the face of a well-planned campaign by environmental groups. Second, there was a serious split in the industry: on the one hand were newer, larger mills, or ones which had invested in

process improvements (particularly in the West) which could shoulder the burden of the new regulations and even potentially profit from it through slower growth in capacity and higher prices; and on the other hand were older, smaller mills (particularly in the East) which faced significant competitive pressures as a result of the need for new pollution abatement investments. This split served to weaken — although by no means eliminate — the overall influence of industry on the new regulations.

One exception to the limited influence of industry has come with the debate over AOX as a measure of toxicity. Paprican in particular has mounted a strong research effort to understand the nature of pulp mill effluents and the specific components of effluent which are toxic to aquatic life. The result of this research has been a significant body of evidence showing that remaining levels of toxicity in treated Kraft pulp mill effluent may result not from residual chlorinated compounds, but rather from other naturally-occurring compounds in wood. This kind of evidence has played a key role not only in forestalling federal limits on AOX but also in buttressing industry efforts to resist imposition of strict provincial AOX limits such as British Columbia's proposed "0 AOX" limit for 2002. More generally, research by Paprican has helped to underscore industry's position that AOX is not a reliable parameter to measure toxicity.

As a result of the 1992 regulations and accompanying provincial restrictions, Canadian pulp and paper producers face effluent standards that are at least as stringent as those prevailing in competitor countries, and in many respects more stringent. Table 4.3 provides an overview of current Canadian federal and provincial guidelines, as well as comparable limits in the United States, and a composite measure of international "good practice" based on a review of performance in a number of countries. One point which needs to be kept in mind — and which will be considered in the empirical analysis in the

next chapter — is that regulatory requirements vary among pulp-producing regions in Canada. The Atlantic provinces are the only major pulp-producing region which has not set provincial regulations; as a result, pulp mills in Atlantic Canada generally face lower BOD and TSS limits than mills in other provinces, and no limits whatsoever on AOX.

Strict numerical comparisons may understate the stringency of Canadian regulations, given the fact that current federal regulations provide few opportunities for exemption from regulations (whereas other jurisdictions frequently set permit levels on a mill-by-mill basis, providing greater opportunities for firms to lobby for lower limits). Moreover, at least one analysis claims that the use in Canada of daily maximum limits on effluents — in addition to the kind of monthly or yearly averages applied in most other countries — increases the effective regulatory burden on mills. Monthly or annual average limits allow for “peaks” and “troughs” in mill effluents, whereas daily maximums provide much less margin for error. As a result, Canadian mills have a higher probability of exceeding limits than do their competitors in other jurisdictions, and may have to operate below permitted levels in order to ensure compliance (Simons Consulting Group, 1994, 3-4). Partly as a result of these kinds of factors, competitive cost analysis shows quite high costs to Canadian firms of meeting prevailing standards, at least in the case of older, smaller mills (Simons Consulting Group, 1994, 10-12).

Table 4.3 : Regulatory Standards in Canadian and Other Jurisdictions (1)			
	Biochemical Oxygen Demand, BOD₅ (kg/adt)	Total Suspended Solids, TSS (kg/adt)	Adsorbable Organic Halides, AOX (kg/adt)
Federal Government	7.5	11.25	No limits set
Alberta (2)	1.5 - 5.5	3.0 - 9.5	0.54 - 1.5
British Columbia (2)	5.0 - 7.5	11.25	2.5 (various dates) 1.5 (by 31.12.95) 0.0 (by 31.12.02)
Ontario (2)	3.35 - 5.0	5.0 - 7.87	2.5 (by 25.11.93) 1.5 (by 31.12.95) 0.8 (by 31.12.99)
Quebec (3)	5.0	8.0	1.5/2.5 (by 31.12.93) 1.0/2.0 (by 31.12.95) 0.8 (by 31.12.00)
International "Good Practice" Levels (4)	Bleached Kraft 15.0 (4.0) Mechanical 10.0 (4.0)	Bleached Kraft 7.0 (5.0) Mechanical 7.0 (3.0)	2.0 (0.8)
United States (5)	5.5 - 8.05	11.9 - 16.4	0.623
<p>(1) Canadian data are taken from Simons Consulting Group (1994), Appendix 2. Canadian regulations at federal and provincial levels set standards for both daily maximum and monthly average discharge levels; monthly figures have been used in this chart since most other jurisdictions do not set daily maximum levels. Federal regulations also set limits for pH, acute lethality, and dioxins/furans, which are not included in this chart.</p> <p>(2) Alberta, British Columbia and Ontario set mill-by-mill discharge limits; figures are range of permit levels.</p> <p>(3) Quebec has set two AOX levels -- one for predominantly softwood-based pulp mills, and one for those using primarily hardwoods. By the end of 2000, a single limit of 0.8 kg/adt will apply to all producers.</p> <p>(4) International data are based on a survey of good practice in mills world-wide; numbers in bracket represent levels possible for new mills with primary and secondary treatment of effluents. See IIED, 1996, 119.</p> <p>(5) United States figures are EPA "cluster rules" discharge guidelines for existing mills, which were approved by the EPA in November 1997. See McCubbin, 1997, 193.</p>			

At the same time, it is important not to overstate the implications of current regulations for Canadian mills. Federal standards in particular are based on levels of performance which can be achieved with the installation of "best available technologies" for primary and secondary treatment of effluents: while mills may choose to pursue other options for

compliance, regulations are not structured to require them to search for novel means of improving environmental performance. Provincial regulations on AOX levels are somewhat more “technology forcing” in nature, since these can only be met by shifting bleaching processes to ECF or TCF methods — and/or by moving toward “closed loop” technologies in which all mill effluents are recycled. Even here, however, the main implication of current standards is the need to move toward proven technologies for chlorine dioxide substitution — particularly since industry has apparently effectively lobbied against the more extreme standards (notably British Columbia’s proposed “0 AOX” limit for 2002, which is now being quietly ignored by industry and regulatory officials alike). This suggests that the principal impact of current regulations may be to spur the diffusion of proven pollution abatement/control technologies, rather than to induce firms to develop new solutions.

c) Recent Environmental Performance of the Industry

The Canadian industry has responded to regulatory and market pressures with a significant level of investment. Pollution abatement expenditures — which had been below \$100 million during the mid-1980s — rose rapidly beginning in the late 1980s, and have averaged more than \$700 million annually between 1990 and 1996. Spending peaked in 1996 at over \$1 billion, but has declined since then, presumably reflecting the fact that deadlines for compliance with new federal regulations have passed.

Latest Statistics Canada figures

show that the pulp and paper industry accounted for almost 40 percent of total capital expenditures on pollution abatement and control by all Canadian industry in 1995 (Statistics Canada, 1998), compared to an average of approximately 20 percent during the latter half of the 1980s (Gagnon, 1996, 13). Moreover, pollution abatement and control expenditures have absorbed an increasing percentage of overall capital spending by the pulp and paper industry, rising from 1-3 percent annually during the mid- to late 1980s to 10-15 percent annually during the 1990s (Gagnon, 1996, 14).

Abatement expenditures have focused in particular on the installation of primary and secondary treatment facilities for liquid effluents, with end-of-pipe expenditures accounting for over 80 percent of all investments in 1995 (Statistics Canada, 1998, 20).

In part, however, this reflects the tremendous capital investment involved in secondary treatment facilities, and may thus understate the extent to which firms have also sought out solutions through internal process changes or better "housekeeping": in their responses to the most recent Statistics Canada survey, 61.9

percent of pulp and paper firms indicated investing in end-of-pipe controls -- but almost as many reported investments in integrated process changes (50.9 percent), and a

significant number mentioned improved control of operations (42.1 percent).

Frequency of investments in integrated process changes was highest out of the 13 industrial sectors surveyed (Statistics Canada, 1998, p. 34). This suggests that while regulatory pressures have provided the principal driver of environmental investments in the pulp and paper industry, there are distinctive patterns of adaptation at individual firms and mills. I return to this point in the analysis of firm- and mill-level data in Chapter 5.

Average effluent levels have also fallen sharply, as Table 4.4 shows. Reductions in dioxin and furan emissions are particularly striking, with overall emissions being essentially eliminated over a 10-year period; the main drop occurred at the beginning of the decade, as mills took action to meet expected regulatory requirements by reformulating defoamers and ceasing the use of treated woodchips. AOX levels have fallen dramatically as well, reflecting the speed at which bleached Kraft pulp producers have phased out the use of chlorine in favour of chlorine dioxide (see also Parsons and Luthe, 1995). BOD and TSS levels have fallen less rapidly, although BOD levels dropped markedly in 1996 as a number of new secondary treatment facilities came on stream due to the requirement for all mills to meet federal regulations by December 31, 1995. Average BOD and TSS levels are now well below federal regulatory guidelines. The drops in effluent levels since 1988 are particularly striking given that there has been relatively little greenfield investment in new pulp mills during this period; reductions thus primarily reflect efforts to improve the performance of existing mills, rather than changes in the average age of plants due to the entry into production of new mills.⁷

⁷ BOD and TSS levels also fell dramatically during the 1960s and 1970s. In this case, however, much of the reduction occurred as a result of the entry into production of new mills and the resulting drop in the average age of mills.

Table 4.4: Trends in Effluent Levels of Canadian Pulp and Paper Mills				
	Biochemical Oxygen Demand, BOD ₅ (kg/adt)	Total Suspended Solids, TSS (kg/adt)	Adsorbable Organic Halides, AOX (kg/adt)	Dioxins and Furans (g/year)
1988	26.3	10.0	4.8	360
1989	25.4	10.0	3.9	190
1990	22.9	9.0	3.4	120
1991	20.0	8.0	2.4	17
1992	16.5	7.0	1.8	12
1993	15.2	6.0	1.3	6
1994	13.3	6.0	1.0	2
1995	11.0	5.0	0.9	n.m.
1996	2.6	4.0	0.6	n.m.
Source: Canadian Pulp and Paper Association, <u>Reference Tables</u> , various years.				

Average effluent levels, of course, may mask wide differences in the performance of individual mills. The Canadian industry has typically included mills of widely differing ages and production efficiencies, and hence differences in effluent levels. In fact, however, recent improvements in effluent levels appear to be generalized across the industry. Environment Canada data on compliance with 1992 CEPA regulations during the 1992- 1994 period show a 99 percent compliance rate for "traditional" pollutants (BOD, TSS and acute lethality), and a 93-99 percent compliance rate for dioxins and furans (Environment Canada, 1998).⁸ Compliance data for 1996 show similarly high

⁸ These compliance rates are based on the number of exceedances as a percentage of all tests performed. They somewhat overstate the compliance rate for the acute lethality test, since this parameter is measured only once per month, as opposed to three weekly measurements of TSS and BOD levels. Even in 1996, a sizeable number of mills still failed to pass all acute lethality tests.

levels of compliance across most firms.⁹

The high rates of compliance for the industry lend support to arguments by Sinclair (1990) and others that earlier estimates of the negative impact of regulations on the economic viability of firms may in fact have been over-stated. Despite industry's claims in the run-up to the new regulations, few if any mills have shut down as a direct impact of the regulations. The relatively strong industry response has no doubt been aided by some of the broader conditions prevailing in the industry. In the first place, a number of the oldest and least competitive mills (particularly in the newsprint sub-sector) were shut down in the period **before** the entry into force of the new regulations, due in particular due to increased competition from lower-cost de-inking operations producing newsprint from recycled fibre — which had in turn been given a boost by regulations stipulating minimum recycling rates (Tremblay, 1994, 83). Given that pollution loads are generally strongly correlated with age and production efficiency of mills, this presumably eased the overall burden of compliance for the industry. Moreover, high pulp and newsprint prices in the 1993–1995 period facilitated financing of new environment-related investments.

One of the key questions explored in the next chapter is the extent to which some mills have moved beyond regulatory limits — and the reasons for such actions. Compliance figures also do not provide a picture of the **kinds** of investments undertaken by

⁹ Two mills in British Columbia had short term problems with their effluent treatment systems (since remedied) which caused them to exceed limits temporarily. Two other mills were out of compliance because of delays in installing treatment systems, but have since undertaken necessary investments (one of the mills was late in installing treatment equipment, and was fined under the terms of the CEPA; the other mill experimented unsuccessfully with zero discharge process but abandoned this because of scaling problems and installed a secondary treatment facility). Only one mill was consistently out of compliance with federal regulations. (David Halliburton, Environment Canada, personal communication, July 1998).

individual firms, nor the extent to which these have resulted in development of innovative capabilities within firms and suppliers. Again, I return to this issue in the analysis of survey and case-study data in Chapter 5.

IV. Conclusions

It appears clear that the main environmental influence on the Canadian pulp and paper as a whole in recent years has come from regulatory pressures. Market-related pressures appear to be a less important force, and the impact of ownership is unclear. Patterns of response to regulatory pressures, meanwhile, are likely to be strongly influenced by the overall structural conditions of the industry, and in particular by the limited innovative potential of the industry. As a result, while the industry has adjusted rapidly to new regulatory requirements, it is likely that this has been primarily via application and adaptation of proven (and largely imported) technologies.

At the same time, however, the analysis presented above suggests that there are likely to be significant differences among firms and mills — in terms of the importance of market factors, the extent of regulatory pressures on the firm, the internal technical resources available to the firm, and the kind of strategy it adopts in responding to environmental pressures. Chapter 5 returns to the Canadian case in order to analyze in more detail patterns of firm- and mill-level response to environmental pressures, and the extent of environment-related innovation evidenced in the industry in recent years.

Chapter 5: Firm-Level Responses to Environmental Pressures -- Canada

I. Introduction

The analysis in Chapter 4 confirmed the significant investments in improved environmental performance carried out by the Canadian pulp and paper industry over the past decade. Levels of pollution abatement and control expenditure have risen dramatically (both in absolute terms and as a percentage of overall capital spending by the industry). Pollution levels have fallen by correspondingly striking amounts, and compliance with existing environmental regulations is widespread. This marks a significant change from the situation prevailing a decade ago.

Preliminary evidence suggests that government regulation has been the principal factor stimulating environmental improvements. The nature and timing of pollution abatement and control investments corresponds with new regulatory pressures which came into force at the beginning of the 1990s. Market demand may also play a role, but is only likely to have affected a minority of firms, particularly those with significant exports to Western Europe. The likely impact of foreign ownership is less clear, given that foreign investment in Canada is overwhelmingly from the United States and Japan, where environmental regulations are no more stringent than in Canada — and possibly less so.

The analysis in Chapter 4 also stressed that the nature of firms' responses to environmental pressures (regulatory or otherwise) will be affected by the structural characteristics of the Canadian industry. The low levels of innovation in the Canadian industry (as measured by R&D spending, patents, or employment of technical

personnel) and the weakness of the domestic equipment manufacturing sector may limit the ability of firms to respond to regulation by developing novel technical solutions. Instead, it is reasonable to expect that the industry's response will continue in a traditional "adopt and adapt" strategy, with a focus on adoption of proven technologies (particularly end-of-pipe technologies), and incremental improvements in production efficiency and environmental performance.

At the same time, patterns of adjustment to environmental pressures are likely to vary widely among firms, depending on the kinds of variables outlined in Chapter 2 — the market orientation and ownership of firms, the age and scale of mills, and the financial and technical resources available to the firm to pursue environment-related innovation. Types of changes introduced, motives for investments and extent of innovation may all differ markedly among firms depending on their characteristics and on their historically-shaped "habits and practices" of innovation and environmental management.

This chapter examines in more detail the ways in which Canadian firms have adapted to environmental pressures, drawing on a detailed survey of Canadian firms/mills and a series of follow-up interviews with company officials and industry observers. It sets out to test some of the hypothesized relationships emerging from the analysis in Chapter 4 and the earlier theoretical discussion in Chapter 2, and to probe in more detail the nature of firm-level strategies.

The next section of the chapter presents a series of research hypotheses to be tested in the chapter, outlines the data sources and methods to be used in testing the hypotheses, and describes the survey sample. This is followed by three analytical sections, each of which discusses one of the central questions in the study:

- Section III discusses the types of changes introduced in survey firms. Particular focus is placed on the balance between end-of-pipe pollution control measures and in-plant process changes, as well as the extent to which investments in capital equipment have been matched by efforts to improve performance through “housekeeping” measures and incremental improvements.
- Section IV discusses the factors motivating firms to undertake environmental improvements. It draws on firms’ own descriptions of their motives, and then contrasts this with the picture emerging from analysis of mill-by-mill variations in investment patterns and effluent levels. This section of the chapter integrates survey data with additional mill-level data on effluent levels both prior and subsequent to the entry into force of new regulations in the early 1990s.
- Section V then examines the extent to which environmental pressures have stimulated innovation by surveyed firms, or by the industry and its suppliers more generally. The analysis draws on survey and interview data, as well as secondary source evidence regarding the extent of innovation in the industry and its supplier networks.

Section VI summarizes the main conclusions of the analysis, and outlines key points for consideration in the discussion of the Chilean experience in Chapters 6 and 7.

II. Background to the Analysis

a) Research Hypotheses

The following hypotheses are used to guide the research in this chapter:

1. Consistent with the analysis in the last chapter, Canadian pulp and paper firms have undertaken significant levels of environment-related investments in the wake of new regulations announced at the outset of the 1990s. Given the nature of the regulations, however (which stipulated relatively rapid compliance with effluent targets attainable using “best available” control technologies), investments have been heavily weighted toward end-of-pipe control measures, notably the installation or updating of primary and secondary treatment systems for liquid effluents.

2. Patterns of response are expected to vary among firms and mills depending on a number of factors:

i) Mills facing higher levels of regulatory burden as a result of the new regulations (due to age of mills and/or the absence of previous investments in improved environmental performance) are likely to register higher levels of capital spending on pollution abatement and control than other firms — but not necessarily higher levels of environmental performance, since much of their spending will be oriented toward “catching up” with industry standards of “good” environmental performance. Levels of regulatory burden are likely to spur investments in end-of-pipe control technologies, with limited impact on firms’ decisions to undertake internal process changes.

ii) Mills in provinces with more stringent regulations are likely to spend more than counterparts in provinces where such regulations are weak or non-existent. Levels of environmental performance are also likely to vary depending on the stringency of provincial regulations. In practice, this means that levels of investment and performance will be lower in the Atlantic provinces (where there are no provincial regulations on effluents) than in other regions of the country (where provincial regulations are in

general more demanding than those at the federal level).

iii) Levels of environment-related investment **and** environmental performance are likely to be positively correlated with the export orientation of firms, particularly with the degree to which a mill's output is destined for environmentally-demanding markets in Western Europe. Whereas high levels of regulatory burden are expected to spur end-of-pipe investments, export orientation is expected to promote internal process changes which are reflected in product characteristics — notably changes in bleaching sequence to reduce or eliminate chlorine use.

iv) Partially or totally foreign-owned firms are likely to exhibit higher levels of abatement expenditures and superior levels of environmental performance, due to the greater internal resources available to them, their sensitivity to home-country public opinion, and the experience gained in ensuring compliance in other jurisdictions.

v) The willingness and ability of firms to undertake environmental improvements will be affected by the level of resource and capabilities available to it, and by the physical characteristics of the mill. More active environmental strategies are likely to be associated with: larger firms with more than one mill (reflecting the greater financial and technical resources available to such firms and the ability to learn from experiences in a number of mills); firms with a history of in-house R&D and innovation; firms with a previous commitment to superior environmental management; and, larger mills (due to the scale economies inherent in much pollution prevention and control equipment). These factors are likely to be correlated with levels of environmental performance, but not necessarily with levels of environment-related investment — which may even be lower per unit of output, due to scale economies at the mill and firm level and the impact

of previous environmental investments.

3. Despite regulatory and market pressures, levels of innovation by the Canadian industry have been limited. Environmental pressures are insufficient to overcome some of the structural impediments to innovation in the Canadian pulp and paper industry (low levels of in-house R&D, weak domestic equipment base). Thus, while there are likely to be some examples of novel solutions, the overriding pattern is likely to remain one of adoption and adaptation of best-practice technologies from external sources.

b) Data Sources and Methods

In order to test these hypotheses, data were assembled from three separate sources.

First, a questionnaire survey was administered to senior officials (vice-president environment or equivalent) in Canadian pulp and paper firms in the fall of 1997.¹ The questionnaire – administered by mail to a total of 71 firms representing 117 mills – asked for a mix of company- and mill-level data regarding current environmental policies and practices, attitudes toward environmental regulation, and recent environmental investments undertaken by firms. Particular emphasis was placed on the ways in which firms had responded to new, more stringent environmental regulations introduced in the early 1990s. A copy of the questionnaire is included in Appendix 1 of this thesis.

Second, questionnaire data was integrated with additional mill-level data, in order to flesh out the information available:

- data on pollution levels circa 1987, as well as estimated capital and operating

¹ I am grateful to the Canadian Pulp and Paper Association for their assistance in compiling the mailing list for this survey, as well as encouraging their member firms to respond.

costs to comply with the 1992 CEPA and Fisheries Act regulations, were taken from a regulatory impact analysis carried out in 1990 as part of the background study for the new regulations (McCubbin et al, 1990).² This provides a better sense of the actual regulatory burden facing individual mills, and also a basis for assessing the extent of improvement in mill-level performance since 1990.

- data on effluent levels (TSS and BOD₅) in 1996 was taken from recent Environment Canada compliance data. In order to maintain confidentiality, these data were released anonymously — mills were identified by codes and matched with questionnaire respondents.

Finally, questionnaire data was supplemented by in-depth interviews with a sub-set of respondents, in order to probe individual company and mill experiences. Additional interviews were conducted with a number of other observers (regulatory officials, industry association representatives, Paprican officials, and representatives of supplier industries).

c) Sample Firms and Mills

This section of the chapter outlines the nature of responses to the questionnaire survey, in order to assess the degree to which the sample is representative of the industry more broadly.

² The sample for the questionnaire included a small number of mills constructed since the late 1980s which were not included in the McCubbin study. For these mills, compliance costs were estimated at zero.

As noted above, the questionnaire asked respondents to provide a mix of firm- and mill-level data. The response rate for both firm- and mill-level data was high: 34 firms (47.9% of the total mail-out) provided responses, with data presented for 56 mills (again 47.9% of the total). The resulting sample is broadly representative of the industry as a whole, and thus permits a fairly high degree of confidence in the results.

Figure 5.1

Figure 5.2

Figures 5.1 and 5.2 provide an overview of respondent firms by size and ownership; as can be seen, the sample includes a mix of large and small firms, and Canadian-owned, foreign and joint-venture firms. The sample slightly over-represents foreign-owned and joint venture mills (which, as noted in the last chapter, account for perhaps 25 percent of the industry as a whole) but the extent of

variation is not large enough to be a source of concern. Twenty-two firms operate only one mill in the sample, whereas twelve operate two or more.

In terms of mill-level responses, Figures 5.3 and 5.4 outline some of the key characteristics of the sample. Dates of construction (Figure 5.3) vary widely, but over half of respondent mills were built

Figure 5.4

before 1950. Age figures refer to date of **initial** construction, and thus do not take into account more recent expansion or modernization programs at some of the older mills. Respondent mills cover all regions of the country, with the largest concentrations in Quebec (30.4%) and British Columbia (26.8%). Compared to the overall population, the sample over-represents mills in British Columbia and the Prairies, and under-represents Ontario and Quebec mills, but the difference is not sufficiently great to be cause for concern.³

Figure 5.3

The majority of mills employ either TMP/CTMP (31 cases) or Kraft (21 cases) processes, with smaller numbers employing groundwood, sulphite or other (primarily de-

³ Based on the McCubbin study quoted earlier, the population of mills subject to the 1992 federal regulations (115 mills) is distributed as follows: British Columbia 19.1%; Prairies 4.3%; Ontario 23.5%; Quebec 37.4%; Atlantic 15.7%.

inking) processes (note that many individual mills employ more than one process). The importance of TMP/CTMP is particularly striking, reflecting the speed with which former groundwood or sulphite mills have been converted over the past decade; 13 mills in the sample reported changing process technology during the period 1990-1996.

Finally, distribution of mill output by destination of sales mirrors the overall export orientation of the Canadian industry, and the dominance of the US as the key market for Canadian pulp and paper production. Average shipments to European and other destinations (primarily Asia) are lower. Actual distribution of sales varies widely among respondent mills. Of particular note is the wide variation in levels of shipments to Western Europe; this is an important variable, permitting analysis of the extent to which higher environmental demands in European markets have had an impact on environmental investments and practices by Canadian mills.

Overall, then, the sample provides a fairly accurate reflection of the overall Canadian industry, and should be sufficient to yield robust conclusions.⁴ One point to consider is the possibility that the sample may be weighted toward stronger environmental performers, and/or to firms facing lower levels of regulatory pressure (who might presumably be more willing to respond than those facing higher levels of regulatory burden). There is some indication that this may be the case. Using McCubbin's estimates of costs of complying with the proposed regulations (total amortized capital

⁴ Given the high response rate and good distribution of responses, in fact, it is probably reasonable to treat the respondents as representative of the population as a whole, rather than as a sample from that population. For this reason, much of the analysis in this chapter does not rely upon probability estimates, at least when making judgements about the specific patterns of behaviour of the Canadian industry. Probability figures are used in the analysis in section IV, however, where an attempt is made to generalize from the Canadian sample to more general patterns of response for pulp and paper firms, regardless of country.

and operating costs per tonne of output) as a measure of regulatory burden on mills, mean scores for the sample were compared to means for the industry as a whole as calculated by McCubbin. The average regulatory burden is lower for the sample (\$13.63) than the industry as a whole (\$17.49). However, this result is strongly influenced by two factors. First, the sample data include four new mills which have entered production since the late 1980s and which were not included in the McCubbin study — and for which compliance costs have been estimated to be zero. Second, the McCubbin study includes two extreme outlier mills, for which estimated compliance costs were **6-8 times** the industry average; neither of these mills is included in the sample for this study. When both of these factors are controlled for, average compliance costs of sample and industry as a whole are very close (less than \$1.00 difference). On balance, then, there does not appear to be any significant bias in the sample toward firms facing lower levels of regulatory burden.

III. Nature of Environmental Activities and Investments

What kinds of changes have been introduced by Canadian pulp and paper producers in response to increasing environmental pressures? In particular, how have firms responded to 1992 pulp and paper effluent regulations under the Canadian Environmental Protection Act and related provincial regulations, which have resulted in more stringent regulatory levels and less scope for exceptions? In order to probe these questions, several sets of data were collected.

Figure 5.5

First, at the firm level, respondents were asked to describe the impact of recent regulations on their firm. Results are presented in Figure 5.5. As can be seen, the vast majority of respondent firms either

introduced new investment plans in response to the regulations (21 responses, or 61.8 % of the sample), or changed existing investment plans in order to respond to new regulatory hurdles (11 responses, or 32.4 %).⁵ A minority of firms either were in compliance and thus felt no impact from the regulations, or were able to comply based on previously planned investment programs. Significantly, only two respondents reported closing mills because of regulatory pressures, and only one reported reducing production levels in order to comply. Overall, then, the results suggest that regulations have had a significant impact in spurring new investment by Canadian firms. There is relatively little evidence of “defensive” actions (mill closures, reductions in production levels) by respondent firms.

⁵ Note that many firms indicated more than one response, such that total responses exceed 100%.

In order to probe in more detail the kinds of changes introduced, respondent mills were also asked to outline specific changes undertaken since 1990 — both “end-of-pipe” control measures and in-plant

Figure 5.6

efforts to reduce pollution. Results are presented in Figures 5.6 and 5.7.

The results tend to support the hypothesis that a primary impact of more stringent regulations has been to spur investment in end-of-pipe controls — a result not surprising given that only about one-third of sample mills had both primary and secondary effluent treatment systems prior to the new regulations, and almost one-fifth had neither primary nor secondary control systems. Over 75 percent of respondents report installation of new or upgraded secondary treatment systems; a further 40 percent report installing new or upgraded primary treatment facilities, or facilities for treatment of gaseous emissions; and almost 60

percent report investments to improve handling and disposal of solid wastes.

Aside from relatively inexpensive house-keeping measures and improvements in process

Figure 5.7

control, investments in in-plant changes were less prevalent, with no single type of change being reported by a majority of respondents. Care must be taken, however, in interpreting these results. In fact, the data show that a significant minority of respondents did undertake various types of in-plant changes, with in each case 30–40 % of respondents reporting increases in the use of recycled fibre, improvements in the energy efficiency of machinery, improved fibre and/or chemical recovery, or changes to bleaching sequences. Even if we set aside relatively simple improvements in housekeeping and process control, the vast majority (87.5 percent) of respondent mills did report undertaking at least one type of internal process change between 1990 and 1996. Rather than opting for internal or end-of-pipe solutions alone, most mills appear to have combined both types of investments, as they struggle not only to ensure compliance with regulations, but also to control production costs and ensure market access.

This is consistent with a recent Statistics Canada survey of pollution abatement expenditures by Canadian industry in 1996, mentioned in Chapter 4. The Statistics Canada survey found that the overall **expenditures** on pollution abatement and control in the pulp and paper industry were strongly weighted toward end-of-pipe controls, with over 80 percent of capital spending oriented toward such investments. On the other hand, the **frequency of use** of different pollution abatement and control measures shows a somewhat different picture: while end-of-pipe controls are still the most frequent choice (mentioned by 61 percent of firms surveyed), fully 51 percent of firms mentioned investments in integrated process changes, and a further 42 percent reported spending on improved control of operations (Statistics Canada, 1998, 20, 34).

In some cases, process changes have been significant. Given the average age of mills and the scale of investments required for end-of-pipe treatment, many firms have chosen to combine such measures with a broader modernization program. Of particular note is the relatively large number of mills which have undergone major changes in process technology during the decade (13 firms, or 23 percent of the sample) — primarily mills which have phased out older sulphite and groundwood lines in favour of newer and less polluting TMP/CTMP production. While clearly environmental concerns are not the only factor militating in favour of such changes, it seems likely that regulatory pressures have affected the timing of new investment programs at the very least. Analysis of questionnaire responses backs up this supposition: mills which switched process technology during the reporting period were on average older than other mills in the sample, and faced higher levels of regulatory burden (estimated control costs to comply with the 1992 federal regulations). They were also more likely to have installed new secondary treatment systems during the reporting period, indicating that end-of-pipe investments are at least in this case linked to process changes, rather than being substitutes.⁶ Process changes have been particularly prevalent among newsprint firms — which, as noted in the last chapter, face considerable cost pressures due to the average age and size of Canadian mills. In order to finance the capital costs of compliance with new environmental regulations — and given the price-based nature of competition for commodity products like newsprint — firms have in most instances chosen to increase output. For older mills, this has often necessitated replacement of

⁶ The Pearson's correlation component between the two types of investment was high and statistically significant (.2691; 56 degrees of freedom; $P = .045$). On the other hand, the decision to shift process technology was not statistically correlated with any of the other independent variables used in the analysis — firm and mill size, export orientation, ownership, R&D expenditures or commitment to environmental management. The next section deals in more detail with the influences on environment-related investments by mills.

existing pulp lines with larger, more efficient, and less polluting alternatives. Thus while environmental regulations have not directly stimulated process changes, they have clearly had an indirect impact on investment decisions.

The results also illustrate significant changes in bleaching process at Kraft pulp mills. Of the 21 mills in the sample employing the Kraft process, 19 have opted to pursue full substitution of chlorine dioxide to produce ECF pulp, with a further 3 mills investing in non-chlorine bleaching methods. On the other hand, only about two-thirds of Kraft pulp mills indicated investments in improved pulp washing, and only 5 (about a quarter of the sample) indicated that they have undertaken oxygen delignification in the pre-bleaching stage, which (while not required by regulations) has been argued to represent a cost-effective means of improving environmental performance.⁷ The next section looks in more detail at the ways in which regulatory and market-based pressures have stimulated particular kinds of process changes.

IV. Determinants of Environmental Behaviour

What factors have prompted environment-related investments by Canadian pulp and paper firms? Has regulatory compliance been the dominant factor, or are other variables (pressures in export markets; influence of parent or partner companies) also at work? In order to examine these questions, three sets of data were analyzed. First,

⁷ One possible explanation for the reluctance of Canadian firms to invest in oxygen delignification may be the impact of such measures on pulp strength. Incorporation of oxygen delignification may decrease pulp strength by 5-10 percent — a potentially important change for Canadian pulp producers, given that the strength of Canadian softwood Kraft pulp remains one of its key competitive advantages (Interview with Richard Berry, Paprican, June 1998). Moreover, while delignification technologies do offer the prospect of some decreases in operating costs, it is not clear that such savings offset capital costs, particularly for existing mills. See also OECD, 1992, 16-17 for a discussion of the barriers to installation of delignification technologies.

respondent firms were asked to rate factors influencing environment-related investments on a five-point scale. Second, actual levels of investment and environmental performance were correlated with possible explanatory variables. Finally, the data were further analyzed to assess whether particular types of investments are correlated with possible explanatory variables.

a) Motives for Environmental Investments

Firms' own ratings of influences on their environment-related investments are presented in Figure 5.8. As can be seen, domestic environmental regulations are by far the most

Figure 5.8

important factor, followed by corporate image/policy, consumer demand in export markets, and expected cost savings. Consumer demand in Canadian markets and influence of parent or partner firms are seen as relatively unimportant. (These results shift slightly if we control for ownership: foreign and joint venture firms place somewhat more emphasis on parent and partner firms, and on consumer demand both domestically and in export markets, with less emphasis on other factors. Differences are not statistically significant, however, and the top three factors — regulations, corporate image and export demand — remain the same for domestic and foreign-owned firms).

Firms were also asked to rate constraints to further environmental improvements, and the results of this question are summarized in Figure 5.9. Overwhelmingly, firms pointed to “cost/impact on

Figure 5.9

competitive position of the firm” as the main constraint to further actions. Uncertainty regarding future regulatory limits was also cited, as were difficulties in securing proven technology for further pollution reductions (in most cases, this was clearly linked to the cost issue, with respondents emphasizing the difficulty of finding cost-effective means of further reducing effluent levels). Interestingly, neither lack of clarity nor lack of flexibility in the application of existing regulations was seen by firms as a key constraint.

b) Levels of Environmental Investment and Performance

Is firms' perception of the dominant role of domestic regulations on environmental investments backed up by data on actual investments and levels of environmental performance? Or are other variables also at play?

In order to explore this further, three separate measures of the environmental activities undertaken by firms were analyzed:

- a measure of capital expenditures on environment-related activities between 1990 and 1996, taken from questionnaire responses. In order to control for size

of mills, this was re-calculated on a per tonne basis, using capacity figures from the study by McCubbin et al (1990).

- a measure of the absolute environmental performance of mills in 1996, based on the average of BOD and TSS levels for 1996, taken from Environment Canada data (annual averages).⁸
- a measure of the percentage reduction in combined BOD and TSS levels⁹ between 1987 and 1996, calculated based on Environment Canada data for 1996 (annual average figures), and 1987 data as presented in McCubbin et al (1990).

Use of these different dependent variables is important, since they can be assumed to reflect different aspects of a firms' environmental behaviour. Capital expenditures primarily measure the **effort** by firms to meet environmental pressures — and hence can be presumed to be affected largely by the kinds of incentive factors introduced in Chapter 2 (regulatory pressures; market demand; ownership; inter-firm competition). The extent to which firms are able to effect reductions in effluent levels, on the other

⁸ In order to reduce confusion in interpreting results of correlation analysis, signs were changed so that larger values represent better levels of environmental performance, rather than the reverse. It should also be noted that annual average figures for effluent levels may overstate the degree of compliance with regulations, which are based on both daily and monthly average figures. Low annual average figures could conceal significant peaks and valleys in day-to-day effluent levels, which could cause a firm to be out of compliance at a particular point in time. Nonetheless, annual average figures are a good indicator of the **relative** performance of different mills.

⁹ Using combined (average) BOD and TSS figures provides a good snapshot of the overall environmental performance of firms in the two time periods. It could, however, underestimate the extent of improvements in a mill which was under-performing against only one of the two parameters in 1987 and achieved significant reductions in that parameter alone over the decade. In practice, this is likely to be extremely rare, given that BOD and TSS levels are fairly highly correlated, and both tend to fall as a result of standard pollution control measures.

hand, reflects not only the extent of investments by firms, but also their efficiency in promoting improvements in mill-level performance — and hence should depend not only on the incentives facing the firm, but also the resources and capabilities it can access in order to promote improvements. In this way, the analysis presented below enriches most existing studies, which rely upon a single measure of environmental performance (usually either abatement expenditures or effluent levels).

In order to probe this further, the three dependent variables were correlated with a series of independent variables. These independent variables are of two main types.

A first block of variables deals with the external influences on firm-level behaviour (the incentives or “motives” for environmental improvement, to use the terminology introduced in Chapter 2). This includes the following:¹⁰

- a measure of the stringency of provincial environmental regulations. As noted in the last chapter, most pulp-producing provinces have adopted regulations which are more stringent than those in place at the federal level: not only do they set more stringent limits on traditional pollutants (BOD, TSS) in most cases, they also regulate additional parameters, notably AOX. The exception is the Atlantic provinces, where federal regulations alone apply. For the purposes of this analysis, therefore, mills located in the Atlantic provinces were coded “0”, and mills in other provinces were coded “1”.

¹⁰ One weakness in the data available is the inability to factor in patterns of inter-firm competition (e.g., the relative cost-competitiveness of individual mills) as a affecting firms’ motives for engaging in environmental improvements. As noted in Chapter 2, some authors have suggested that this may be an important variable, but the evidence is sketchy at best. I return to this issue in the concluding chapter.

- a measure of regulatory burden facing individual mills. Actual regulatory burden will vary widely, depending on the age of plant and equipment and the kinds of previous environmental investments made by the mill. Estimates of amortized capital and operating costs required to meet the 1992 federal regulations (calculated on a per tonne basis) were taken from McCubbin et al (1990) and used as a measure of the relative burden placed on mills by the new regulations. Two separate figures were used — one for costs of meeting BOD and TSS limits and one for costs of meeting limits for both traditional pollutants **and** dioxins and furans.¹¹ The latter, more inclusive measure is used to predict levels of capital expenditure by mills; the former, more restrictive measure is used in assessing factors which have contributed to reductions in BOD and TSS levels between 1987 and 1996.
- a measure of market-related environmental pressures. Percentage of 1996 output sold to Western Europe was calculated based on questionnaire data. As noted in previous chapters, it is expected that market-related pressures will primarily apply to those mills exporting to European countries where there is strong consumer demand for products with superior environmental performance, and/or formal eco-labeling programs.
- a measure of foreign ownership, with Canadian-owned firms coded "0", and foreign or joint venture firms coded "1".

¹¹ Many existing studies rely on age of mills as a proxy to assess the extent of regulatory burden facing individual firms; given the extent of improvements in mills over time (due to incremental changes and more extensive modernization programs), however, date of construction of mills is a poor measure of the "vintage" of capital equipment and hence the relative burden of adjustment to new regulations. For this reason estimated compliance costs were used instead.

A second block of variables deal with the internal resources and capabilities of the firm to effect change (the “means” available to the firm, as defined in Chapter 2). The following specific variables were included in the analysis:

- a measure of the size of the firm, meant to capture the impact of scale economies in financial and technical resources, and the ability to learn from experiences in a variety of plants.¹² Firm size is measured in terms of total employment by the firm in 1996 based on questionnaire data.¹³ A logarithmic measure of employment is used in order to achieve a more linear relationship between firm size and key dependent variables.
- a measure of the size of the mill, meant to capture scale economies in particular investments. Total capacity (tonnes/day) was taken from McCubbin’s 1990 study, with the exception of new mills where questionnaire data were used.¹⁴
- a measure of firms’ research and development expenditures in 1996; firms which reported R&D expenditures in questionnaire responses were coded “1”, those which did not were coded “0”.

¹² A second measure of firm size/resources was also explored, distinguishing between firms with only one mill and those with more than one mill in the sample. Given the high degree of correlation with employment size (greater than .75), this variable has not been used in the statistical analysis presented in the following pages.

¹³ One weakness with figures on firm size (or number of mills) is that they deal only with Canadian operations of foreign-controlled firms. Thus, they are probably a strong indicator of the technical and financial resources of Canadian firms, but weaker in the case of partially or wholly foreign-owned mills.

¹⁴ There were some inconsistencies in the reporting of capacity figures in questionnaire responses, and hence McCubbin’s earlier data were used except in the case of recently-constructed mills. This may not reflect recent changes in output at some mills — but is likely to give a better sense of the scale of the mill at the time of entry into force of new regulations, which is the most relevant measure of scale economies.

- a measure of the extent of the firms' previous investments in environmental improvements, and the extent of commitment to environmental management. This is potentially important, as previous efforts to deal with environmental problems should increase the ease with which firms can adapt to new environmental challenges. It is difficult to assess this variable on the basis of questionnaire data, but the extent of corporate reporting on environmental issues was used as a proxy: firms which report on environmental performance in annual reports and/or separate annual environmental reports were coded "1", those which did not were coded "0".

There are a number of weaknesses in the data which should be kept in mind when analyzing the results. One immediate weakness is that 1996 effluent data is available only for "traditional" pollutants (BOD and TSS) rather than levels of organochlorines (AOX). This makes it somewhat more difficult to assess the overall environmental performance of mills in the wake of regulations, and to assess the extent to which provincial regulations and/or market pressures have forced mills to reduce organochlorine use. In order to partially correct for this gap, the analysis in the next section looks at the specific types of investments made by respondent mills, including changes introduced in Kraft mills to deal with the chlorine bleaching problem.

More generally, a number of the explanatory variables above are fairly weak proxies for underlying factors (e.g., the data on environmental reporting as a measure of commitment to environmental management), and/or are based on questionnaire data supplied by firms which cannot be verified from outside sources (e.g., employment, export and capital expenditure figures). But while these limitations argue for some caution in interpreting the results, they are not sufficiently serious to call the analysis into

question.

Recapping the hypotheses outlined at the outset of this chapter, the following relationships can be expected:

- Levels of environment-related capital spending will be **positively** correlated with the stringency of provincial regulations, the extent of regulatory burden facing individual mills, the extent to which output is sold on Western European markets, whether the firm is foreign-owned, and the commitment of the firm to environmental management. Levels of capital spending will be **negatively** correlated with firm and mill size, reflecting economies of scale in pollution prevention and control measures. Capital spending is not expected to be related to be related to R&D spending.
- Levels of environmental performance will be **positively** correlated with the stringency of provincial regulations, export orientation, foreign ownership, firm and mill size, extent of R&D expenditures, and commitment of the firm to environmental management. They will be unrelated to the degree of regulatory burden facing the mill (which is primarily a function of the vintage of equipment at the mill and the extent of previous environmental investments), since regulations will have forced “laggard” mills to catch up with industry standards of good environmental practice, but will have exerted little pressure on firms which were already at or below regulatory limits.
- Reductions in effluent levels between 1987 and 1996 will be **positively** correlated with stringency of provincial regulations and degree of regulatory

burden — in other words, the extent to which mills improve their environmental performance compared to previous levels will depend on the stringency of regulatory pressures facing them, and the gap between the mill's pre-regulatory performance and the requirements of regulations. It is not expected to be correlated with other independent variables.

Results of bivariate correlation tests are presented in Table 6.1. Statistically significant relationships (two-tailed significance less than or equal to .05) are shown in bold. A full correlation matrix is included in Appendix 2. The results appear to be relatively robust: the independent variables are not strongly related to each other (aside from the two measures of regulatory burden on firms — which are of course strongly correlated — and a relatively strong correlation between firm size and commitment to environmental management). No serious statistical problems are expected to interfere with the analysis — although as noted above there is still the possibility of measurement error for at least some variables.

Bivariate correlation analysis suggests some support for the hypotheses set out above. Levels of environment-related investment are correlated both with the regulatory burden facing individual mills and with the export orientation of mills, indicating that both regulatory and market-related factors have played a role in stimulating investment by firms. On the other hand, more stringent environmental regulations in some provinces do not appear to be correlated with levels of investment, nor are foreign-owned firms likely to spend more on environmental improvements. Moreover, there are no strong economies of scale evident at either the firm or mill level. Surprisingly, there is a negative correlation between R&D spending and capital investments by respondent mills.

The extent of reductions in effluent levels is, as predicted, correlated with the stringency of provincial regulations and with the regulatory burden facing individual mills.

Finally, absolute levels of environmental performance are correlated with the stringency of provincial regulations, as well as with the firms' overall R&D spending and its prior commitment to environmental management. On the other hand, neither export orientation nor foreign ownership is correlated with superior environmental performance. Larger firms also appear to be able to achieve superior levels of performance, but there is no correlation between scale of mills and effluent levels.

Table 5.1: Determinants of Environmental Behaviour and Performance (bivariate correlation coefficients)			
Independent Variables	Dependent Variables		
	Pollution Abatement and Control Expenditures per Tonne of Output	Percentage Reduction in Combined BOD and TSS Levels Between 1987 and 1996	Environmental Performance, ca. 1996 (based on combined BOD and TSS levels)
Regulatory Stringency (Stringency of Provincial Regulations)	.1539 (52) P = .276	.3712 (51) P = .007	.4219 (56) P = .001
Regulatory Burden I (Estimated Control Costs to Meet BOD and TSS Limits)	.2656 (51) P = .060	.2961 (51) P = .035	.0002 (55) P = .999
Regulatory Burden II (Estimated Control Costs to Meet BOD, TSS and Dioxin/Furan Limits)	.3239 (51) P = .020	.2288 (51) P = .106	-.0619 (55) P = .653
Export Orientation (Percent of 1996 Output Exported to Western Europe)	.3264 (42) P = .035	-.0513 (42) P = .747	.0028 (46) P = .985
Foreign Ownership	-.0792 (49) P = .589	-.1855 (49) P = .202	-.0633 (53) P = .652
Firm Size (log of total employment, 1996)	-.1575 (49) P = .280	.2434 (48) P = .096	.3545 (53) P = .009
Mill Size (total production capacity ca. 1990, t/day)	.0292 (52) P = .837	-.1188 (51) P = .406	-.1980 (56) P = .143
R&D Expenditures ca. 1996	-.2826 (52) P = .042	.0571 (51) P = .691	.2957 (56) P = .027
Commitment to Environmental Management (Environmental Reporting by Firm)	.1196 (51) P = .398	.1121 (51) P = .433	.3012 (56) P = .024

In order to explore relationships with more confidence, partial correlation coefficients were also calculated, controlling for all other independent variables. For partial

correlation analysis, two variables were dropped from the analysis. First, in order to reduce the number of variables (and hence increase the degrees of freedom for analysis) only one of the two measures of regulatory burden was used. This is not expected to have an appreciable impact on the results, given the extremely high degree of correlation between these two variables. Second, mill size (total production capacity in 1990) was also dropped from the analysis. Capacity figures are largely a function of the type of process in use (with Kraft mills being much larger, newsprint mills smaller, and secondary fibre or de-inking mills smaller still). Thus, while mill size may be a useful variable for exploring patterns of environmental expenditure/performance among a group of homogeneous mills, it is less reliable when dealing with a heterogeneous set of mills like the one in this sample. I return to this issue later in this section by looking in more detail at the situation of different types of mills (Kraft versus other). Results of partial correlation analysis are presented in Table 5.2. Once again, statistically significant correlations (two-tailed significance less than or equal to .05) are shown in bold face. Given the relatively large number of variables and the resulting lower degrees of freedom for analysis, fewer coefficients are statistically significant than in the case of bivariate analysis. For the purposes of interpretation, it is probably reasonable to treat the respondents as a population rather than a sample (based on the high response rate, discussed in Section II above), and thus to base analysis on the magnitude of coefficients rather than probability statistics. Clearly, however, care must be taken in extrapolating beyond the Canadian case.

Table 5.2: Determinants of Environmental Behaviour and Performance (partial correlation coefficients, controlling for all other independent variables)			
Independent Variables	Dependent Variables		
	Pollution Abatement and Control Expenditures per Tonne of Output	Percentage Reduction in Combined BOD and TSS Levels Between 1987 and 1996	Environmental Performance, ca. 1996 (based on combined BOD and TSS levels)
Regulatory Stringency (Stringency of Provincial Regulations)	.2798 (26) P= .149	.3518 (26) P= .066	.6417 (26) p= .000
Regulatory Burden I (Estimated Control Costs to Meet BOD and TSS Limits)	.3084 (26) p= .110	.2053 (26) P = .295	.0449 (26) P= .821
Export Orientation (Percent of 1996 Output Exported to Western Europe)	.3904 (26) P=.040	-.0622 (26) P= .753	-.2969 (26) P= .125
Foreign Ownership	-.1654 (26) P= .400	-.0298 (26) P= .880	.1034 (26) P= .601
Firm Size (log of total employment, 1996)	-.4221 (26) P= .025	.1801 (26) P= .359	-.2256 (26) P = .248
R&D Expenditures ca. 1996	.0251 (26) P= .899	-.0734 (26) P= .711	.3452 (26) P= .072
Commitment to Environmental Management (Environmental Reporting by Firm)	.2792 (26) P= .150	.0288 (26) P = .884	.3942 (26) P = .038

Results of the partial correlation analysis provide substantial support for the hypotheses set out above, although with some important exceptions.

Levels of investment show relatively strong levels of correlation with all of the predicted influences, with one important exception: there is no significant correlation between foreign ownership and levels of investment, even when other factors are controlled for.

Spending correlates most strongly with export orientation, but regulatory stringency, regulatory burden and commitment to environmental management all show substantial degrees of correlation as well. These findings mirror fairly closely the opinions of firm management themselves with regard to influences on environment-related investment (see Figure 8), where regulations, corporate image and export market demand were signalled as the most important influences, with the influence of parent and partner firms playing a less important role. Again as predicted, partial correlation coefficients show a strong negative correlation between the size of the firm and the level of investment per tonne of output, suggesting that there are in fact significant scale economies in pollution-related expenditures, at least at the firm level.

Reductions in effluent levels between 1987 and 1996 are strongly correlated with the stringency of provincial regulations (as predicted) but show a weaker-than-expected correlation with levels of regulatory burden facing individual mills. This suggests that while federal regulations have indeed forced laggard mills to reduce their effluent levels by a significant margin, more stringent regulations in some provinces have induced mills to surpass federal standards.

This is supported by the correlations between **absolute** levels of environmental performance in 1996 and the various independent variables. Stringency of provincial regulations shows by far the highest correlation, suggesting that more stringent regulations have been successful in forcing higher levels of environmental performance, even when we control for other factors. As predicted, the regulatory burden for individual mills to comply with federal regulations is not correlated with levels of environmental performance: mills' ability to surpass the requirements of federal

regulations is apparently unrelated to their pre-regulatory performance or the vintage of capital stock at the mill. This reinforces the suggestion made earlier that federal regulations have worked primarily by narrowing the gap between “leading” and “laggard” mills.

Somewhat surprisingly, levels of environmental performance are not correlated with either the ownership of mills nor their export orientation. Nor do firm-level scale economies in pollution abatement investments (noted above) appear to translate into better levels of environmental performance by mills belonging to larger firms. However, there are fairly strong correlations between levels of environmental performance and both R&D expenditures by firms, and the extent of corporate commitment to environmental management.

Returning to the hypotheses set out in Section II of this chapter, what conclusions can be drawn from this analysis?

In the first place, regulatory pressures have played a leading role in stimulating improvements in environmental performance. Stringency of regulations is the most important determinant of absolute levels of environmental performance in the wake of regulations, and is also correlated with levels of environmental investment, and with the extent of reductions in effluent levels from pre-regulatory levels. Regulatory pressures appear to work primarily by narrowing the gap between leading and laggard firms: mills which had faced higher levels of burden in complying with federal regulations registered higher levels of environment-related investment per tonne of output over the reporting period, and by 1996 were not significantly outperformed by mills which had faced lower levels of compliance costs.

Export orientation of mills is also strongly correlated with levels of environment-related spending, but unrelated (or even negatively correlated) with absolute levels of environmental performance in 1996. In a sense, this is not surprising, since the measures of environmental performance used in the analysis (BOD and TSS levels) are most responsive to external treatment, and are less strongly affected by the kinds of process changes (e.g., changes to bleaching sequences) likely to be induced by export market pressures. Unfortunately, the lack of data on other parameters of environmental performance makes it impossible to judge whether export orientation is correlated with other aspects of firms' environmental performance. But it appears that export market pressures on their own are not likely to spur the kinds of end-of-pipe treatment technologies needed to assure rapid decreases in BOD and TSS. The next section looks in more detail at the kinds of investments prompted by regulatory and market-related pressures on firms.

Foreign ownership appears to have no impact on the level of environment-related investment undertaken by firms, or on their resultant levels of environmental performance. To a certain degree, this is not surprising: as noted in Chapter 4, the primary sources of foreign investment in the Canadian industry are the United States and Japan, and there is no reason to expect that home-country environmental pressures on these firms are any more stringent than the regulatory pressures facing their Canadian operations. Moreover, as will be pointed out below, questionnaire respondents did not point to parent or partner firms as a significant source of technical expertise for environmental improvements: as one interviewee (representing the Canadian subsidiary of a US forest products firm) noted, the experience of the parent firm with regulatory compliance in other jurisdictions at times meant that it "saw issues

coming" faster than the Canadian subsidiary, but its impact on technical activities at the Canadian mill was limited. The limited impact of foreign ownership on pollution abatement investments or environmental performance is consistent with the results of recent World Bank studies mentioned in Chapter II, which found no relationship between ownership and pollution abatement (Dasgupta et al, 1998; Hartman et al, 1995; Hettige et al, 1996). The next chapter looks at the issue of foreign investment in the Chilean context, where it can be expected that differences in environmental demands on foreign-owned versus locally-owned firms may be a more important factor, given differences in regulatory requirements between Chile and the home countries of foreign investors.

The impact of firms' internal characteristics and resources (size, R&D activity, commitment to environmental management) is perhaps the most complex. These sorts of factors **have** affected firms' environmental investments and performance, but not entirely in the manner expected.

Scale factors do appear to play an important role, but primarily at the firm- rather than mill- level. Larger firms appear to spend less per tonne of output to attain given levels of environmental performance once other factors are controlled for. On the other hand, larger firms are not likely to outperform smaller firms in terms of absolute levels of environmental performance, at least when we control for other possible influences. The relatively strong bivariate correlation between firm size and environmental performance disappears entirely once other variables are controlled for. One plausible explanation for this situation is that the benefits of firm size relate primarily to the greater R&D resources of large firms, and their greater likelihood to have well-developed internal environmental policies -- and much less to other possible benefits of firm size (greater

financial resources, ability to learn across a number of mills). As Table 5.2 shows, partial correlation analysis results in fairly strong degrees of correlation between environmental performance and both R&D spending and commitment to environmental management.

Moreover, there appears to be no significant correlation between the scale of mills (as opposed to firm size) and either levels of investment per tonne of output, or levels of environmental performance in 1996. This is somewhat at odds with other research which has suggested strong plant-level economies of scale in pollution abatement and control (Hartman et al, 1995; Hettige et al, 1996).¹⁵ Scale of plants is strongly correlated with total capital expenditure (large firms spend more on abatement), but not with expenditure per tonne of output, nor with levels of pollution achieved in the wake of new investments.

In part, the absence of a correlation between scale of mills and capital spending per tonne of output may be a statistical problem, related to the fact that different types of pulp and paper mills are characterized by different average levels of scale. If we examine Kraft mills alone, for example, there is a fairly high (bivariate) correlation between mill size and levels of capital spending.¹⁶ Unfortunately, however, the sample is

¹⁵ One point which should be considered is that earlier studies mentioned above all measure scale in terms of plant-level employment levels, whereas the current study relies upon capacity figures as a measure of size. Given the limited variations in employment levels across mills of varying production capacity (i.e., the number of employees needed to operate a pulp and paper mill varies little, regardless of output), production capacity appears to be a better determinant of scale than employment figures. Employment size, on the other hand, may in fact be capturing the greater visibility of plants — and hence their sensitivity to informal regulatory pressures and public opinion — rather than true economies of scale in pollution prevention and control (Dasgupta et al, 1995, 7).

¹⁶ Export orientation is also a more significant determinant for Kraft versus other mills (reflecting the greater sensitivity of market Kraft producers to European market demand). Other factors do not vary markedly from the overall picture presented in Table 5.1.

not large enough to permit reliable partial correlation analysis for sub-sets of mills grouped by type of process technology.

Even for individual sets of mills, however, there still appears to be no correlation between scale and absolute levels of environmental performance (as opposed to investment). In part, this may be due to the nature of recent Canadian regulations: while smaller firms and mills might have enjoyed cost disadvantages due to economies of scale, regulatory pressures have obliged them to shoulder the extra costs, particularly for end-of-pipe controls. Another possibility, however, is that smaller firms have placed more emphasis on incremental process optimization measures, where there are possibilities of cost savings which could offset some of the disadvantages of size. This issue is explored in more depth in the case-study analysis of Chilean firms in Chapter 7.

Finally, the resources and capabilities of firms appear to have a significant impact on the environmental performance of mills. In particular, the extent to which firms are involved in R&D activities, and the extent of their prior commitment to superior environmental management (as measured by the extent of corporate environmental reporting), are both strongly correlated with levels of environmental performance. This result suggests that the primary impact of regulatory pressures is to promote capital investments necessary in order to meet a specified environmental performance target. Regulatory factors thus promote the diffusion of best-practice control technologies, and work to standardize levels of environmental performance by bringing “laggard” firms up to mandated levels of performance. But the extent to which firms go **beyond** these limits to achieve additional improvements in environmental performance appears to be related not simply to regulatory factors, but also to firm-specific resources, capabilities and

practices. Firms with a history of environmental action and those with internal R&D resources are significantly more likely to achieve superior levels of environmental performance than are other firms. This result has important policy implications: rather than regulatory pressures alone promoting innovation, it is the dynamic, innovative firms which appear to be most likely to take advantage of regulatory pressures to achieve major improvements in environmental performance.

c) Types of Environmental Investments by Respondent Firms

In addition to impacts on overall levels of environmental investment and performance, the hypotheses set out at the beginning of this chapter also predicted that different types of environmental pressures would be linked to different patterns of investment. In particular, while regulatory pressures may have directed firms largely toward end-of-pipe controls, export pressures are more likely to spur internal process changes necessary to meet consumer demand in (some) export markets.

Table 5.3 examines this issue in more detail, by looking at the influence of various independent variables on types of changes introduced by respondent mills. Changes are split according to the four categories of environment-related investments outlined in Chapter 3: major process change, minor process change, process optimization, and end-of-pipe treatment.

The data provide fairly strong confirmation of the hypothesized relationships. Spending on key end-of-pipe control measures (new primary and/or secondary treatment of liquid effluents) is strongly correlated with the degree of regulatory burden facing mills, but unrelated to export market pressures. The opposite holds for some of the key internal

process changes (notably changes to bleaching and pre-bleaching stages): these types of changes are strongly correlated with the export orientation of firms, but unrelated to levels of regulatory burden. Similar results hold if analysis is restricted to bleached kraft pulp mills, for whom export market pressures can be expected to be most salient — although in this case the smaller number of mills means that statistically significant correlations cannot be obtained). Shifts in bleaching sequences also appear to be more prevalent among foreign-owned firms, and for larger mills — although once again this latter factor may reflect differences in average scale for Kraft and non-Kraft mills rather than differences in scale among mills using the same process. Other variables (R&D, environmental management) do not show any significant correlations with types of investments. Major process changes (shifts in pulping process) are not significantly correlated with any of the variables, reinforcing the conclusion that environmental pressures have at most an indirect impact on firms' decisions to undertake major modernization programs. And process optimization measures appear to be spread relatively uniformly across respondents (although in this case the tendency of most firms to report at least some optimization measures makes it difficult to isolate causal factors). Partial correlation analysis (not presented here) results in no significant changes presented in Table 5.3: once again regulatory factors are closely related to investments in end-of-pipe controls, and export orientation is linked to process changes in the bleaching and pre-bleaching stages.

Table 5.3: Determinants of Environmental Investments, by Type of Investment
(Bivariate Correlation Coefficients)

Independent Variables	Types of Changes Introduced at Respondent Mills					
	Major Process Change	Minor Process Change			Process Optimization	End-of-Pipe Treatment
		Bleaching	Pre-Bleaching	Other		
Regulatory Stringency	-.1854 (56) P=.171	.1685 (56) P= .214	.1767 (56) P= .193	.0766 (56) P = .574	-.1293 (56) P = .342	.1204 (56) P = .377
Regulatory Burden I	.2222 (55) P = .103	-.2234 (55) P =.101	-.2412 (55) P = .076	.1187 (55) P = .388	.1712 (55) P = .211	.4425 (55) P = .001
Regulatory Burden II	.1498 (56) P = .275	-.0619 (55) P = .653	-.1364 (55) .321	.1262 (55) P = .359	.1755 (55) P=.200	.3908 (55) P = .003
Export Orientation	-.2149 (56) P = .152	.3975 (46) P = .006	.3742 (46) P = .010	-.4108 (46) P=.005	-.0329 (46) P = .828	-.1242 (46) P = .407
Foreign Ownership	-.1196 (53) P = .394	.4165 (53) P = .002	.2234 (53) P = .108	-.1825 (53) P = .191	.1186 (53) P = .397	-.1768 (53) P =.205
Firm Size	.0660 (53) P=.639	-.0047 (53) P = .973	-.1817 (53) P = .193	.0955 (53) P = .496	.0370 (53) P = .792	-.1025 (53) .465
Mill Size	.0731 (56) P = .592	.4490 (56) P - .001	.2306 (56) P = .087	.1515 (56) P = .265	.0202 (56) P = .882	.0791 (56) P = .562
R&D Expenditures	-.0984 (56) P = .872	.0764 (56) P = .575	-.1450 (56) P = .286	.1073 (56) P = .431	.1760 (56) P = .195	-.0764 (56) P = .575
Commitment to Environmental Management	-.0221 (56) P = .872	-.0449 (56) P = .742	-.0772 (56) P = .572	-.0187 (56) P = .891	.0241 (56) P = .860	.0449 (56) P = .742

Notes: "Major Process Change" indicates respondents who reported changes in process technology between 1990 and 1996. "Bleaching" includes firms reporting partial or total chlorine dioxide substitution, or introduction of non-chlorine bleaching. "Pre-bleaching" includes improved pulp washing and oxygen delignification. "Other Minor Process Change" includes respondents who indicated increased use of recycled fibre, or co-generation of electricity. "Process Optimization" includes fibre/chemical recovery, improved process control, improved energy efficiency, and minor house-keeping measures. "End-of-Pipe Treatment" includes respondents who indicated installing new primary and/or secondary treatment facilities for liquid effluents.

V. Impacts on Innovation and Technological Capabilities

Having discussed the ways in which regulatory and other pressures have affected level and types of environmental investments and patterns of environmental performance, this section of the chapter looks at the broader impact of environmental pressures on innovation within respondent firms and the industry more generally. Two issues are of particular interest. First, what has been the impact of environmental measures on the competitive position of firms? Have environmental pressures represented a dead-weight costs to firms, or have they also been able to take advantage of opportunities for cost-reductions and/or other positive impacts? Second, in a more dynamic sense, is there evidence that environmental pressures have served as a stimulus to innovation by respondent firms? The two issues are related — since the ability of firms to realize cost-saving environmental improvements is central to much of the literature which asserts an innovative stimulus as a result of regulatory pressures.

As a first step, respondent firms were asked to describe positive and negative impacts of environmental measures on the overall competitive position of their firm. Results are presented in Figures 5.10

and 5.11. Several interesting observations can be made.

In terms of positive impacts, the most frequently cited factors are those dealing with overall corporate image

Figure 5.10

and employee morale. Cost-savings are the second most-frequent mention — particularly reduced wastage/improvements in yields, but also savings on energy and other input costs. Somewhat surprisingly, less than half of respondents indicated that a primary impact of environmental improvements was an enhanced capacity to sell products in export markets. By far the least frequent responses, however, were those dealing with impacts on innovation by firms: nine respondents indicated development of new “green” products in response to environmental pressures, six reported the development of new process technology, and only 3 (less than 10 percent of the sample) indicated that environmental measures had translated into improvements in the overall R&D or engineering capabilities of the firm.¹⁷

In terms of negative impacts, two factors — declines in product quality and input supply problems such as shortages of recycled fibre — were rated as unimportant by respondent firms. Other

Figure 5.11

factors, however — dealing with increased costs for maintenance/repair, energy, training, and solid waste disposal — were rated as being of considerable importance, warranting mention by between 50 and 70% of respondents each.

¹⁷ It is possible that respondents misunderstood this last issue, focusing (for example) on whether new technical staff had been hired at the mill level, rather than on a broader understanding of “capabilities”. For this reason, results should be interpreted with caution.

Two tentative conclusions can be advanced regarding the impact of environmental investments on respondent firms. In the first place, most firms appear to see limited opportunities for cost-savings through improved environmental performance. To the extent that firms see positive impacts from environmental improvements, these are primarily linked to improved corporate image, both internally (employee morale) and externally (public image and to some degree enhanced export potential). Input cost savings and improved yields are important, but are likely to be outweighed by concerns for increases in other operating costs. This is reinforced by responses regarding the overall impact of environmental measures on operating costs at the mill level: less than one-fifth of respondent mills indicated that operating costs (excluding capital costs) had decreased or remained constant because of environmental measures, compared to almost three-quarters of respondents who reported either “moderate” or “significant” increases.

Significantly, the ability of firms to realize savings in operating costs as a result of environmental measures appears to be unrelated to most of the independent variables employed in the analysis in the last chapter. Trends in operating costs appear to be largely determined by whether or not firms installed external treatment systems during the reporting period — those mills which reported falling or stable operating costs tended to be ones which had already installed secondary treatment systems prior to the entry into force of new regulations, and which therefore were able to concentrate on internal process changes which offered more scope for cost savings. Other variables — export orientation, ownership, levels of R&D spending, or previous commitment to superior environmental management — do not appear to have a strong bearing on the ability of firms to realize cost savings. Moreover, there is no strong correlation between

those firms which rated “Expected cost savings” as a key variable determining environmental investments, and those which actually were able to realize such cost savings at their mills. This suggests that expectations of cost savings as a result of environmental actions have not been realized in practice, at least in the short run. As one respondent noted, while “theory predicts” that operating costs should fall as a result of actions taken, there is little evidence of such savings to date.

Obviously, these findings may be due to measurement errors: firms may be anxious to emphasize the competitive burdens placed on them by regulators (and thus to minimize cost savings), or they may find it difficult to disentangle impact on operating costs from the capital costs of environmental improvements. It may also simply reflect the nature of recent federal environmental regulations, which have obligated firms to shoulder fairly extensive investments in end-of-pipe treatment, with limited flexibility for firms to explore other, potentially more cost-effective options for reducing pollution. One example of this is provided by a mill which attempted to comply with federal regulations by pursuing total closure of its pulping operations, thus obviating the need for costly secondary treatment facilities. Eventually, the mill abandoned the project because of scaling problems associated with recirculation of effluents, and has since invested in a secondary treatment plant; while problems with process closure could in all likelihood have been remedied over the longer-term, the need to comply with short-term regulatory constraints forced a change in strategy.

Even so, the limited incidence of cost savings — and the lack of correlation between cost savings and other measures of the overall “innovativeness” of firms (R&D spending, environmental management) suggest a note of caution about the extent to which one can expect “win-win” approaches to environmental management to emerge in

pulp and paper, at least in the short run. This in turn casts some doubts on the conclusions of Porter (1990; 1995) and others regarding the ability of regulations to stimulate innovation. Porter's conclusions hinge critically on the existence of significant opportunities for cost-saving innovations, which may not hold in an industry like pulp and paper where technology changes slowly, competition is based on price, and capital costs are high. The concluding chapter of this thesis returns to issues of regulatory design.

A second broad conclusion is that there appears to have been little impact of environmental pressures on the process of innovation within most case-study firms. As noted above, only a minority of firms have

Figure 5.12

introduced new product or process technology in response to environmental demands, and almost none report improvements in overall R&D or engineering capabilities. Even when firms **have** introduced innovations, these have primarily been relatively simple changes in product technology (recycled paper products) rather than more complicated process innovations which hold out the promise of longer-term improvements in environmental performance. Significantly, firms which reported introducing environment-related innovations did not enjoy (on average) superior levels of performance at their mills — nor were they more likely to report savings on operating costs, as would be expected in the case of many process innovations.

The factors prompting more innovative behaviour on the part of respondent firms are by no means clear. The tendency of respondent firms to mention product and process innovations does not appear to be linked to the main explanatory variables introduced in this chapter. Extent of reported innovation is not correlated with degree of regulatory burden, export orientation, ownership, or extent of R&D spending. In fact, the only significant correlation is with the firms' degree of commitment to (reporting on) environmental management. This suggests that the main type of innovation has been product alterations which have a pay-off in terms of public image and profile, but limited impact on longer-term cost-competitiveness or environmental performance. The lack of correlation between innovations and R&D spending, moreover, suggests that where product/process innovations **have** been introduced, the main source of technology is external to the firm. In-house R&D resources of Canadian pulp and paper firms — as noted in the last chapter — continue to be geared primarily to adaptation of external innovations, rather than toward major breakthroughs. Thus, while R&D spending may promote superior environmental performance (see Section IV of this chapter) by improving the efficiency with which external technology is used at the mill level, it is less clear that R&D spending should be expected to increase markedly in response to environmental pressures, nor is it likely to result in radical new innovations.

This is further reinforced by data on trends in environment-related R&D by respondent firms. Only 21 firms (62 % of the sample) reported carrying out **any** environment-related R&D, and for half this number environment-related R&D accounts for less than 10 % of total R&D spending. Moreover, only slightly more than half of those firms with environmental R&D spending reported that this had increased as a percentage of overall R&D over the past five years, despite increasingly stringent environmental

demands on firms (Figure 5.12).

In fact, this result is not surprising, and reflects the overall dominance of outside sources of technology and technical know-how. As Figure 5.13 indicates, aside from in-house production and

Figure 5.13

engineering expertise, the principal sources of technical know-how for environmental improvements are seen as equipment suppliers, consulting engineering companies, and jointly-funded research programs such as those operated by Paprican. In-house R&D, the expertise of parent and partner firms, and university or public sector R&D institutions are all seen as relatively unimportant.¹⁸ Environmental pressures have not altered this overall picture: despite record high levels of pollution abatement and control expenditures in recent years, overall intramural R&D spending by the industry has been stagnant during the 1990s (Statistics Canada, 1996c), and leading firms like MacMillan Bloedel have closed in-house R&D facilities in recent years (Ross, 1998). To the extent that environmental regulations spur innovation in the Canadian pulp and paper industry, this is likely to occur not because of breakthroughs by individual firms, but instead as a result of incremental improvements at the mill level, and because of indirect impacts on suppliers and collaborative research programs funded by the industry.

¹⁸ Interestingly, there is little variation in responses between Canadian and foreign or joint venture firms: in neither case are parent or partner firms seen as key sources of technical expertise for environmental improvements.

The evidence on this latter front is incomplete, and this thesis has not been able to include a detailed analysis of the way in which environmental pressures on pulp and paper firms have affected individual supplier firms or research institutes. As will be pointed out in the concluding chapter, this is one area where further research is required. There is, however, some evidence regarding the extent of stimulus which environment-related spending in the pulp and paper industry has given to outside sources of technology.

As noted in the last chapter, there is some evidence that overall levels of output by supplier firms have been increasing, indicating that regulatory-induced investments had spill-over effects on supplier firms. But the base remains very small, and most equipment continues to come from foreign suppliers or their affiliates. Recent data compiled by Statistics Canada on environmental industries (Statistics Canada, 1997) suggest growth in this sector during the period under study — although much of the growth has been via export market sales. It is not possible to disaggregate data on environmental industries by “client” industry, and as a result it is difficult to assess the extent to which demand from the pulp and paper industry has been responsible for increased sales — although the dominant role of the pulp and paper industry in overall pollution abatement expenditures by Canadian industry in recent years (see Chapter 4) would suggest that it represents a key stimulus to environmental companies. In terms of collaborative research programs, environment-related R&D at Paprican rose rapidly during the early 1990s (see the discussion in Chapter 4), although it has since fallen both in absolute terms and as a percentage of overall Paprican spending.

More anecdotal evidence suggests that there has been some impact of environment-related investments by pulp and paper companies on development of new technologies

by outside suppliers. A number of individual companies have developed specific technologies or processes — such as a small Nova Scotia chemical company which developed a new process to improve the efficiency of primary effluent treatment (and hence decrease the size and capital requirements of secondary treatment systems required), or a major consulting engineering company which has worked with firms to develop a zero-discharge process for TMP-based newsprint mills. At a broader level, work at Paprican on zero-effluent technologies holds out the promise of longer-term gains for Canadian industry, although at this point work remains short of commercial application. Unfortunately, it is beyond the scope of this thesis to assess the extent and significance of such developments.

VI. Conclusions

Based on the above analysis, the following conclusions can be advanced:

- in terms of the level of environmental investments by pulp and paper firms, survey data confirms the picture portrayed in Chapter 4. Increasing environmental pressures — and notably the new regulations introduced in the 1990s — have spurred a significant level of environment-related investment by most pulp and paper firms operating in Canada. Firms have overwhelmingly chosen to invest in improved environmental performance rather than closing mills or reducing production levels to ensure compliance.
- as might be expected, investments have been weighted toward end-of-pipe controls, as well as relatively minor internal house-keeping measures. However, a significant minority of firms have also chosen to invest in more far-reaching

internal process changes. There is some indication that the need to shoulder high levels of pollution abatement expenditure has also had an indirect impact on some firms' decisions to undertake major modernization programs.

- levels of environment-related **investment** at individual mills are influenced both by the degree of regulatory pressure facing the mill, and by the export orientation of the mill (particularly the percentage of output going to Western Europe). The two factors appear to spur different types of investments — with key in-plant changes more likely to be linked to export-orientation, and end-of-pipe controls linked to levels of regulatory burden.
- levels of environmental **performance** of mills, on the other hand, are linked not only to regulatory pressures, but also to the internal resources and capabilities available to the firm because of its R&D expenditures and overall commitment to environmental management. This suggests that external environmental pressures work primarily by narrowing the gap between “leading” and “laggard” firms, largely by promoting the diffusion of proven technologies. The ability of firms to go beyond mandated levels of environmental performance, however, depends on their overall resources and innovative potential. Export orientation does not appear to be linked to superior environmental performance, but this may be due to limitations in the data available for this study.
- ownership does not appear to be a significant determinant of levels of environmental investment by firms, nor resulting levels of environmental performance. There is no evidence that the environmental strategies of foreign or joint venture firms are strongly influenced by the influence of foreign

parents/partners, nor do they look to parent and partner firms as key sources of technical expertise for environmental improvements.

- there are strong scale economies in pollution abatement expenditures at the firm-level — and possibly also at the mill level, although data are less clear on this point. But scale economies do not translate into superior levels of environmental performance at larger firms and mills.
- the main positive impacts associated with environmental investments have to do with improvements in public image and employee morale, and (to some degree) ability to compete in export markets. Cost savings and improved yields are important, but are likely be outweighed by increased costs in other areas like maintenance and repair, training, energy and solid waste disposal. Only a small minority of firms have found that operating costs have fallen as a result of environmental investments
- the main sources of technical know-how for environmental improvements are external to the firm — equipment suppliers, consulting engineering firms, and joint research programs (Paprican). As a result of this, the impact of environmental pressures on innovation within firms themselves has been limited, with only a small minority of firms reporting development of new product or process technology, or more general improvements in R&D and engineering capabilities. Overall levels of in-house environmental R&D are relatively low, and have not risen dramatically as a result of recent environmental pressures.
- there is anecdotal evidence that environment-related spending by the pulp and paper industry has given rise to the development of new technologies by outside

equipment suppliers, consulting firms, and research institutes. There is also some evidence that overall output of machinery and equipment suppliers and environmental technology firms has risen as a result of the boom in spending by the pulp and paper industry. But the evidence is not conclusive, and there is no evidence that environment-related spending has reversed the overall weak innovative potential of the industry and its supply base.

The next two chapters turn to the Chilean case, in order to examine the situation of firms operating in a less-regulated environment. Chapter 6 provides an overview of the overall situation of the industry, and Chapter 7 presents the results of empirical analysis of the situation of individual Chilean mills.

Chapter 6: The Pulp and Paper Industry in Chile

I. Introduction

There are a number of similarities between the pulp and paper industries in Canada and Chile. Both industries are heavily export-oriented, with a marked emphasis on production and export of market pulp and (to a lesser degree in Chile) newsprint. In both cases the industry has flourished largely on the basis of natural advantages in wood production. Production of higher-value-added paper products is less important, and the domestic pulp and paper machinery and equipment industry is relatively weak by international standards.

At the same time, there are a number of important differences between the two industries. Scale is the most obvious factor: Canada is the world's leading exporter of newsprint and market pulp, whereas the Chilean industry, despite its rapid growth, still accounts for only a small proportion of world output. There are also important differences in term of the range of products produced, the number, average size and age of plants, and the nature of promotional policies facing the two industries. Most critically, however, the two industries differ markedly in the level of direct regulatory pressures facing firms. As a result, analysis of the Chilean industry represents an opportunity to explore the extent to which environmental pressures in export markets and/or the influence of parent firms are likely to lead to environmental improvements by firms despite relatively weak domestic environmental regulations. This chapter sets out some of the main features of the Chilean industry, as a prelude to the more detailed analysis of firm-level responses in Chapter 7.

The next section of this chapter describes the structure and historical evolution of the industry, the nature of trade and industrial policies confronting firms, and the overall level and direction of innovative effort in the industry. This section argues that the rapid growth of the Chilean industry is not simply a product of natural resource endowments, but also reflects a series of direct and indirect promotional activities by Chilean authorities over a 40-year period.

The combination of natural resource advantages and promotional policies has resulted in explosive growth in production and exports of market pulp, and improvements in productivity levels due to new capital investment and the increasing scale of plants. But the impact on innovative resources and capabilities available to firms (the “means” by which firms can respond to environmental pressures) has been more limited.

Corporate R&D is relatively low by international standards, and is oriented primarily toward improvement in the forest resource base. There are some production-oriented R&D projects, and an active process of human resource development as a result of firm-level training, mobility of workers among plants, and the activities of the local professional association. But technological effort is oriented primarily to mastery of imported production technology, and (to a lesser degree) improvement of product characteristics to assure market access. The extreme weakness of the local capital goods industry limits the possibility of linkages with equipment suppliers -- although there has been a gradual sophistication of local consulting engineering companies as a result of recent investment projects. Public-sector R&D support is limited to a small number of discrete projects, and there has not been the development of the kind of collaborative institutions to support R&D witnessed in Canada and other countries. And while new investments over the past decade have dramatically improved the average

technical efficiency (and environmental performance) of the industry, foreign investors primarily play a financial role, rather than acting as an ongoing source of technical resources and expertise. All of this suggests that the ability of the Chilean industry to innovate in response to environmental pressures will be limited, with the main responses being incremental improvements to existing plant and equipment, and continued imports of foreign technology and technical expertise.

The third section of the chapter turns its attention to the environmental pressures facing Chilean firms (the “motives” for environmental improvement, to return to the concepts outlined in Chapter 2). The primary influence on the industry at present is market demand, notably the environmental requirements of access to key European pulp markets. Market pressures are only an issue for market pulp producers, however, with newsprint manufacturers facing fewer environmental restrictions due to their focus on regional markets in Latin America. Regulatory pressures do not appear to be a principal constraint on firms, due to the weakness of current regulations and the limited enforcement capability of authorities. Beginning in the mid-1990s, however, the issue of **future** regulatory requirements became a more contentious issue, spurred by new environmental legislation and increasingly detailed environmental impact assessments for new mills. Finally, the impact of ownership on environmental activities remains unclear. Foreign investors have in at least some cases insisted on strict environmental practices, and may have indirectly raised the “floor” for environmental performance for other firms as well. On the other hand, dominant local firms are sensitive to public opinion, and in particular to the increasing public debate over environmental policy in Chile.

The final section of the chapter summarizes the main arguments, and outlines the central issues for analysis in Chapter 7, where field study research results are presented.

II. Industrial Structure, Policies and Performance

a) Structure and Evolution of the Industry

Pulp and paper is an important sector in the overall Chilean economy, accounting for some 7.4 percent of manufacturing value-added in 1994, and approximately three percent of the industrial labour force. It is an even more important contributor to export revenues, accounting for 6.1 percent of total export earnings, or 17 percent of manufacturing exports (excluding copper) in 1992.

The Chilean pulp and paper industry is of relatively recent origin, particularly with regard to its role as a major producer of market pulp. As of the 1950s, the industry was limited to a few small paper manufacturers, producing exclusively for the local market and relying entirely on imports of pulp from Scandinavian countries.

Beginning in the 1950s, public sector support via the Corporacion de Fomento Industrial (CORFO) led to the growth of new capacity in the pulp and newsprint sub-sectors. Capacity increased markedly (albeit from a very small base) and by the beginning of the 1970s Chilean firms were producing over 300,000 tonnes per year of pulp, and over 100,000 tonnes of newsprint. Export ratios were still relatively low, hovering around 50 percent, and regional markets predominated.

The 1970s saw a marked shift in the structure of production and export. While the

newsprint and mechanical pulp sub-sectors grew slowly, production of chemical pulp for export markets expanded rapidly, tripling between 1970 and 1980. Export ratios also began to increase, reaching 65 percent of chemical pulp production by the end of the decade.

Table 6.1: Production and Export, by Products (000 tonnes)						
	Pulp		Paper and Board		Newsprint	
	Production	Export	Production	Export	Production	Export
1980	632.0	414.8	324.4	86.3	131.0	65.4
1981	617.9	412.4	319.7	59.2	130.7	42.7
1982	552.3	462.1	262.6	71.7	124.4	54.9
1983	656.2	523.4	324.9	113.3	155.2	92.2
1984	682.3	492.7	365.8	136.2	167.6	110.4
1985	679.6	503.1	369.4	144.7	172.1	116.4
1986	693.5	565.2	387.8	152.3	168.8	131.5
1987	708.4	524.6	441.9	136.6	179.5	126.4
1988	728.0	479.2	449.8	131.4	184.3	120.7
1989	679.8	481.6	437.8	139.9	166.5	125.6
1990	644.3	581.1	462.0	131.0	171.0	115.0
1991	934.0	664.5	485.0	155.1	171.0	114.9
1992	1499.0	1,210.0	508.0	131.5	161.0	111.5
1993	1,491.0	1,160.0	552.0	154.0	180.0	125.0
1994	1,940.0	1,370.0	569.0	167.0	190.0	130.0
1995	1,646.0	1,040.0	557.0	160.0	220.0	140.0
1996	2,060.0	1,340.0	638.0	185.0	300.0	160.0
1997	2,040.0	1,100.0	665.0	210.0	280.0	180.0
Source: 1980-1992 figures are taken from Stumpo, 1995, based on INFOR data; 1993 to 1997 figures are from <u>Pulp and Paper International</u> Annual Reviews, various years.						

The early to mid-1980s was a period of much slower growth in overall production, reflecting the slowdown in the national and regional economies. Beginning in the late

1980s, however, a number of new, large-scale market pulp operations began to come on stream, resulting in a new phase of rapid expansion in output and exports. By the mid-1990s production of chemical pulp had surpassed 2 million tonnes, making Chile the second largest Latin America pulp producer after Brazil. Growth was fuelled largely by export markets, with pulp exports now accounting for 90% percent of total pulp production -- and almost 50% percent of total forest product export revenues.

Production is dominated by chemical (Kraft) pulp -- primarily softwood pulp produced from radiata pine, but also hardwood pulp from eucalyptus¹. Mechanical pulp is produced in much smaller quantities (less than 10% of total pulp production), and used exclusively in domestic paper manufacture, particularly for newsprint. Paper production is relatively limited, with newsprint the most important single paper product.

Both Kraft pulp and newsprint are destined largely for export markets, but with important differences in destinations. As Figure 6.1 illustrates, pulp is sold largely on international markets, with Europe and Asia the most important destinations. In 1992, the top five destinations were Germany, Japan, Belgium, China and France. In contrast, over 90 percent of newsprint is sold on regional markets: the leading destinations in 1992 were Peru, Brazil, Ecuador and Argentina (Stumpo, 1994, 15-16). One consequence of this divergence -- as will be examined later -- is that environmental pressures in export

¹ Currently only one mill produced hardwood (eucalyptus) pulp, accounting for approximately 16 % of total pulp production, but another firm has announced plans to convert one of its mills to hardwood production over the next few years.

Figure 6.1

markets are a significant factor only for market pulp producers, not newsprint mills.

Stumpo (1995) argues that the recent evolution of the pulp and paper industry in Chile illustrates a more general trend in Latin American economies away from import-substituting

industrialization, and toward the

large-scale production and export of "industrial commodities" based on natural resource endowments. Paper production for the domestic market has grown slowly over the past decade, and imports now account for an increasingly important share of paper consumption in Chile.

The competitiveness of Chilean market pulp exports has been based largely on cost advantages in wood production. Rates of timber growth are much higher than in industrialized countries, with the dominant species (*radiata* pine) maturing to harvestable size in 20-22 years, compared to as much as 60 years for comparable species in some competitor countries. This natural advantage has been compounded by government policies providing incentives to the development of forest plantations (see next section).

As a result, Chilean producers enjoy a significant cost advantage over most of their

competitors. Table 6.2 provides an overview of the principal cost items for the production of a tonne of bleached chemical softwood pulp in five competing countries in 1990. As can be seen, Chile is the lowest-cost producer, largely due to advantages in the cost of wood, plus smaller advantages in personnel and capital costs.²

It is a mistake, however, to suggest that natural advantages alone can explain the recent surge in Chilean pulp production and exports. While these have provided a platform for the recent export boom, their impact has been compounded by the efforts of leading firms to exploit economies of scale and to increase the technological sophistication of production. The average scale of chemical pulp mills in 1994 was approximately 725 adt/day, a figure which is likely to increase over the coming years due to modernization programs and the expected entry into production of at least one large (1500 adt/day) mill. As a result, most mills are now producing at or close to internationally competitive scale.

² Note that cost comparisons are likely to have changed since 1990, due to the devaluation of the Swedish and Finnish currencies, as well as increases in labour and capital costs in Chile. The situation for bleached chemical hardwood pulp are in many respects similar, although in this case Chile's cost advantage is less marked, and is overshadowed by Brazilian producers who enjoy advantages in wood (eucalyptus), energy and chemical costs. See Stumpo, 1995, 30-31.

Table 6.2: Comparative Costs of Production ca. 1990, Bleached Softwood Kraft Pulp (USD/adt)					
	Southern USA	Canada	Sweden	Finland	Chile
Wood	130 (25%)	170 (28%)	337 (51%)	390 (55%)	120 (25%)
Energy	20 (4%)	30 (5%)	15 (2%)	12 (2%)	25 (5%)
Chemicals	58 (11%)	55 (9%)	39 (6%)	44 (6%)	62 (13%)
Labour	45 (9%)	85 (14%)	81 (12%)	49 (7%)	40 (9%)
Other Variable Costs	70 (14%)	65 (11%)	55 (8%)	35 (5%)	58 (12%)
Total Variable Costs	323 (63%)	405 (67%)	527 (79%)	530 (75%)	305 (64%)
Capital	110 (21%)	80 (13%)	85 (13%)	120 (17%)	80 (17%)
Other Fixed Costs	84 (16%)	122 (20%)	55 (8%)	58 (8%)	88 (18%)
Total Costs	517 (100%)	607 (100%)	667 (100%)	708 (100%)	473 (100%)
Source: Asociacion Tecnica de la Celulosa y el Papel (ATCP), reprinted in Stumpo, 1995, 29.					

The push to export markets has meant that firms have also had to improve the quality and technical sophistication of their production. All pulp mills have automated process control, and the newest mills incorporate most of the latest developments in process technology. Quality of pulp has improved steadily, and all of the chemical pulp mills are now capable of producing ECF pulp – and in one case TCF as well. Several mills have undergone ISO 9000 or similar quality certification, and in at least one case a firm is considering ISO 14000 certification.

The industry is heavily concentrated, with five firms (and eight mills) accounting for all of the chemical pulp produced in the country, and newsprint production shared among only three firms, each of which operates a single mill. There are also significant levels of inter-corporate holdings in the sector, with the largest pulp and paper firm also holding major stakes in one newsprint and one market pulp mill, and a minority share in another market pulp operation. On the other hand, levels of integration are low: of the chemical pulp producers, only one has paper-making interests as well, and only one of the eight

Kraft pulp plants is (partially) integrated for paper production.

The industry is based in large measure on local capital. The largest firm in the industry is entirely locally-owned, with almost all of the stock owned by one of the large, diversified conglomerates which dominate much of the Chilean economy.³ The second largest firm (and the largest market pulp producer) is a joint venture between another of the Chilean “groups” and the New Zealand conglomerate Carter-Holt-Harvey, although management is entirely in the hands of the Chilean partners. During the late 1980s, foreign investment became an increasingly important factor in the industry, due in part to the opportunities for investment via debt-for-equity swaps. Three of the four new pulp plants constructed between 1990 and 1994 involved significant levels of foreign investment, either independently or in joint ventures with local firms — although in one case the foreign partner sold its interests to a local forest products firm in 1996.

In the newsprint sub-sector, production has been relatively stagnant in recent years, with only one new mill (a small, 150 adt/day operation) coming on stream in recent years. Average scale of the mills is below 275 adt/day, well below internationally-competitive levels. Two of the three mills are locally-owned, while the other is foreign-owned.

b) Industrial and Trade Policy

Conventional wisdom attributes the surge of export-oriented growth in Chile over the past two decades to strict ‘laissez-faire’ policies: macroeconomic stability, avoidance of an overvalued exchange rate, and a dismantling of trade barriers. But while these

³ For a discussion of the role of industrial conglomerates (or “economic groups”) in the Chilean economy and the transformation of their holdings over time, see Sanchez and Paredes (1994).

factors are certainly crucial, it is also necessary to look beyond them, by examining both the roots of export-oriented growth in the pre-1973 period, and the continued existence of promotional policies which have played a role in fostering and sustaining growth of exports (Bielchowsky and Stumpo, 1995, 28). This is clearly the case in the pulp and paper industry.

Stumpo (1995) argues that Chilean policy toward the pulp and paper industry can be split into two distinct phases: a phase of **direct** promotion between the early 1940s and 1973; and a phase of **indirect** promotion from 1974 to the present.

The key role during the phase of direct promotion was played by the state development agency CORFO – originally geared to promote self-sufficiency in paper production in the country, and subsequently shifting to focus on export-oriented production. In the mid-1950s, CORFO developed an initial strategy for the development of the sector which included plans for an integrated chemical pulp mill; it then worked to convince private investors (initially wary of the scale of investment required) to undertake the project, and negotiated World Bank funding for this project and a subsequent newsprint mill.

By the late 1960s, CORFO came to play a more aggressive role, taking control of one of the two newsprint plants in the country through debt capitalization, and then launching two new market pulp plants – initially with the participation of British and French investors, and subsequently as sole shareholder.

By the time the second round of plants had come on stream in the mid-1970s, government policy had shifted dramatically. The Pinochet government moved quickly to

divest itself of CORFO's holdings in the industry, which were sold to private interests (at prices below their value at the time). While the earlier phase of direct promotion had (arguably) helped to 'crowd in' reluctant private investors, the subsidized divestiture of state assets served to consolidate what are now the two main firms in the pulp and paper industry.⁴

At the same time, however, the new government introduced a series of indirect promotional measures geared to expanding forest product exports. The most important of these was Law 701, promulgated in 1974, which provided for a subsidy of up to 75 percent of the costs of forestation and maintenance of plantations, and also provided guarantees against state expropriation of plantations. Along with special lines of credit from the Central Bank during the latter half of the 1970s, the subsidies resulted in a massive increase in forestation, with annual plantings growing from just over 30,000 hectares in 1973 to over 130,000 in 1992. At the same time, the role of the state as a plantation owner declined substantially, with all new forestry activity now carried out by private interests. Stumpo (1995, 9) estimates the level of subsidy at approximately \$5 million USD annually over the period 1975 to 1992 – or \$7 million annually if additional subsidies to maintenance and administration of plantations are included.

While forestation subsidies were not directed specifically at pulp and paper production, much of the benefit has flowed to pulp and paper firms, which have been responsible for a sizeable percentage of the total area forested over the past two decades. Forestation subsidies have promoted the backward integration of pulp and paper firms into forest

⁴ The sell-off of state holdings resulted in a significant expansion of what is now the major pulp and paper firm in the country, and the creation of the second-largest firm (which was created specifically to take control of the two market pulp facilities created by CORFO in the late 1960s and early 1970s).

holdings, which has become one of their great competitive strengths over the past decade. Subsidies also indirectly helped to spur research efforts by these same firms aimed at genetic improvement of species, improved cultivation practices, and better forest management (see below). As a result, there is no doubt that this has been a key factor in the growth of the industry.⁵

In addition, pulp and paper production has been spurred by a series of more general export promotion measures. This has included not only a lowering of tariffs on imports of capital goods and other inputs, but also special incentives offering tax rebates for purchases of capital goods and intermediate inputs (such as chemicals) used in the production of goods for export (see Cerda, Olavarria and Abalos, 1992, 136-7 for details). As Stumpo (1995, 48) has noted, in 1975 the Pinochet government also prohibited the export of non-processed timber, thus providing a further stimulus to investment in processed forest products like pulp and paper.

Overall, it can be argued that both periods were of crucial importance to the current dynamism of the industry (see also the discussion in Richards, 1997, 147-148). The initial period of direct state support was indispensable in attracting local capital to the

⁵ On the other hand, it is not clear that forestation subsidies will continue to play such a key role in the future. The percentage of total area forested which has received a subsidy declined from as much as 90 percent in the early 1980s to approximately 40 percent by the end of the decade (in other words, non-subsidized forestation now makes up a majority of total area forested). Moreover, the key impact of Law 701 probably came in the early years of its existence, when the Chilean forest products industry was still in its infancy, and when an unstable political and economic environment served as a disincentive to private investments with a 20-year time horizon. It is not clear that further state subsidy is required to maintain forestation activities, and at least one analysis (Arze and Swensson, 1993) argues that the real challenge at present is not ensuring adequate forestation, but rather ensuring an adequate processing capability for the vastly-increased amounts of harvestable timber which will soon come to maturity. At the time of field research for this thesis, Law 701 was under review, and early proposals called for a strict limitation of subsidies, focussing them on small- and medium-sized producers only, and on plantings on marginal and severely degraded lands.

industry and in negotiating with foreign sources of technology for early projects. The later period of indirect support – combined with political and economic stability – was critical in increasing private investment, and in channelling the industry toward export markets.

c) Level and Direction of Innovative Effort

Productivity levels in the Chilean pulp and paper industry have grown rapidly over the past two decades. Productivity grew by an annual average of 5.0 percent between 1974 and 1994 – compared to a rate of 1.5 percent annually for the manufacturing sector as a whole. Rates of productivity growth were particularly high in the 1974 to 1982 period, with slower growth in productivity between 1982 and 1990, and a recovery in the 1990s.

High rates of growth have been largely due to increases in the scale of pulp and paper plants, and to continuous improvements in forest production and management. During periods of rapid growth in the 1970s and early 1990s, construction of new mills (and to a lesser degree modernization of existing mills) has led to an inflow of up-to-date foreign production technology. New plants constructed since the late 1980s are relatively up-to-date technologically, as reflected both in overall production efficiency and environmental measures included in mill design.

Not surprisingly, strategies of firms have been largely geared to adoption and mastery of imported technology, in a fashion similar to the “adopt and adapt” strategy characterizing the Canadian industry. Levels of R&D are modest. While sectoral data on R&D expenditures are not available, reported R&D spending by the two largest firms in the industry (the only two with any sizeable in-house R&D capability) stood at 0.13

and 0.29 percent of gross sales respectively in 1994.

R&D spending is concentrated in the areas of forest development (improvement of species, better forest management and harvesting practices) and to a lesser degree improvement in pulp characteristics and quality. In other words, firms' research efforts are concentrated on improving the forest resource (which is the industry's key competitive advantage) and on enhancing product quality in order to ensure competitiveness in export markets. Despite the modest level of R&D spending by international standards, R&D activities are of crucial importance in these areas. On the other hand, there is little or no research geared to improvements in core process technology, reflecting the relatively easy access of firms to up-to-date production technology from abroad, and the weakness of the domestic capital goods sector.⁶

Less formal channels of technological "learning" are better developed. All firms interviewed have active training programs for mill staff⁷, and in a number of cases have organized visits to pulp and paper facilities abroad as part of the preparation for major investment programs. In at least one case, a firm has developed a program of scholarships to permit managerial staff to study abroad for up to two years (Stumpo, 1995, 41). The local professional association (Asociación Técnica de la Celulosa y el Papel, or ATCP) is relatively active. Based in Concepción (the centre of Chilean pulp

⁶ There are, it should be noted, some research efforts underway by firms on alternative bleaching technologies, including work on ozone-based bleaching at one firm (for details, see Osses and Jara, 1995) and a joint project between industry and university researchers (partially funded by the Chilean government research council Conicyt) on biotechnology-based bleaching. In both cases, this is relatively early-stage, exploratory work.

⁷ A survey of five of the leading firms in the sector found that the incidence of training was high, with the percentage of staff receiving training during 1992 varying from just under 60 percent of semi-skilled workers, to almost 85 percent of middle management (Stumpo, 1995, 42).

and paper production), the association's members include technical managers and staff from all mills in the country, as well as representatives of suppliers and consulting firms. It publishes a technical journal, organizes a biennial conference, and assists in training through short courses and the maintenance of a reference library. The forest products industry association (Corporación de la Madera, or CORMA) plays a less important role in training and technical upgrading, although it does sponsor a technical conference in conjunction with its annual trade fair.

One of the weaknesses of the industry, however, is the relative absence of linkages with domestic support institutions. The domestic capital equipment sector is extremely weak; as Bielchowsky and Stumpo (1995, 28) note, the sector has been hobbled by the small size of the Chilean economy and its distance from principal export markets, as well as by import liberalization and exchange rate appreciation in the 1974-80 period, which forced incipient local firms out of the market. Not surprisingly, then, the local pulp and paper equipment and machinery sector consists almost entirely of distributors for major European, American and Brazilian firms. Aside from minor components, investment projects carried out in the late 1980s and early 1990s relied entirely on imported machinery and equipment. While backward integration of pulp and paper firms into forestry is high, levels of forward integration are low. As will be pointed out in Chapter 7, ongoing technological links with foreign parent and partner firms are also relatively weak, with the primary role of foreign investors being financial and market-related, not technological.

Links with domestic research institutions are also limited. Both the public sector Instituto Forestal (INFOR) – a subsidiary of the national development corporation CORFO – and

the privately-funded Fundación Chile have research and technology transfer programs in the forestry field. But these are oriented primarily toward forest management issues and to a lesser degree to research and technical support for small- and medium-sized firms in the sawmilling, wood products and furniture-making industries. The public sector industrial research institute INTEC is not active in the pulp and paper field. In terms of research funding, both CORFO and the national science and technology commission CONICYT have programs for shared-cost funding of private sector research: FONTEC (managed by CORFO) supports projects directly with private-sector firms, while FONDEF (managed by CONICYT) funds collaborative university-industry research projects. There have been some projects oriented toward the pulp and paper industry -- FONDEF projects have included work on biotechnology-based bleaching, development of visual sensors for quality control in paper production, and use of tall oil (a by-product of Kraft pulping) in the production of hormonal steroids. But once again research has tended to concentrate on smaller-scale wood products firms, and on forest management issues. There has been none of the kind of large-scale, public-private research programs witnessed in Canada, nor is there a collaborative industry research body equivalent to Paprican.

This is not surprising, given the structural features of the Chilean pulp and paper industry. The focus of research on improving forest resources (and to a lesser degree improvements in product quality) is sensible in light of the overriding need of firms to ensure their continued competitiveness in export markets, both in terms of costs and quality. The overall number of firms in the industry is probably not sufficient to support a major collaborative research program, particularly given the concentration of ownership and the dominance of the two largest firms. At the same time, the strong international

links of most firms -- and the relatively easy access to up-to-date production technology on the world market -- act as disincentives to domestic R&D on process improvements.

The one area where linkages do appear to be taking root is in the field of consulting engineering services (Arze and Swensson, 1993; Stumpo, 1995). The surge of new pulp and paper investment in the late 1980s and early 1990s contributed to the growth of a base of local consulting expertise. In the initial investment projects carried out during this period, basic design work was entrusted entirely to foreign firms (Scandinavian or Canadian) with only some of the detailed engineering carried out locally. Over the course of the period, however, several local consulting firms formed alliances with foreign firms, resulting in a process of learning and capacity acquisition. These local firms have come to take on increasing responsibility for all phases of design work, due in large measure to cost advantages over foreign firms and greater familiarity with use of the local radiata pine species. In the case of the most recent mill, almost all design and engineering work was entrusted to a local firm. There have also been growing linkages with local universities -- in some instances for research projects, but even more commonly for environmental impact assessments and effluent monitoring studies.

Overall, then, the innovative situation of the industry is mixed. On the one hand, new investment has resulted in increased scale of production and overall upgrading of the technological sophistication of mills relative to the situation a decade ago. But investment (particularly foreign investment) has resulted primarily in a "one-time" boost in productivity, and is not accompanied by ongoing transfers of expertise and technology from foreign partners. Innovation-related activities of firms have increased, but are

primarily oriented toward improving the forest base and to a lesser degree improving pulp quality to safeguard market access. Linkages with other local sources of equipment and technical know-how are limited, with the exception of a small number of consulting engineering companies and some university-based research and consulting services. All of this suggests that the ability of the Chilean industry to introduce major innovations in response to environmental pressures is likely to be limited. The primary focus of innovative activity is likely to be on incremental improvements to existing plant and equipment, and continued import of foreign technology. There is also likely to be a significant schism between older and newer plants, with cost concerns being an overriding motive at the former plants.

III. Environmental Pressures and Policies

Whereas the last section concentrated on the resources and capabilities of Chilean firms to pursue innovation in response to environmental pressures, this section of the chapter concentrates on the “motives” of Chilean firms, by outlining the nature of market, regulatory and ownership-related environmental pressures on Chilean firms, and the way these can be expected to affect their behaviour.

a) Market Pressures

Given the high levels of export orientation of the Chilean industry, market-related factors constitute the most obvious pressure to improve environmental performance. Market-related factors are salient only for market pulp producers, who (as noted earlier) export the majority of their output to relatively demanding destinations in Europe. Newsprint production, on the other hand, is exported almost entirely to regional markets in South

America, and environmental demands in export markets are not an issue.

During the early to mid-1990s, a number of observers raised concerns about growing environmental restrictions on access to European markets due to eco-labelling practices, and their potential impact on Chilean pulp and paper producers (see Scholz et al, 1994, 49-58; or Hermosilla, 1994). There is little doubt that export market requirements have had a major impact on the kinds of environmental measures included in new plants constructed in the 1989-1994 period (all of which are 100% export-oriented, with significant shares of production destined for Europe). As will be pointed out in Chapter 7, they also have influenced investment decisions in established market pulp producers.

There is some doubt, however, about the extent to which market demand remains a strong determinant of ongoing environmental activities. Measures included in the design of new mills -- full chlorine dioxide substitution in bleaching, oxygen delignification and extended cooking, primary and secondary treatment of effluents -- have been more than sufficient to guarantee compliance with existing environmental requirements of European markets (Scholz et al, 57). Meanwhile, continued international debates over the environmental impact of alternative bleaching methods -- combined with the slowdown in the world pulp market from late 1995 on -- have meant that environmental demands on Chilean producers have increased more slowly than anticipated at the beginning of this decade.⁸ In particular, the growth of the market for

⁸ At least one analysis argues that the impact of export-related environmental pressures on Chilean pulp and paper producers may be less than often expected. Dresdner et al (1995) attempted to simulate the impact of complying with foreign-market environmental requirements on various industrial branches, by using US figures for pollution abatement and control expenditures (percentage of value of output) and a measure of the price elasticity of exports in the various branches. The result suggests that the impact of raising environmental spending to US levels on

TCF pulp has been slow, and price premiums over ECF pulp are small or non-existent. As a result, pressures to shift to TCF production have slowed.

Perhaps as a result of this, the overall attitude of the Chilean industry has been relatively passive and cautious; Scholz et al (1994, 57) for example, note that there has been no effort by Chilean producers to develop their own ecological labels/standards, nor have they actively lobbied in domestic or international fora. As one industry official pointed out during interviews, market-related pressures on firms remain more latent than actual. Nonetheless, the sensitivity of Chilean industry to export market demand means that firms must pay attention not only to current environmental requirements in foreign markets, but also expected future trends.

b) Regulatory Pressures

In contrast to market-related factors, regulatory pressures on Chilean firms do not appear to be a major issue for the industry as a whole. Current regulations facing the pulp and paper industry are not particularly stringent by international standards, and capacity to enforce regulations is severely limited.

A central feature of Chilean regulatory policy remains the high degree of overlapping responsibility among government bodies (Faranda and Parra, 1993, 147-148; see also Trucco, 1995, 6-7. For a general review of environmental issues in Chile, see O'Ryan, 1995). With regard to liquid effluents from pulp and paper plants, the following

pulp and paper exports would be marginal – a drop of 0.52 percent in overall export levels, one of the lowest levels of any of the branches studied. These results, however, are open to serious question: it is not clear that percentage pollution control expenditures in the US are an accurate reflection of either the true barriers to pulp exports to European markets, or the actual costs of improved environmental performance for Chilean mills, especially older ones.

government bodies play a role:

- The Ministry of Public Works (via the Superintendencia de Servicios Sanitarios, or SSS) is responsible for the implementation of Law 3.133 ("Neutralization of wastes from industrial establishments"). This legislation, originally passed in 1916, forbids discharge of contaminated water into any receiving body without prior authorization from the Presidency. The act is woefully out of date, and like much other environmental legislation in the country, does not back up general principles with specific regulatory limits, fines, or inspection procedures. Updates in 1992 and 1993 developed more specific guidelines and administrative procedures to accompany the law.
- The Ministry of Health is responsible for the oversight of 1967 Sanitary Code (Law No. 725), which "forbids the discharge of industrial or mining wastes into waters that serve as a source of drinking water, for irrigation, or for recreational purposes, without treatment according to established norms". Authorities can temporarily shut down a facility which does not comply. Again, however, no clear guidelines or procedures are set out, and enforcement is limited.
- The Ministry of Agriculture is responsible for the Law of Protection of Agriculture (Decree 3.557, 1980), which stipulates that industrial, mining or other activities which involve products which could result in contamination of agricultural lands should adopt techniques and practices to avoid or restrain pollution. As with the other general laws, practical application of the law is extremely limited.
- The Ministry of Defence (via the Directorate General of Marine Territory and

Merchant Marine, or DGTMMYMM) has far-reaching powers particularly over establishments discharging to coastal waters, based on the 1978 Navigation Law (Decree No. 2.222), which forbids discharges which cause harm to waters within national jurisdiction, as well as ports, rivers and lakes. More specifically, a 1987 Resolution (“Environmental Impact Assessment in Coastal Ecosystems”, No. 12.600) requires an environmental impact assessment in order to approve any project involving discharges to coastal waters.

Faranda and Parra (1993, 148) argue that the current situation is characterized by lack of specific regulations to facilitate the application of laws; repetition and overlap among statutes, leading to a passive and complacent attitude among those responsible for implementation; limited coordination among various government agencies responsible; lack of uniform technical criteria to set guidelines for polluters; and, limited compliance with the terms of legislation, leading to a loss of credibility in the regulatory system.

Of the actors outlined above, the most important have been the SSS and the DGTMMYMM – the former through its permitting responsibilities, and the latter because of the 1987 environmental impact regulations. In both cases, it should be noted, legislation does not cover **existing** mills: permits and/or EIA studies are only required for new mills, or for new investment programs at existing mills.

Comparing regulatory limits across jurisdictions is extremely difficult, due to differences in the parameters applied and the way in which measurements are taken; in addition, judging regulatory stringency depends upon the state of enforcement as much as the technical norms applied. Nonetheless, it is clear that existing standards in Chile are well below those found in key competitor countries, particularly in Europe and North

America.⁹ Table 6.3 attempts to contrast existing Chilean regulatory limits (as established by the SSS) with both the actual performance of Chilean pulp and paper mills as of 1992, and with international standards of “good” environmental practice as set out by the World Bank. Comparison is difficult because of the use of different parameters and measurement techniques, but in general it can be concluded that Chilean standards lag behind international practice, and also behind the actual performance of the leading firms in the Chilean industry. Also of note is the relatively wide variation in actual pollution levels, which indicates the gap in performance between leading firms (primarily new market pulp producers) and older, less efficient firms.

⁹ For an attempt to compare pulp and paper regulations across a number of countries, see Simons Consulting Group, 1994. Unfortunately, this report does not include Chile, and the nature of regulatory limits currently in place in Chile makes direct comparison with other jurisdictions (including Canada) extremely difficult.

Table 6.3: Environmental Parameters for Chilean Pulp Mills			
	Current Regulatory Limits (1)	Actual Performance, ca. 1992 (2)	World Bank Reference Levels (3)
pH	5.5-9.0	4.0-8.3	6.0-9.0
Biochemical Oxygen Demand, BOD ₅ (mg/l)	300	12-188	n.a.
Chemical Oxygen Demand, COD (mg/l)	n.a.	256-4,600	300 (Kraft) 700 (sulfite) 10 (mechanical)
Total Suspended Solids, TSS (mg/l)	300	14-1,350	n.a.
Temperature (C)	35.0	26.6-45.0	n.a.
<p>(1) Maximum levels permitted for discharges to water by industrial sources, as established by the Superintendencia de Servicios Sanitarios. See SSS, 1992, p. 4. The SSS does not mandate levels of COD.</p> <p>(2) Actual performance based on tests at a sample of seven pulp and paper plants discharging to the Bio-Bio river near Concepcion, Chile, and to the adjacent coastal areas. See Faranda and Parra, 1993, p. 146.</p> <p>(3) Guidelines for new pulp and paper mills, as set by World Bank (1997, p. 5). The World Bank guidelines do not include levels for BOD or TSS; for temperature, they suggest a maximum increase of no more than 3 degrees Celsius, 100 metres from the point of discharge.</p>			

Two other characteristics of the SSS limits are worth mentioning. In the first place, limits are not specific to a given industrial activity, but instead are meant to be applied across all activities. Second, key limits (BOD, TSS) are expressed in maximum concentrations, rather than pollutant loads per tonne of output. The latter type of measurement is used in most jurisdictions, including Canada, and SSS practices complicate comparison with other jurisdictions. Moreover, setting maximum concentrations can have a perverse effect in that it works **against** efforts to conserve water; most new pulp and paper mills (including those in Chile) use significantly less water per tonne of output than older mills.¹⁰ Industry officials have argued in favour of

¹⁰ An indication of trends in water use is outlined in a 1995 environmental impact assessment for a proposed 1,500 ton/day Kraft pulp mill in the south of Chile: the study suggests water usage of only about 30 m³ per tonne of output – approximately one-third of the water usage of Kraft pulp mills constructed in the country in the late-1980s and early 1990s.

changes to existing norms on both of these counts (see below).

One reason for the relatively lack of stringency in formal regulations has been the absence until quite recently of “informal” regulatory pressure in the form of public opinion. As noted in Chapter 2, studies in other countries have suggested that “informal” regulation of this kind may be a key factor in explaining differences in pollution intensity among firms. In the case, of Chile, this kind of public pressure is only beginning to emerge. Indeed, as recently as 1995, one review of environmental issues in Chile concluded that in the case of pulp and paper production, “there are no environmental problems technically identified by authorities nor perceived as significant by the public” (Trucco, 1995, 22). Compared to atmospheric pollution in Santiago or contamination of groundwater from mine tailings in the northern provinces, environmental impacts of pulp mill operations have not been a major source of public concern.

This situation is changing, however, due to a number of factors. In the first place, there has been a general increase in publicity around environmental issues in Chile, particularly as a result of air pollution problems in Santiago. Second, the rapid growth of the industry in Chile over the past decade has increased its visibility, while the international debate on the environmental impacts of pulp bleaching has increased publicity around possible environmental impacts.¹¹ There has been particular concern about the quality of the Bio-Bio river system, which is the receptor for a large share of current Chilean pulp and paper effluent flow. Finally, environmental policy in Chile has

¹¹ Although of less direct concern to this thesis, there has also been increasing scrutiny of Chilean forest management practices, particularly the destruction of native forests by new plantations.

gradually been changing, with the establishment of the National Environmental Council (CONAMA) in 1990, and the approval of a framework environmental law in 1994.

CONAMA's main role is to coordinate environmental policy across government agencies – it is not a regulatory body, and has limited enforcement capability. The framework law does not set limits for industrial pollution, but it does set out the basis for a program of environmental impact assessments, and for the development and implementation of “decontamination plans” in severely degraded areas. The Bío-Bío river basin around Concepción is one candidate for early action.

These changes have helped to push pulp and paper firms to be more sensitive to environmental issues, and particular to possible **future** regulatory requirements.

Progress on the environmental impact assessment front has been particularly fast.

While not formally required, recent plants in the country have all carried out EIAs prior to construction. For the most part, EIAs have not placed significant restrictions on firms, in part reflecting asymmetries in technical capabilities between firms and regulatory bodies. Under the terms of the framework environmental law, responsibility for initiating EIAs and ensuring public input rests with the provincial environmental councils (COREMAs), which are small and under-staffed. Again, however, this situation may be changing. A 1995 EIA for a new pulp mill in the 10th region in the south of Chile has resulted in unexpected pressure on the firm to modify its plans by changing the plant location, installing tertiary treatment facilities, or piping effluent away from sensitive wetland areas.

Table 6.4: Current Performance of Pulp Mills and Anticipated Requirements				
	Mill D (1)	Mill F (2)	Design Parameters for Proposed New Mill (3)	International "Good Practice" Levels (4)
Biochemical Oxygen Demand, BOD (kg/adt)	< 10	6.7	1.5	15 (4)
Chemical Oxygen Demand, COD (kg/adt)	n.a.	52.0	25.0	70 (25)
Total Suspended Solids, TSS (kg/adt)	< 3	9.0	2.0	7 (5)
Adsorbable Oxygenated Halides, AOX (kg/adt)	< 0.5	n.a.	0.5	2.0 (0.8)
<p>(1) Interview data. Mill D is a 700 adt/day bleached hardwood kraft mill, which entered into production in 1991.</p> <p>(2) Interview data. Mill F is a 230 adt/day bleached softwood kraft mill, which entered into production in 1994.</p> <p>(3) Interview data. These are the suggested parameters for the design of a proposed 1,500 adt/day bleached softwood Kraft mill, based on the 1995 environmental impact assessment report.</p> <p>(4) Estimates of good environmental performance, based on survey of plants world-wide in 1995. Numbers in brackets represent levels which can be reached by "modern" mills with primary and secondary treatment. IIED, 1996, p. 119.</p>				

More generally, firms have come to expect tightening of regulatory requirements in the future. The design study for the proposed new pulp mill mentioned above reflects this change. As Table 6.4 shows, recently constructed mills in Chile are at or below accepted international standards of good practice in terms of effluent levels. But the suggested parameters for the new plant go even further. At the time of field work for this thesis, proposals were being developed by the Superintendencia de Servicios Sanitarios and the Instituto Nacional de Normalización (INN) for development of new effluent guidelines for pulp and paper mills, which were expected to result in significant increases in stringency in comparison with existing norms.

The position of the industry with regard to the development of new norms has been relatively passive. Firms have participated in discussions over new norms and

environmental impact procedures either individually, via the sectoral association (CORMA) or via the national industry association (SOFOFA) which has an active environmental affairs directorate. Technical staff of pulp mills have also been involved in consultations with regard to new limits, via committees of the professional association ATCP. But industry's involvement has been very low-key, and there is no evidence of a concerted effort to shape future regulatory requirements. Scholz (1994, 57) argues that since firms have not yet experienced significant constraints on their activities as a result of environmental pressures (either problems complying with regulations or problems selling into European markets) their participation in domestic and international debates on environmental issues has remained limited.

(c) Inter-Firm Linkages and Patterns of Technology Supply

The final set of factors which may well exert an important influence on the environmental behaviour and performance of Chilean pulp and paper firms have to do with linkages with other firms (notably foreign parent and partner firms) and with overall patterns of technology supply in the industry.

Chapter 7 returns in more detail to the issue of ownership and links with foreign pulp and paper firms, drawing on interview data. One important feature of the recent period in the development of the Chilean industry, however, has been the rising level of foreign direct investment in the sector. While the majority of the industry remains in local hands, foreign owners and joint venture partners have played a role in all but one of the mills constructed between 1989 and 1994. It is reasonable to suggest that foreign linkages may to a degree be responsible for the superior environmental performance of recent mills.

On the other hand, it is not clear that links with foreign firms are likely to have an impact on ongoing environmental measures after start-up, particularly since the primary role of foreign investors has been financial and market-related, with limited involvement in the day-to-day management of most mills. Nor is it clear that foreign investment has had an impact on environmental management strategies of older newsprint mills (where there is a mix of local and foreign ownership). And it may also be that local forest product firms work to emulate international “best practice” in the environmental field as part of their own corporate policy – particularly given the visibility of the local conglomerates active in the pulp and paper industry, and their long history of involvement in the industry.

Another possible explanation of the superior environmental performance of the new pulp mills in the country is that this results not from market pressures or from ownership, but rather from overall patterns of technology supply in the industry. As noted earlier in this chapter, the Chilean pulp and paper industry is almost completely reliant upon external sources of production technology, and large international consulting engineering companies (Scandinavian and North American) have played a dominant role in design and engineering work for new mills. Mill designs have tended to reflect prevailing standards and design parameters in these countries. These kinds of “technology push” factors, therefore, may be significant influence on the environmental measures included in new plants – although they are less likely to affect ongoing environmental activities at mills, and should primarily influence internal process technology choices, rather than decisions with regard to external effluent treatment. Again, I return to this issue in Chapter 7.

IV. Conclusion

The analysis in this chapter suggests that the determinants of environmental activities and investments by Chilean firms are more complex than originally expected. Rather than facing a situation of strong market pressures for environmental improvement and weak regulatory pressures, firms in fact confront a broader set of determinants, whose impact may vary widely from mill to mill. Export market pressures are clearly a major factor, but are perhaps less pressing than anticipated at the beginning of the decade -- and in any case affect only market pulp producers. The impact of foreign ownership is attenuated by the strong position of local firms, and by the limited role which foreign parent and partner firms play in day-to-day management decisions. Regulatory pressures are indeed weak by international standards, but the policy environment remains fluid, and anticipated future regulatory levels may well be a key determinant for some firms. Moreover, at least for new mills, the overall conditions of technology supply in the industry -- rather than the motives of firms -- may be the deciding factor.

In addition, the ways in which Chilean firms respond to environmental pressures will be conditioned by structural features of the industry, notably the weak domestic R&D/equipment supply base. As a result, incremental improvements and ongoing purchase of foreign technology are likely to remain the main channels of response. Chapter 7 looks in more detail at this issue, drawing on case studies of individual firms.

One question for the future concerns the role of the industry in shaping regulatory pressures. As noted above, the position of the industry with regard to regulatory issues has to date been low-key and relatively passive. In fact, this is not surprising, given the relative weakness of domestic regulations and the rapid expansion of the industry over

the past decade. But as the industry heads into a period of slower expansion in capacity and increased regulatory pressure (through the permitting process and EIA requirements), it may well begin to play a more active role. Indeed, as the average age of plants begins to increase over the coming years, the initial boost in environmental performance provided by the influx of new investment in the late 1980s and early 1990s may provide less of a "cushion" for the industry vis-a-vis regulators. In such a scenario, a much more vocal industry position regarding regulations can be expected.

Chapter 7: Firm-Level Responses to Environmental Pressures -- Chile

I. Introduction

The analysis in Chapter 5 suggests that in the case of Canada, regulatory pressures -- notably the strengthened regulations governing liquid effluents which entered into force in the early 1990s -- have played a key role in stimulating investments in improved environmental performance at pulp and paper mills. Market pressures have also played a role, but regulatory factors have been the overriding determinant for most mills. At the same time, the extent to which firms are able to successfully respond to environmental pressures depends upon the in-house resources and capabilities of the firm -- and in particular on the firm's size, its level of R&D activity, and its commitment to environmental management. How does this compare with the case of Chile, where regulations governing pulp and paper production are much less strict, but where many of the other structural features of the pulp and paper industry (low levels of R&D, weak equipment supply capacity, dominance of low value-added products) are similar to Canada?

As noted in Chapter 5, the Chilean pulp and paper industry has grown rapidly over the past decade, with overall installed capacity more than doubling between 1985 and 1995. Increases in capacity have been due almost entirely to the entry into production in the early 1990s of a number of new market pulp mills -- in many cases foreign-owned or based on joint ventures with foreign companies, and in all cases oriented entirely to export markets. As a result of this boom in greenfield investment, export ratios for chemical pulp production have increased from 50 percent in 1970 to 90 percent in the 1990s. Moreover, the industry has shifted from one based largely on local capital, to

one in which foreign forest product companies now play a significant role.

At the same time, local capital remains important, with a number of firms -- including the largest pulp and paper manufacturer in the country --entirely locally owned, and with many foreign joint venture partners playing only a minor role in management. And while the dominant bleached Kraft pulp industry is increasingly oriented toward European, Japanese and North American markets, other segments of the industry produce almost exclusively for local and regional markets (newsprint) or for Asian markets (unbleached Kraft pulp) -- both of which are much less demanding in terms of environmental requirements.

The Chilean industry thus represents an interesting opportunity to explore the interplay of market factors, patterns of ownership and domestic regulation in spurring environmental improvements by firms. In particular, it represents an opportunity to explore the extent to which environmental pressures in export markets and/or the influence of parent firms are likely to lead to environmental improvements by firms despite relatively weak domestic environmental regulations.

Based on the conceptual framework outlined in Chapter 2 and the empirical data presented in the last three chapters, three sets of hypotheses can be advanced regarding expected patterns of environmental behaviour in Chilean pulp and paper firms:

1. Given the relatively weak regulatory pressures facing Chilean mills, ongoing environmental improvements are likely to be limited, and levels of environmental spending -- and environmental performance -- are likely to be lower than for comparable Canadian mills. This is expected to be particularly true for existing

mills, where there are few incentives for environment-related expenditures. In the case of greenfield mills constructed over the past decade, environmental measures included in original plant design are likely to be relatively up-to-date – and the gap between Chilean and Canadian mills less significant – reflecting the nature of technology supply for new mills.

2. Variations among mills of similar ages are due largely to their export orientation and ownership, with foreign-owned mills and those exporting to industrialized country markets undertaking more significant environmental measures than those which are locally-owned and sell on local and regional markets.

Regulatory factors are not an important determinant of the industry's behaviour as a whole, but may be a factor for some individual existing mills, reflecting the case-by-case nature of environmental permitting in the country. Finally, based on the Canadian experience, scale of mills and firms is not likely to play a critical role in determining patterns of environmental behaviour, but the firms' overall innovative capacity and previous commitment to environmental management may induce it to take a more active stance in response to a given level of environmental pressure.
3. Overall, the main pattern of behaviour on the part of the Chilean industry is expected to be adoption and adaptation of imported technology in order to ensure compliance with short-run market or regulatory requirements. More "offensive" strategies involving development of new technology are likely to be rare or non-existent. In part, this reflects low levels of regulatory burden, which have decreased the incentives for ongoing improvements in environmental performance. But it also results from the low levels of R&D spending and limited

history of innovation of the Chilean industry – and the weakness of domestic supply linkages – which militate against significant levels of innovation in response to environmental pressures.

II. Survey Sample and Methods

In order to explore these hypotheses, this chapter draws on a series of interviews and site visits with major pulp and paper manufacturers in Chile, carried out in the spring of 1996. Interviews were carried out using a standardized questionnaire, relying primarily on open-ended questions. As in the Canadian survey, interviews concentrated on three issues:

- the nature of recent environmental improvements carried out at respondent mills (or, in the case of newer mills, environmental measures included in the original project design);
- motives for environment-related investments, and overall corporate attitudes toward environmental management and environmental regulation; and,
- sources of technology for environmental improvements, and the impact of recent changes on the innovative capabilities of firms and the industry as a whole.

Interviews were carried out with representatives of six of the seven major pulp and paper firms in the country¹. In each case, interviews concentrated on environmental improvements at a single mill owned by the company. The six case-study mills account for 90 percent of total newsprint production in Chile as of 1996, and over 50 percent of

¹ The seventh firm (the second largest pulp and paper producer and largest producer of market pulp) declined a formal interview, but did provide secondary materials regarding environmental improvements at its mills.

market pulp production. As can be seen from Table 7.1, they also capture significant differences in ownership and export orientation, as well as age and scale of mills, types of products, and process technologies. (More detailed profiles of each case-study mill are included in an Annex at the end of the chapter). As a result, the sample provides a relatively good basis for analyzing the environmental performance of the industry as a whole, and for exploring the links between ownership, export orientation and environmental performance. Firm- and mill-level interviews were complemented by collection of available secondary data, and by interviews with other observers of the industry (industry associations; university experts; representatives of consulting engineering companies active in the forest products sector; environmental NGOs; and regulatory officials).

Three caveats should be made regarding the analysis presented in this chapter. First, while the sample represents the majority of Chilean pulp and paper production, the absolute number of respondents is small, and care should be taken in extrapolating the results beyond the Chilean case. Given the small number of firms in the sample, no attempt is made at quantitative analysis of firms' responses. Instead, this chapter concentrates on describing the main patterns of firm-level behaviour in firms in the survey firms, and advances a series of tentative conclusions about the factors explaining observed patterns. The annex at the end of the chapter details patterns of environment-related activities at individual mills. In order to maintain the anonymity of responses, firms are not identified by name.

Second, there is a strong correlation in the sample between age of plants and export orientation: recently-constructed plants in Chile are almost entirely export-oriented, whereas older plants devote a greater share of their output to local and regional

markets. As a result, it is difficult to disentangle the impact of export orientation from questions of vintage of technology. As will be argued below, age of pulp mills is the most obvious predictor of the nature of environmental measures in place at plants — much more so than in the Canadian sample, where upgrading of older mills has reduced the degree of variation between old and new mills somewhat. But the analysis suggests that export orientation is also a potent factor in motivating particular types of environmental improvements, and that ownership and regulatory factors also play a role in some cases.

Third, the small number of mills in the sample means that it is difficult to ensure sufficient variation in mill-level characteristics to explore all of the factors expected to play a role in shaping patterns of environmental behaviour. In particular, the low levels of R&D spending by all firms in the industry make it difficult to gauge differences in their innovative potential. Capturing differences in mill- and firm-level characteristics is made even more difficult by the high degree of inter-corporate holdings in the industry (one local forest products firm holds a majority stake in three of the six firms in the sample, and has more recently acquired a stake in a fourth).

The next section of the chapter provides a brief overview of the nature of environmental measures at case-study mills, and contrasts this with the situation in comparable Canadian mills; it focuses in particular on the distinctive patterns of behaviour witnessed in greenfield versus existing mills. Section IV provides a more detailed description of the determinants of environmental behaviour, and in particular the ways in which ownership, export orientation and regulatory pressures appear to have affected firms' behaviour. Section V then examines the sources of technology for environmental improvements at respondent mills, and the extent to which environmental pressures

have spurred innovation in case-study firms and/or the industry more generally. The final section advances a series of conclusions, returning to the hypotheses set out in the Introduction.

Table 7.1: Overview of Respondent Pulp and Paper Mills, ca. 1996						
Mill Code	Date of Const.	Products	Process	Export Orientation *	Output ('000 t/year)	Ownership
A	1957	newsprint	groundwood	low	110	foreign
B	1959	market pulp; printing and wrapping, writing papers	bleached softwood Kraft	moderate	385	local
C	1965	newsprint	TMP (previously sulphite, groundwood)	low	140	local
D	1991	market pulp	bleached hardwood Kraft	high	260	joint venture (foreign mgt)
E	1991	market pulp	bleached softwood Kraft	high	315	joint venture (local mgt)
F	1994	market pulp	bleached softwood Kraft	high	80	foreign
* Degree of export orientation refers to the percentage of output destined to extra-regional markets, circa 1996, rated as follows: "low" (less than 25%); "moderate" (25 to 75%); "high" (over 75%).						

III. Nature of Environmental Activities and Investments

The first and most basic finding emerging from case-study data is that despite relatively weak domestic regulatory pressures by international standards, Chilean firms have invested significantly in improving the environmental performance of pulp and paper manufacturing facilities over the past decade. Somewhat more surprisingly, environment-related investments have **not** been limited to new mills, those which are highly export-oriented, or those which are wholly or partially foreign-owned: all firms in the sample pointed to a series of environment-related measures undertaken between

1990 and 1996 at their plants (either measures included in design of new mills, or retrofitting of older mills). Table 7.2 provides a summary of some of the main environmental measures in force at the time of the survey.

Table 7.2: Overview of Environmental Measures at Case-Study Mills, ca. 1996					
Mill Code	External Effluent Treatment	Control of Atmospheric Emissions	Bleaching	House-keeping and Process Optimization Measures	Other Recent or Planned Changes
A	none	scrubbers	n.a. (production is unbleached)	fibre recovery	shift from wet to dry de-barkers (planned); cooling system for effluent (planned)
B	primary control system under construction	scrubbers; electrostatic precipitators	ECF pulp capability, improved pulp washing added 1993	reduced water use, improved energy efficiency, separation and recovery of waste streams	new recovery boiler, digester, improved pulp washing (in progress)
C	primary	scrubbers	n.a (production is unbleached)	fibre recovery; partial closure of circuits	shift from sulphite to TMP production (in progress)
D	primary	electrostatic precipitators in recovery boiler and lime kiln; stripping of gases to reduce odours	designed with ECF pulp capability, oxygen delignification; TCF capability added after start-up	various efforts to reduce water use, tighten circuits	studying possibility of use of ozone in bleaching
E	primary, secondary	electrostatic precipitators in recovery boiler and lime kiln; stripping of gases to reduce odours	designed with ECF pulp capability, oxygen delignification	limited, other than efforts to optimize performance of secondary treatment	
F	primary, secondary	electrostatic precipitators in recovery boiler; scrubbers in lime kiln; stripping of gases to reduce odours	designed with ECF pulp capability, oxygen delignification	fibre and chemical recovery; reduction in water use; research on alternate treatment methods (aquatic plants, fish) and re-use of effluents	electrostatic precipitator for lime kiln (planned); substitution of peroxide for oxygen in bleaching

At the same time, however, there are clear differences among case-study mills, with a clear divergence between greenfield mills and older mills. Of the mills entering production since 1990, all but one incorporate secondary treatment facilities for liquid effluents (the exception is the sole plant producing hardwood pulp from eucalyptus; it has been able to meet targets for effluent quality without secondary treatment due to the lower lignin content of eucalyptus, and the extent of in-plant measures included in the original design). All include electrostatic precipitators and scrubbers to reduce airborne emissions. And all are capable of producing ECF pulp (and in one case TCF pulp as well).

This contrasts sharply with the older plants in the sample. Of the three older plants in the sample, only one currently includes primary external treatment of liquid effluents – although primary treatment is planned for one of the other two, and under study for the third plant. Control technologies for reducing airborne emissions also differ from those encountered in the newer plants: older plants rely on less efficient “scrubber” technology – although electrostatic precipitators have been introduced to a limited degree in one of the plants, and are under study in another plant.

Differences between older and newer plants are partly a matter of different product mixes and process technologies – two of the three older mills are newsprint producers relying on unbleached mechanical pulp (which not only avoids some of the liquid effluent problems resulting from chlorine bleaching, but also means that electrostatic precipitators are generally not required to control gaseous emissions). But this is clearly not the only factor at work. The contrast between the three new Kraft pulp producers and the one older plant in the sample producing Kraft pulp is particularly illuminating. Like the newer plants, the older plant has invested in chlorine dioxide

substitution to enable it to produce ECF pulp, but with fewer changes to the pre-bleaching stage (e.g., no oxygen delignification). Control of airborne emissions is less extensive than in the newer plants, and no external treatment (primary or secondary) of liquid effluents exists. In the case of this plant, retro-fitting to reduce environmental impact has been further complicated by the physical location of the plant (limited space for installation of external treatment of liquid effluents) and by the multi-product nature of the plant (which complicates in-plant effluent reductions, recirculation of effluents, etc.).

As noted above, there **have** been a series of environmental improvements introduced in the older plants, but the types of changes differ significantly from newer plants. Not surprisingly, older plants have tended to focus on minor in-plant process optimization measures which are relatively low-cost, and which promise savings to the firm in terms of reduced energy, water and chemical use. External treatment of liquid effluents (which represents a net cost to the firm, with no associated cost savings) lags well behind newer plants. More ambitious in-plant process changes have been introduced in two of the three cases, but in both cases as part of a larger modernization program, in which environmental motives are only one factor. Thus, for example, one of the newsprint producers was at the time of the survey in the process of switching its production from older suphite technology to a new TMP line; while environmental considerations were an important factor in spurring this change, broader economic concerns (increased production capacity, reduced costs, improved pulp quality) were the major factor. Similarly, the one older Kraft pulp producer in the sample initiated a major modernization program in 1995, calling for installation of a new recovery boiler and digester, and improvements in pulp washing; motives for the changes were (in order) increased capacity, improved efficiency, and better environmental performance.

The divergence between existing and greenfield mills is even more apparent when comparisons are made between matched pairs of Canadian and Chilean mills. Table 7.3 presents data on three pairs of mills, chosen to reflect mills with similar characteristics in three separate “profiles”: an older newsprint mill; an older integrated Kraft mill; and a greenfield market Kraft mill. This kind of comparison is of necessity somewhat tentative and does not do justice to the variations in the characteristics and performance of individual mills in the two countries.² But it does illustrate some clear divergences between Canadian and Chilean mills, and between newer and older mills within the Chilean sample. As can be seen, the primary impact of the more stringent regulatory environment prevailing in Canada appears to have been with regard to investments in end-of-pipe control technologies, with differences in other mill-level characteristics (e.g., bleaching sequences) appearing less significant. This is consistent with the results presented in Chapter 5, which concluded that one of the main effects of regulations in Canada has been to spur widespread adoption of secondary treatment technologies for liquid effluents. The impact of these control technologies is at least partially responsible for the relatively large variations in effluent levels between Canadian and Chilean firms, and for the large decreases in effluent levels for Canadian mills between 1987 and 1996.

² The three Canadian mills chosen are fairly typical of the range of mills within each “profile” — with the partial exception of Mill 3, which has invested more heavily in internal process changes (non-chlorine bleaching) than many Kraft mills of similar ages. Given the much smaller number of Chilean mills in the overall sample, “representativeness” is less of a problem; Mill 4, for example, is the only older integrated Kraft mill in the country, and the only older Kraft mill in the sample. Even so, care should be taken in extrapolating from these individual mills to the industry as a whole.

Table 7.3: Comparison of Matched Pairs of Canadian and Chilean Mills

	1950s Vintage Newsprint Mill		1950s Vintage Integrated Kraft Mill		1990 Vintage Market Kraft Mill	
	Canada (1)	Chile (2)	Canada (3)	Chile (4)	Canada (5)	Chile (6)
Effluent Treatment	Primary and secondary	None	Primary and secondary	Primary treatment system under construction	Primary and secondary	Primary
Control of Airborne Emissions	scrubbers, electro-static precipitators	scrubbers	scrubbers, electro-static precipitators and stripping of gases to reduce odours	scrubbers, electro-static precipitators	scrubbers, electro-static precipitators and stripping of gases to reduce odours	scrubbers, electro-static precipitators and stripping of gases to reduce odours
Bleaching	n.a.	n.a.	ECF and TCF capability, improved pulp washing oxygen delignification	ECF capability, improved pulp washing	ECF and TCF capability, improved pulp washing, oxygen delignification	ECF and TCF capability, improved pulp washing, oxygen delignification
Effluent Levels, ca. 1996 (kg/adt)	BOD 1.46 TSS 2.36	TSS > 25 BOD data not available	BOD 1.35 TSS 2.38	No data available	BOD 0.93 TSS 3.2	BOD < 10 TSS < 3 AOX < .5
Effluent Levels, ca. 1987 (kg/adt)	BOD 35.3 TSS 8.2	No data available	BOD 23.5 TSS 10.1	No data available	n.a.	n.a.

(1) Mill 1 is a 200,000 adt/year newsprint mill, originally constructed in the 1930s but upgraded since. It is Canadian owned, and sells all of its output on North American markets.

(2) Mill 2 is a 110,000 adt/year newsprint mill which entered production in the late 1950s. It is foreign owned and sells its output entirely to local and regional markets in Latin America.

(3) Mill 3 is a 365,000 adt/year integrated Kraft mill constructed in 1957. It is foreign-owned, and exports approximately 25 percent of output to Western Europe, with the result sold in the US and Asia.

(4) Mill 4 is a 385,000 adt/year integrated Kraft mill constructed in 1959. It is locally-owned, and exports approximately 40 percent of its production, primarily to Europe.

(5) Mill 5 is a 400,000 adt/year market Kraft mill constructed in 1990. It is foreign-owned, and exports its entire production to Asia, the US and Europe.

(6) Mill 6 is a 260,000 adt/year market Kraft mill constructed in 1991. It is a joint venture with management in the hands of the foreign partner. Its production is entirely exported to Europe, Asia and North America.

Variations between Canadian and Chilean mills are less pronounced for newer mills: the two greenfield Kraft mills show no significant differences in internal process technologies, and limited differences in end-of-pipe control technologies.³ While there is a gap in effluent levels between the Canadian and Chilean mills, levels of performance at the Chilean mill would be sufficient to comply with current Canadian federal (and in most cases provincial) regulations. In the case of established mills, however, the differences in environmental measures undertaken -- and in resulting levels of environmental performance -- are more significant. This provides support to the hypothesis outlined in the introduction. The nature of technology supply in the pulp and paper industry means that newly-constructed mills in Chile are relatively up-to-date by international standards. Older mills, on the other hand, have faced few incentives to undertake environmental improvements, particularly for end-of-pipe measures unrelated to issues of export market access.⁴

Overall, then, the findings provide at least partial confirmation of the first hypothesis set out above. While environment-related investments were somewhat more widespread than expected, there are distinctive patterns of environmental investment in greenfield and older plants. Variations with similar Canadian firms are relatively slight for greenfield mills, but much more significant for older mills -- with the primary difference being in the nature of end-of-pipe control technologies present in the Canadian mills.

³ The other three recently-constructed market Kraft mills in Chile, it should be noted, all include both primary and secondary treatment of liquid effluents. The mill included in Table 7.3 was chosen because it is of a similar scale to the Canadian mill, and because relatively complete data on changes undertaken and effluent levels was available from the firm.

⁴ The greater levels of investment and superior environmental performance of Canadian mills cannot be entirely linked to recent regulatory pressures; longer-term regulatory pressures and financial incentives for plant modernization have clearly played a role as well (see the discussion in Chapter 4). But the extent of reductions in effluent levels since 1987 does suggest once again that increases in the stringency of regulations has been a critical factor.

This lends support to the findings of the Canadian study that the most important short-run impact of regulatory pressures on Canadian firms has been to stimulate adoption of proven pollution control technologies.

The tendency of newer plants to incorporate the latest vintages of pollution prevention and control technology – even when not required by domestic environmental regulation – reflects the nature of the market for pulp and paper technology worldwide. As noted in Chapter 3, control of pulp and paper technology is concentrated in the hands of a relatively small number of industrialized country firms, and tends to be designed to meet Northern environmental standards. Moreover, specialized consulting engineering firms (again primarily from industrialized countries) play a key role in new plant construction or modernization programs, integrating technology from a number of supplier firms and carrying out most design, layout and engineering work. In order to control costs, they tend to apply similar designs in a number of plants. As a result, there is relatively little scope for variation in the design and construction of greenfield pulp and paper plants – particularly for basic process technology. Foreign equipment suppliers and consulting engineering companies are also a key source of technology and technical expertise for older, existing plants – but here the high costs of retrofitting shifts attention to minor process improvements, with more far-reaching changes introduced only in the context of broader modernization programs. As a result, there is more scope for variation in mill characteristics, both within and among countries.

Age of plant, of course, cannot completely explain the patterns of environmental measures observed at survey firms. While the basic design parameters of greenfield pulp and paper mills may well be set largely by outside suppliers and consultants, firms could still (for example) choose not to install external treatment equipment in cases

where local regulations did not demand it. Yet this has not happened in recently-constructed mills in Chile, all but one of which have included secondary treatment. Nor does age of plant account for the differences observed among the three older mills in the sample. Instead, attention must also be directed to the other four factors mentioned above: export orientation; ownership; regulatory pressures; and the internal characteristics and capabilities of the mill itself.

IV. Determinants of Environmental Behaviour

In addition to questions regarding the nature of environmental improvements pursued at their mills, respondents were asked to identify the main factors motivating recent environment-related investments. Responses to this question are presented in the table below.

Overall, market factors and corporate policy/image are rated as the most important determinants of environmental investments. In many respects, the pattern of responses is similar to that of Canadian firms reported in Chapter 5, except that regulatory factors figure much more prominently in the Canadian responses. As in the Canadian results, both export market demand and corporate policy and image are important factors, with expected cost savings rated as a much less important driver of environmental spending.

Consistent with the discussion in the last section, patterns of responses differ markedly between newer, greenfield investments and older, established plants. Among the former group of firms, market pressures are viewed as the most important determinant, followed closely by issues of corporate policy and image. Regulatory pressures and expected cost savings are of negligible importance. In the case of older, established firms, on the other hand, the pattern is more complicated. Regulatory factors are the

most important factor, followed by expected cost savings, corporate policy and image, and (at a slightly lower level) market pressures.

Table 7.4: Factors Influencing Environmental Investments				
	Market Demand	Policy/Image of Firm, Parent Company	Domestic Environmental Regulations	Cost Savings
1) All Mills (n=6)				
- responses	6	5	4	4
- average score (max = 4)(*)	2.8	2.8	1.7	1.5
Older Mills (n=3)				
- responses	3	2	3	3
- average score (max = 4)(*)	2.0	2.3	3.0	2.3
New Mills (n=3)				
- responses	3	3	1	1
- average score (max = 4)(*)	3.7	3.3	0.3	0.7
Source: Interview data				
(*) Responses (unprompted) were rated on the following scale: first mention = 4 points; second = 3 points; third = 2 points; fourth = 1 point.				

In order to explore these motivations in more detail, the following pages discuss observed patterns of environmental behaviour in terms of four sets of determinants: export orientation, ownership, local regulatory pressures, and mill-level resources and characteristics.

a) Export Orientation

While less clear-cut than the findings with regard to age of mills, interviews confirmed that export orientation – and in particular the extent to which production is destined for environmentally-demanding markets in Europe and North America – is a critical factor in

determining the nature of environmental measures adopted at mills. When questioned about the factors motivating environmental improvements at mills, issues of market demand were the only factor mentioned by all respondents.

As in the Canadian survey, export orientation appears to be a particularly important factor with regard to investments in improved process technology, but less important with regard to external treatment technologies. Of the four export-oriented plants included in the sample, all have incorporated chlorine dioxide substitution to enable them to produce ECF pulp. On the other hand, only two have secondary treatment facilities for liquid effluents, and one of the plants (the only older bleached pulp producer in the sample) does not yet have primary treatment facilities. As noted above, the high costs of retrofitting have also limited the extent of process changes at this mill, with the result that a number of changes which could improve the efficiency of the bleaching process (e.g., oxygen delignification) have not been included.

Given the small number of firms in the sample, these results should be interpreted with caution. But they do suggest that the principal impact of environmental pressures in export markets may be to promote process changes which are easily reflected in product characteristics (e.g., chlorine content of pulp). They are less likely to spur the adoption of external treatment technologies which do not affect product characteristics and which represent a net cost to firms, and in the case of older mills they are unlikely to overcome the physical and economic barriers to more far-reaching process changes. This in turn suggests a note of caution about the extent to which pressures from export markets alone can be relied upon to induce firms to protect the local environment.

To some extent, this finding may also reflect the booming international market for pulp which predominated in the period immediately preceding the Chilean survey. A number

of the firms surveyed mentioned the kinds of detailed questionnaires demanded by European pulp purchasers, which probe firms for information not only on product characteristics, but also on process technology, external effluent treatment, and upstream issues of forest management. Yet it remains unclear to what extent such information has actually been factored into purchasing decisions. The period of strong demand and record high pulp prices between 1994 and early 1996 resulted in a seller's market, in which firms had little difficulty finding buyers for their product; this in turn may have limited the willingness of buyers to demand more far-reaching environmental measures as a pre-condition to purchases. Perhaps as a result, production of TCF pulp by Chilean firms has not expanded rapidly (only one of the surveyed firms was producing TCF pulp, and this accounted for a relatively stagnant five percent of overall production). Lower pulp prices since early 1996 may well change the environmental pressures on exporting firms, with more far-reaching environmental measures viewed as a means of gaining advantage in a tighter buyers' market.

The situation with regard to the two firms producing for local and regional markets is less clear. As noted above, both of these firms are newsprint producers, so direct comparison with the more export-oriented Kraft pulp producers is difficult; moreover, the age of the two plants (constructed in 1957 and 1965) makes it difficult to separate market-related pressures from questions of vintage of technology.

Clearly, however, lack of environmental pressures in key markets has not led to a stagnant environmental performance on the part of either firm. While neither plant has secondary treatment facilities, one has incorporated primary treatment of liquid effluents, and the other is currently studying the feasibility of adding primary treatment facilities. A number of in-plant process optimization measures have been pursued by

both firms. Effluent levels have been falling in both plants, and will continue to fall (in one case because of the shift from sulphite to TMP; in the other case because of a mix of minor process changes and possible installation of primary treatment equipment). Perhaps most surprisingly, one of the two plants has actively pursued international certification: it was the second Chilean pulp and paper firm to be certified ISO 9002, and is currently implementing an ambitious environmental management plan which should culminate in ISO 14000 certification.

b) Ownership

At first glance, ownership does not appear to be a critical factor in determining the extent or nature of environmental measures pursued by firms, a finding consistent with the results of the Canadian survey. While once again the number of firms in the sample makes generalization difficult, local and foreign-owned firms of similar ages and product lines do not appear to differ markedly in terms of external treatment measures or in-plant process improvements. On the other hand, when asked about factors motivating environment-related measures, all of the foreign-owned or joint venture firms in the sample mentioned corporate policy and image, or the impact of foreign owners and financiers, as a primary factor influencing environmental behaviour.

This apparent contradiction can be explained in the following manner. The primary influence of foreign owners has not been in terms of direct transfer of technology or production experience. None of the firms surveyed mentioned parent firms or joint venture partners as a major source of technology, and in many cases foreign investors have limited technical expertise to bring to the partnership: the European owner of one of the new Kraft pulp plants has experience only with sulphite pulp production; the

American joint venture partner in another new plant had limited impact because of its lack of experience in other greenfield investments. In other cases there has been more interaction between parent and partner firms (particularly with regard to training of staff), but as one respondent noted, the primary impact has been to provide the Chilean operation with a set of contacts outside the country, facilitating flows of technical information and decreasing reliance on external consultants.

Foreign investors have played a role in two regards, however. First, they have been influential in setting initial design parameters for new plants. In the case of one plant, for example, the World Bank/International Finance Corporation (which provided initial financing in return for a seven percent equity stake in the mill) played a key role, demanding an environmental impact study and insisting that relatively stringent World Bank effluent standards be adopted as a guideline for the plant. In other cases, parent and partner firms intervened directly during the design and construction phase to influence aspects of plant design and operation -- one plant manager, for example, noted that the European parent firm had vetoed a proposal by plant personnel to employ only partial chlorine dioxide substitution as a means of saving costs. As noted above, however, the concentrated nature of the market for pulp and paper technology and the limited scope for variation in overall plant design mean that such interventions have not resulted in dramatic differences among new plants in terms of control and treatment technologies.

Second, foreign ownership has tended to influence the less concrete aspects of environmental behaviour. Foreign-owned and joint venture firms are more likely to have a formal environmental policy, and to have designated a specific individual to take responsibility for environmental matters at the plant level. They are also more likely to

have pursued (or be pursuing) international certification. These last points may in turn push firm toward more active pursuit of ongoing, incremental improvements in environmental performance.

In both of these areas, however, it is the indirect transfer of corporate policies and standards -- not the direct transfer of technology and production experience -- which appears to be central. In no case did respondents point to a direct, ongoing influence of parent or partner firms in the operations of the plant after start-up. While this may reflect the nature of foreign investment in the Chilean pulp and paper industry (i.e., the presence of investors with limited relevant production experience and few previous overseas investments) and the relatively well-established base of local technical and managerial expertise prior to the recent investment boom, it also emphasizes some of the structural characteristics of the pulp and paper industry, notably the dominance of outside supplier and equipment firms and consulting engineering companies.

c) Domestic Environmental Regulations

The third factor to be considered is the impact of domestic environmental regulations on the environmental behaviour of firms. In this case, the results are relatively straightforward, and confirm the hypothesis advanced in the introduction. Older firms -- particularly those which are locally-owned -- are much more likely to rate domestic environmental regulations as an important influence on environmental behaviour than are newer plants. Newer, export oriented firms rate environmental regulations as either a minor or irrelevant factor in their decision-making with regard to environmental measures (see Table 7.4). As one of the new market pulp producers remarked, existing norms provide the firm with plenty of "breathing space" -- current effluent levels

are well below permit levels.

Overall, firms are more concerned about the lack of clarity in existing norms and the overlap among regulatory bodies than about the stringency of norms themselves: in only one case did a respondent argue that current regulatory limits are unrealistic, but almost all firms pointed to regulatory overlap and lack of clarity. This represents a significant additional cost to firms at the time of design and start-up (either for new projects or major modifications), due to the need to negotiate with a variety of authorities, and the difficulty of establishing clear norms for the project; after start-up, it is a relatively minor issue, adding only to the paper burden on firms.

Two other points should be stressed with regard to domestic environmental regulations. First, the case-by-case approach to permitting practised in Chile means that regulatory burdens differ widely between firms (see Chapter 6). While the case-by-case approach in theory provides flexibility to adjust the stringency of regulations to the environmental and economic reality of each mill, it also leads to inconsistency in application of norms -- particularly since new permits are not required for new mills except in cases of major investment programs. This in turn may reinforce the tendency of existing mills to pursue incremental, in-plant changes rather than more costly retrofitting or external treatment which would necessitate new permits.

Second, uncertainty regarding future regulatory limits has increased the degree of effective regulatory pressure on firms. In the absence of clear guidelines, most firms have chosen to adopt external guidelines -- World Bank reference levels, parameters from parent company plants, etc. -- as targets for their operations. This is not surprising: as one respondent put it, while new regulatory limits have not yet been

established, firms “simply have to look at other countries” to know the direction in which regulations are likely to evolve. Given the long-term nature of investments in pulp and paper production, firms have tended to base decision-making on **anticipated** future regulatory limits, not just actual limits. This suggests that informal effluent targets are likely to shift more rapidly than official limits, and that regulatory bodies may wish to “signal” proposed changes in regulatory limits at an early stage, both to increase pressure on firms and as a means of allowing existing plants time to adjust to proposed changes.

As noted in Chapter 6, there has also been a spread of environmental impact assessment processes, even in advance of formal legislation requiring EIAs to be carried out. While legislation has only recently been passed requiring EIAs for new plants and major modernization programs, all of the new plants constructed since 1990 have included an EIA. In some cases this was a result of formal requirements imposed by external financiers, but in most cases it reflects a concern by firms to anticipate future regulatory pressures. To date, impact of EIAs on design and operation of plants has been limited – in part because of the differing technical capabilities of firms and local regulatory authorities (as noted in Chapter 6, responsibility for managing the EIA process falls to local environmental commissions in each of Chile’s 12 regions). This may be changing, however, and a 1995 EIA for a new Kraft pulp plant in the 10th region in the south of Chile has resulted in unexpected pressure on the firm to modify its plans by changing the plant location, installing tertiary treatment facilities, or piping effluent away from sensitive wetland areas.

d) Internal Characteristics and Capabilities

Finally, patterns of response may be affected by the characteristics of specific mills, or by the internal resources, capabilities and history of action of the firm in question.

One interesting point is the impact of size of mills on patterns of environmental activity. Varying patterns of environmental behaviour between greenfield and older mills appear to be accentuated by the differences in average scale between the two sets of mills. As noted in Chapter 3, average scale of pulp and paper mills worldwide has increased markedly over the past two decades, and increasing scale (and decreased unit costs) is one of the main competitive strategies of firms in the industry. For older mills, as a result, cost considerations are a key concern, and environmental improvements have been heavily oriented toward minor process optimization measures which are inexpensive and promise some return in terms of longer-term cost-savings. This conclusion is further reinforced by the findings with regard to one of the new Kraft pulp mills, which is much smaller than the others and well short of what is generally considered minimum efficient scale. While the mill incorporates latest vintage technology, its overall environmental management strategy is in many respects similar to that of older mills in the industry. Small scale and relatively high unit costs have focussed the firm on cost-saving measures, and as a result it has been more aggressive than other new firms in pursuing minor process optimization measures which can boost performance and cut costs, and in examining the scope for low-cost, alternative methods of increasing the efficiency of treatment systems (e.g., experiments in the use of aquatic plants and fish in the secondary treatment lagoon). This finding provides partial support to the results of analysis of the Canadian survey, where (contrary to expectations) the relationship between scale of mills and levels of environmental performance was unclear -- and if anything negative. While there may well be scale economies in pollution control investments (due to the high capital costs of end-of-pipe

treatment technologies) any cost-savings by larger mills may be offset by the greater incentives for smaller mills to pursue ongoing process optimization measures in order to cut operating costs.

The impact of other firm-level attributes is less clear. There is some indication (as in the Canadian survey) that a firms' previous commitment to superior environmental management plays a key role in determining its patterns of behaviour. As noted above, one of the main impacts of foreign owners and joint venture partners appears to have been at this level of overall corporate environmental policy, which in turn has translated into different attitudes toward certification, auditing, and assignment of responsibilities for mill-level environmental performance. Similarly, internal R&D resources and past history of innovation may play a role in determining patterns of response. As noted above, of the three older mills in the sample, two have undertaken significant process changes over the past decade (chlorine dioxide substitution in bleaching in one case, and a shift from sulfite to TMP pulping in the other); in contrast, the third mill has relied almost entirely on minor process optimization measures to improve its environmental performance, resisting pressures for more far-reaching process changes. The former two mills are both owned by a diversified Chilean forest products company with in-house research capabilities, a number of mills, and a 40-year history in the industry. While process changes at the mills were largely dependent on outside sources of technology, it is reasonable to conclude that the research and production experience of the firm made it more receptive to the possibility of undertaking new investments geared (partially) to improving environmental performance. In contrast, the third mill (owned by two separate sets of foreign investors) has no in-house research capability, is the only Chilean mill owned by the group, and has changed hands several times over the course of its history. Given the small sample size and the extent of intercorporate holdings

among local firms, it is not possible to advance any hard-and-fast conclusions regarding the impact of these kinds of firm-level resources and capabilities, but this is clearly an issue deserving additional study in the future.

V. Impact on Technological Capabilities

How have efforts of firms to improve their environmental performance affected the accumulation of technological capabilities within firms and within the Chilean economy more broadly?

As Table 7.5 illustrates, outside equipment suppliers and consulting engineering companies are by far the dominant source of technology and technical expertise to carry out environmental measures at mills. All six firms in the sample rated this as the most important source. In-house technical expertise and direct production experience was the second most important factor, with universities a distant third. As noted earlier in this chapter, parent companies and foreign joint venture partners were not seen as important sources of technology and expertise -- only one firm mentioned this factor, and even in this case felt the role of the parent firm had been minimal. Other potential sources -- in-house R&D, public sector research laboratories -- were not mentioned by any respondents. These responses are in many respects similar to those of Canadian firms, who as reported in Chapter 5 also rated external equipment suppliers/consultants and in-house production experience as the most important sources of technical expertise for environmental improvements.

Table 7.5: Principal Sources of Technology and Technical Expertise				
	Outside Suppliers and Consulting Engineers	In-House Technical Expertise and Direct Production Experience	Parent Firm or Joint Venture Partner	Local Universities
Number of Responses (n=6)	6	6	1	5
Average Score (max =4)*	4.0	3.0	0.5	1.7
Source: Interview responses * Responses were ranked as follows: first mention = 4 points; second = 3 points; third = 2 points; fourth = 1 point.				

Overall, then, firms continue to be dependent on outside sources of technology and technical expertise, particularly in terms of the capabilities need to design and carry out new, greenfield investment projects or major process changes. In a sense, this is not surprising, and reflects the nature of technological change in the pulp and paper industry worldwide, in which equipment suppliers and consulting engineering companies play the dominant role. In the case of Chile, however, this condition is exacerbated by the almost complete lack of countervailing sources of technical expertise. In-house R&D is limited (only one of the firms in the sample responded that it carries out in-house R&D of any significance) and is almost completely oriented toward forest management issues. Public sector research laboratories do not play any significant role, and there are none of the kinds of collaborative private sector (or joint private-public sector) research programs which have played an important role in Canada and other countries. Contract research with universities has been limited, aside from contracts for effluent quality monitoring and impact assessment studies -- and a few scattered research projects funded jointly by firms and public sector programs (e.g., some exploratory work on biotechnology-based bleaching).

The small size of the Chilean market has limited the growth of a domestic capital goods industry, and it is thus not surprising that no firms in the sample mentioned any significant role of local equipment suppliers (aside from some limited subcontracting of components). Similarly, consulting engineering services have been dominated by foreign (notably Swedish and Canadian) firms. As noted in the last chapter, there has been a noticeable increase in the capacity of local consulting engineering companies, owing largely to their participation in the large greenfield pulp and paper mills constructed since the late 1980s. Originally hired as junior partners to foreign firms, several local consulting firms have gained increasing experience in design and implementation of major investment projects, to the point that in the case of the newest mill (which entered into production in 1994) a Chilean firm carried out the lion's share of the work, including all of the detailed engineering and start-up work. For the most part, the increasing capabilities of the local consulting engineering industry can be attributed to the investment boom in the pulp and paper industry since the late 1980s, which has dramatically increased demand for their services -- and, at least in the case of the most recent greenfield mill, a desire on the part of investors to limit costs, which has increased the attractiveness of local engineering firms vis-a-vis their foreign counterparts. Specific environment-related projects at existing mills have played less of a role in spurring the growth of local consulting engineering capabilities -- in part because of the focus of existing firms on minor in-plant changes and process optimization measures, which have relied primarily on in-house sources of technical expertise, with a more limited role for outside consultants.

Not surprisingly, then, there is little evidence of major innovations by Chilean pulp and paper firms or supplier industries in response to environmental pressures. As hypothesized at the outset of this chapter, the primary response of the industry has

been process optimization measures and adoption of imported technologies; they have followed an “adopt and adapt” strategy similar to that witnessed in Canada, but with more focus on housekeeping measures and process optimization, and less scope for environment-related R&D activities. At the same time, however, the longer-term impact of this kind of strategy should not be dismissed, as it has helped to build in-house (and external) innovative capabilities — primarily for minor housekeeping measures, but increasingly for more ambitious process improvements as well.

In fact, the growth of in-house technical capabilities within Chilean pulp and paper firms has been significant. While there are few mechanisms to promote formal R&D in the industry, more informal channels of technical learning are well established. Older plants in the industry have served as a training ground for technical staff in the industry, and relatively concentrated patterns of ownership have promoted movement of staff among various mills. The local professional association, ATCP (Asociación Técnica de la Celulosa y el Papel) is well established, and supports a range of seminars and short courses, as well as a technical journal for the industry. Its environmental committee is strong, and has played a significant role in discussions on future environmental standards. And in most cases, firms have devoted resources to upgrading the capabilities of local staff, through on-the-job training, collaborative work with foreign consultants, and (in some cases) travel abroad to visit other mills, equipment suppliers and engineering companies.

The result has been a steadily increasing role for in-house technical staff, both in general and with respect to environmental improvements. All firms pointed to an important role of in-house technical expertise in designing and implementing environmental measures at their mills, and in some cases firms have carried out

significant work independently. For the most part in-house efforts have been limited to basic production and minor change capabilities, but in some cases firms have begun to develop more significant reservoirs of in-house expertise. Perhaps most notable is a project by one of the firms in the sample to produce TCF pulp (the only firm in the sample with this capability); in this case, the program was carried out entirely by in-house staff, except for one external advisor who worked alongside local staff.

This combination of increasing in-house technical expertise and expanding local consulting engineering capabilities -- and to a lesser degree the expertise of some of the universities, which have taken particular responsibility for effluent monitoring and impact assessment studies -- may well alter the sources of technology for future environmental improvements in the industry. Increasing environmental pressures on existing firms are likely to increase demands for both in-house and contract expertise. Moreover, the complicated nature of improvements at these mills may well put a premium on in-house expertise (as opposed to greenfield investments, which are more easily amenable to direct transfer of technical solutions from abroad). And the greater cost-sensitivity of established firms will in all likelihood further tilt the balance toward local sources of technical expertise, at the expense of more expensive foreign consultants. Thus, while the Chilean industry is likely to continue to depend on foreign equipment suppliers for the hardware needed to comply with more stringent environmental regulations, other components of the overall technology "package" may well increasingly come from within the local economy.

VI. Conclusions

The results presented in this chapter provide partial support to the hypotheses set out in

the introduction, but they also suggest that patterns of environmental behaviour among Chilean firms are less clear-cut than originally anticipated. Despite relatively weak domestic regulations by international standards, Chilean firms have taken significant steps to advance their environmental performance during the 1990s. Environmental improvements, moreover, have **not** been limited to export-oriented firms, nor to those which are wholly or partially foreign-owned. Instead, all firms surveyed pointed to a series of environment-related measures at their mills.

As expected, patterns of environmental behaviour differ considerably among the case-study mills, and particularly between greenfield and older mills. While generalization is difficult, environmental considerations appear to interact with other aspects of the competitive strategy of the firm in a different manner in the two groups of firms.

- For greenfield market pulp producers (Mills D, E and F), the main influences on environment-related investments are external, arising from the nature of technology supply on one hand, and environmental requirements in export markets on the other. Given the dominant role of industrialized country equipment suppliers and consulting engineering firms in supplying pulp and paper technology, new mills tend to be designed to meet industrialized country standards. This is further reinforced by market demand, particularly in European markets which are of critical importance to all three firms. As a result, all plants tend to be relatively up-to-date in terms of both in-plant measures and external control.
- In the case of established mills (Mills A, B and C), on the other hand, motivations are more likely to be internal — in particular the need to ensure continued

compliance with domestic environmental regulations, while at the same time controlling costs to maintain competitiveness with larger, more efficient plants in an increasingly open trading environment. Older mills, therefore, have tended to focus on relatively minor in-plant process optimization measures which are relatively low-cost, and which may promise savings to the firm in terms of reduced energy, water and chemical use. The older mills are now beginning to move beyond these changes and incorporate more far-reaching process changes and/or external treatment measures — but in each case this is due primarily to efficiency and capacity concerns, with environmental measures of secondary importance.

Variations with similar Canadian mills are relatively large for older, established mills (particularly with regard to external treatment technologies and effluent levels) but much smaller for greenfield mills.

Within the two groups, however, there is considerable variation, particularly in terms of the less concrete aspects of environmental investments (relatively priority attached to ongoing process optimization and housekeeping measures; commitment to internal environmental management systems and certification). All of the factors listed at the outset (export orientation, ownership, domestic regulations, and internal characteristics and resources of the firm) have at least some impact on patterns of environmental behaviour — although the relationships are not entirely straightforward.

Export orientation (in particular the extent to which production is destined for environmentally demanding markets in Europe and North America) is a critical factor. But the primary impact of export orientation has been to promote process changes which are easily reflected in product characteristics (e.g., chlorine content of pulp).

Market factors are less likely to spur the adoption of external treatment technologies which do not affect product characteristics and which represent a net cost to firms. In the case of older mills, market factors alone are unlikely to overcome the physical and economic barriers to more far-reaching process changes and/or external treatment of effluents.

Ownership does not appear to be a critical factor in determining the extent or nature of environmental investments: local and foreign-owned firms of similar ages and product lines do not differ markedly in terms of either in-plant process improvements or external treatment measures. However, foreign owners have played a role in setting initial design standards for mills, and have tended to influence the less concrete aspects of environmental behaviour (auditing practices, certification, etc.). Overall, it is the indirect transfer of corporate policies and standards — not the direct transfer of technology and production experience — which appears to be central. In no case did respondents point to a direct, ongoing influence of parent or partner firms in mill operations after start-up.

Environmental regulations are relatively unimportant to newer mills, but an important influence on the behaviour of established mills. The uncertainty regarding future regulatory limits has in particular worked to increase the degree of effective regulatory pressure on established firms, most of which have adopted external guidelines — World Bank reference levels, parameters from parent company mills — as targets for their operations. As a result, mill-level targets vary much less than official permit levels. In an analogous fashion, there has also been a spread of environmental impact assessment processes, even in advance of formal legislation requiring EIAs for new plants and modernization programs.

Finally, the manner in which firm-level characteristics and resources have affected levels

of environmental performance is less clear-cut than in the Canadian case — where there are strong correlations between performance and firm size, R&D spending, and commitment to environmental management. There is no obvious link between firm size and environmental performance, and insufficient evidence regarding R&D activities to make any judgements. Clearly, however, corporate commitment to strong environmental performance constitutes an important factor, colouring ongoing actions by the firm. And it is also clear that the habits and practices of the firm with regard to innovation shape its current behaviour. At times this may result from relatively minor actions — recruitment of key staff, for example. In other cases it reflects a longer-term commitment of the firm to innovation in non-environmental aspects of its performance (costs, product quality) which also help to create scope for environmental improvements. Scale of mills also appears to play a role: of the newer plants, those which are below international standards of minimum efficient scale were particularly concerned with cost-saving measures and hence tended to devote considerable attention to ongoing process optimization, in a manner similar to some of the older firms which face similar cost pressures.

Overall, efforts by firms to improve their environmental performance have not led to significant levels of innovation by firms or domestic suppliers. Foreign equipment suppliers and consulting engineering companies are by far the dominant sources of technology and technical expertise for environmental projects. At the same time, however, local consulting engineering companies have gained increased experience in design and implementation of investment projects over the past decade, and there has been a steady increase in technical expertise in the environmental field within mills themselves. Increasing technical capabilities are not uniquely related to environmental factors, but instead reflect the overall investment boom in the industry over the past

decade. But there is evidence of increasing local capacity in the environmental field as well. The combination of increasing local capacity, more stringent environmental regulations and continued cost pressures on established mills may well continue to shift the balance of technology supply in the future, with positive impacts on the overall innovative capability of the industry. Dominance of outside equipment suppliers will undoubtedly continue, but with greater local content in engineering and design services, and greater customization by mill-level staff.

Annex: Profiles of Case-Study Mills

Mill A

Mill A is a medium-sized newsprint mill, originally constructed in 1957 by local investors with backing from the national development agency CORFO. It was acquired by foreign investors in the mid-1980s, and is now entirely foreign-owned. Approximately 45 percent of production is sold on the Chilean market, with the remainder exported primarily to other Latin American countries. Extra-regional exports (primarily to Asia) account for less than 10 percent of output.

Environmental pressures on mill operations stem largely from the age of the mill (the first pulp and paper mill in Chile) and its physical location (it is situated within a major urban centre). Given the age of the mill, no new permits have been required to allow the mill to discharge effluents. However, in 1990 the DGTMYMM demanded an environmental impact assessment study of the mill, which recommended actions to decrease levels of TSS, reduce the temperature of liquid effluents, and limit particulate emissions.

The strategy chosen by the firm has been strongly influenced by its overall competitive position in the Chilean newsprint market. Given that its principal local rival has had to shoulder a considerable capital investment to switch from sulphite to TMP production, the mill enjoys a significant cost advantage at least in the short term, which has provided it a “breathing space” within which to undertake environmental improvements. At the same time, however, the age of the plant means that cost considerations are always front and centre, while its physical layout makes far-reaching process changes difficult (e.g., it is difficult to combine various effluent streams for closure). Low water levels in

the adjacent river have also served to increase pressures on the firm to undertake in-plant measures to conserve water.

As a result, the strategy of the firm has been largely oriented toward minor process optimization and “housekeeping” measures. No external treatment of effluents has been instituted, but instead the firm has invested in improved fibre recovery and better process control. Investments to date have totaled just under \$1.5 million USD, with another \$4.9 million in planned spending by 1999 (29 percent of total capital spending). Actions to date have reduced TSS levels by almost two-thirds, but the mill is still well short of its own targets for TSS; meanwhile, BOD levels are largely unchanged, and temperature of effluent has increased. At the time of interviews, the firm was grappling with a strategy for further changes: should it continue to pursue internal process changes which are risky but hold out the possibility of producing cost-effective results, or should it opt for the more certain — but far more costly — route of external effluent treatment? Similarly, with regard to treatment of atmospheric emissions, mill management is exploring the feasibility of installation of an electrostatic precipitator for the main boiler, which would permit the mill to surpass existing emissions standards but at relatively high cost.

The overall strategy of the mill has been cautious, reflecting uncertainties regarding future regulatory limits and the need to limit costs. At the same time, however, the mill has not simply reactive. Faced with uncertainties regarding future regulatory limits, the firm has chosen to adopt World Bank standards as informal targets, and has developed an ambitious environmental management plan which will culminate in ISO 14000 certification.

The need to pursue internal process changes has put a premium on in-house

engineering expertise. While outside equipment suppliers and consulting firms have played a dominant role, the mill has striven to increase opportunities for in-house learning, through direct participation of mill staff in investment programs, travel to other countries to observe other mills owned by the parent company, visits from outside experts, and review of technical journals. The parent company of the mill has played a limited role as a direct source of technical know-how for environmental improvements, although it has helped to facilitate flows of information and to some degree has decreased reliance on external consultants as a source of information.

Mill B

Mill B was constructed in 1959, and remains the only large integrated Kraft pulp and paper plant in the country - producing both market pulp for export and a variety of paper products for local and regional markets. Locally-owned by a large, diversified forest products company, it has served as a training ground for many of the technical staff now employed at other mills in the country. Approximately 40 percent of pulp production is exported, with Western Europe being the most important destination of exports.

Company officials argue that the principal factors driving environmental investments have been local regulations, followed (closely) by concern for the public image of the company. At the same time, however, market considerations are increasingly important, particularly pressures from European purchasers concerned in particular with chlorine content of pulp. Some savings on input costs have been enjoyed, but these are not sufficient to override the scale of investments in external treatment and in-plant process changes.

Early environmental initiatives at the mill consisted largely of low-cost housekeeping

measures — closing circuits, separating waste streams to permit recycling, and ongoing efforts to improve energy efficiency and reduce water use. By the early 1990s, however, pressure from export markets was sufficient to convince the company to invest in a new chlorine dioxide plant to enable it to produce ECF pulp. Significantly, this kind of in-plant process change was undertaken at a time when the plant had neither primary nor secondary effluent treatment systems in place. Oxygen delignification was not included as part of the ECF project — in part because of costs, but also because of worries about the limited capacity of the recovery boiler.

By the mid-1990s, concerns about the overall capacity and efficiency of the mill led to plans for a major modernization program, notably a new recovery boiler and digester. This in turn necessitated new environmental permits, with the result that by 1996 a number of major environmental improvements had been or were being instituted — notably an improved pulp washing system, electrostatic precipitators for boilers and lime kiln, a clarifier for primary treatment of liquid effluents, and facilities for disposal of solid wastes . The modernization program has also been designed to permit future environmental upgrades: the new recovery boiler is designed such that oxygen delignification can be added at a later date, and initial plans for secondary treatment of liquid effluents have also been made (even though the existing primary treatment system will be sufficient to meet 1995 permit levels).

The primary source of technical expertise for measures introduced to date has come from outside consulting engineering companies — initially foreign, but with an increasing role for local Chilean engineering firms. In-house production expertise has also been important, particularly for less far-reaching process optimization measures. On the other hand, the company — one of only two Chilean forest products firms with

significant in-house R&D activities — has not devoted its own research budget to industrial pollution management concerns. Company officials argue that as opposed to other areas where Chile faces peculiar challenges demanding local research (e.g., genetic improvement of the dominant *radiata pine* species) this is a field in which purchasing technical solutions from outside makes both technical and economic sense.

Mill C

Mill C is a locally-owned newsprint mill, constructed in the mid-1960s. It is similar in scale to Mill A, and like that mill sells almost all of its production on local and regional markets: only about three percent of total output is exported outside Latin America, primarily to Europe. The company is publicly-traded, with the majority of shares held by one of the two leading forest product firms in the country.

Given the market orientation of the firm, export market pressures have not been an important factor in environmental decisions. Company officials argue that the primary factor driving environmental investments has been the local regulatory environment, although they admit that existing regulations have not been particularly exigent. Largely due to regulatory pressures, the mill made a number of in-plant changes in the early 1990s (improved fibre and chemical recovery; optimization of combustion processes to reduce atmospheric emissions), and also constructed a primary treatment system for liquid effluents.

Perhaps the most significant change in the environmental “profile” of the plant, however, has been motivated not by environmental concerns, but rather by pressures to improve the overall performance of the plant by phasing out existing sulphite and groundwood pulping machinery in favour of a new thermo-mechanical pulping (TMP) line. The new

line will significantly reduce BOD and TSS levels at the mill, while also boosting pulp quality and overall production efficiency. At the time of interviews in 1996, the plant was closed down to permit completion of the investment program.

This shift illustrates the difficulty of separating environmental management decisions from other aspects of corporate strategy. For company officials, the principal benefits of the modernization program are economic, with regulatory compliance at most an ancillary motive. But the investment costs of switching to TMP are high, and as a result the company is particularly concerned about **future** environmental regulations in the country — will these be sufficiently high to justify some of the costs of the modernization program (in particular by forcing competitor firms to undertake similar investments), but not so high as to require the firm to make additional investments to ensure continued compliance?

Mill D

Mill D is one of three relatively large market Kraft pulp mills which entered production in Chile in 1991 and 1992. The mill is majority foreign-owned (a local forest product firm acquired a 20 percent stake in 1995, buying out one of the original foreign joint venture partners); the majority foreign partner (a large, diversified transnational resource company) plays the dominant role in management.

The mill is the only Chilean mill which produces hardwood pulp, relying on eucalyptus plantations rather than the dominant *radiata* pine species. It is somewhat smaller than other new mills in the country, and at just over 700 adt/day rated output, is slightly below industry standards for scale of plants constructed world-wide in recent years. The mill was built on a site previously prepared for a smaller (385 adt/day) softwood mill, which

had been partially constructed before being abandoned by local owners in the mid-1980s. The new mill was engineered by Finnish firm Jaakko Poyry (one of the industry leaders), and is based in large measure on Scandinavian design and environmental standards.

Like other Chilean mills constructed in recent years, the mill is relatively up-to-date in environmental terms. It incorporates full chlorine dioxide substitution along with oxygen delignification in the bleaching stage, and is the only Chilean mill currently capable of producing TCF pulp — although company officials note that TCF production has remained limited due to a relatively stagnant market worldwide, and the limited price differential between ECF and TCF pulp. Current production is split approximately 50 percent standard pulp (high chlorine dioxide substitution), 45 percent ECF, and only 5 percent TCF. Effluent levels compare relatively well with international standards (BOD < 10kg/adt; TSS < 3 kg/adt; AOX < 0.5 kg/adt).

The environmental strategy pursued at the mill, however, differs in two respects from that at some of the other new mills constructed in Chile in the early 1990s. First, the mill has primary effluent treatment systems only. Despite the absence of secondary treatment, the mill has had no trouble meeting its own environmental targets — in part because of the lower lignin content of eucalyptus relative to softwood species, but also because of the original mill design, which placed considerable emphasis on in-plant environmental measures. Second — and related to this point — mill management has been relatively aggressive in pursuing ongoing in-plant changes: ECF/TCF capability was added after start-up, and additional work has been devoted to improving process control, and overall process optimization.

The commitment to ongoing environmental improvements in part reflect a concern for

overall corporate image, and particularly the reputation of the majority foreign owner. The mill was the first Chilean pulp and paper facility to receive ISO 9002 certification, and the company is pursuing BS5750 certification (which includes greater attention to environmental issues than the ISO 9000 series), with plans to pursue ISO 14000 certification. But the environmental strategy of the firm also reflects concern for its overall competitive position: the firm has worked to improve its ability to sell high-value products in demanding markets, but at the same time has limited costs by focusing on internal process changes and limiting investments in external treatment. Cost-saving measures are particularly important given the smaller-than-average size of the mill by recent world standards.

Like all other mills surveyed, outside engineering companies — particularly foreign ones — have played a key role as sources of technology for environmental improvements. However, the plant has also worked relatively closely with the local university, undertaking joint research on pulp characteristics and quality. And while the firm does not have a formal R&D department, in-house engineering capabilities have played an important role: the TCF project, for example, was carried out largely by in-house staff, with only one external advisor working at the plant.

Mill E

Mill E is one of the largest market pulp mills in the country, with a daily output of approximately 920 adt. The mill's size is comparable to recent industry standards worldwide, and it is also relatively up-to-date technologically. The mill includes both primary and secondary treatment of liquid effluents, and electrostatic precipitators in recovery boilers and lime kilns to reduce atmospheric emissions. These external

treatment measures are in addition to in-plant measures to reduce contamination, including full chlorine dioxide substitution and oxygen delignification in the bleaching stage. Effluent levels are at or below international levels.

Local environmental regulations have played a limited role in determining the nature of environmental measures at the plant. Instead, the main factors appear to have been market demand and — at least in the design stage — the influence of outside investors.

The ownership situation of this mill is unique. While formally a joint venture between a large local forest products firm and a US-based partner, in practice management decisions are almost entirely in the hands of the local partner. The two majority partners are joined by the World Bank's International Finance Corporation, which provided initial financing in return for a 7 percent stake in the company. While the US joint venture partner has had a limited impact on design or operation of the plant (this is its first overseas investment in greenfield production) the IFC has had a significant impact particularly during design and construction. The IFC insisted on an environmental impact assessment study prior to construction (even though not required by Chilean law at the time); it mandated reference levels for effluents based on international standards; and it requires environmental reports from the company twice per year.

Since start-up, the main influence on environmental management at the mill has been market considerations. The mill has gradually been shifting toward ECF production, reflecting the fact that some 60 percent of its output is sold to European customers, particularly in Germany and the UK. Overall, however, the environmental strategy of the mill has been relatively passive since start-up. It has adjusted to changes in market requirements and has pursued ongoing housekeeping measures (e.g., continued efforts to optimize performance of the its secondary aerated stabilization basin) to maintain

performance within design parameters. But given the overall competitive advantages enjoyed by the firm, there has been little emphasis on further environmental measures, and no effort to “lead” the market. Unlike Mill D, for example, there has been no effort to invest in TCF production, with company officials arguing that market demand does not yet warrant such a move.

Technical know-how for the initial plant design and engineering came largely from foreign firms (Swedish and Canadian) with some participation of local firms in detailed engineering work. As noted above, environmental activities since start-up have been limited, and have depended primarily on in-house staff and contracts with local universities (for impact studies and effluent monitoring).

Mill F

The defining characteristic of Mill F is its size. At just 230 adt/day production in 1996, the mill is far below international standards for the minimum efficient scale of a new Kraft pulp mill, and only one-third to one-quarter the size of other new mills in the sample. The mill, which entered production in 1994, is owned by a European pulp and paper firm, and exports approximately 75 percent of output to European markets via its parent company's marketing networks. Remaining output is sold on spot markets throughout Latin America.

Company officials argue that the mill is best seen as an experiment — an effort to demonstrate that a cost-efficient plant can be built and operated at a scale far below what is commonly seen as economically viable. Whatever the original motivations, there is little doubt that cost-cutting measures have represented a key component of overall corporate strategy, with important implications for environmental measures as well.

Investment costs were kept relatively low, and as a result the capital cost of the mill is roughly comparable with other new Chilean mills on a per-tonne basis. Pressures to economize on operating costs, however, are a constant concern, given that employment levels at the mill are roughly similar to mills producing 3–4 times as much pulp.

Pressures to cut investment costs meant that some “bells and whistles” were omitted from the original design, with capacity to add them at a later stage (e.g., only partial automated process control in bleaching stage; scrubbers rather than electrostatic precipitators in the line kiln). The company made extensive use of less-expensive Chilean engineering firms (see below) and also searched for cheaper sources of materials and equipment from local and regional (Brazilian) suppliers. On the other hand, overall environmental measures at the plant are relatively up-to-date: the plant includes both primary and secondary treatment of liquid effluents, electrostatic precipitators in power and recovery boilers; “stripping” of non-condensable gases to limit odour; and full chlorine dioxide substitution with oxygen delignification in the bleaching stage. Effluent levels are well below permit levels, and compare favourably with other Chilean mills and international standards.

According to company officials, the principal factors affecting environmental investments during design and start-up were on the one hand market demand, and on the other hand the influence of the parent company. At one point, for example, the parent firm vetoed a proposal to switch from full to partial chlorine dioxide substitution in order to limit costs). Local regulations were less important: while the plant did have to undergo an environmental impact study and negotiate permit levels with local authorities, these did not result in significant changes to design (although it did confirm the need for a submerged outfall for liquid effluents due to periodically low water-levels; permits also

stipulate a minimum dilution level of effluents, and the company has constructed a reservoir to hold effluent prior to discharge in times of low water levels).

Since start-up, cost considerations have been the primary influence on ongoing environmental measures, followed by market demand and the need to ensure continued compliance with local regulations. While additional environmental investments have been limited, mill management has been relatively aggressive in pursuing process optimization measures (e.g., efforts to cut water use and improve the performance of secondary treatment facilities). They have also begun to explore non-traditional control measures, including the use of fish and aquatic plant in the stabilization lagoon, and partial “closure” by storing and re-using effluent within the plant.

As noted above, pressures to cut costs have resulted in a greater-than-average level of reliance on local Chilean engineering expertise, as well as in-house engineering staff, as sources of technical expertise. On the other hand, the parent company has been relatively unimportant as a source of technical know-how, given its limited prior experience with Kraft pulping technology. As with other plants, universities have played a secondary role, principally for impact studies and effluent monitoring.

Chapter 8: Conclusions

As noted in Chapter 1, the general objective of this thesis has been to explore the ways in which environmental regulations affect the process of innovation in a particular industrial sector, and the way in which this impact is mediated by other, non-regulatory influences on corporate environmental behaviour. In order to address this issue, an analysis of pulp and paper firms in Canada and Chile has been undertaken, focused on three more specific research questions:

1. What kinds of strategies do firms adopt in response to environmental pressures, and what kinds of investments do they undertake in order to improve their environmental performance?
2. How is the impact of regulations mediated by other factors? What are the principal factors which influence firms' investments in improved environmental performance? What explains the varying strategies they pursue, and their relative success in meeting environmental targets?
3. To what extent do environmental regulations spur a process of innovation, stimulating firms to develop and/or adopt novel means of meeting environmental targets, and encouraging them to make ongoing improvements to existing plant and equipment?

This chapter begins by outlining the main conclusions of the study, organized around these three research questions. Section II then proceeds to discuss the policy implications of the research, while Section III discusses some of the limitations of the research and directions for further analysis.

I. Principal Findings

a) Level and Types of Environmental Investments

The first and most obvious conclusion to emerge from this study is the significant level of investment in improved environmental performance by pulp and paper firms in both Canada and Chile during the period under study. Survey and case-study data confirm that firms have made significant efforts to reduce the environmental impacts of mill operations over the past decade. Negative environmental impacts of pulp and paper production remain, but firms in both countries have invested heavily in improved environmental performance, and have gradually moved toward levels of “good” environmental practice.

Environment-related investments, moreover, are more widespread than hypothesized at the outset of this study. In the case of Canada, environment-related investments have been spread across literally all firms in the industry, resulting in a significant change in the environmental profile of the industry. Not only have average effluent levels dropped dramatically — to levels below those mandated in existing regulations — but the gap in environmental performance between “leading” and “laggard” firms has also narrowed. Whereas a decade ago many older mills were far from compliance with regulatory limits, levels of compliance are now extremely high across the industry.

In Chile, environmental performance is more varied. Newer, export-oriented mills have made the greatest strides in the environmental field. Levels of environmental performance of new Chilean pulp and paper mills are not significantly different from those in industrialized countries, and are within international standards of “good

practice". On the other hand, older, established mills are less up-to-date in terms of environmental control measures, and the gap in performance compared to Canadian mills of similar vintage is relatively large. Gaps between newer and older Chilean mills are more striking than in the case of Canada, reflecting the way in which regulatory pressures have narrowed the range of environmental performance among Canadian mills. But even in older Chilean mills and those producing for local and regional markets, there have been a series of environmental improvements over the past decade, despite relatively weak regulatory pressures by international standards.

The types of changes introduced by firms also vary somewhat from those hypothesized at the outset of the study, particularly with regard to the balance between end-of-pipe controls, internal process changes, and process optimization measures. In the case of Canada, regulatory pressures have clearly steered firms toward investments in end-of-pipe controls. But while internal process changes are less frequent — and represent a smaller percentage of overall environment-related spending — the fact remains that a significant percentage of mills do report investments in internal process changes of one kind or another. More than anything else, this combination of internal and external abatement measures reflects the extremely high capital costs of end-of-pipe controls. Faced with the need to spend millions of dollars on environmental controls to comply with regulations, many firms have chosen to combine this with broader modernization programs, including in-plant environmental measures. As will be pointed out below, these kinds of in-plant measures have been motivated in part by export market considerations (e.g., changes to bleaching sequences). In other cases, however, the main driver appears to be production-related (e.g., shifts from groundwood or sulphite pulping to TMP or CTMP), with regulatory or market-related issues at best secondary.

The need for firms to finance environmental investments by increasing scale of output has also increased the likelihood that end-of-pipe controls will be accompanied by internal process changes.

In Chile, the situation is more clear-cut. In the absence of strong regulatory pressures, older mills have had little impetus to invest in end-of-pipe controls, and internal changes have predominated. Cost considerations have in particular influenced firms to undertake ongoing process optimization and housekeeping measures. Newer mills, on the other hand, have for the most part incorporated latest generation technologies for effluent control, in addition to internal environmental measures. As will be pointed out below, this reflects the nature of technology supply in the industry rather than specific regulatory or market-related pressures facing individual mills.

In addition to examining the kinds of specific investments made by individual mills, it is also instructive to look at the overall “strategy” of the industry and member firms in response to environmental pressures. In Chapter 2, it was argued that three broad strategies could be envisioned:

- **defensive** strategies, oriented toward forestalling environmental pressures on the firm and industry;
- **compliance-oriented** strategies, oriented toward ensuring that firms are able to meet current and expected environmental demands, whether regulatory or market-driven; and,
- **offensive** strategies, oriented toward anticipating future environmental pressures and positioning the firm to meet them — or even to profit from environment-

related pressures on the industry by developing new innovations or using environmental regulations as a competitive weapon vis-a-vis other firms.

It was further hypothesized that given the nature of the innovation process in pulp and paper, offensive strategies would be rare: the main pattern of behaviour would be compliance-oriented, with shades of more “defensive” strategies particularly among firms facing greater levels of regulatory burden.

This expectation is borne out by the evidence regarding behaviour of the Canadian and Chilean industries over the past decade. Offensive strategies in terms of environmental management have been rare. As will be pointed out below, there are few examples of far-reaching product and process innovations by the industry in response to environmental pressures, and none which have reached widespread commercial application. Moreover, there is no evidence in either country of firms with superior environmental performance promoting more stringent regulations as a competitive weapon vis-a-vis competitor firms.

Instead, the overall strategy of the industry in both countries has been more compliance-oriented. Levels of investment have been significant, but have been geared largely to specific changes which were either required by regulations (e.g., end-of-pipe controls installed by Canadian mills) or demanded as a condition of market access (e.g., chlorine dioxide substitution by bleached Kraft pulp producers in both countries). More far-reaching process changes have been made at some mills, but largely for economic rather than environmental reasons; regulatory pressure may have affected the timing of such investments, but has not been the decisive factor in spurring changes. Levels of environment-related R&D remain low, and overall R&D spending continues to be

concentrated on adaptation of imported technologies, rather than seeking major breakthroughs.

This kind of compliance-oriented strategy should not be dismissed as unimportant. Significant progress has been made on the environmental front, and the need to ensure a comfort zone with regard to current (and expected) regulatory and market pressures means that in practice most firms exceed current requirements. Moreover, there is surprisingly little evidence of more “defensive” actions by the industry in either country, in contrast to the situation expected — and prevalent up until the past decade at least in Canada. In Canada, very few firms are now out of compliance with regulatory requirements, and almost no firms have chosen to react to new regulations by closing mills or scaling back production. In neither country, moreover, was there a strong industry attempt to resist current regulatory pressures or forestall new regulations. The one exception, of course, has been the behaviour of the Canadian industry with regard to the AOX debate. In the late 1980s, Canadian industry lobbied strongly — and successfully — to resist the imposition of federal limits on AOX, and invested heavily in research to characterize bleached Kraft pulp effluents in order to divert pressures for a shift to TCF production. Defensive positions with regard to the TCF issue continue to the present day: relatively few firms have chosen to invest in TCF production, and provincial regulations requiring the total elimination of AOX are being quietly ignored by industry and regulators. To some degree this is not surprising, given the limited market premium for TCF pulp and the new scientific evidence regarding the causes of toxicity in bleached Kraft pulp effluents. Nonetheless, the resistance of the Canadian industry to total phase-out of chlorine use is evidence that defensive strategies can still prevail on key issues.

Even here, however, the position of the industry may be shifting. Over the past few years, research spending by the Canadian industry has shifted from purely defensive actions (studies on Kraft mill effluent to forestall pressures for elimination of chlorine) toward consideration of alternatives to TCF (total process closure options). What remains to be seen, of course, is whether the industry will maintain this commitment to staying ahead of regulatory requirements in the future, or whether the focus on cost-competitiveness prevailing in the last two-three years will reduce commitment to forward-looking research with limited short-term pay-offs. Similarly in Chile, the relatively acquiescent attitude of industry toward possible new regulations may shift as the aging of the capital stock in the Chilean industry exposes firms to more significant environmental pressures.

b) Principal Influences on Corporate Environmental Behaviour

The second main issue of concern to this thesis is the determinants of firms' environmental behaviour. What are the main influences on firms' decision-making with regard to environmental investments, and how do these vary across firms and countries?

In the case of Chile, it appears that the main factor explaining variations in environmental performance is the age of mills, and in particular the distinction between older, established mills and new, greenfield mills constructed during the last decade. As noted above, types of environmental control measures employed in greenfield mills do not differ markedly from those found in new mills in North America or Europe, and effluent levels are within international standards for good practice. This suggests that in a mature, supply-driven industry like pulp and paper, new investment projects are

likely to be designed according to prevailing international standards of environmental performance, rather than being customized to domestic regulatory constraints. The nature of technology supply in the industry — external to firms themselves and concentrated in a relatively small number of Northern suppliers and consulting firms — exerts a powerful influence on the types of environmental measures included in new plants. In circumstances where overall production capacity is rising quickly because of the construction of new mills, therefore, technology supply conditions will strongly influence the overall environmental profile of the industry.

Clearly, however, “technology-push” factors are not the only determinant of Chilean firms’ behaviour. Market considerations have also played a significant role. One weakness of the current study is the fact that all of the new mills constructed in Chile over the past decade have a similar export profile: highly export-oriented, with a significant share of exports destined for Western Europe. As such, it is impossible to ascertain whether environmental improvements would also be integrated into new mills producing for local or regional markets where environmental pressures are weaker. Nonetheless, the situation of the one older mill with significant exports to Western Europe gives some indication of the impact of market factors on environmental improvements: as noted in the last chapter, the mill has invested in internal process changes to produce ECF pulp, but at the time of field study had not yet implemented primary treatment of liquid effluents — let alone the kind of secondary treatment facilities generally seen as the industry standard worldwide. Market pressures, it would appear, are likely have an impact only on those aspects of environmental performance which are easily reflected in product characteristics — such as chlorine content of bleached pulp. Costly external effluent treatment is unlikely to be implemented except in

the case of greenfield mills or where domestic regulations specifically require it.

In contrast to newer mills, the environmental behaviour of established mills has been shaped by expectations of future regulatory requirements — and even more so by the need to maintain cost competitiveness in an increasingly open trading environment. As a result, they have tended to focus on relatively minor process optimization measures which imply limited capital costs and which may generate savings as a result of reduced energy, water and chemical use. While some mills are beginning to move beyond these changes to incorporate more far-reaching process changes and/or external treatment measures, these are linked primarily to efficiency and capacity concerns, with environmental benefits of secondary importance.

In the case of Canada, regulatory pressures and market orientation both exert an influence on firms' investments in environmental improvement. It would appear, however, that the two factors work in different directions. Mills which face higher levels of regulatory burden are significantly more likely to have invested in end-of-pipe controls, whereas mills with high levels of sales to Western European destinations are more likely to have pursued internal process improvements such as changes to bleaching sequences. (It is likely, however, that regulatory pressures have also had an indirect influence on internal process changes, given the tendency of firms to combine regulatory-related control investments with broader modernization and capacity expansion plans).

Levels of environmental performance (as measured by BOD and TSS levels for 1996) are affected by the stringency of provincial regulations facing mills, but not by their export orientation — although this latter fact may in part be due to the lack of data on

AOX levels for respondent mills, which would be expected to have fallen as a result of changes to bleaching sequences at export-oriented mills. Even more interesting, however, is the significant correlation between firms' R&D expenditures and overall commitment to environmental management on the one hand, and levels of environmental performance at company mills on the other hand. This suggests that the factors prompting firms to engage in environment-related **investments** are somewhat different from the factors which allow firms to achieve improvements in environmental **performance** as a result of these investments. Whereas levels of investment are primarily a function of the external environmental pressures facing the mill, the ability of mills to ensure superior levels of environmental performance depends critically on the internal resources and characteristics of the firm. It is the more dynamic firms (in environmental and technical terms) which are able to ensure positive outcomes from environment-related investments.

Contrary to the hypothesis set out in Chapter 2, ownership does not appear to be a significant influence on environmental behaviour in either country. Canadian data show no correlation between foreign ownership and either levels of capital spending on environmental improvements, or levels of environmental performance. While this may reflect the particular nature of foreign investment in the Canadian industry (dominated by US and Japanese firms, rather than by European producers where differences in environmental standards might be more pronounced) it casts doubt on much of the literature suggesting that foreign-owned firms will have greater incentives to improve their environmental performance and/or greater resources to effect changes. Similarly in Chile, foreign ownership does not appear to be a significant factor in explaining inter-firm differences in environmental investments or environmental performance. In no

case do firms view foreign parent or partner firms as a key source of technology or expertise for environmental improvements. There may be some impact of foreign partners on the “softer” aspects of environmental policy (decisions by firms to pursue certification; formalization of corporate environmental policies and responsibilities), but again the relationship is far from clear-cut.

Finally, the research points to some interesting conclusions with regard to scale economies in pollution control. While much of the existing literature suggests that there are strong plant-level economies of scale in environment-related activities, this thesis finds a different picture. Canadian data show some correlation between levels of environment-related spending (measured per tonne of output) and both the size of firms and the scale of mills (at least among mills employing similar production processes). But these economies of scale in pollution-related **investments** do not translate into superior levels of environmental **performance** by larger firms and mills, at least once other variables are controlled for. In part this may simply reflect the nature of recent regulations in Canada: while the costs of compliance may have been lower for larger firms and mills, strict enforcement of regulations has meant smaller firms/mills have had little choice but to shoulder the additional costs – and thus have achieved similar improvements in performance as their larger counterparts. On the other hand, it may also be that smaller firms and mills choose to pursue lower-cost options to improve their environmental performance, which have only a minor impact on overall levels of investment. Field work in Chile suggests that smaller mills may in fact have a greater incentive to pursue in-plant environmental measures, as a result of the greater cost pressures they face.

The results with respect to economies of scale raise significant questions regarding future patterns of adjustment by the Canadian and Chilean industries. Small size of firms and mills has long been seen as a barrier to the competitiveness of the industry, particularly in Canada, and recent years have seen an increasing trend toward concentration of ownership and increases in the scale of mills. While these sorts of changes may well ease the burden of future environmental investments, increasing scale on its own appears unlikely to trigger improvements in environmental performance, unless it is linked to broader improvements in environmental policy and R&D activities. In fact, however, recent mergers and acquisitions have been prompted largely by cost considerations and efforts to improve short-run financial returns to investors in a tight pulp and paper market. Far from improving the overall technological strengths of the industry, they have in many instances gone hand in hand with reductions in R&D activities and cuts in technical staff at the mill level.

c) Impact on Innovation and Technological Capabilities

This brings us to the third main question introduced at the outset of this thesis: the ways in which environmental pressures (regulatory or market-driven) affect innovation in the industry. As noted in Chapter 1, innovation needs to be understood broadly, incorporating three distinct elements:

- the diffusion of existing technologies
- incremental adaptations and improvements to technologies currently in use
- the development of new technological solutions.

As will be pointed out below, the evidence emerging from this thesis suggests that the primary impact of environmental pressures on Canadian and Chilean pulp and paper firms has been to spur the adoption and adaptation of technology developed outside the industry — and for the most part outside the country. In other words, the first two elements of innovation listed above have predominated, with relatively less impact on the development and application of novel technical solutions. It is worth examining each type of change in more detail.

The most obvious impact of environmental pressures has been to spur the diffusion of existing “best practice” technologies for pollution prevention and control. In fact, the extent of diffusion of such technologies has been impressive in both countries. Particularly in the Canadian case, regulatory pressures have induced practically universal application of up-to-date pollution control equipment, and have thus significantly narrowed the gaps in environmental performance between leading and laggard firms. It also appears that regulatory pressures have had an indirect impact on firms’ decisions to undertake broader process change, by increasing the pressures on mills to modernize their overall operations and increase capacity in order to finance environmental improvements. Market-related pressures in both countries have similarly stimulated fairly widespread adoption of new process technologies, particularly changes to bleaching processes at bleached Kraft mills. A tentative conclusion, therefore, is that environmental pressures work primarily by promoting the diffusion of “best practice” technology, rather than by stimulating firms to look for entirely new technical options to reduce pollution. It is this distinction between proven, best-practice technology and novel solutions — rather than between in-plant and end-of-pipe measures — which best characterizes the kinds of changes made at mills in the sample.

There is also evidence of considerable effort by mills in both countries to make incremental, ongoing improvements to existing plant and machinery, searching for both environmental and economic improvements. Almost all firms in both countries showed evidence of at least some internal “housekeeping” improvements, and in most cases more complicated process optimization measures. At least in the Chilean case, minor improvements appear to be linked to scale and age of mills, with older and smaller mills more likely to engage in incremental improvements — reflecting the greater cost pressures facing such mills.

On the other hand, there is relatively little evidence of development of new technologies by respondent firms. This is not surprising in the Chilean case, given that overall R&D spending is low and is geared largely to improvements in the forest resource base. But even in Canada, where there is a stronger tradition of in-house research, the extent of innovation is limited. Only a minority of respondent firms indicated introducing product or process innovations in response to environmental pressures, and for the most part these involved relatively straightforward changes in product characteristics (recycled paper products, chlorine free papers) rather than process innovations. Innovations do not appear to have resulted in significant advantages in terms of environmental performance, nor cost savings for the firms involved. And the lack of a correlation between R&D spending and introduction of product/process innovations indicates that most innovations have originated outside the firm. There is no doubt that the need to respond to environmental pressures has resulted in a measure of research and development activity in both Canada and Chile. But the strong supplier-dominated nature of technical change in pulp and paper means that the extent of innovative stimulus is relatively weak, and is felt largely by outside technology suppliers and

consultants. Given the weakness of the domestic equipment supply base in both countries, this means that much of the innovative stimulus provided by environmental pressures in fact affects foreign technology suppliers rather than domestic firms.

Overall, then, regulatory pressures have not altered the pre-existing patterns of innovation in the two industries. There has been rapid diffusion of best-practice technology (end-of-pipe and process integrated), and continued incremental improvements to existing technologies. There has been some strengthening of technological capabilities within firms and in domestic engineering consulting firms in both countries. But R&D remains limited, and is oriented largely toward adaptation of imported technologies rather than development of new technical solutions. This continued “adopt and adapt” strategy has resulted in significant improvements in environmental performance, and considerable strengthening of capabilities for ongoing process improvements. But it seems unrealistic to expect that regulatory pressures will induce more radical innovations given the structural features of the industry.

One possible exception concerns recent research in Canada on closed-process technologies for Kraft pulping. This is a potentially important field of research, which could result in major advances in environmental performance. It is also more realistically within the grasp of the Canadian industry since in contrast to TCF technology or other process changes, it depends less on the existence of strong domestic equipment manufacturers, and more on mill-level technical expertise, strong scientific research, and adaptive R&D at the firm level.

II. Policy Implications

This thesis provides strong justification that environmental regulations do indeed “work”, at least in terms of their environmental objectives. Regulatory pressures have been the key influence on the environmental behaviour of Canadian pulp and paper firms over the past decade, and have stimulated a significant level of investment in improved environmental performance. Differences in regulatory pressures among Canadian provinces also appear to have exerted a significant influence on the environmental performance of mills, again reinforcing the extent to which regulations do promote environmental improvements. And comparisons of matched sets of Canadian and Chilean mills suggests that differences in regulatory pressures between the two countries exert a powerful influence on the nature of pollution abatement investments by firms and the resulting levels of environmental performance of mills — at least for older, established mills.

On the other hand, the extent to which regulations stimulate innovation is limited. Overall, this thesis suggest considerable caution in using environmental policy as instruments of innovation policy. Especially in a mature, supplier dominated industry like pulp and paper, the ability of policy-makers to induce innovation as a result of environmental regulations appears extremely limited. Frontier technology advances relatively slowly, with major advances coming almost entirely from outside suppliers. In countries like Canada and Chile where the domestic machinery and equipment industries lag well behind pulp and paper production, any innovative stimulus is likely to be directed almost entirely to foreign firms.

In fact, key relationships seem to go the opposite way — strengthening the innovative capabilities of industry and the domestic supply base is important to ensure strong environmental performance. Even though firms and domestic suppliers are not sources

of novel technical solutions, the existence of in-house R&D capabilities and strong networks of outside consultants/research institutes appears to be a pre-condition for successful adoption and adaptation of external sources of technology.

This suggests a number of tentative conclusions both for environmental policy and for innovation policy.

In terms of environmental policy, the effectiveness of policy instruments depends on the situation of the industry in question (patterns of innovation and technology supply, capital-intensity, etc). Clearly, however, relying on market pressures or foreign investment to promote environmental improvements in the absence of regulations is unlikely to deal adequately with the range of pollution problems faced by an industry like pulp and paper. There is no evidence that foreign ownership on its own translates into higher levels of environmental performance. Nor are export market pressures alone likely to promote across-the-board improvements in environmental performance: their impact is likely to be limited to process improvements which are easily reflected in product characteristics (e.g., changes to bleaching sequences) but may not spur other changes needed to deal with location-specific pollution problems. A rapidly growing industry like the Chilean pulp and paper industry — particularly one which is highly export-oriented — can probably count on new investment to significantly alter the overall environmental profile of the industry, but this will be not necessarily extend to older established mills.

Given limited enforcement capability, countries like Chile may wish to rely in particular on environmental impact assessment requirements, at least where there are significant new investments and a relatively small number of sources of pollution. But care also

needs to be taken to ensure that strict EIA and permitting requirements for new investments do not act as a disincentive to modernization plants at existing mills. For existing mills, flexible, negotiated approaches to compliance may yield benefits over mandated compliance approaches to regulations, providing older firms with an opportunity to adjust and consider cost-effective strategies for improving environmental performance. But care is needed on this front. The Canadian experience is unclear: on the one hand, provinces like Alberta which have more flexible, negotiated approaches to compliance appear to have been successful in promoting a mix of end-of-pipe and internal process changes at mills; on the other hand, earlier federal experiences with negotiated timetables for compliance resulted in widespread avoidance of regulations by the industry. The enforcement capacity of regulatory officials is critical here: in cases where regulators are weak and there are extreme information asymmetries between firms and regulators, negotiated approaches are probably less effective than mandated compliance strategies.

Research results also suggest that corporate-level environmental policies exert a significant influence over mill-level performance. While most regulatory attention has been focused at the mill level, there may well be options for governments to enhance corporate-level commitments to environmental management — through public education campaigns, information-based measures to publicize pollution problems, or public support to environmental management and certification programs.

In terms of innovation policies, two issues appear to be critical. The first of these is how to improve overall R&D and technical capabilities within firms. As noted earlier, adaptive R&D at the firm and mill level appears to exert a powerful influence on the ability of firms to realize environmental improvements. A variety of options are possible here, from

direct public sector funding of R&D programs (e.g., Industry Canada's support to Paprican research on closed cycle processes) to training subsidies to improve the overall technical skills of mill staff. Canada's experience with industry-funded consortia for pre-competitive R&D has been a strong success, and holds out the promise of continued contributions to improved environmental performance by Canadian mills. While the number of firms in a country like Chile makes this kind of approach less feasible, there may be scope for more restricted experiments in collaborative R&D, either in Chile on its own or in collaboration with other firms in the region (Brazil, Argentina).

The second, longer-run challenge concerns measures to strengthen the local supply base. Given weaknesses in the domestic equipment supply industry in both countries, rapid creation of a strong pulp and paper "cluster" along Finnish or Swedish lines appears unrealistic. But more limited, targeted measures may have some impact. In particular, the shift of public sector research funding in Canada away from individual projects and toward broad "memoranda of understanding" involving pulp and paper firms, research institutions and supplier firms may hold out promise for the development of stronger supply capabilities in particular niches in the future (e.g., the process closure activities mentioned above). Continued efforts in both countries to encourage linkages with consulting enterprises (e.g., for effluent monitoring) may also help to build a base of expertise outside pulp and paper firms necessary to ensure innovation and improved environmental performance over the longer run.

III. Directions for Future Research

As always in a project of this scope, a number of key questions remain unanswered – or

at least incompletely answered. While the thesis has been able to advance at least tentative responses to the main research questions, the analysis also suggests a number of areas in which further research is warranted. Some of these arise from limitations in the data available for the current analysis. As noted at the outset, it has not been possible to give adequate attention to all aspects of the conceptual framework outlined in Chapter 2. In particular, more detailed work is clearly needed to assess the ways in which outside technology suppliers have been affected by environmental regulations (particularly in the Canadian case) and to understand the manner in which the broader competitive and financial picture of firms affects their responses to environmental pressures.

Beyond this, research would clearly be enriched by examining additional country and sectoral experiences in order to provide greater variation in some of the key explanatory variables advanced in the current study. While the pulp and paper industry is an ideal case in terms of its pollution intensity, it is not clear whether the main conclusions outlined above would also apply in other industries which are less supply-driven, where there is greater variation (and more rapid change) in core process technology, or where there is a greater variation in firm and plant size.

Within the pulp and paper industry, it would also be instructive to examine additional country experiences – particularly countries like the United States and the Nordic countries, where the domestic equipment supply base is more developed, and where it might be expected that regulations would be more likely to induce major technological breakthroughs. Analysis of the Chilean case has also been constrained by the small number of mills and the high degree of inter-corporate holdings, as well as by the high correlation between age and export orientation of Chilean mills. It would be interesting

to compare the findings of the Chilean case with other developing countries (e.g., Brazil, Argentina) both to increase the number of cases available for analysis and to permit examination of a broader range of established pulp and paper firms serving both domestic and international markets. In the case of Canada, meanwhile, the particular nature of foreign ownership in the industry (almost entirely from US and Japanese sources) limits our ability to draw conclusions about the ways in which home-country regulations affect firms' responses to regulation in host markets; future research should focus on countries where there is significant greater variation in home- and host-country regulatory requirements, and/or greater variation in the sources of foreign investment.

In terms of methodological approaches, future research should continue to combine aggregate analysis with more in-depth case studies. Many of the issues raised by this thesis demand a detailed assessment of decision-making within individual firms, of a kind which can only be achieved through case-study analysis. While this thesis has taken some steps in this direction (notably in Chile) there is still a need for analysis of longer-term trends in environmental action by particular firms, and for careful analysis of matched pairs of firms in more- and less-regulated settings.

Finally, the thesis has raised a number of new questions not foreseen at the outset which would benefit from additional research. One of these concerns the impact of alternative policy instruments on the process of innovation. Chapter 2 discussed the debate over the merits of "market-based" versus "command and control" instruments for pollution control, and this clearly needs more empirical analysis from an innovation perspective. As noted, the use of market-based instruments is still a rarity in industries like pulp and paper. But other types of instruments beyond traditional regulations may be important, and deserve additional study. (e.g., information-based measures to

ensure greater public awareness of pollution problems, which were mentioned in Chapter 2). There is also need for closer analysis of the way in which environmental impact assessment requirements may affect the process of innovation, and the conditions under which they are most likely to be successful. This is particularly true of countries like Chile where new investment has been significant, and where EIAs may well constitute an effective alternative to traditional regulations, at least in the short-run. There are also a number of unresolved issues concerning some of the finer points of regulatory design, as noted in the last section. Of particular interest are the relative merits of negotiated vs mandated compliance approaches: while a number of Canadian respondents argued that more flexible, negotiated approaches would permit them to achieve more significant internal pollution prevention actions at less cost, the past history of the industry with negotiated compliance approaches raises significant concerns about the extent to which such an approach may lead to “capture” of regulatory officials, and thus forestall significant improvements in environmental performance.

The other unexpected finding of this thesis concerns the impact of firm- and mill-scale on environmental performance. The results reported in this thesis suggest a somewhat more nuanced view of scale economies than that found in some earlier studies. There may well be some scale economies at the mill level as a result of the capital costs of pollution prevention and control equipment — at least among mills using similar production processes. But these are not a critical determinant of levels of investment, and do not appear to translate into superior performance by larger mills. In fact, small scale may increase the cost pressures on mills, and thus induce them to search more actively for lower-cost, higher-return opportunities for pollution reduction through

process optimization and minor process changes. Firm-level scale appears more significant, with larger firms enjoying significant advantages in terms of the scale of investment required in order to meet specified levels of environmental performance. But once again, this does not necessarily result in superior environmental performance by larger firms. To the extent that larger firms enjoy better levels of performance at their mills, this is due to their greater average R&D spending than smaller firms, and the greater likelihood that large firms will have well-developed corporate environmental policies. Other attributes of larger firms (greater financial resources, ability to learn across a number of mills) appear less important. Clearly, the scale issue is one which demands significantly greater research attention in the future.

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Appendix 1:
Survey Instrument, Canada

**Questionnaire Survey : Regulation, Environmental Management and
Innovation in the Canadian and Chilean Pulp and Paper Industries**

Instructions to Respondents

This questionnaire is part of a larger research project examining the ways in which pulp and paper firms in Canada and Chile are responding to changing environmental policies and practices. The research will form the basis for a PhD dissertation to be submitted to the Faculty of Graduate Studies, Carleton University .

The current survey is being administered to senior executives (Vice-President Environment or equivalent) in pulp and paper firms in Canada and parallels a series of interviews carried out in Chile in 1996. Responses to this survey will be treated confidentially, with data appearing only in aggregate form.

The survey is organized in two sections. Part I consists of a short series of questions designed to provide basic background information on respondent firms, current environmental policies, and attitudes toward environmental regulation. Part 2 is a one-page checklist of recent environmental investments, to be completed for individual pulp and paper mills. In cases of companies with more than one mill, separate responses are requested to Part 2, with information provided on a mill basis.

Completed questionnaires should be returned in the enclosed pre-addressed envelope. For more information, please contact me at the following address:

Brent Herbert-Copley
237 Lennox Street
Ottawa, Ontario
K1G 0K3
tel (613) 733-9255 or 236-6163, ext 2322
fax (613) 567-7749
e-mail: bherbert@idrc.ca

THANK YOU IN ADVANCE FOR YOUR COOPERATION

Please detach and return this form with the completed questionnaire if you would like to receive a summary of the survey results, or if you would be willing to participate in follow-up interviews and/or site visits.

☐ I would like to receive a summary of the survey results.

☐ I would be willing to participate in follow-up interviews and/or site visits

Name:

Position:

Company:

Address:

Phone/Fax:

PART 1: Corporate Environmental Policies and Practices

Note: This section of the questionnaire is to be completed on a company basis; Part 2 deals with individual mill-level information.

1. Name of firm: _____

2. Size of firm: 1996 sales, \$000 CAD _____
Number of employees _____

3. Ownership: ☐ wholly Canadian-owned
☐ joint venture with foreign firm
☐ wholly foreign owned

4. Does your firm have a formal environmental policy?
☐ Yes
☐ No

5. Do you publish an annual environmental report, or include information on environmental performance in your corporate annual report?
☐ Yes
☐ No

6. Approximately what percentage of your 1996 R&D was devoted to environmental issues?

- ☐ less than 10%
☐ between 10 and 50%
☐ more than 50%
☐ no formal R&D spending by firm
☐ don't know

7. Over the past five years, has environment-related R&D spending by your firm

- ☐ increased substantially
☐ increased marginally
☐ remained constant
☐ decreased marginally
☐ decreased substantially

8. How important is each of the following factors in your firm's decisions to engage in environment-related investments? Please rate on a scale from 1 (not at all important) to 5 (very important):

	Not at all important			Very important	
	1	2	3	4	5
a) domestic environmental regulations	1	2	3	4	5
b) consumer demand in Canadian market	1	2	3	4	5
c) consumer demand in export markets	1	2	3	4	5
d) corporate image/policy	1	2	3	4	5
e) influence of parent or partner firms	1	2	3	4	5
f) expected cost savings	1	2	3	4	5
g) other (specify) _____	1	2	3	4	5

9. What do you see as the main constraints to improvements in environmental performance by your firm? Please rate each factor on a scale from 1 (not at all important) to 5 (very important):

	Not at all important			Very important	
	1	2	3	4	5
a) unclear or overlapping regulations	1	2	3	4	5
b) lack of financing	1	2	3	4	5
c) cost/impact on competitive position of firm	1	2	3	4	5
d) lack of proven technology	1	2	3	4	5
e) uncertainty regarding future regulations	1	2	3	4	5
f) lack of flexibility in enforcement of regulations	1	2	3	4	5
g) other (specify) _____	1	2	3	4	5

10. How important is each of the following sources of technological know-how in achieving environmental improvements by your firm? Please rate on a scale from one (not at all important) to 5 (very important):

	Not at all important			Very important	
	1	2	3	4	5
a) in-house R&D efforts	1	2	3	4	5
b) in-house production and engineering experience	1	2	3	4	5
c) parent or partner firms	1	2	3	4	5
d) equipment suppliers	1	2	3	4	5
e) consulting engineering companies	1	2	3	4	5
f) joint industry-funded research programs (Paprican)	1	2	3	4	5
g) universities or public sector research institutions	1	2	3	4	5
h) other (specify) _____	1	2	3	4	5

11. Have environmental improvements resulted in any of the following positive impacts on your firm? Please check all that apply.

- ☐ decreases in energy costs
- ☐ decreases in other input costs
- ☐ reduced wastage, higher yields
- ☐ development of new "green" products
- ☐ development of new process technology
- ☐ improvements in R&D or engineering capabilities
- ☐ improved public image
- ☐ improved employee morale
- ☐ enhanced ability to sell products in export markets
- ☐ other (specify) _____

12. Aside from capital costs, have environmental improvements resulted in any of the following negative impacts on your firm? Check all that apply.

- ☐ decline in product quality
- ☐ increased maintenance and repair costs
- ☐ increased energy costs
- ☐ increased training costs
- ☐ input supply problems (e.g. shortages of recycled fibre)
- ☐ increased costs for solid waste disposal
- ☐ other (specify) _____

13. How have recent changes to federal and provincial environmental regulations (for example, changes to the Fisheries Act and Canadian Environmental Protection Act introduced in 1992) affected your firm? Please check all that apply.

- ☐ no impact; firm was already in compliance
- ☐ upgrades were part of investment programs planned in advance of regulatory changes
- ☐ changes in specific aspects of investment plans due to regulatory changes
- ☐ introduction of new investment plans specifically in response to regulations
- ☐ closure of mills
- ☐ decrease in production levels to ensure compliance
- ☐ other (specify) _____

14. In developing new environmental regulations (federal and/or provincial) do you feel that government consultation with the pulp and paper industry has been

- ☐ good?
- ☐ adequate?
- ☐ inadequate?
- ☐ don't know

15. Do you have any further comments or observations which might clarify your responses to any of the above questions?

Part 2 : Current Environmental Investments

Note: The following questions are to be answered on an individual mill basis. In the case of companies with more than one pulp mill, separate responses should be prepared for each mill, using the response sheets provided.

1. Mill location: Dryden

2. Date of construction: _____

3. Production capacity (adt/day)

- Pulp _____
- Paper and board _____

4. Approximate distribution of 1996 sales, by destination (percent):

- _____ Canada
- _____ United States
- _____ Western Europe
- _____ Other

5. Type of process (please check all that apply)

- ☐ groundwood
- ☐ TMP/CTMP
- ☐ Kraft
- ☐ sulphite
- ☐ other (specify): _____

6. Is pulp production at the mill:

- ☐ bleached
- ☐ unbleached
- ☐ both

7. Please indicate the types of environment-related changes introduced at the mill since 1990. Note that not all categories will be applicable to each mill.

a) In-plant changes

Change of process (e.g., sulphite to CTMP)

☐

General "housekeeping" measures (tightening circuits, reduced water use)

☐

Changes to bleaching stage

- partial ClO₂ substitution
- full ClO₂ substitution
- non Cl bleaching (ozone, peroxide)

☐

Improved process control

☐☐

Improved energy efficiency of machinery

☐☐

Increased use of recycled fibre

☐

Changes to pre-bleaching stage

- oxygen delignification
- improved pulp washing

☐

Co-generation

☐☐

Other (specify): _____

☐

Improved fibre and/or chemical recovery

☐

b) External treatment

New primary treatment of liquid effluent

☐

Improved solid waste handling/disposal

☐

Upgrades to existing primary treatment

☐

New/upgraded treatment of gaseous emissions

☐

New secondary treatment of liquid effluent

☐

Other (specify) _____

☐

Upgrades to existing secondary treatment

☐

8. Approximate value of environment-related investment expenditures, 1990-1996 (\$000 CAD): _____

9. How have environmental improvements affected operating costs (excluding capital costs) at your mill?

- ☐ decreased
- ☐ no change
- ☐ moderate increase
- ☐ significant increase
- ☐ don't know/too early to tell

THANK YOU FOR YOUR COOPERATION

Appendix 2:
Correlation Matrices, Canada

- - Correlation Coefficients - -

	KEXP3	COMBRED	PERFORM	NONATLAN	CONCOST2	CONCOST3
KEXP3	1,0000 (52) P= ,	,1520 (47) P= ,308	,0307 (52) P= ,829	,1539 (52) P= ,276	,2656 (51) P= ,060	,3239 (51) P= ,020
COMBRED	,1520 (47) P= ,308	1,0000 (51) P= ,	,4859 (51) P= ,000	,3712 (51) P= ,007	,2961 (51) P= ,035	,2288 (51) P= ,106
PERFORM	,0307 (52) P= ,829	,4859 (51) P= ,000	1,0000 (56) P= ,	,4219 (56) P= ,001	,0002 (55) P= ,999	-,0619 (55) P= ,653
NONATLAN	,1539 (52) P= ,276	,3712 (51) P= ,007	,4219 (56) P= ,001	1,0000 (56) P= ,	-,0238 (55) P= ,863	-,0049 (55) P= ,972
CONCOST2	,2656 (51) P= ,060	,2961 (51) P= ,035	,0002 (55) P= ,999	-,0238 (55) P= ,863	1,0000 (55) P= ,	,9706 (55) P= ,000
CONCOST3	,3239 (51) P= ,020	,2288 (51) P= ,106	-,0619 (55) P= ,653	-,0049 (55) P= ,972	,9706 (55) P= ,000	1,0000 (55) P= ,
EUSALE	,3264 (42) P= ,035	-,0513 (42) P= ,747	,0028 (46) P= ,985	,0852 (46) P= ,573	-,1298 (45) P= ,395	-,0748 (45) P= ,626
FOREIGN	-,0792 (49) P= ,589	-,1855 (49) P= ,202	-,0633 (53) P= ,652	-,1486 (53) P= ,288	-,1145 (52) P= ,419	-,0492 (52) P= ,729
LOGEMPL	-,1575 (49) P= ,280	,2434 (48) P= ,096	,3545 (53) P= ,009	,1677 (53) P= ,230	,0879 (52) P= ,535	,0983 (52) P= ,488
TOTCAP2	,0292 (52) P= ,837	-,1188 (51) P= ,406	-,1980 (56) P= ,143	,1666 (56) P= ,220	-,0381 (55) P= ,782	,0663 (55) P= ,630
R_D2	-,2826 (52) P= ,042	,0571 (51) P= ,691	,2957 (56) P= ,027	,1854 (56) P= ,171	-,0875 (55) P= ,525	-,0955 (55) P= ,488

(Coefficient / (Cases) / 2-tailed Significance)

" , " is printed if a coefficient cannot be computed

- - Correlation Coefficients - -

	KEXP3	COMBRED	PERFORM	NONATLAN	CONCOST2	CONCOST3
ENVRPT	,1196 (52) P= ,398	,1121 (51) P= ,433	,3012 (56) P= ,024	-,0162 (56) P= ,905	,0770 (55) P= ,576	,1080 (55) P= ,433

(Coefficient / (Cases) / 2-tailed Significance)

" , " is printed if a coefficient cannot be computed

	EUSALE	FOREIGN	LOGEMPL	TOTCAP2	R_D2	ENVRPT
KEXP3	,3264 (42) P= ,035	-,0792 (49) P= ,589	-,1575 (49) P= ,280	,0292 (52) P= ,837	-,2826 (52) P= ,042	,1196 (52) P= ,398
COMBRED	-,0513 (42) P= ,747	-,1855 (49) P= ,202	,2434 (48) P= ,096	-,1188 (51) P= ,406	,0571 (51) P= ,691	,1121 (51) P= ,433
PERFORM	,0028 (46) P= ,985	-,0633 (53) P= ,652	,3545 (53) P= ,009	-,1980 (56) P= ,143	,2957 (56) P= ,027	,3012 (56) P= ,024
NONATLAN	,0852 (46) P= ,573	-,1486 (53) P= ,288	,1677 (53) P= ,230	,1666 (56) P= ,220	,1854 (56) P= ,171	-,0162 (56) P= ,905
CONCOST2	-,1298 (45) P= ,395	-,1145 (52) P= ,419	,0879 (52) P= ,535	-,0381 (55) P= ,782	-,0875 (55) P= ,525	,0770 (55) P= ,576
CONCOST3	-,0748 (45) P= ,626	-,0492 (52) P= ,729	,0983 (52) P= ,488	,0663 (55) P= ,630	-,0955 (55) P= ,488	,1080 (55) P= ,433
EUSALE	1,0000 (46) P= ,	,1571 (43) P= ,314	,1101 (43) P= ,482	,1322 (46) P= ,381	-,0788 (46) P= ,603	-,0319 (46) P= ,834
FOREIGN	,1571 (43) P= ,314	1,0000 (53) P= ,	-,3638 (51) P= ,009	,1104 (53) P= ,431	-,0100 (53) P= ,944	-,3917 (53) P= ,004

(Coefficient / (Cases) / 2-tailed Significance)

" , " is printed if a coefficient cannot be computed

- - Correlation Coefficients - -

	EUSALE	FOREIGN	LOGEMPL	TOTCAP2	R_D2	ENVRPT
LOGEMPL	,1101 (43) P= ,482	-,3638 (51) P= ,009	1,0000 (53) P= ,	,2249 (53) P= ,105	,4865 (53) P= ,000	,6350 (53) P= ,000
TOTCAP2	,1322 (46) P= ,381	,1104 (53) P= ,431	,2249 (53) P= ,105	1,0000 (56) P= ,	,0735 (56) P= ,591	,0347 (56) P= ,800
R_D2	-,0788 (46) P= ,603	-,0100 (53) P= ,944	,4865 (53) P= ,000	,0735 (56) P= ,591	1,0000 (56) P= ,	,1252 (56) P= ,358
ENVRPT	-,0319 (46) P= ,834	-,3917 (53) P= ,004	,6350 (53) P= ,000	,0347 (56) P= ,800	,1252 (56) P= ,358	1,0000 (56) P= ,

(Coefficient / (Cases) / 2-tailed Significance)

" , " is printed if a coefficient cannot be computed

IMAGE EVALUATION TEST TARGET (QA-3)

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Fax: 716/288-5989

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