HEC MONTRÉAL
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What really drives environmental disclosure?

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Résumé

La responsabilité sociale est un sujet important dans le milieu des affaires et dans les médias à cause des pressions provenant des différentes parties prenantes. Le gouvernement, les investisseurs, les dirigeants et les administrateurs des entreprises, les organisations des industries, les environnementalistes et le milieu académique demandent une meilleure qualité de la communication environnementale des entreprises, ainsi qu'une meilleure évaluation de l'impact présent et futur de leurs activités sur l'environnement. Les recherches sur la fiabilité de la communication environnementale portent sur la relation entre la performance environnementale de l'entreprise et sa communication environnementale. Une communication environnementale fiable devrait refléter la performance environnementale réelle de l'entreprise, avec tous ses aspects. Tant qu'une relation positive qu'une relation négative entre la performance environnementale et la communication environnementale des entreprises ont été mises en évidence dans la littérature scientifique. Les entreprises qui ont une meilleure performance environnementale tendent à communiquer plus sur leurs réalisations que les autres entreprises. Par contre, les managers peuvent aussi utiliser la communication environnementale de leur entreprise comme un moyen de cacher une moins bonne performance environnementale.

La motivation de cette étude réside dans la demande accrue d'une communication environnementale fiable de la part d'une gamme élargie des parties prenantes. Cette recherche porte sur la fiabilité de la communication environnementale et analyse la relation entre la performance environnementale et la communication environnementale de l'entreprise, en considérant l'innovation environnementale comme un facteur important qu'influence cette relation. Par innovation environnementale, nous entendons la révision et la mise à jour du design des produits et des processus de production avec une focalisation sur la réduction ou l'élimination des inefficiences et la diminution des émissions et des déchets polluants.

Sur un échantillon de 210 entreprises américaines, provenant des industries reconnues les plus polluantes, nous mettons en évidence le rôle modérateur joué par l'innovation environnementale. Nos résultats nous portent à croire que le niveau de divulgation environnementale est associé à la performance environnementale, mais l'amplitude de la divulgation diffère selon que l'entreprise est innovante ou non en matière d'environnement. Les entreprises non innovatrices ont tendance à divulguer significativement plus lorsque leur performance environnementale augmente. Nous observons l'effet contraire pour les entreprises innovantes. De façon générale, ces entreprises ont tendance à divulguer significativement plus que les entreprises non innovantes. Mais, cet écart tend à se résorber au fur et à mesure que leur performance environnementale s'accroît. Nos résultats empiriques montrent que cet écart est totalement résorbé lorsque la performance environnementale atteint un certain niveau. Pour les firmes innovantes, il semblerait y avoir un effet de substitution des déterminants de la divulgation environnementale. À bas de niveau de performance, les firmes innovantes divulguent leur stratégie d'innovation et leur plan d'action pour est plus performant en matière d'environnement. Lorsqu'ils deviennent performants, le contenu de leur divulgation est plus centré sur les éléments de performance.

Cette étude surligne le rôle important de l'innovation environnementale par rapport à la communication environnementale d'une entreprise. Les résultats de cette recherche pourront être utilisés par les législateurs et les organismes de régulation pour encourager les entreprises à trouver des solutions innovatrices dans le but de réduire l'impact de leurs activités sur l'environnement. Une réglementation qui favoriserait l'innovation environnementale devrait conduire à un plus haut niveau de développement durable. Les entreprises qui adoptent des stratégies environnementales proactives et innovatrices seront capables de réviser et restructurer leurs processus technologiques, réduire le niveau d'inefficiences et de retombées polluantes Cette recherche contribuera à une meilleure compréhension par les acteurs corporatifs et le public du rôle important joué par l'innovation environnementale dans la stratégie de communication environnementale de l'entreprise.

Mots clés: communication environnementale, performance environnementale, innovation environnementale, fiabilité de la communication environnementale.

Abstract

Sustainability is a hot topic in business and the media due to increasing pressure from different stakeholders. Governments, investors, managers, industry organizations, environmentalists, and academics require better disclosure of firm environmental performance and better evaluation of actual and future environmental impact. The accuracy or reliability of environmental disclosure has been investigated by examining the relationship between environmental performance and environmental disclosure. Accurate or reliable environmental disclosure should reveal an organization's true environmental performance. Both a positive and a negative association between environmental performance and environmental disclosure have been noted in the literature. Firms with better environmental performance tend to disclose more about their good performance than other types of firms. But, it has also been argued that managers may use environmental disclosure as a legitimizing tool to conceal their bad environmental performance.

This study is motivated by the growing need for reliable environmental disclosure from a wide range of interested stakeholders. It analyzes the reliability of environmental disclosure by examining the relationship between environmental performance and environmental disclosure and considers environmental innovation as an important factor that influences this relationship and explains environmental disclosure. Environmental innovation implies reviewing and updating product design and the production process with a focus on reducing inefficiency and lowering waste.

Using a sample of 210 US firms from environmentally sensitive industries in 2011, we find empirical evidence of the moderating role played by environmental innovation. Results show that the level of environmental disclosure is positively associated with environmental performance, and also with environmental innovation. Firms with no environmental innovation tend to disclose more when their

environmental performance is better, contrary to environmental innovative firms. Generally, environmental innovative firms disclose significantly more than non-innovative firms, but the disclosure gap tends to be mitigated as their environmental performance increases. Empirical results show that the gap is completely absorbed when environmental performance reaches a certain high level. For environmental innovative firms, it seems to be a substitution effect of determinants of environmental disclosure. At low level of environmental performance, environmental innovative firms disclose more about their innovative strategy and action plan to become a better environmental performer. When they become good performers, environmental disclosure is more focused on performance elements. This study contributes to a better understanding of firms' environmental disclosure.

Keywords: Environmental disclosure, environmental performance, environmental innovation, reliability of environmental disclosure.

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List of Acronyms

CSR – Corporate Social Disclosure

EMS – Environmental Management System

GRI - Global Reporting Initiative

IFRS - International Financial Reporting Standards

IPC - International Patent Classification

ISO – International Organization for Standardization

R&D – Research and Development

SD – Standard Deviation

TRI - Toxic Release Inventory

US GAAP - Generally Accepted Accounting Principles in the United States

VIF - Variance Inflation Factor

WIPO - World Intellectual Property Organization

À Aida et Felix

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Introduction

Pollution, climate change, and the preservation of life and health on our planet are subjects on agenda of increasing numbers of stakeholders, such as corporate management, employees, governments, investors, environmentalists, researchers, and analysts. Stakeholders are concerned about ethical performance and keeping the environment healthy for present and future generations. Consequently, corporate social responsibility (CSR), including environmental strategies, activities, and innovation, is being actively scrutinized. In reaction, more and more firms voluntarily disclose information about their environmental activities, performance, and impacts.

In spite of this growing interest in the corporate environment activities, pollution continues to increase and environmental incidents happen. This raises questions about the accuracy or reliability of environmental information disclosed by organizations. Is the environmental disclosure a true reflection of the firm's environmental performance? Do firms use this channel mainly to legitimize their environmental actions? Does an efficient tool exist with which to appropriately discern the reliability of environmental information? What really drives environmental disclosure? This research strived to shed light on these questions by examining the reliability of corporate environmental disclosures. Environmental innovation is considered a key determinant of environmental disclosure.

Generally Accepted Accounting Principles in the United States (US GAAP) define verifiable and objective information as reliable. International Financial Reporting Standards (IFRS), in their 1989 framework, indicate

> *"Information has the quality of reliability when it is free from material error and bias and can be depended upon by users to represent faithfully that which it either purports to represent or could reasonably be expected to represent" 1989 IFRS Framework, para.31*

The 2014 conceptual framework of IFRS uses the term *faithful representation* instead of the term *reliability* as one of fundamental qualitative characteristics of useful financial reporting. Information is reliable when is a faithful representation of a transaction, event or condition, reflecting the economic substance and not the legal form, complete, neutral and free from error. Other fundamental qualitative characteristics of financial reporting are relevance and materiality. Environmental disclosure should also present these characteristics to be useful to firm's stakeholders for making decision.

The relationship between a firm's environmental performance and environmental disclosure is an indicator of the reliability of its environmental disclosure. A reliable corporate environmental disclosure should therefore properly and fairly report a firm's environmental performance.

Prior research on the relationship between environmental performance and environmental disclosure finds mixed evidence. A number of studies find evidence of a positive relationship: Al-Tuwaijri et al. (2004), P. Clarkson et al. (2006), Dawkins and Fraas (2011); other studies highlight a negative relationship: Hughes et al. (2001), Patten (2002), Charles Cho and Patten (2007), Cormier et al. (2011), while others find no association between environmental performance and environmental disclosure: Ingram and Frazier (1980), Wiseman (1982), Freedman and Wasley (1990), Fekrat et al. (1996). These disparate results could be caused by the fact that different methods were used to measure environmental disclosure and performance, the use of different samples from different industries that are more or less environmentally sensitive, and research conducted in countries with different environmental regulations. Omitted variables such as environmental innovation could also be a source of these discrepancies.

This research investigates competing predictions of the relationship between environmental performance and environmental disclosure from two different theoretical perspectives: economic voluntary disclosure theory and sociopolitical theories. We contend that environmental innovation plays an important role in this relationship. Environmental innovation interacts with environmental performance to determine

environmental disclosure. Environmental innovative firms have incentives to disclose more about their environmental innovations when they are poor environmental performers. They will tend to inform stakeholders about their innovation and strategies to become better environmental performers.

Environmental disclosure includes both voluntary and mandatory disclosure, such as that collected from the firm's annual report (Form 10-K), sustainability report, CSR report, and other environmental information disclosed on the firm's website, such as a sustainable development portal or a health, safety, security, and environment commitment.

Results confirm economic voluntary disclosure theory prediction of a positive association between environmental performance and environmental disclosure. The level of environmental disclosure is positively associated with environmental performance, but is also positively associated with environmental innovation. We find evidence of a significant moderating effect of environmental innovation on the association between environmental performance and environmental disclosure. Environmental innovative firms tend to disclose significantly more than non-innovative firms when both are considered poor environmental performers. Disclosure gap tends to be mitigated as their environmental performance increases. Empirical results show that this disclosure gap is completely absorbed when firms reach a certain level of environmental performance. For environmentally innovative firms, there seems to be a substitution effect. At low level of environmental performance, environmental innovative firms disclose more about their innovative strategy and action plan to become better environmental performer. When they become good environmental performers, environmental disclosure is more focused on performance.

These findings provide new evidence of the meaningful role played by environmental innovation in improving environmental disclosure.

This paper is structured as follows: Chapter I reviews the literature on environmental disclosure and environmental innovation, Chapter II describes the hypothesis development, and Chapter III provide details about the sample and the research method. Empirical findings are presented in Chapter IV, followed by a discussion and conclusion in Chapter V.

Chapter I. Literature review of environmental disclosure and environmental innovation

Social and environmental accounting deals with a wide range of voluntary and mandatory disclosures of the social and environmental activities of an organization that are designed to respond to stakeholders' demands. The social and environmental accounting literature has a recent history, starting only in the 1970s. It includes research with a focus on employees, products and activities that concern local communities, society and customers. But, the main focus has been on environmental accounting. This research specifically investigates environmental disclosure and its presumed link with environmental performance.

Literature on environmental innovation is scarce. Research considers mainly general innovations instead of specific environmental innovation. The link of environmental innovation with environmental disclosure is not enough studied.

In this section we will first review the main theoretical framework and empirical studies on environmental disclosure and environmental innovation. We will then cover related studies from non-accounting literature and the regulatory framework surrounding environmental disclosure. The last section will be dedicated to radical/critical literature.

1.1. Theoretical framework development of environmental disclosure

One of the first contributors to the theoretical development of environmental accounting was Ramanathan (1976). This study has set up objectives and clarified key concepts for social accounting. Also in 1976, A. E. Ullmann (1976) developed a corporate environmental accounting model that includes non-financial and physical measures of environmental inputs and outputs. With the purpose of

measuring and reporting the economic activities that affect society, Ullmann criticizes the monetary input approaches used in environmental accounting. The weakness of these CSR financial costs approaches is that they do not reflect the efficiency or the adequacy of the money spent. Ullmann's model measures financial costs and nonmonetary environmental effects of economic activities, including discharge of pollutants in air, water and soil and consumption of resources, as materials and energy.

Environmental disclosure can be used to signal good environmental performance, but, in the case of poorer performance, it also can be used as a legitimacy tool. Two competing theories, economic and sociopolitical, explain these two determinants of environmental disclosure. However, as Gray et al. (1995) indicate, the use of different theoretical perspectives to explain environmental disclosure does not imply a competition between explanations. These theories complete each other and enrich our comprehension of environmental disclosure.

1.1.1. Economic theories

Economic theories model environmental disclosure as a tool to signal good environmental performance. Voluntary disclosure theory derives from agency theory applied to environmental disclosure.

Agency theory

A permanent asymmetry of information exists between principals and shareholders and between agents and managers. M. C. Jensen and W. H. Meckling (1976) define the agency relationship as a contract under which the principal engages the agent to perform some service on its behalf, which involves delegating some decision making authority to the agent. This contractual relationship creates information asymmetry between the principal and the agent because their interests diverge.

Figure 1-1 presents the model of a firm derived from the agency theory. Agency theory considers that firm value is diminished by the underlying cost of the agency relationship, that is, the principal's

monitoring expenditures, the agent's bonding expenditures, and the residual loss, a reduction in the principal's welfare. And, this cost varies across firms.

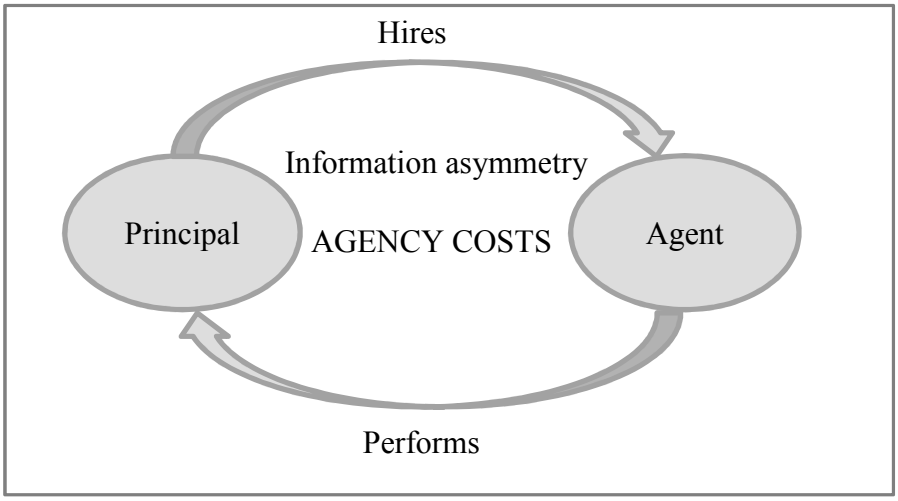

Figure 1-1: Model of a firm in agency theory (M. Jensen & W. Meckling, 1976)

Voluntary disclosure theory

According to Lev (1992) a voluntary information disclosure strategy contributes to narrowing the information gap between investors and management and decreases agency costs. A firm's voluntary disclosure strategy can increase a firm's value in terms of reduced cost of capital and improved terms of trade and covenants by changing the stakeholders' perceptions about the firm and its market value.

Voluntary disclosure theory posits that firms with good environmental performance have incentives to send a signal to the market about their good performance through voluntary disclosure and to increase their firm valuation. Bad performers will take profit from remaining silent and being considered by the stakeholders as average performers (P. Clarkson et al., 2008). Li et al. (1997) and Bewley and Li (2000) find that firms with good environmental performance have incentives to inform investors and stakeholders about their performance by providing extensive voluntary environmental disclosure. Bad performers refrain from disclosing information about their environmental performance, arguing that

disclosure implies costs. Verrecchia's model (1983) shows indeed that disclosure-related costs explain managerial discretion in the disclosure of information. Managers can also choose to selectively disclose good information and suppress bad information (Dye, 1985).

Agency theory can be generalized to stakeholders, including employees, customers, suppliers, creditors, governments, communities, industry associations, and the general public (Hill & Jones, 1992). The relationship between managers and shareholders is seen as a nexus of contract, but it could be extended to include other contracts between stakeholders and managers. Economics-based voluntary disclosure theory predicts a positive association between environmental performance and environmental disclosure (P. Clarkson et al., 2008). Good environmental performers have incentives to disclose more about their good environmental performance through voluntary environmental disclosure. Voluntary environmental disclosure is value relevant for stakeholders and leads to increased firm valuation.

Lyon and Maxwell (2011) consider as environmental greenwash the selective disclosure of positive information while withholding negative information about environmental performance. They develop an economic model of greenwash and conclude that greater activist pressure discourages greenwash and triggers less environmental disclosure.

1.1.2. Sociopolitical theories

Sociopolitical theories explain the use of environmental disclosure from the perspective of stakeholder theory, institutional and legitimacy theory.

Stakeholder theory

A stakeholder in an organization is defined by Freeman (1984) as any group or individual who can affect or is affected by the achievement of the organization's objectives. The model of the firm under the stakeholder theory is presented in Figure 1-2.

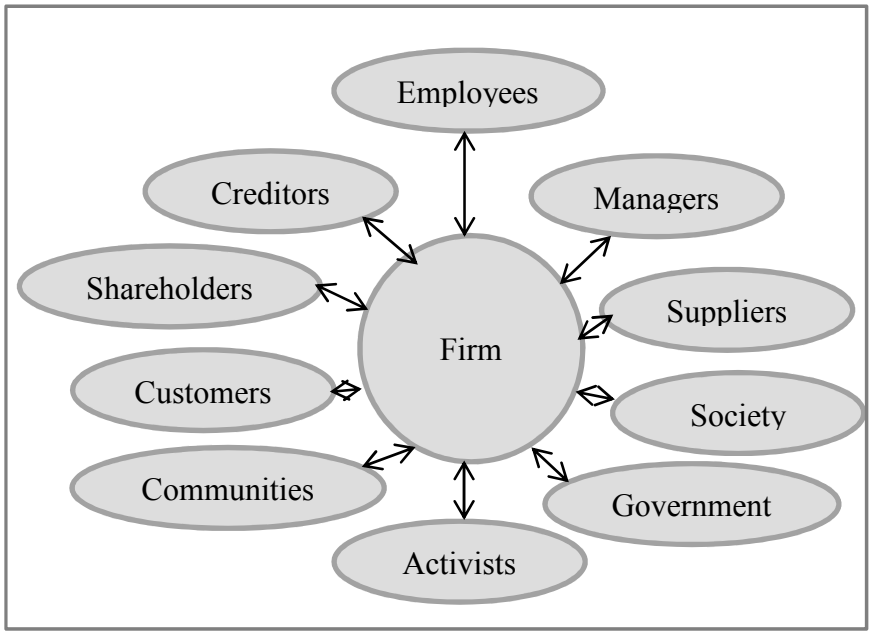

Figure 1-2: Model of a firm in stakeholder theory

Stakeholders include shareholders, employees, customers, suppliers, creditors, governments, communities, activists, industry associations, the media, and the general public. Stakeholder attributes identified by Mitchell et al. (1997) are power (control of material, financial, or symbolic resources), legitimacy (desirable social good), and urgency (imperative, criticality). These attributes are not fixed and evolve over time (Magness, 2008).

Stakeholder pressure typically triggers two types of behavior. Reactive stakeholder management looks at past activities and at lessons learned from the past. They will minimize or avoid past weaknesses or problems and will solve them differently in the future. Proactive stakeholder management look forward

to future activities and adapt their actions to changing environments, to obtain a better cooperation between firms and stakeholders (Smudde & Courtright, 2011).

Based on conflicting external demands received by a firm, stakeholder theory explains the corporations' engagement in CSR activities[1] (Freeman, 2004), including environmental disclosure. A. A. Ullmann (1985) analyzes the level of power of different stakeholders' to control organization resources. Organizations selectively respond to stakeholder requirements as a function of their relative power. Stakeholder power tends to be positively correlated with the organization's social performance when stakeholders control its critical resources. The organization will tend to ignore stakeholder demands when their power is weak.

Institutional and legitimacy theory

Institutional theory, seen by Scott (2013) as a widely accepted theory focuses on rational myths, isomorphism, and legitimacy. Rational myths such as legal environments (law firms and regulators) play an important role in organization (Suchman & Edelman, 1996). Rule and belief systems are used to increase legitimacy. Isomorphism is a similarity between organizations, as a result of mimic process or reproduction under similar conditions (DiMaggio & Powell, 1983). Legitimacy, as defined by Suchman (1995), is a generalized perception or assumption that the actions of an entity are desirable, proper or appropriate within some socially constructed system of norms, values, beliefs, and definitions. As a sociopolitical theory, legitimacy theory sees environmental and social disclosure as a measure of an entity's environmental and social responsibility. A hypothetical social contract exists between the company and society (Mathews, 1993). Firm responsibilities go beyond financial performance demanded by shareholders, including social and environmental performance in response to their demands. Neu, Warsame, and Pedwell (1998) define the relevant public of environmental disclosure as

[1] CSR activities are policies or actions that identify a company as being concerned with societal issues (Roberts, 1992).

the financial stakeholders, such as shareholders and creditors, and regulators, such as the government. The secondary public for environmental disclosure consists of environmentalists.

Legitimacy is identification with values, symbols, and practices accepted by society, to demonstrate congruence between organizational practices and the values of the social environment (Solomon & Lewis, 2002). Perceptions held by the relevant public and by society play a central role in legitimacy theory. Environmental disclosure can then be used as a tool to change stakeholder perceptions, to legitimize a firm's activities as acceptable, and to conform to stakeholders' values, symbols, and methods. Firm's credibility and industry legitimacy are factors with a significant impact on perceived environmental legitimacy (Cormier & Aerts, 2009).

Stakeholder expectations concerning environmental performance increase over time and poor environmental performance threatens firm legitimacy. Environmental disclosure, used as a tool to change stakeholder perceptions, legitimizes a firm's environmental activities. A negative relationship between environmental performance and voluntary environmental disclosure is predicted by socio-politically based legitimacy theory. Gray et al. (1995) find that firms with poor environmental performance have incentives to disclose more.

Organizations use either social/environmental performance or social/environmental disclosure or both as a tool to manage their relationships with stakeholders. Cormier et al. (2011) recently studied the effect of substitution versus complementary role of environmental and social disclosure in reducing information asymmetry between managers and stock market participants. Environmental disclosure and social disclosure substitute for each other in reducing information asymmetry; consequently, their total effect on information asymmetry is not the addition of their separate effects. Hence social disclosure strengthens the informativeness of environmental disclosure for investors.

In conclusion, we do not have an integrated theoretical framework to describe and predict the level or effects of environmental disclosure. Several overlapping theories are employed to explain different aspects of environmental disclosure, but there is room for development.

1.2. Theoretical framework of environmental innovation

Rennings (2000) defines environmental innovations as the actions of a firm's relevant actors that (i) develop new ideas, behavior, products and processes, apply or introduce them, and(ii) contribute to a reduction of environmental burdens or to ecologically specified sustainability targets. According to R. Kemp et al. (2001), environmental innovation consists of creating or modifying processes, techniques, systems and products to better protect the environment. A distinction should be made between incremental and radical innovation. Incremental innovations are minor changes of existing product or processes, while radical innovation arises from technological discontinuity, an important technological or process advance.

Theoretical framework of environmental innovation derives from theories for general innovations and is improved by environmentally specific factors as institutional or political factors.

Innovation theories focus on the relevance of technology push, demand pull or market factors (Horbach, 2008).

Technology push

Scientific field has a strong influence on innovation (Nemet, 2009). New environmental technology pushes a firm to innovate and obtain a better position on the market and an increased competitiveness (Less & Araya, 2008). Environmental innovation can be considered as investments in knowledge capital

(Smolny, 2003). This knowledge capital induces future innovation, hence innovation triggers innovation. Technology push theory on innovation ignores innovation's profitability (Nemet, 2009).

Market structure has an influence on innovation. Monopolistic market structures encourage large firms to innovate; these firms will be less exposed to competitor's imitation. Scale economies generated by innovation will be more important in this case. Small firms in competitive market try to demarcate from competitors by developing new products. In conclusion, the effect of firm's size on environmental innovation is still unclear (Smolny, 2003).

Demand pull

Technology push factors are more relevant in initial phase of developing a new product. In diffusion phase, demand from stakeholders (consumers, social responsible investors, government, industry, society etc.) pulls innovation (Less & Araya, 2008). Variation in demand drives innovation; increase in demand will determine more investments in innovation to satisfy unmet needs (Nemet, 2009).

Institutional and political factors

Environmental innovation are driven by environmental policy (Porter & van der Linde, 1999). Environmental regulation, fiscal system, international protocols or peers agreements are incentives to environmental innovation (Ozusaglam, 2013). On the other side, René Kemp and Pontoglio (2011) conclude that the link between regulator and regulated is not unidirectional and that multiple policies affect innovation.

1.3. Empirical studies

In this sub-section we will present the development of the methods to measure environmental disclosure and environmental innovation and the main studies on environmental disclosure's evolution, reliability, determinants and value relevance.

1.3.1. Environmental disclosure evolution and measurements

In the early stages of environmental accounting research, empirical studies focused on the development of methods to measure the incidence of environmental disclosure. Table 1-1 presents the main papers on the development and the results of such methods.

As the literature shows, measurement methods evolved over time, starting from a simple yes/no analysis of the presence of social/environmental disclosure in annual reports (Ernst & Ernst, 1978), followed by quantitative measures of the volume of environmental disclosure (Wiseman, 1982), to complex scores based on both the quantity and quality of environmental disclosure (Cormier & Magnan, 2003); (Aerts et al., 2006). Based on an index including quantitative and qualitative measures, Wiseman (1982) concludes that environmental disclosure is incomplete and does not adequately reflect organization's environmental performance.

Later, Gibson and O'Donovan (2007) use content analysis of environmental disclosure in Australia from 1983 to 2003 and note an increased volume of environmental disclosure over time. Findings for Australian firms using sentence or pages counts show an increased level of the media besides annual reports used for environmental disclosure, such as separate environmental reports (Tilt, 2008). Brammer and Pavelin (2008) employing content analysis examine the quality of environmental disclosure of UK companies and find that firm size and industry are important factors influencing environmental disclosure.

Tagesson et al. (2009) study, using an index, social disclosure in Swedish municipalities and the factors that explain its extent and content. Organization size, its tax base and tax rate, financial performance, and the political majority drive the extent of social disclosure, including environmental disclosure.

Alternative methods for analyzing environmental disclosure are proposed by C. Cho et al. (2010). Their measure of the language and verbal tone used in environmental disclosure is based on two dimensions: "optimism," viewed as a language supporting particular groups, concepts, or events that presents the performance positively, and "certainty," which refers to the inflexibility and completeness of the disclosure. Using content analysis, the authors find evidence that worse environmental performers use more optimism and less certainty in their disclosures than better environmental performers do, as a tool for managing stakeholder impressions.

Delmas and Blass (2010) examine the possible trade-offs of different environmental performance evaluation methods. Sustainability ratings used by socially responsible investors in their decision process reflect a trade-off between a focus on penalties for poor performers and a focus on rewards for good performers. Other possible trade-offs the authors identify are those between activities and processes with a direct and immediate environmental impact versus less directly activities and processes or those with no current impact; the trade-off between reporting and management practices as a proxy for future performance at the expense of presenting current performance; and the trade-off between the choices of different measures based on data availability.

Focusing on environmental capital expenditures as a measure of mandatory environmental disclosure, Charles Cho et al. (2012) find that environmental capital expenditures amounts are mostly immaterial, with worse polluters disclosing more immaterial amounts. The lack of materiality could be an explanation for non-disclosing firms.

Analyzing the quality of environmental disclosure using a disclosure index derived from Global Reporting Initiative framework, Rupley et al. (2012) note an increase in environmental disclosure quality over time. They find a positive association between voluntary environmental disclosure and environmental media coverage and negative environmental media as a proxy for firm's environmental legitimacy. Board attributes of independence, diversity, and expertise are positively associated with voluntary environmental disclosure, suggesting that good governance is associated with firm transparency.

In conclusion, the measures used in environmental disclosure research evolve with time and forms of disclosure, from quantitative measurements to qualitative and quantitative evaluations. Moreover, we note the introduction of different forms of environmental disclosure, such as stand-alone environmental reports, environmental information published on the Web, and mandatory disclosure in 10-K forms. Present measurement methods in environmental disclosure, based on scores or indexes, contingent on measurement error, subjectivism, or the cost and availability of data, can be improved. Even if the actual measurement is not perfect, research can help stakeholders better evaluate a firm's environmental disclosure or pressure the government and legislators to regulate environmental disclosure.

Table 1-1 - Prior research on development of methods to measure the environmental disclosure and their results

Development of methods to measure the environmental disclosure and their results	
Article	**Findings**
(Ernst & Ernst, 1978)	Survey on social responsibility disclosure of Fortune 500 annual reports. Social responsibility disclosure types identified: environment, energy, fair business practice, human resources, community involvement and products.
(Wiseman, 1982)	Examine the quality and the reliability of environmental disclosure in annual reports using an index to measure the content of disclosure. Conclusion:

	corporate environmental disclosure is not related to environmental performance.
(Cormier & Magnan, 2003)	A synthesis of environmental disclosure research: voluntary disclosure, external disclosure and mandatory disclosure. Sixty papers reviewed and grouped by: reliability of disclosure, value relevance or determinants of environmental disclosure.
(Aerts et al., 2006)	An analysis of intra-industry imitation in corporate environmental reporting for a sample from Canada, France and Germany over a six-year period. Mimetic behaviors are generated by high quality reporting and the mimetic process is enhanced in highly concentrated industries.
(Gibson & O'Donovan, 2007)	The volume of environmental disclosure in an Australian context increased over the period analysed: 1983-2003, as result of new government policy and standards, changes in legislation, or best practice recommendations for the sector.
(Tilt, 2008)	Examine the use of environmental disclosure outside the annual report in Australian companies from 1994 to 1999. The use of stand-alone environmental reports increased and the use of other type of environmental disclosure diminished.
(Brammer & Pavelin, 2008)	Find as determinants of the quality of environmental disclosure for a sample of 450 UK companies: firm and industry characteristics. High quality disclosure is associated with larger firms and with firms from environmental-sensitive industries.
(Tagesson et al., 2009)	Study of the extent and variation of content in social disclosures, including human resources, ethics and environmental disclosure, in annual reports and official statistics of Swedish municipalities. Findings: significant differences between municipalities concerning the volume and the content of social disclosures. The volume of social disclosure is associated with size, tax base and

	tax rate, financial performance and political majority of the municipality.
(C. Cho et al., 2010)	Content analysis of environmental disclosure to determine if the language and tone of environmental disclosure are used as a tool for managing public impressions. They find that worse environmental performers use more «optimism» and less «certainty» in their environmental disclosure than better performers.
(Delmas & Blass, 2010)	Analysis of trade-offs existent in the evaluation of environmental and social performance. There are differences in the evaluation when the measure is based on toxic releases and regulatory compliance or on the quality of environmental policy and disclosure. Firms with the most advanced environmental disclosure and environmental management practices are likely to have higher levels of toxic releases and lower environmental compliance, so worse environmental performance.
(Charles Cho et al., 2012)	Examine, for a US sample, if disclosure of environmental capital expenditures is a function of materiality of spending. They find that the disclosed amounts of environmental capital expenditures are not material, for the majority of 119 US companies analysed, suggesting that non-disclosure is determined by immateriality. The choice to disclose is associated with worse environmental performance.
(Rupley et al., 2012)	Examine the relationship between governance and media coverage and the quality of voluntary environmental disclosure, on a sample of 416 US firms, from 2000 to 2005. They conclude that there is a positive association between the quality of voluntary environmental disclosure and environmental media coverage, negative environmental media and some characteristics of governance: the independence, diversity and expertise of the board. They also find an increased quality of environmental disclosure over time.

1.3.2. Empirical literature on environmental innovation

The empirical literature on environmental innovation is scarce. Jaffe and Palmer (1997) and Brunnermeier and Cohen (2003) examine the impact of pollution abatement expenditures on innovative activity. They conclude that research and development expenditures and patents induce innovation. Carrión-Flores and Innes (2010) find evidence of bidirectional causal links between the number of environmental patents as a proxy for environmental innovation and toxic air pollution as a proxy for environmental performance. In conclusion, environmental innovation plays an important role on firm's environmental performance.

Jaffe and Palmer (1997) test the relationship between environmental regulation and innovation, using two measures of innovation, R&D expenditures and successful patent application, in relationship to compliance expenditures. They conclude that, within an industry, increases in compliance expenditures are related to increases in R&D shortly thereafter, hence environmental regulation will stimulate innovation.

Wagner (2007) investigates, in a German context, the relationship between environmental management, environmental innovation, and patents. The author concludes that patent data is a better measure of environmental innovation than self-reported environmental innovation. According to this study, the implementation of environmental management systems has a positive effect on environmental process innovation. Wagner (2009) also explores the relationship between environmental management systems and environmental innovation in an international context and finds evidence of an relationship between environmental management systems and process innovations, moderated by the interaction between environmental management systems and a country's culture and regulatory regime. Lower flexibility of regulatory policy, as prescribing specific technologies for specific environmental performance targets,

has a negative effect on process innovation. Environmental management system implantation has an effect on innovation only for Netherlands, Germany, Norway, Sweden and UK, countries with strong environmental policies.

Brunnermeier and Cohen (2003) analyze the determinants of environmental innovation. They find that regulators' increased monitoring and enforcement activities do not provide additional incentives to innovate. Horbach (2008) also explores the determinants of environmental innovation and suggests the importance of improvements in technological capabilities by R&D, increase in future demand, and historical innovative orientation. Other relevant determinants are environmental regulation, environmental management systems, and organizational changes. H. Hammar and S. Löfgren (2010) find evidence that R&D expenditures related to environmental protection are a determinant of clean technology adoption through internal learning, that is, learning by searching.

1.3.3. Environmental disclosure reliability

A large number of empirical studies examine the reliability of environmental disclosure. The definition of reliability in the Accounting and Financial Management Dictionary[2] is a "Qualitative characteristic of the information published in financial statements, such that users can trust that the presentation of operations and underlying events is consistent with the facts and reasonably free of error and bias."

This definition can be extended to environmental disclosure, as a form of information published in financial statements or stand-alone reports, such as sustainability, corporate responsibility, citizenship, and other corporate reports. The IFRS conceptual framework uses the term *faithful representation* instead of *reliability* for financial reporting. Accordingly, environmental disclosure should be a faithful representation of a firm's environmental performance. Environmental disclosure accuracy or reliability

[2] (Louis Ménard, 2011), p. 1177).

is empirically examined by looking at the association between organizational environmental disclosure and environmental performance. Table 1-2 presents a summary of the findings of prior research on this subject.

Prior empirical research finds contradictory results about the relationship between environmental disclosure and environmental performance. A positive association is noted by Al-Tuwaijri et al. (2004), P. Clarkson et al. (2006), P. Clarkson et al. (2008), and Dawkins and Fraas (2011). For their part, Hughes et al. (2001), Patten (2002), C. Cho and Patten (2007), P. Clarkson et al. (2011), and D. Cormier et al. (2011) find a negative relationship. Finally, Ingram and Frazier (1980), Wiseman (1982), Freedman and Wasley (1990), and Fekrat et al. (1996) do not find any significant relationship between these variables.

Possible explanations for the mixed empirical results are the different measures employed for environmental disclosure or performance (P. Clarkson et al., 2006; Patten, 2005) or the application of different theoretical perspectives, such as economic or sociopolitical theories of voluntary disclosure (P. Clarkson et al., 2008). According to Fekrat et al. (1996) there could be a combined industry and regulation effect. P. Clarkson et al. (2011) underline the difference between "hard" and "soft" environmental disclosure, hard disclosure being based on objective and verifiable items and soft disclosure on more subjective items. Quantitative methods do not measure soft disclosure adequately. Different results could be obtained using qualitative measurements.

Another possible explanation for these mixed results is the influence of disclosure strategy on environmental disclosure (P. Clarkson et al., 2011) or an interaction between environmental performance and media or climate change visibility (Dawkins & Fraas, 2011). Firms are less likely to provide environmental disclosure when media or climate change visibility is lower. The authors highlight the potential for other factors to interact with environmental performance to influence

environmental disclosure. Bouten et al. (2012) consider that the operationalization of the dependent variable and the choice of method could also be a reason for inconsistent results. The level of social and environmental disclosure is typically set to zero for non-disclosing firms and that may triggers the choice of an inappropriate estimation method, with effects on empirical findings. Hence, they limit their sample only on disclosing firms, excluding non-disclosing firms to avoid setting the environmental disclosure to zero for them.

Guidry and Patten (2012) review 13 environmental disclosure studies and analyze the use of financial control variables based on voluntary disclosure theory. They admit an important limitation of their study: the lack of comparability of disclosure measures used. This lack of comparability could also be an explanation for prior empirical mixed results. Concerning control variables they conclude that, at the exception of firm size, the exclusion of financial control variables based on voluntary disclosure theory does not lead to incorrect inferences on the relationship between environmental performance and environmental disclosure. Financial control variables are deemed to be associated with financial disclosure, viewed as a tool to reduce information asymmetry between managers and investors. Using legitimacy theory, voluntary environmental disclosure represents a tool to legitimate environmental activities and differs from financial disclosure representation. In conclusion, the authors failed to find evidence of systemic association between financial control variables and voluntary environmental disclosure.

Rupley et al. (2012) use longitudinal analysis and find evidence of an increase in environmental disclosure quality over time, from 2000 to 2005. This result could also explain the disparity of previous empirical studies, because the general picture of environmental disclosure evolved over time. Combs et al. (2011) explain that variables and relationships between variables describing social phenomena are historically dependent and may vary over time. The variability of empirical results could also be explained by misspecified models with important omitted variables (e.g. firm's level of environmental

innovation) or to the lack of consideration of moderating effects (Dawkins & Fraas, 2011). We consider environmental innovation as an important determinant of environmental disclosure, in addition to environmental performance. This subject is developed further in Chapter II.

Table 1-2: Results of prior research on the relationship between environmental performance and environmental disclosure

Prior research on the relationship between environmental performance and environmental disclosure	
Positive relationship	
Article	**Findings**
(Al-Tuwaijri et al., 2004)	Management strategy affects environmental disclosure, environmental performance and economic performance. Good environmental performance with good economic performance relate with more extensive environmental disclosure.
(P. Clarkson et al., 2006)	Analysis of the relationship between environmental performance, measured by toxic emissions and waste management data, and environmental disclosure, measured by an index based on guidelines of Global Reporting Initiative. Analysis of five polluting industries in 2003.
(P. Clarkson et al., 2008)	Focus on purely discretionary environmental disclosure. Positive association: consistent with the predictions of economics disclosure theory, but inconsistent with socio-political theories' predictions.
(Dawkins & Fraas, 2011)	Company visibility and climate change visibility interact with environmental performance to influence the level of environmental voluntary disclosure.
Negative relationship	
Article	**Findings**
(Hughes et al., 2001)	Poor performers made significantly more disclosure in notes and MD&A than did the good and mixed performers. Disclosure classified as: quantitative, descriptive,

	vague, and immaterial.
(Patten, 2002)	Companies with worse environmental performance include more extensive environmental disclosures in their 10-K reports. Worse environmental performance means higher levels of size-adjusted toxic releases.
(C. Cho & Patten, 2007)	Companies use environmental disclosure as a tool to mitigate the potential negative impact of actual performance information.
(P. Clarkson et al., 2011)	Results contradictory to (P. Clarkson et al., 2008): Higher polluters disclose more. Measure based on GRI disclosure index in an Australian context.
(Cormier et al., 2011)	Results on determinants of environmental disclosure show that environmental performance is an important determinant of CSR disclosure. Evidence of a negative relationship between environmental performance and CSR disclosure.
No relationship	
Article	**Findings**
(Ingram & Frazier, 1980)	Environmental disclosure in annual report is not significantly related with CEP index of environmental performance.
(Wiseman, 1982)	The volume of environmental disclosure is not representative of its quality and voluntary disclosure is incomplete and provides only general information about environmental performance of a company. Index criticised: focus on quantitative disclosure rather than qualitative.
(Freedman & Wasley, 1990)	Environmental disclosure in annual and 10-K reports is not related with environmental performance indices as published by the Council of Economic Priorities.
(Fekrat et al., 1996)	Environmental disclosure in annual reports is not associated with environmental performance. There are significant differences concerning environmental

	disclosure between industries and countries. 18 countries and 6 industries were analysed.

1.3.4. Determinants of environmental disclosure

A summary of past research on the determinants of environmental disclosure is presented in Table 1-3. To test stakeholder theory in the context of social responsibility disclosure, Roberts (1992) uses a sample of 80 Fortune 500 companies. Stakeholder power—including the potential stakeholder power of passive investors, governmental risks, and potential creditors is shown to be a function of the stakeholder's degree of control over resources used by the firm. This author finds evidence of a positive association between stakeholder power or demands and the level of social responsibility disclosure. The strategy of a firm determines the response to stakeholder's social demands. The presence of a philanthropic foundation is an indicator of a corporate strategic plan to make charitable contributions as a tool to manage stakeholders' demands. Firms with corporate public affairs departments and with contribution to charity reflect an active strategic posture seen as a positive attitude toward social responsibility activities. The active strategic posture is translated into greater social responsibility activities (Roberts, 1992).

Economic performance, measured by either an accounting-based measure (return on equity) or a stock market-based measure (systematic risk), also determines the level of social responsibility disclosure. Roberts (1992) finds evidence that return on equity is positively associated with social responsibility disclosure; a good economic performance will supply resources to meet firm's social demands. Systematic risk is negatively associated with social responsibility disclosure. Firms with low systematic risk, having more stable stock market returns, will allow more resources to social activities than firms with less stable stock market returns (Roberts, 1992). In conclusion, firms with a better economic

performance, for both accounting and stock-market measures, will be likely to record a higher level of social responsibility disclosure.

Cormier and Magnan (1999) find that information costs and the firm's financial condition are the most important determinants of environmental disclosure. Information costs refer to reputational, proprietary, contracting, and other similar costs for firm if the information is used by stakeholders against the firm's interest (e.g., competitors or environmentalists). The authors use an index of quantitative and qualitative items to measure environmental disclosure. Their index is an improvement over the index derived from Wiseman's (1982) model, also considering the quality of environmental disclosure through a rating based on a scale from one to three, one for an item described in general terms, two for a specific description and three for description in monetary or quantitative terms. This scale allows differentiating specific and monetary description of environmental items (as environmentally related capital expenditures or environmental liabilities and commitments) from general, irrelevant and repetitive information. The results of this study suggest that information costs, measured by firm's risk, reliance on capital markets and trading volume, are positively associated with the level of environmental disclosure. Firm's financial condition, as measured by return on assets and leverage, also determine the level of environmental disclosure. Firms in a better financial condition will disclose more than those in a poor financial condition.

Brammer and Pavelin (2008) conclude that a firm's size and industry are determinants of the quality of environmental disclosure. The quality of environmental disclosure is higher in environmental-sensitive industries, as a result of higher stakeholders' pressure. Larger firms are more visible and scrutinized by stakeholders and the quality of their voluntary environmental disclosure is higher. Authors expect a positive association between media exposure and the quality of voluntary environmental disclosure, based on the increased scrutiny of firm's activities for firms with higher media exposure and increased

pressures to publicly account for their performance. Their US sample results suggest that media exposure, as news media coverage of the firm, is not associated with voluntary environmental disclosure. Media exposure seems to be more related to the industry than to the firm.

Aerts and Cormier (2009) study the role played by media legitimacy on corporate environmental communication. Firm's environmental legitimacy, as general perceptions held by relevant publics about firm's activities, is measured through media coverage and media evaluations. Contrary to Brammer and Pavelin (2008), the results of this study suggest that environmental media exposure is positively associated with firm's environmental disclosure. Community and public concerns, reflected in firm's environmental media exposure, will pressure firms to increase their environmental disclosure.

Da Silva Monteiro and Aibar-Guzmán (2010) examine the voluntary environmental disclosure of 109 firms in Portugal using annual reports from 2002 to 2004. Despite the low level of environmental disclosure in that period, the authors find that firm size and stock market listing are positively related to the level of voluntary environmental disclosure. Large firms are subject to higher pressure from stakeholders and also they can afford the costs of producing and disclosing environmental information. Stock market listing increases the interest of investors for information in general, including environmental information.

Gamerschlag et al. (2011) use content analysis to find the determinants of voluntary corporate social disclosure, including environmental disclosure, for German firms from 2005 to 2008. Company visibility, shareholder structure, share ownership concentration, and relationships with US stakeholders, whether the company is listed on a US stock exchange or not are identified as determinants of corporate social disclosure, next to size, industry membership, and profitability. The results of this study are consistent with prior research on the determinants of environmental and social disclosure: higher firm

visibility, more dispersed share ownership and US stock market listing are associated with higher levels of CSR disclosure.

Bouten et al. (2012) explore the determinants of disclosure decisions and the level of social disclosure in Belgium and the United States. The authors suggest different determinants for the decision to disclose and for the level of social disclosure. Size is a determinant only in the decision to disclose. Industry, strategic posture, and media exposure are related to the level of disclosure only for Belgian firms, while industry and strategic posture are associated with the decision to disclose for US firms. In conclusion, country effects are considerable factors in the level of disclosure or the decision to disclose. Hence, research on social disclosure in different countries could lead to different results. This could be an explanation for the inconsistence of prior empirical findings.

Table 1-3: Results of prior research on determinants of environmental disclosure

Determinants of environmental disclosure	
Article	**Findings**
(Roberts, 1992)	Empirical test of stakeholder theory on social responsibility disclosure. Stakeholder power, strategic posture and economic performance are determinants of corporate social disclosure.
(Cormier & Magnan, 1999)	Cost-benefit analysis for a Canadian sample. Determinants of environmental disclosure identified by the authors are information costs, firm's financial condition, size, regulation and industry.
(Brammer & Pavelin, 2008)	Firm's size and industry determine the quality of environmental disclosure. Media exposure has no impact on environmental disclosure.
(Aerts & Cormier, 2009)	Environmental legitimacy is positively associated with the quality of environmental disclosure and with the reactive environmental press releases.

(Da Silva Monteiro & Aibar-Guzmán, 2010)	Determinants of environmental disclosure in Portugal: firm size and the presence of the company on the stock market.
(Gamerschlag et al., 2011)	Determinants of social corporate disclosure, including environmental disclosure, for a German sample: visibility, shareholder structure, relationship with their US stakeholders, profitability, size and industry membership.
(Bouten et al., 2012)	Determinants of the decision to disclose are different from determinants of the level of disclosure, in both Belgian and US contexts.

1.3.5. Value relevance of environmental disclosure

Several studies employ an event study methodology to examine the value relevance of environmental disclosure. They examine the market reactions of environmental disclosure subsequent to a specific event with a significant environmental impact. A limitation of these studies is that it is impossible to determine the exact response of the market to environmental disclosure due to multiple other announcements made by companies and other confounding events. A summary of the research on the value relevance of environmental disclosure is shown in Table 1-4.

After the Bhopal ecological catastrophe, Blacconiere and Patten (1994) note that environmental disclosure in 10-K forms is positively and significantly associated with abnormal negative returns measured in a window of five days following the event. More extensive environmental disclosure ex ante the catastrophe has led to a less negative market reaction. Cormier and Magnan (2001) do not find a direct relationship between voluntary environmental disclosure and firm stock market value. Their findings suggest such an association only for firms that incurred fines or penalties and with pollution levels exceeding standards. According to Berthelot et al. (2003), in a Canadian context, provisions for

future expenditures for the removal of fixed assets and site remediation are negatively and significantly related to stock market value.

P. M. Clarkson et al. (2004), using data from an environmentally sensitive industry, pulp and paper, conclude that the market valuation of environmental capital expenditure investment related to pollution abatement varies as a function of the firm's level of pollution. Value added is associated with environmental capital expenditure investments for low polluters over-complying with regulations. For high polluters, there is no value added; investors use the firm's poor environmental performance information to assess unbooked environmental liabilities.

Murray et al. (2006) test the relationship between social and environmental disclosure and financial market performance. Their longitudinal data analysis study reveals a relationship between high/low returns and the predilection to high/low environmental disclosure. No direct relationship between stock returns and social and environmental disclosure was found. The authors cannot find a clear theoretical explanation for these results (or absence of results). More theoretical and empirical investigation is needed.

Moneva and Cuellar (2009) analyze the value relevance of financial and non-financial environmental disclosure in annual reports for a Spanish sample. Their findings suggest a significant relationship between stock market values and financial environmental disclosure and no association between stock market values and non-financial environmental disclosure. According to this study, investors do not value non-financial environmental disclosure.

Table 1-4: Results of prior research on value relevance of environmental disclosure

Value relevance of environmental disclosure	
Article	**Findings**
(Blacconiere & Patten, 1994)	Examine the market reaction for chemical firms except Union Carbide, subsequent of Bhopal catastrophe, India – pesticide leak. As expected, a significant negative reaction results. Firms with higher level of prior environmental disclosure were exposed to a less negative market reaction to the event. Results also suggest intra-industry market reactions occurred to announcements concerning future regulatory costs.
(Cormier & Magnan, 2001)	Authors find no relationship between voluntary environmental disclosure and stock market value of the company. For firms with fines and penalties and with pollution level exceeding standards, the study provides evidence that voluntary environmental disclosure is value relevant.
(Berthelot et al., 2003)	Analyse environmental provisions for a Canadian sample in environmentally sensitive industries. Environmental provisions are used to smooth out variations of earnings and are value relevant for the stock market.
(P. M. Clarkson et al., 2004)	Analysis of market valuation of environmental capital expenditure investment related to pollution abatement. An asset, environmental capital expenditures investment, would be capitalized when future economic benefits are anticipated. Findings for pulp and paper industry in US: for low polluters, value added is associated with environmental capital expenditures investments. For high polluters, investors use environmental performance of the company in order to assess unbooked environmental liabilities.

(Murray et al., 2006)	No relationship was found between share returns and social disclosure for the UK sample. Companies with high returns produce a high level of social and environmental disclosure over a period of time. Those with low returns produce a low level of environmental and social disclosure.
(Moneva & Cuellar, 2009)	In a Spanish context, financial environmental disclosures in annual report are value relevant, while non-financial environmental disclosures are not.

1.3.6. Relationship between environmental performance and financial performance

Studies analyzing the relationships between environmental performance and financial performance focus on two aspects: the direction of causality, whether environmental performance influences financial performance or vice versa or whether it is a bidirectional relationship (Ambec & Lanoie, 2008; Makni, Francoeur, & Bellavance, 2009), and the nature of the relationship, whether positive, negative or null, (P. M. Clarkson et al., 2011; Hassel et al., 2005).

The theoretical framework employed in this type of study is the resource-based view of the firm. A firm's key resources should be identified and protected to obtain a sustainable competitive advantage and improve organizational performance. Firm's key resources are rare, valuable, inimitable, and non-substitutable. Consistent with the predictions of the resource-based view of the firm, P. M. Clarkson et al. (2011) find a positive relationship between environmental performance and financial performance; a green strategy that is difficult to mimic is associated with better financial performance.

Another perspective focuses on environmental investments as a net cost with a negative impact on financial performance and on stock market valuation. Reaching for a good environmental performance is costly, and the benefits from the environmental investments are lower than the costs involved. Hassel et al. (2005) find evidence of a negative relationship between environmental performance and financial

performance. Makni et al. (2009) also find evidence of a negative relationship between the environmental dimension of corporate social performance and financial performance, consistent with the trade-off hypothesis and the negative synergy hypothesis. The trade-off hypothesis reflects neoclassical economists' idea that a better social or environmental performance will provide few economic benefits and will be costly, reducing firm's profits and shareholder wealth. The negative synergy hypothesis presents the relationship between social performance and financial performance as a vicious circle, better social performance leading to decreased financial performance, which limits socially responsible investments. Hence both hypotheses predict a negative relationship between social performance and financial performance.

The recent meta-analysis of Endrikat et al. (2014) reviews the relationship between environmental performance and financial performance. The authors conclude that there is a positive and partially bidirectional relationship between environmental performance and financial performance, highlighting the moderating effects of methodological artifacts. This relationship is stronger for proactive strategic approaches than reactive approaches. A proactive strategic approach implies the redesign of production process, the reduction of wastes and inefficiencies of production and environmental process innovations. Firms which adopt a reactive approach tend to merely comply with regulation, generally by employing filters or similar environmental solutions at the end of the production process. The methodological artifacts include the type of sample (single industry or cross-sectional samples) or different control variables, controlling for possible endogeneity, and the timing of the research. These artifacts could interact with the explanatory variable and change the relationship between environmental performance and financial performance.

1.4. Related studies from the non-accounting literature

Researchers in the field of management and economy have been very productive in the area of social and environmental innovation and strategies. We will present in this section the studies that are closely related to this thesis.

Environmental strategy was the object of several studies. Environmental strategies range from the most reactive environmental strategies to the most proactive, in a continuum (Hunt & Auster, 1990) (Hart, 1995) (Aragon-Correa, 1998). Buysse and Verbeke (2003) use cluster analysis to categorize these strategies as reactive, pollution prevention, and environmental leadership. Reactive environmental strategies use traditional methods, end-of-pipe[3] solutions, to solve problems when they arise (Aragon-Correa, 1998). End-of-pipe solutions do not improve the production process as such; they only measure the level of pollution and prevent the spread of pollutants (H. Hammar & Å. Löfgren, 2010). The aim of reactive environmental strategies is to minimize risk, liabilities, and costs (Roome, 1992). Sharma et al. (1999) indicate compliance with environmental standards and regulations and accepted industry practice as the main characteristic of reactive strategies.

Pollution prevention and environmental leadership groups are seen as proactive strategies, going beyond compliance. Proactive strategies are innovative and imply prevention, the development of environmental products, and process innovation. Proactive strategies integrate modern methods in their management systems (Hart, 1995), such as environmental management systems built according to ISO 14001 standards (see appendix A for details about international standard ISO 14001). Environmental management systems are quality management systems concerning environmental impact of firm's activities. The publication of an environmental policy and objectives, environmental reviews,

[3] An end-of-pipe solution reduces waste and pollution at the end of the production cycle.

environmental training programmes or environmental communications such as a stand-alone report or environmental statement are activities associated with the implementation of an environmental management system. External audits can be performed to certificate the environmental management systems based on international standard ISO 14001. Environmental management systems are associated with process innovation (Wagner, 2009) and the goal of proactive strategies is to prevent the occurrence of problems at their source (Schmidheiny, 1993). Early and innovative actions are undertaken by proactive organizations to gain competitive advantage and proactive environmental strategies involve environmental innovation (Sharma et al., 1999).

An important paper in economic research is that of Pearce et al. (1989). This study presents, from a political and economic perspective, the trade-off between economic development and growth and environment preservation. By evaluating optimistic/pessimistic scenarios and the perspectives of economic growth, the authors conclude that environmental policy response can be anticipatory or reactive, but the equilibrium solution is sustainable development. Moreover, according to Porter and van der Linde (1999), a proactive environmental strategy based on innovation and ensuring sustainable development should increase financial performance. The authors identify product and process design to lower the total cost of a product, improve its value through innovation and improve an organization's environmental performance.

Ambec and Lanoie (2008) find that firms' innovation strategy has a crucial impact on opportunities for increasing revenues and reducing costs and obtaining both better financial performance and better environmental performance. As shown in Figure 1-3, the opportunities for increasing revenues derived from firms' innovation strategy are a better access to certain markets, differentiating products or the possibility of selling pollution-control technologies. Stakeholders will appreciate better environmental performance resulted from firms' innovation and the risk associated with the relationships with these stakeholders decreases. Better environmental performance will also permit anticipating and reducing

risk associated with future regulation. Pollution is generally associated with resource waste, lost energy, and the suboptimal use of raw materials. Better environmental performance through innovation would generate economies of resources and also a reduction of cost of material energy and services. Consumers will note the green image and purchasing policies reward green suppliers. The opportunities for reducing costs include a better risk management and better relations with external stakeholders, reduction of cost of material, energy and services through a better productivity and reduced waste, reduction of cost of capital and cost of labor. Shareholders perceptions are influenced by environmental disclosure. Green or ethical mutual funds are interested in CSR investments and that have a positive effect on the capital cost. In conclusion, an innovative firm strategy could lead to both a better environmental performance and a better financial performance.

Porter and van der Linde (1999) consider a reactive environmental strategy to be one strictly based on compliance with standards, without innovating. Under a reactive environmental strategy, we expect a negative association between environmental performance and financial performance. Pollution means inefficiency and economic waste from using resources incompletely, inefficiently, and ineffectively. The authors conclude that the cost of meeting environmental standards increases in a pollution control model, whose focus is on end-of-pipe solutions. According to this study, the traditional model of pollution control applied in a reactive environmental strategy, consisting in filters at the end of the production process or other end-of pipe solutions does not significantly reduce inefficiency. Innovative and efficient models of pollution prevention, with source reduction, material substitution, and re-engineered processes, will have a stronger effect on pollution.

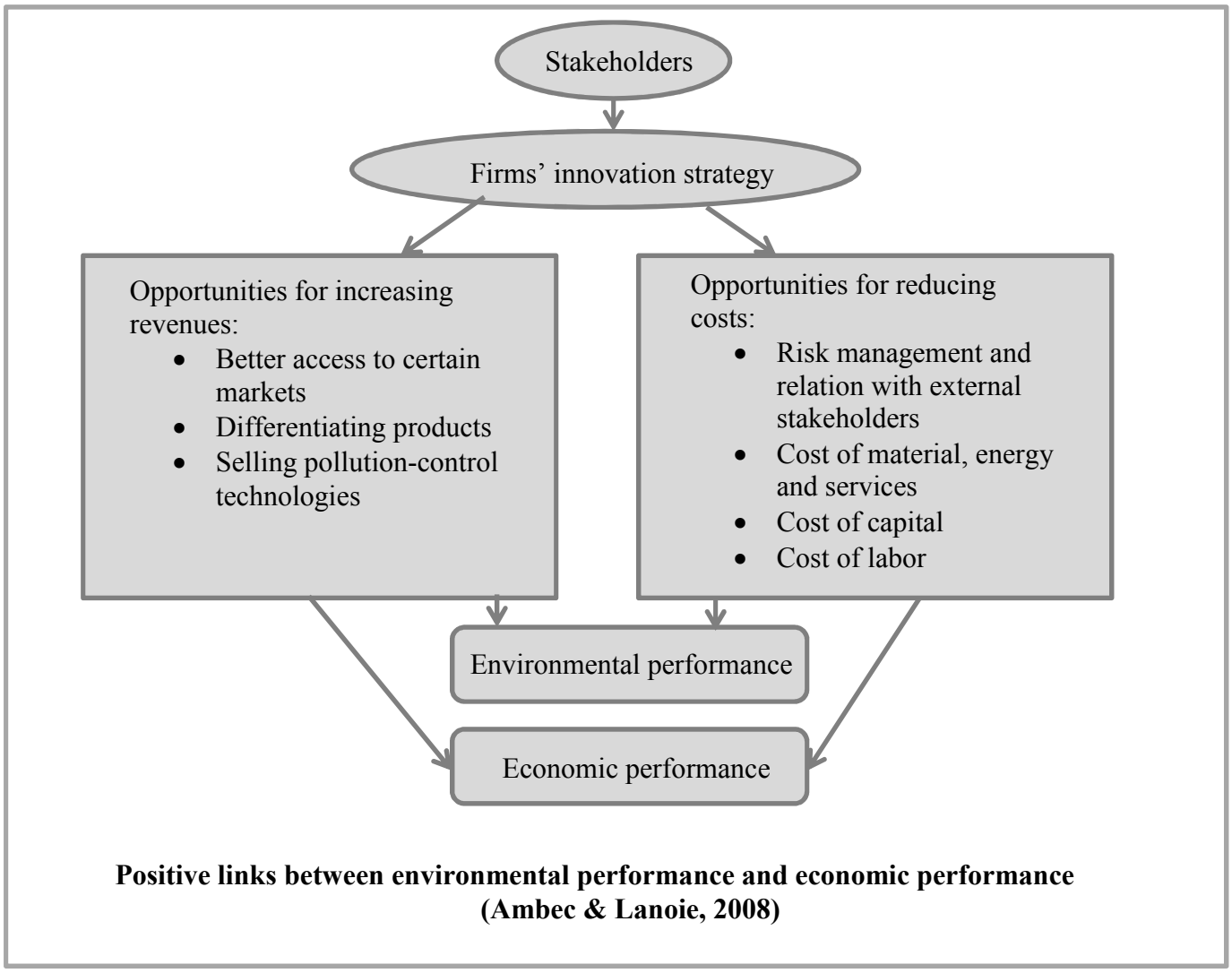

Figure 1-3: Positive links between environmental performance and economic performance

These studies analyzing environmental strategy and environmental innovation constitute a valuable source of information for social and environmental accounting research. Environmental innovation and environmental strategy are key factors that play a crucial role on firm's environmental performance. Hence environmental innovation and environmental strategy are important variables omitted from prior research that could improve the explanatory power of current models. These studies should lead managers to extensively use innovation to solve their environmental problems and improve environmental performance. In this thesis, we use studies that overlap the economic, management, and accounting research to better understand the drivers of environmental performance and disclosure. A literature review of environmental innovation is presented in chapter II.

1.5. Regulatory framework

The regulatory framework, i.e. the lack of regulations, has a major impact on environmental disclosure since it basically stems from a voluntary decision. Environmental disclosure requirements are set as guidelines. Only certain environmental information, such as environmental risk and environmental liabilities are mandatory.

Following the regulation in Canada, firms that are listed on a stock exchange must provide an annual report in which they disclose all material information[4] about the financial and operational effects of environmental protection requirements on capital expenditures, earnings, cash flow, and competitive position for the current year and future period expectations. Management's discussion and analysis must disclose environmental risk and environmental liabilities. According to International Accounting Standard 37, provision for land contamination, clean-up obligations, or removal costs must be recognized in the financial statements if a current obligation is due to a past event, payment is probable, and the amount can be estimated. Contingent environmental liabilities must also be disclosed in a note to the financial statements.

In the United States, firms listed on a stock exchange must provide information in their 10-K reports about costs related to environmental regulation and any ongoing matters with a potential effect on their financial condition. US Generally Accepted Accounting Principles (GAAP), also prescribe the disclosure of environmental liabilities, including contingent losses, such as liabilities associated with legacy remediation obligations, asset retirement obligations, and contingent asset retirement obligations (e.g., closure or decommissioning requirement expenditures). Environmental liabilities and contingencies must be disclosed in financial statements or as an accompanying note thereto if the

[4] Information is material if a reasonable investor's decision would likely be influenced if this information were omitted.

amount of expenditures cannot be reasonably estimated. In addition, US firms must provide information in their 10-K reports about risk factors, including environmental risks and legal proceedings related to environmental issues. Specific disclosure is required for environmentally sensitive industries, for example, safety disclosure in the mining industry.

To foster more and better quality disclosure, regulators and independent organizations have published guidance on environmental disclosure. For instance, the Global Reporting Initiative (GRI)[5] has developed Sustainability Reporting Guidelines since 1999. GRI is an international standard that analyses and recommends environmental communication. In 2010 the Canadian Securities Administrators issued CSA Staff Notice 51-333 Environmental Reporting Guidance. The GRI uses a multi-stakeholder input approach with the objective that environmental reporting should meet the needs of all interested stakeholders, such as shareholders, employees, suppliers, communities, academics, business, and governments. A more recent GRI development is the integrated report, which combines the analysis of financial and non-financial performance, including important sustainability topics and a focus on the value creation of the organization over time. Reliability and completeness of disclosure are integrated within the GRI's guiding principles of the integrated report. On page 5 of the International Framework of the Integrated Reporting, one can read "An integrated report should include all material matters, both positive and negative, in a balanced way and without material error".[6]

Other providers of sustainability reporting guidance are the Organisation for Economic Cooperation and Development (OECD), the United Nations Global Compact, and the International Organization for Standardization.

[5] See https://www.globalreporting.org/information/sustainability-reporting/Pages/default.aspx.

[6] See http://www.theiirc.org/wp-content/uploads/2013/12/13-12-08-THE-INTERNATIONAL-IR-FRAMEWORK-2-1.pdf.

Several scientific papers address environmental accounting standards, environmental audits, social environmental regulatory framework, international or by country, changes in regulation and their implications on the level and quality of environmental disclosure (see Milne (1992) for New Zealand and Bates (1992), for Australia). Buhr and Freedman (2001) compare US and Canadian environmental disclosure by large listed companies, both voluntary and mandatory, and conclude that Canadian environmental disclosure increased more than US disclosure for the years analyzed, namely 1988 and 1994. One possible reason for this difference is the collectivistic nature of Canadian society, which leads to more voluntary disclosure and environmental reports. The litigious nature of US society leads more to mandated disclosure in the 10-K form or in the annual report.

Palmer et al. (1995) also note that tightening environmental standards is costly. Firms in the United States have increased their costs and reduced their profits as a result of new environmental regulation. In 2001 the European Commission released a recommendation on the recognition, measurement, and disclosure of environmental issues in companies' annual reports. Spain implemented mandatory environmental reporting regulations in conformity with European recommendations in 2002. Moneva and Cuellar (2009) test the value relevance of different types of financial and non-financial Spanish environmental disclosures. They note an increase in the value relevance of compulsory environmental information in response to the new regulation, significant market valuation of financial environmental disclosure—investments, costs, and contingencies—and no valuation for non-financial disclosure.

Environmental reporting and environmental performance in Australia is examined by P. Clarkson et al. (2011). The first Australian mandatory environmental reporting requirements were issued in 1989 and concern the disclosure of costs associated with the restoration and rehabilitation of sites in the annual report. Other ambiguous requirements followed, complemented by practice notes of the Australian Securities and Investment Commission, documents meant to give guidance to regulated entities (practical examples and guidance). Even since these practice notes, it seems that environmental

disclosure remains mostly voluntary, firms considering the significance of environmental regulation differently. In addition to the annual report, firms should report their emissions of land, air, and water pollutants to the National Pollutant Inventory, as well as their energy use and efficiency.

C. Cho et al. (2012) focus on a specific item's disclosure in the annual Form 10-K, environmental capital expenditure, a mandatory disclosure in the United States. They note low levels of disclosure of environmental capital spending. They find evidence that the disclosed amounts are not quantitatively material for the majority of the sample and suggest that non-disclosure could be due to immateriality. An interesting paper by Matisoff (2013) analyzes the effectiveness of two different US environmental disclosure programs: the mandatory public state reporting requirements for the disclosure of carbon dioxide emissions and the voluntary private, non-profit Carbon Disclosure Project. The author concludes that state reporting requirements have no impact on plant level carbon emissions and that the Carbon Disclosure Project has a modest impact, possibly due to different ways of environmental information communication. Deficiency in the communication of collected environmental data may be due to the ineffectiveness of the mandatory state reporting program.

A good environmental regulation is also necessary to improve environmental performance. Porter and van der Linde (1999) analyze environmental standards and regulation for different industries and different countries. A good environmental regulation encourages innovation. The competitiveness and a good environmental performance are both possible through innovative solutions. The example of Swedish pulp-and-paper industry regulation that introduces gradually standards and encourages innovative solution for reducing environmental pollution proves that a good environmental regulation has important positive effects on the environment through innovation. Swedish companies, as 'Sunds Defibrator and Kamyr', developed and sold innovative pulping and bleaching equipment that lower emissions, lower operation costs and create a niche-market for chlorine-free paper. U.S. was the first country that regulated pulp-and-paper industry, imposing the adoption of «best» available technologies

quickly. Companies had not have the time to improve their own processes or to innovate, to find better technologies than existent «best» available technologies that provide only end-of-pipe solution such as secondary treatment of wastes. The result was that U.S. companies only installed secondary treatment of wastes, being locked in a particular existent technology, while Swedish companies go beyond that. Porter and van der Linde (1999) conclude that a good environmental regulation should create maximum opportunity for innovation.

Previous studies tend to show that the lack of regulation leads to incomplete and low-quality environmental disclosure. We conclude that environmental regulation should provide a framework for the complete, reliable, and qualitative disclosure of the environmental impact of firm activities. A standardized format for disclosure should be developed. Good regulation would be the first step to better environmental disclosure, improved environmental management, and better environmental performance.

1.6. Radical/critical literature

In the 1970s, social and environmental accounting literature was seen as radical and critical, because the accepted model of an organization included only accountability to its shareholders and creditors and non-traditional disclosure was aimed to inform and satisfy stakeholder requirements. Attitudes changed, theoretical frameworks and empirical methods for accounting research were developed and social and environmental accounting literature moved from critical research to being the object of criticism. Spence, et al. (2010) criticism is directed toward the theories used in the social and environmental accounting literature. In their opinion, these theories were developed in isolation and mimic those of other types of organizational literature. In imaginative terms, legitimacy theory is seen as a “coconut

radio"[7] and stakeholder theory as "boil-in-the-bag rice," ready to be served by social and environmental accounting islanders. The authors recommend putting an end to cargo cult science[8] and moving beyond it.

Another critical perspective is that of Parker (2005), who recommends a change in the direction of the social and environmental accounting literature toward qualitative and inductive research, cross-disciplinary explorations of environmental management, environmental law, and environmental economics. Future research areas suggested by Parker are corporate governance, corporate ethics, corporate philanthropy, and the history of social and environmental accounting.

These critics have their merit, for they encourage the development of better theoretical backgrounds. This research area has to critically analyze its limitations and go forward by following the directions outlined previously or by finding new and valuable directions.

[7] In French Polynesia, gossip transmitted from person to person is called a coconut radio.
[8] The term *cargo cult science* was used by the physicist Richard Feynman to name practices that looks to be scientific but, in fact, they do not follow a scientific method: "So I call these things cargo cult science, because they follow all the apparent precepts and forms of scientific investigation, but they're missing something essential" (Feynman, 1985) p. 340).

Chapter II. Hypothesis development

The lack of regulation or standardized format for disclosure gives rise to great variability in the forms, levels, and quality of environmental disclosure among firms. As mentioned in Chapter I, the reliability of environmental disclosure is very important in guiding investors and other stakeholders in their decision processes. The reliability or accuracy of environmental disclosure is reflected in a firm's association between environmental performance and its level of environmental disclosure. This relationship allows determining whether a firm's environmental disclosure is a faithful, ideally complete, neutral and free of error, representation of its environmental performance.

The aim of this study is to examine this relationship. We consider that environmental innovation plays an important role on this relationship. This research will test competing predictions of the relationship between environmental performance and environmental disclosure from different theoretical perspectives: economic versus socio-political theories. It will also empirically test the influence of environmental innovation on the relationship between these two constructs. Compared to previous literature, this study introduces a new explanatory variable, environmental innovation, to better explain and understand the determinants of environmental disclosure. As mentioned in Chapter I, prior research on the relationship between environmental performance and environmental disclosure leads to mixed results. We posit that environmental innovation is an important omitted variable that needs to be considered when examining the relationship between environmental performance and environmental disclosure. We also hypothesize that environmental innovation interacts with environmental performance to influence the relationship between environmental performance and environmental disclosure.

2.1. Hypothesis development

This research will empirically test competing predictions on the relationship between environmental performance and environmental disclosure from different theoretical perspectives.

Economics voluntary disclosure theory posits that firms with good environmental performance have incentives to disclose their good performance through voluntary disclosure (Bewley & Li, 2000); (P. Clarkson et al., 2008), (P. Clarkson et al., 2011). Hence, voluntary disclosure theory predicts a positive association between environmental performance and voluntary environmental disclosure: better performers should disclose more about their good environmental performance. Figure 2-1 illustrates the relationship between environmental performance and environmental disclosure for good performers, using voluntary disclosure theory. A positive association is expected: a better-performing firm will have higher quality and more extensive environmental disclosure.

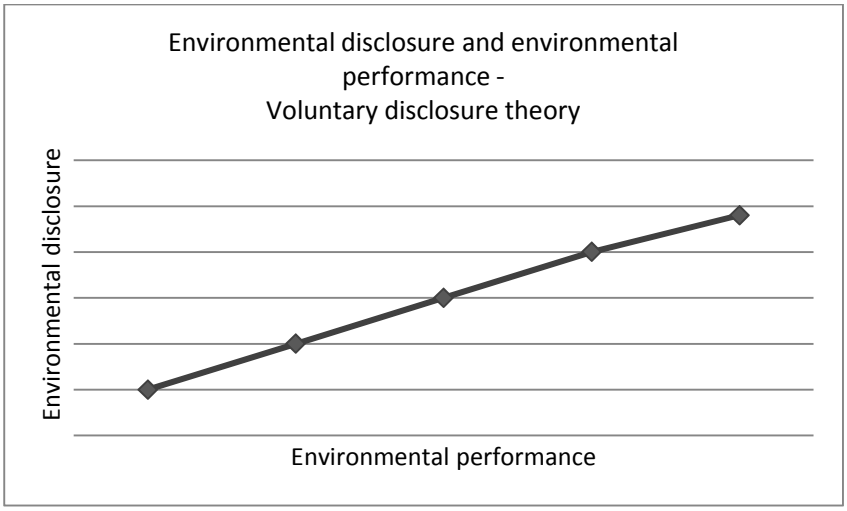

Figure 2- 1: The relationship between environmental performance and environmental disclosure -Voluntary disclosure theory

Our first hypothesis is then as follows.

> ***H_{1a}***: *There is a positive association between environmental performance and environmental disclosure.*

From a sociopolitical point of view, environmental disclosure is used as a tool to change stakeholders' perceptions about a firm and legitimize its environmental activities ((Solomon & Lewis, 2002); (Cormier & Aerts, 2009)). As stakeholders' expectations regarding environmental performance and activities have increased over time, the legitimacy of firms with poor environmental performance has been threatened and these firms have incentives to disclose more (Gray et al., 1995). Hence, socio-politically based legitimacy theory predicts a negative association between environmental performance and environmental disclosure.

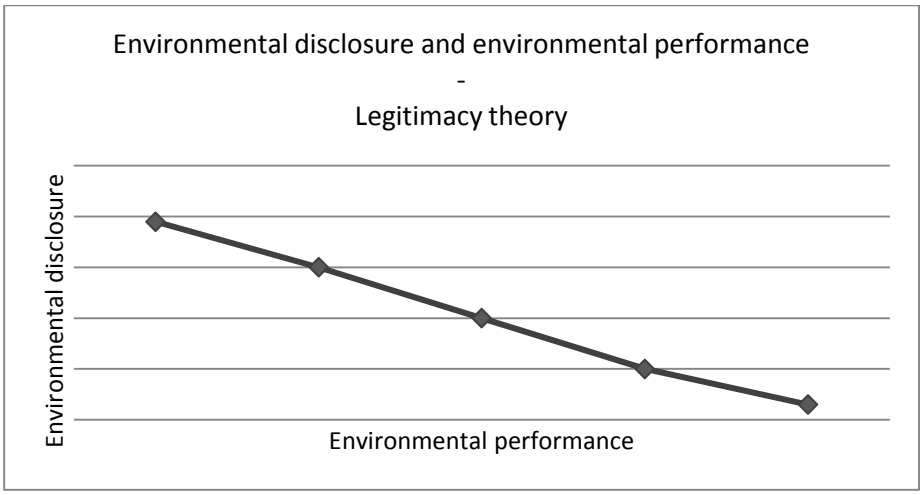

Figure 2- 2: The association between environmental performance and environmental disclosure- Legitimacy theory

Figure 2-2 shows the predicted association between environmental performance and environmental disclosure according to legitimacy theory. Firms with poor environmental performance should disclose more than firms with good environmental performance to legitimize their environmental activities.

Sociopolitical theories, in opposition to economic theories, predict a negative association between environmental performance and environmental disclosure. Hence the hypothesis H_{1b} is:

> ***H_{1b}***: *There is a negative association between environmental performance and environmental disclosure.*

Innovation has an important impact on environmental performance. A proactive environmental strategy based on environmental innovation should lead to a positive association between financial performance and environmental disclosure (Porter & van der Linde, 1999). Based on the affirmation that pollution means inefficiency, the authors claim that we should change our thinking about environmental performance. The traditional view of environmental improvement efforts is centered on pollution control, focusing on waste management (identification, processing or waste disposal). This form of pollution reduction is a costly one. Companies perceive waste management as an additional activity performed and as an additional cost, with no value for customers. A better approach is to focus on pollution prevention instead of pollution reduction. Through process and product innovation, companies use inputs more efficiently, identify and eliminate unnecessary materials and activities, recycle and improve secondary treatment, and create value for customers. Process and product innovation result in material savings, lower energy consumption, reduced material storage, conversion of waste into valuable forms, lower packaging costs, etc. (Ambec & Lanoie, 2008).

Environmental innovation is also deemed to have an impact on environmental disclosure. A proactive, innovative environmental strategy provides incentives for managers to disclose more and to inform stakeholders about improved environmental performance (Bewley & Li, 2000). Environmentally innovative firms are expected to disclose more about their environmental performance.

The second hypothesis is then as follows.

> ***H_2**: There is a positive association between environmental innovation and environmental disclosure.*

Figure 2-3 presents the expected form of the relationship between environmental innovation and environmental disclosure for innovative firms. Environmental innovative firms have incentives to disclose more about their environmental activities.

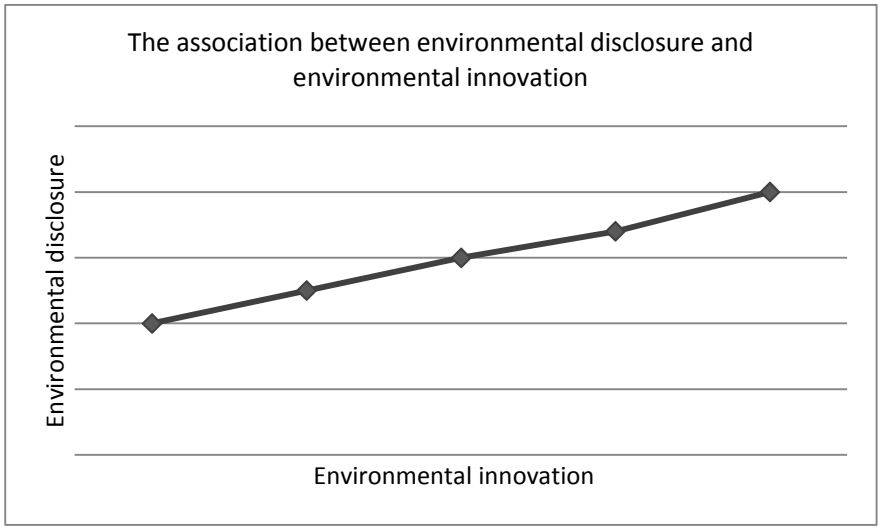

Figure 2- 3: The graphic of the expected association between environmental innovation and environmental disclosure (H_2)

Firms that adopt proactive, innovative strategies to accommodate stakeholders have environmental performance positively associated with voluntary climate change disclosure (Dawkins & Fraas, 2011). Environmental innovation is likely to influence the relationship between environmental performance and environmental disclosure. Environmentally innovative firms have incentives to disclose about their environmental activities, especially when they are in a situation where their environmental performance is not quite up to par. But when they reach a certain level of environmental performance, they will be

more likely to disclose information about their performance. Environmental performance and environmental innovation act as substitutes in their relationship with environmental disclosure.

The third hypothesis is as follows.

> ***H_3**: At low levels of environmental performance, environmentally innovative firms disclose more than non-innovative firms. At higher levels of environmental performance, the latter is the dominant driver of disclosure.*

Environmental innovation involves processes, techniques, systems, or products that are designed to avoid or reduce environmental damage. Since environmental innovation is a new research area, few papers related to environmental innovation have been published. To our knowledge, no existing empirical research addresses the influence of the environmental innovation on environmental disclosure.

Technical environmental innovations include environmental product innovations and environmental process innovations (Ziegler & Seijas Nogareda, 2009). Environmental product innovation refers to the introduction of an environmentally improved or new environmentally friendly product, such as photovoltaic solar panels or solar heat collectors used as a green source of energy. Environmental process innovations imply the introduction of environmentally friendly internal processes, such as industrial extraction using supercritical carbon dioxide to obtain decaffeinated coffee and tea or to extract spice and aromatic plants, with no residual traces on product[9].

Technological environmental innovation is also related to the environmental management systems (EMS) adopted by firms, but the causal relationship is not clear (Ziegler & Seijas Nogareda, 2009). Environmental management systems are "part of an organizational management system used to develop

[9] Supercritical carbon dioxide is carbon dioxide above its critical temperature (31.1°C) and critical pressure (73 atm).

and implement its environmental policy and manage its environmental aspects."[10] The general international standard used to certify an organization's environmental management systems is the ISO 14001 (see Appendix A).

The environmental management system model used by ISO14001 is presented in Figure 2-4. A continual improvement or innovation links planning, implementation and operation and review processes.

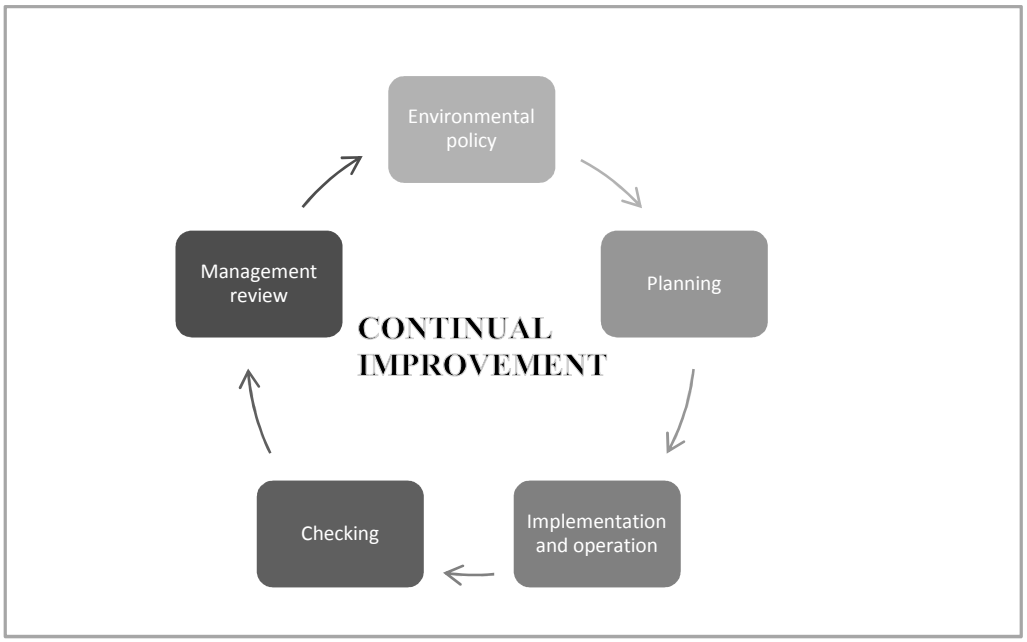

Figure 2- 4: Environmental management system model for ISO14001

As Ziegler and Seijas Nogareda (2009) conclude, technological environmental innovation and environmental strategy are related. Environmental strategy is a part of firm's general strategy. Consequently, environmental innovation, general business strategy, and environmental management systems form a nexus with multiple and complex interconnections.

[10] As defined by ISO 14001: 2004 at 3.8, https://www.iso.org/obp/ui/#iso:std:iso:14001:ed-2:v1:en

Wagner (2007) studies environmental management systems and their association with process innovations. He finds that environmental innovation can be appropriately and meaningfully identified using patent data. This research therefore also uses patent data as a proxy for environmental innovation.

Statistically, a moderator is a variable that affects the direction and/or strength of the relationship between independent and dependent variables. Different levels of the moderator determine different relationships between independent and dependent variables.

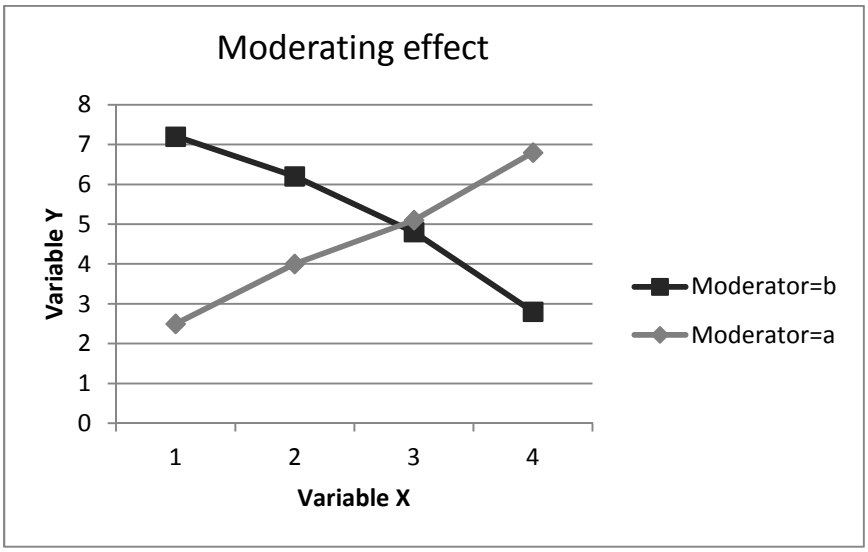

Figure 2- 5: Moderating effect – an example

Figure 2-5 presents an example of moderating effects. The relationship between the variables X and Y changes when the moderator changes value from a to b; a positive relationship is noted when moderator takes value a and the relationship switch to negative when moderator takes value b.

2.2. Conceptual model

As put forward in the previous section, environmental innovation is expected to have a moderating effect on the relationship between environmental performance and environmental disclosure (***H_3***), such

that environmentally innovative firms will be more likely to make environmental disclosure when their environmental performance does not reach a high level. When they reach a high level of environmental performance, they will be more likely to disclose information about their performance.

In this research, we use a dichotomic variable to measure the level of environmental innovation: environmentally innovative firms are coded 1 and those with no environmental innovation, zero. Figure 2-6 illustrates the conceptual model of this research.

Figure 2-6 presents the predicted association between environmental performance, environmental innovation and environmental disclosure and the substitution effect of environmental performance and environmental innovation.

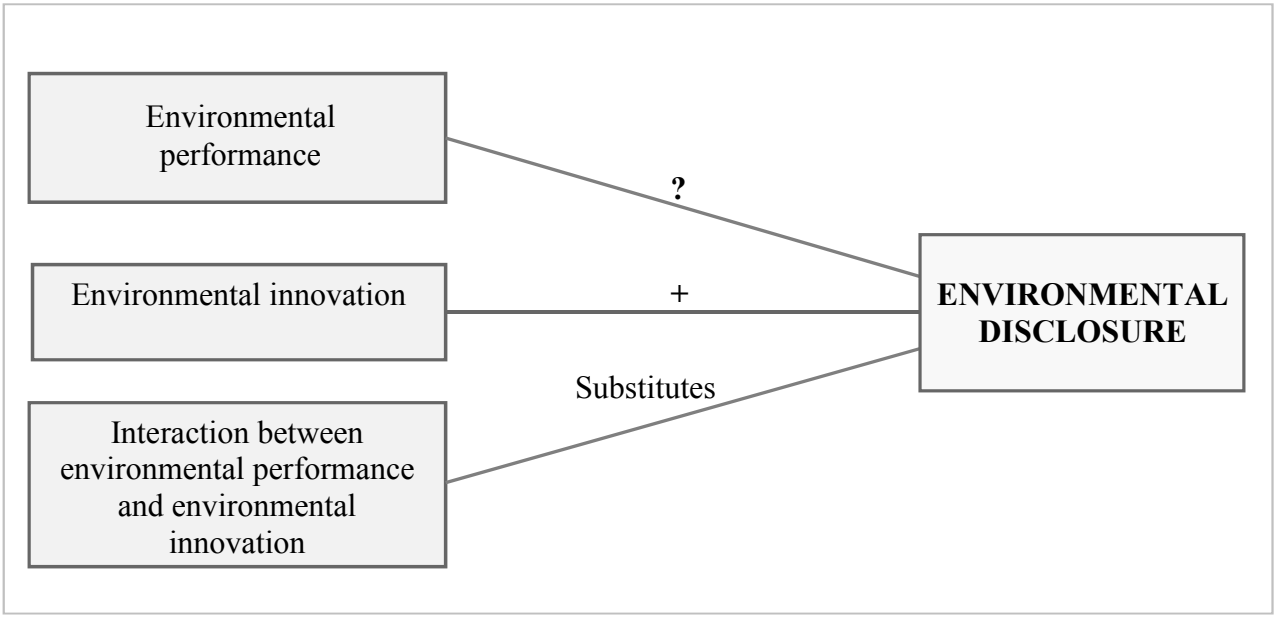

Figure 2- 6: The influence of environmental innovation on the association between environmental performance and environmental disclosure

In this study, we measure environmental disclosure by using an index developed by Cormier and Aerts (2009) and also used by Cormier and Magnan (2003) and Aerts et al. (2006). Environmental information is collected from annual reports (Form 10-K) and stand-alone environmental reports, such as sustainability reports, CSR reports, citizenship reports and firm's website, such as a sustainable

development portal or a health, safety, security, and environment commitment. Environmental performance includes emission of pollutants, discharges, spills, waste management, recycling, the presence of installations and process controls, environmental management systems, compliance status and facilities. Environmental performance is measured using the environmental component of the Jantzi Sustainability Index provided by Sustainalytics[11] for US firms. Similar measures are used in recent papers by (Orij, 2010) and (Dawkins & Fraas, 2011). Environmental innovation consists of "new or modified processes, techniques, systems and products to avoid or reduce environmental damage", as defined by R. Kemp et al. (2001). The measure used for environmental innovation is the number of a firm's environmental patents (Carrión-Flores & Innes, 2010; Popp, 2002; Wagner, 2007).

Chapter III presents detailed descriptions of the sample, variables, and regression model used to test our hypotheses. Results and analysis follow in Chapter IV and discussion and conclusion are presented in Chapter V.

[11] See http://www.sustainalytics.com/indexes.

Chapter III. Methodology

Our sample is composed of 210 US listed firms from environmentally sensitive industries for which environmental performance data from Sustainalytics[12] and environmental innovation data from the patent database by Thomson Innovation in 2011[13] was available. The control variables were obtained from the Compustat database.

3.1. Sample selection

The sample includes 661 US listed firms scored by Sustainalytics for their environmental performance for the fiscal year 2011. Available environmental patent data were collected from the Thomson Innovation's database. To identify environmental patents specifically, the International Patent Classification (IPC) Green Inventory was used. The IPC Green Inventory is the World Intellectual Property Organization's[14] (WIPO, 2010) list of green or environmentally sound technologies, used by over 100 patent offices worldwide. The IPC Green Inventory was created in 2010 to facilitate the search for patent documents related to green technologies in different areas, including energy production and conservation, waste management, nuclear power generation, and transportation. The IPC Green Inventory includes 1,097 IPC codes that were used to collect data from the Thomson Innovation environmental patent database (see Appendix D – IPC Green Inventory for details about

[12] See http://www.sustainalytics.com/indexes

[13] See http://info.thomsoninnovation.com/.

[14] See http://www.wipo.int/portal/en/.

environmentally sound technology used to collect environmental patents in this research). A total of 2,401 firms with 6,146 environmental patents were identified for fiscal year 2011. The environmental performance scores were merged with the data on the number of environmental patents for each US firm scored by Sustainalytics , for a total of 661 firms.

The level of environmental disclosure was manually scored using a grid developed by Aerts et al. (2006) and Cormier and Aerts (2009). The manual collection consisted of gathering each of the 39 items from this grid for all the firms by searching through all the available data from annual reports, sustainability reports, citizenship reports, CSR reports, and any other information available on the firms' websites. The data collection was carried out by myself and took more than five months of full-time work. Each firm's website was identified and each report susceptible to contain environmental disclosure downloaded and examined. The examination included all pages of the reports, because each firm presents its environmental information differently. For the firms in the sample, stand-alone environmental reports generally ran from 50 to 150 pages and 10-K forms generally involved 100 to 200 pages. The data was collected by industry and a scoring test was performed at the end to ensure uniformity of scoring between the first and last firms scored in each industry.

The data was collected for environmentally sensitive industries, as identified by P. Clarkson et al. (2008), Cormier and Aerts (2009), and C. Cho et al. (2010). The environmentally sensitive industries selected are:

- Materials, including chemicals, steel, aluminum, diversified metals and mining, and construction materials;
- Industrials, including aerospace and defense, transportation, electrical equipment, and machinery;
- Energy, including oil, gas, and fuels and energy equipment services; and

- Utilities, including electric, gas, and water utilities, power producers, and energy transportation.

The sample of environmentally sensitive industries comprises 214 firms. Control data were not available for four firms, due to mergers and acquisitions; these firms were removed from the sample. This provided a final sample of 210 firms for the fiscal year ended in 2011: 39 from materials, 73 from industrials, 56 from energy, and 42 from utilities.

3.2. Moderation effect

Hypothesis ***H₃*** predicts that environmental innovation plays a moderator role on the relationship between environmental performance and environmental disclosure. Environmental innovation interact with environmental performance to influence this relationship such that environmentally innovative firms will be likely to disclose significantly more than non-innovative firms when both are consider poor performers. Disclosure gap tend to be mitigated when environmental performance increases.

Statistically, a moderator is "a qualitative or quantitative variable that affects the direction and/or strength of the relationship between an independent or predictor variable and a dependent or criterion variable" (Baron & Kenny, 1986). It is also a variable that affects the relationship between two other variables. The moderator model adapted from Baron and Kenny (1986) is shown in Figure 3-1.

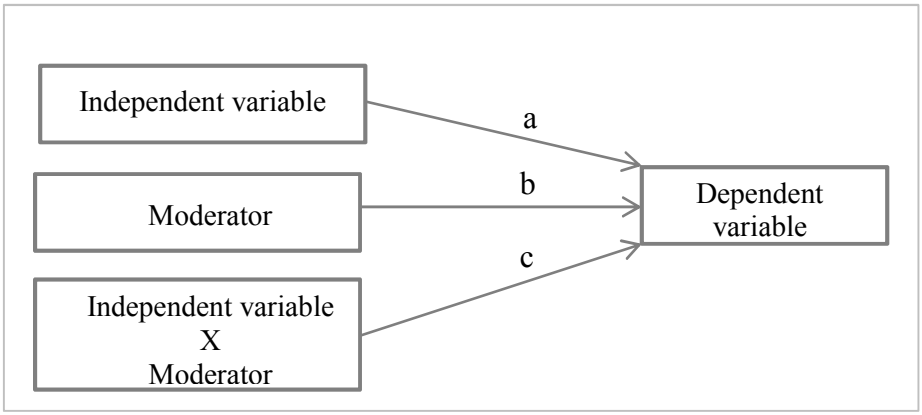

Figure 3- 1: Moderator model

The moderator model includes the impact of an independent variable (path a), a moderator (path b), and the interaction or the product of independent variable and moderator (path c) on the dependent variable. The moderation hypothesis is tested by adding the product of the moderator and the independent variable to the regression. The hypothesis is supported if the path c or the interaction term *Independent variable x Moderator* is significant. Path a and b could also be significant, but there are not relevant for testing moderator hypothesis.

A common example of a moderator effect is when the slope of the relationship between the dependent and independent variable changes across values of the moderator variable (Hair et al, 2006). Other possible moderator effect is when the strength of the relationship changes.

The regression coefficients should be carefully interpreted to capture the overall effect of a variable, including separate and moderated effects. In the moderator model presented in Figure 3-1, a and b coefficients represent the effect of independent and moderator variable, respectively, when the other variable is zero. The c coefficient represents the unit change in the effect of independent variable as moderator value changes. The overall effect of independent variable for any value of moderator is represented by (a + c x Moderator).

3.3. Regression model

The following regression is the simplified model of the relationship between environmental performance and environmental disclosure (P. Clarkson et al., 2008; Patten, 2002):

$$ED_i = \alpha + \beta_1 EP_i + \beta_{2\ to\ 6} Control_i \quad (1)$$

where, for firm *i*,

ED_i represents the total environmental disclosure score,

EP_i represents the firm's environmental performance, and

$Control_i$ represents the control variables deemed to affect environmental disclosure.

The regression (1) is used to test competing predictions from different theoretical perspectives of the relationship between environmental performance and environmental disclosure ($\boldsymbol{H_{1a}}$ and $\boldsymbol{H_{1b}}$). Economics voluntary disclosure theory predicts a positive association between environmental performance and environmental disclosure ($\boldsymbol{H_{1a}}$), in contrast with sociopolitical theories that predicts a negative association ($\boldsymbol{H_{1b}}$).

At this simplified model a new explanatory variable is added: environmental innovation.

$$ED_i = \alpha + \beta_1 EP_i + \beta_2 EI_i + \beta_{3\ to\ 7} Control_i \quad (2)$$

where, for firm *i*,

ED_i represents the total environmental disclosure score,

EP_i represents a firm's environmental performance,

EI_i is a dummy variable that equals one for environmentally innovative firms and zero otherwise, and

$Control_i$ represents the control variables deemed to affect environmental disclosure.

Regression (2) is used to test the statistical significance of environmental innovation as an explanatory variable of environmental disclosure. A positive association between environmental innovation and environmental disclosure is expected (***H₂***).

The regression model of the relationship between environmental performance and environmental disclosure, including environmental innovation as a moderator, is:

$$ED_i = \alpha + \beta_1 EP_i + \beta_2 EI_i + \beta_3 EP_i * EI_i + \beta_{4\ to\ 8} Control_i \quad (3)$$

where, for firm *i*,

ED_i represents the total environmental disclosure score,

EP_i represents the firm's environmental performance,

EI_i is a dummy variable that equals one for environmentally innovative firms and zero otherwise, and

$Control_i$ includes a set of control variables deemed to affect environmental disclosure.

Environmental innovation is expected to moderate the relationship between environmental performance and environmental disclosure (***H₃***), such that environmentally innovative firms will be likely to disclose more than non-innovative firms when they are poor performers. This disclosure gap is absorbed as environmental performance increases.

The coefficient of the interaction term, β_3, is expected to be statistically significant. The overall effect of environmental performance on environmental disclosure, for any value of environmental innovation, is represented by the combination of separate and moderated effect: $(\beta_1 + \beta_3 * EI_i)$. The overall effect will be represented by $(\beta_1 + \beta_3)$ for environmental innovative firms and by β_1 for firms with no environmental innovation.

3.4. Variables

Environmental disclosure is the dependent variable in the regression, while environmental performance and environmental innovation are the independent variables. The control variables in the model are industrial sector, size, leverage, market-to-book value, and financial performance.

3.4.1. Dependent variable

The dependent variable, environmental disclosure, is known to be difficult to measure because of the differences in disclosure methods. Some firms prefer to voluntarily disclose environmental information in their annual reports or as part of a CSR report; health, safety, and environment report; or corporate citizenship report, while others prefer to do so in a stand-alone report, such as sustainability or environmental report. Other sources of environmental information include press releases or other media releases, the firm's official website, and analyst reports or scores. There is also variability concerning the quality of environmental information disclosed. Some firms disclose detailed environmental reports, including environmental operation costs, investments and liabilities, level of emissions or number of spills, while others only general environmental information as description of environmental policies, recycling process or firm's involvement in environmental projects.

Recent work on environmental reporting (Cormier & Magnan, (2003); Aerts et al. (2006); Cormier and Aerts (2009)) measures environmental disclosure by using a combination of scores based on both the quality and the quantity of environmental disclosure. The present study uses a coding instrument based on the environmental disclosure grid developed by Cormier and Aerts (2009) to score environmental disclosure. As mentioned by the authors of the instrument, the use of this coding scale is appropriate,

since it allows the integration of different types of information in the same framework and assures comparability across industries and firms.

This study scores firms' annual reports (Form 10-K) and sustainability reports and any other information available on a firm's website. As presented previously, the environmental disclosure index includes 39 items, each manually collected. This represents an important volume of collected data and the collection process was fastidious. This manual data collection is unique to our research.

The environmental disclosure grid is divided into six groups of factors: expenditures and risks, compliance with laws and regulation, pollution abatement, sustainable development reporting, land remediation and contamination, and environmental management (see Appendix B for the environmental disclosure index for all 39 items and Appendix C for an example of collected environmental disclosure score). The rating scale scores are one for an item described in monetary or other quantitative or qualitative terms and zero for an item that is not discussed. A limitation of the data collection is its potential subjectivity, because the collection was carried out by only one researcher. To reduce the risk of subjectivity, the data were collected by industry and then recollected for a selected test sample to ensure that the process of scoring was uniform and unbiased.

3.4.2. Variables of interest

Environmental performance is another variable that is difficult to measure, mainly due to the diversity of industries and business areas; the complexity of a firm's activities and operations; the multiple ranges of emissions and environmental impacts, from nuclear waste to noise pollution; difficulties in finding instruments and technological methods to measure emissions, accidental emissions, discharges, or spills; different perceptions about firms' environmental activities, a scarcity of diverse resources, and different levels of efficiency and consumption.

As a proxy for environmental performance, the environmental literature (Cormier & Aerts, 2009) uses the Toxic Release Inventory[15] (TRI), a public database of the US Environmental Protection Agency that includes more than 650 toxic chemicals released into the air or water or on land, as self-reported by firms. Other measures used in the environmental performance literature are scores from organizations specialized in quantitative performance measurement, such as the Environmental Impact Score, calculated by Trucost and reported by Newsweek (C. Cho et al., 2012), or the environmental performance ratings of KLD Analytics (Dawkins & Fraas, 2011). A database similar to KLD's is provided by Sustainalytics and contains data on social corporate disclosure, including environmental, social, and governance performance scores.

As in Orij (2010), the measure for environmental performance used in the present research is Sustainalytics' environmental performance rating, which evaluates exposure to environmental issues, management systems, public reporting, impact and initiatives, regulatory compliance, the environmental impact of products/services, and miscellaneous environmental data. The environmental indicators used by Sustainalytics to score environmental performance are presented in Appendix D. Each indicator has a scoring range and a weight to reflect its importance compared to the firm's peer group. Each firm has a raw score for each indicator, normalized between zero and one. A firm's total is obtained by a weighted average of the scores for each group of indicators. The scoring scheme is based on the sectors or industries best practices.

Environmental innovation consists of "the production, assimilation or exploitation of a product, production process, service or management business methods that is novel to the organization and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other impact of resources use", as defined by R. Kemp, Pearson, P. (2007). As these authors suggest, a possible measure

[15] See http://www.epa.gov/enviro/facts/tri/index.html.

for environmental innovation is patent analysis. The proxy used for environmental innovation is a binary variable derived from the number of environmental patents issued by firms. The number of patents is largely used in prior research on environmental innovation (Brunnermeier & Cohen, 2003; Popp, 2002); (Carrión-Flores & Innes, 2010). Wagner (2007) concludes that patented environmental innovations are "the most desirable measure of environmental innovation activities." Wagner (2007) and de Solla Price (1976) find that a small number of firms hold a high number of patents. The sample in the current study has the same distribution. Only 22 of 210 firms hold environmental patents and their number varies from one to 42, for a total of 143 environmental patents. A binary variable was therefore used as a proxy for environmental innovation that equals one if the firm has at least one environmental patent and zero otherwise. The distribution of environmental patents in the sample for firms with at least one environmental patent is presented in Figure 3-2.

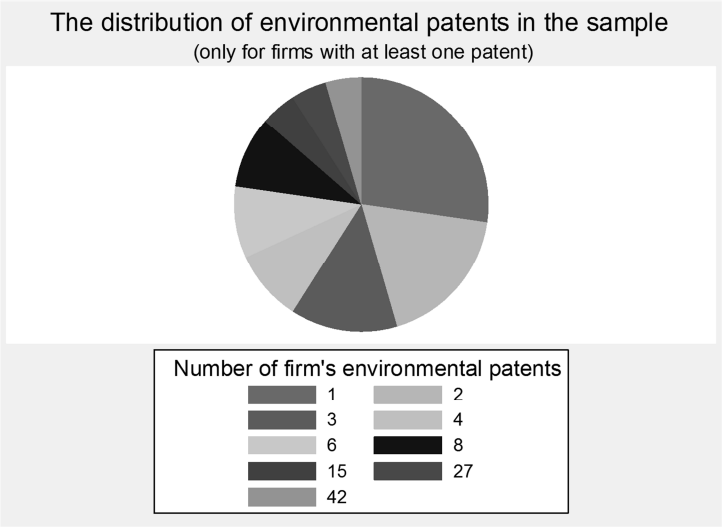

Figure 3- 2: The distribution of environmental patents in the sample

Patent data for US firms were collected from the Thomson Innovation[16] database, which provides data on patents and published applications from the Americas, Europe, and Asia. Environmental patents were identified and collected using the IPC Green Inventory. The IPC Green Inventory is a list compiled by

[16] See http://info.thomsoninnovation.com/en/features/search.

the World Intellectual Property Organization[17] of green or environmentally sound technologies as listed by the United Nations Framework Convention on Climate Change.[18] It includes 1,097 IPC codes that were used to collect data from the Thomson Innovation database on environmental patents in different industries and areas, such as alternative energy production; transportation; energy conservation; waste management; agriculture; forestry; administrative, regulatory, or design aspects; and nuclear power generation (see Appendix E – IPC Green Inventory).

3.4.3. Control variables

Prior research finds evidence of significant relationships between a firm's industry membership, size, leverage, market-to-book value, profitability, and environmental disclosure. We control for these variables associated with environmental disclosure. The control variables are collected from Compustat for the fiscal year ending in 2011.

A number of studies find evidence of industry membership association with environmental disclosure (Brammer & Pavelin, 2008; C. Cho & Patten, 2007); (Da Silva Monteiro & Aibar-Guzmán, 2010). Firms in environmentally sensitive industries are subject to greater environmental scrutiny and pressure from stakeholders than in other industries (Cormier & Aerts, 2009). As a result, these firms will disclose more and, consistent with prior research, a positive association is expected between environmental disclosure and membership in an environmentally sensitive industry. Firms from the same industry face the same regulatory context; hence, industry membership also controls for sector regulations (Patten, 2002). Industry membership is a dummy variable for each industrial sector.

[18] See http://unfccc.int/2860.php.

The sample includes four industries: materials, industrials, energy and utilities. As industry membership is a qualitative variable that has four categories, only three dummy variables was introduced. Energy sector was considered as the base category and a dummy variable was introduced for each of materials, industrials and utilities sector.

Firm size is also associated with environmental disclosure and prior evidence on the relationship between firm size and voluntary disclosure highlight a positive association (Patten (1992), Brammer and Pavelin (2008)). Firm size could also be a proxy for other firm characteristics, such as a firm's exposure to publicity and stakeholder scrutiny (P. M. Clarkson et al., 2011). Firms with increased exposure have an increased risk of litigation and would pay more attention to environmental issues. According to P. Clarkson et al. (2008) and Al-Tuwaijri et al. (2004), larger firms disclose more due to lower information production costs. Accordingly, a positive association between environmental disclosure and firm size is expected. Firm size is measured using the natural logarithm of total assets.

According to Roberts (1992), Cormier and Magnan (2003), and Aerts et al. (2006), debtholders can pressure a firm to disclose more. We measure leverage by using the debt ratio, total liabilities to total assets. Consistent with prior evidence, a positive association between a firm's leverage and its environmental disclosure is expected.

The market-to-book ratio is used as a proxy for the extent of intangible assets not reflected in financial statements. Financial analysts pressure firms in an attempt to obtain supplementary disclosure (Aerts et al., 2006). For firms with higher levels of intangible capital assets, a positive relationship between environmental disclosure and the market-to-book ratio is expected, with a higher level of intangibles related to better disclosure. Besides patents, intangible capital assets include computer software and copyrights.

Several papers (Gray et al., 1995); (Neu et al., 1998) have studied the association between firm profitability and environmental disclosure, with mixed empirical results. Hackston and Milne (1996) conclude that there is no significant association between profitability and the level of environmental disclosure, while other studies (Cormier & Magnan, 2003; Murray et al., 2006) note a positive association between firm performance, as measured by the accounting-based return on assets (ROA), and environmental disclosure. Since the impact of profitability on a firm's environmental disclosure is unclear, no prediction is made for the sign or significance of the relationship. Table 3-1 presents a summary of the variable measurements.

Table 3- 1: Variables measurement

Variable	**Measure**
Environmental disclosure	The total score of the 39 items of environmental disclosure grid, as presented in Appendix B. For each item, the rating is 1, if the item is described in monetary, quantitative or qualitative terms, and 0 for an item not discussed.
Environmental performance	The total score provided by Sustainalytics, obtained by weighting average of the scores for each group of indicators (see Appendix D).
Environmental innovation	Dummy variable taking value 1 for the environmental innovative firms, with at least 1 environmental patent in 2011, and 0 otherwise.
Industry membership	Dummy variable for each industrial sector.
Firm's size	Natural logarithm of firm's total assets in 2011.
Leverage	Total liabilities on total assets at year-end 2011.
Market-to-book ratio	Stock market value on equity at year-end 2010.
Firm's profitability	Return on assets for the fiscal year ended in 2011.

Chapter IV: Results and analysis

This chapter presents a review of our empirical findings.

4.1. Descriptive statistics and correlations

The final sample comprises 210 firms from four environmentally sensitive industries: energy, industrials, materials, and utilities. Table 4-1 presents the sample's industry composition, ranging from 34.76% firms from the industrial sector to 18.57% from materials. Table 4-2 presents descriptive statistics for the sample.

Table 4- 1: Sample industry composition

Industrial sector	*Number of firms*	*Percentage*
Energy	56	26.67
Industrials	73	34.76
Materials	39	18.57
Utilities	42	20.00
Total	210	100

Figure 4-1 represents the graphic of industry composition.

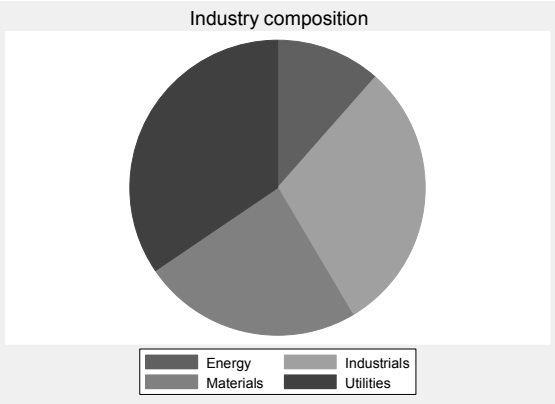

Figure 4- 1: Industry composition

Table 4- 2 : Descriptive statistics

Variable	Mean	Median	Std. deviation	Min	Max
Variables of interest					
Environmental disclosure	17.14	18.00	7.90	0	33
Environmental performance	50.88	49.62	9.11	26.02	76.34
Environmental innovation	0.11	0	0.31	0	1
Control variables					
Size	9.75	9.50	12.38	3.25	26.53
Leverage	0.62	0.63	0.18	0.13	1.37
MTB	1.76	1.97	8.62	-93.40	25.94
ROA	0.05	0.05	0.08	-0.75	0.21

Note: n = 210 firms.

Descriptive statistics are presented in Table 4-2. Environmental disclosure is evaluated as the sum of 39 items, with possible values of one and zero for each item; hence, environmental disclosure has a

theoretical maximum of 39. The sample's mean is 17.14 and the maximum is 33. The industry with the best score for environmental disclosure is utilities, with a mean score of 19.45, followed by materials, with a score of 18.74, the energy sector with 16.13, and industrials with 15.74. In our sample, 4 firms have an environmental disclosure score of 0, all of these firms are non-innovative as to the environment.

Firm environmental performance varies from 26.02 to 76.34, with a mean of 50.88. Detailed statistics by industry reveal the following means: 46.67 for the energy sector, 52.54 for industrials, 51.00 for materials, and 53.51 for utilities. Utilities are also the best environmental performer.

Figure 4-2 illustrates the means of environmental disclosure and environmental performance. The utilities sector is the best environmental performer and has the higher mean value of environmental disclosure. The worst environmental performer is the energy sector, while the industry with the lowest level of environmental disclosure is the industrial sector. The difference between the environmental disclosure of firms from the energy sector and of those from industrials is 0.39 and not visible in the figure.

Environmental innovation ranges from zero for firms with no innovation to one for innovative firms, with a mean value of 0.10. Environmentally innovative firms represent 10.48% of the sample. Figure 4-3 presents environmental innovation means by industry. The industry with the highest level is the materials sector, with 15.38% innovative firms, followed by energy with 14.29%, industrials with 8.22%, and utilities with 4.76%.

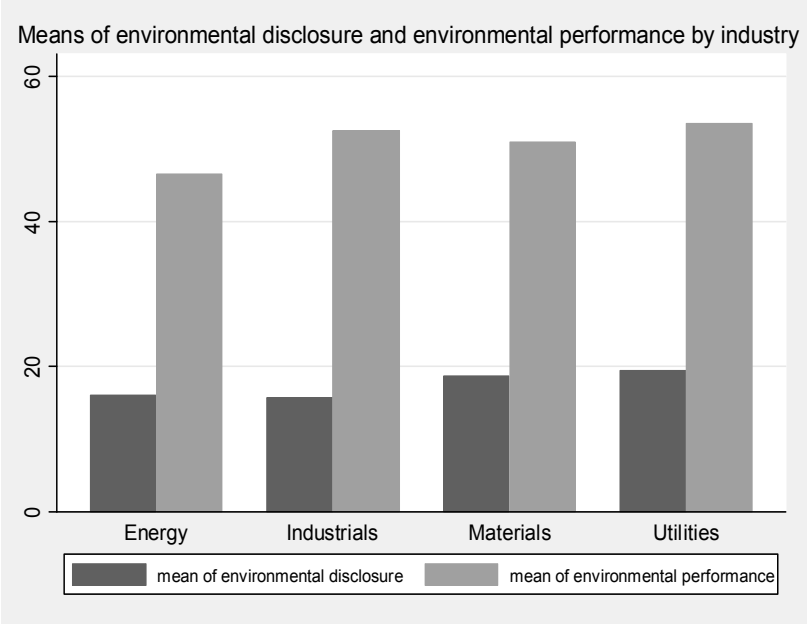

Figure 4- 2: Environmental disclosure and environmental performance by industry

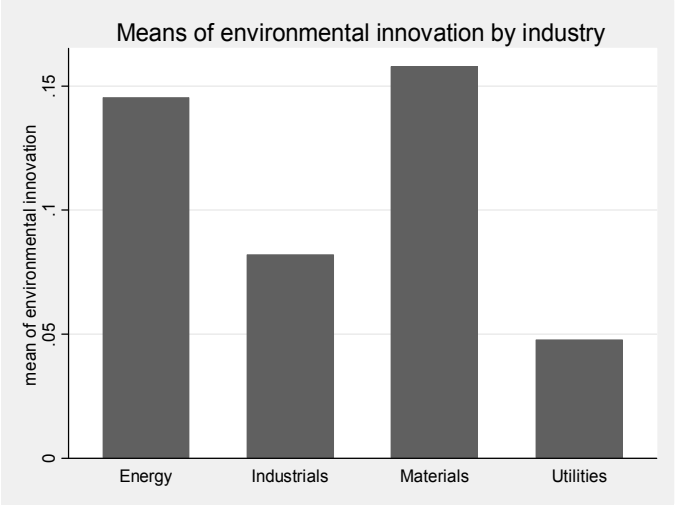

Figure 4- 3: Environmental innovation by industry

Descriptive statistics by environmental innovation are presented in Table 4-3. There is a significant difference between environmental disclosure for environmentally innovative firms (mean 21.50 and SD

5.51) and environmental disclosure for non-innovative firms (mean 16.63, SD 7.99), t(208)=2.77, $p \leq 0.05$, $CI_{.95}$ 8.32, 1.41, environmentally innovative firms disclosing more than non-innovative firms.

Table 4- 3: Descriptive statistics by environmental innovation

Variable	Mean	Median	Std. deviation	Min	Max
Variables of interest by environmental innovation					
Environmental disclosure for environmentally innovative firms	21.50	21.00	5.51	10	33
Environmental disclosure for non-innovative firms	16.63	17.00	7.99	0	33
Environmental performance for environmentally innovative firms	53.71	54.49	9.69	37	68.67
Environmental performance for non-innovative firms	50.55	49.33	9.01	26.02	76.34

The mean of environmental performance is 53.71 for environmentally innovative firms and is 50.55 for non-innovative firms. The difference between environmentally innovative firms and non-innovative firms is 3.16, environmentally innovative firms with a better environmental performance than non-innovative firms, but not statistically significant.

Figure 4-4 presents the graph of the mean of environmental disclosure by environmental innovation and figure 4-5 shows the mean of environmental performance by environmental innovation. Environmentally innovative firms disclose more and have a better environmental performance than non-innovative firms.

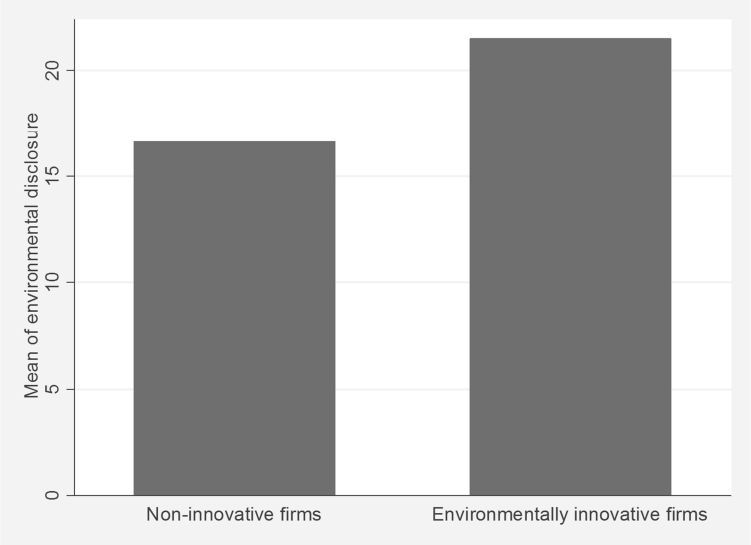

Figure 4- 4 : Mean of environmental disclosure by environmental innovation

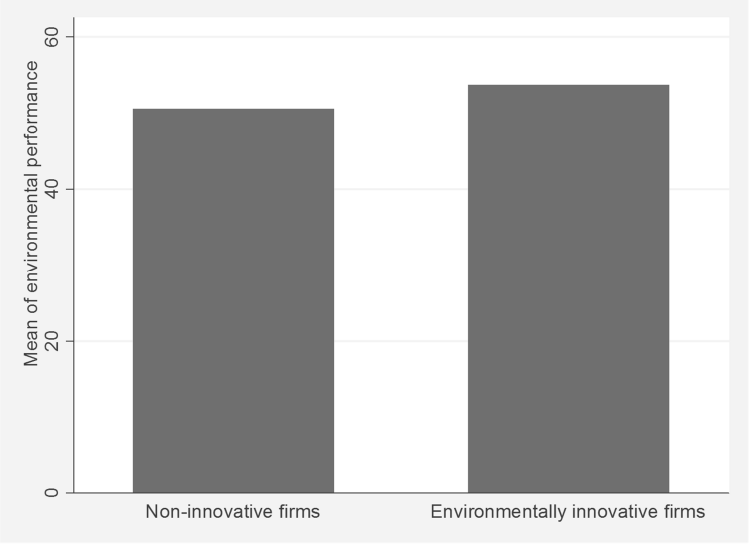

Figure 4- 5: Mean of environmental performance by environmental innovation

Table 4- 4: Correlations matrix

Variable	*ED*	*EP*	*EI*	*Size*	*Leverage*	*MTB*	*ROA*
ED	1.00						
EP	0.23**	1.00					
EI	0.19**	0.11	1.00				
Size	0.20**	0.05	0.12	1.00			
Leverage	0.07	0.23**	-0.01	0.00	1.00		
MTB	0.09	-0.06	0.06	0.07	-0.19**	1.00	
ROA	0.04	0.04	0.10	0.17**	-0.17**	-0.04	1.00
Industrial sectors[a]	0.04	0.09**	0.02	0.01	0.15**	0.01**	0.05

[a] Industrial sectors are represented by three dummy variables. Energy sector is the base category. The correlation values listed for industrial sectors are multiple R values. These multiple R values are obtained with multiple linear regression models.

n = 210 observations

Table 4-4 provides the correlations coefficients between the variables of the models. Environmental performance (0.23), environmental innovation (0.19), and firm size (0.20) are highly correlated with environmental disclosure. Leverage is correlated with environmental performance and market to book, ROA and industrial sectors. To ensure that highly correlated variables do not confound hypothesis testing, the variance inflation factor (VIF) for each regression model is calculated and reported in Tables 4-5, 4-6 and 4-7.

4.2. Multivariate analysis

Regression (1) models the basic relationship between environmental performance and environmental disclosure. This model was used to test competing predictions of the relationship between environmental performance and environmental disclosure from two different theories: economic voluntary disclosure theory H_{1a} and sociopolitical theories H_{1b}.

Table 4- 5: Results of regression analysis for hypothesis H_{1a} and H_{1b}

	Environmental disclosure			
Variable	**Estimated coefficient**	**Standard error**	**p-value**	**VIF**
EP	0.194	0.060	0.002***	1.18
Size	0.544	0.224	0.016**	1.08
Debt	1.550	3.361	0.645	1.28
Risk	0.0867	0.062	0.163	1.06
ROA	3.796	6.895	0.583	1.14
Industrials	-1.582	1.444	0.275	1.77
Materials	1.670	1.626	0.306	1.50
Utilities	1.718	1.691	0.311	1.71
_cons	0.585	3.837	0.879	
p	0.000***			
r2	0.130			
N	210			

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$ Mean VIF = 1.32

Table 4-5 presents the results of regression (1) used to test H_{1a} and H_{1b}. The results for regression (1) show a significant and positive relationship between environmental performance and environmental disclosure, consistent with economic voluntary disclosure theory predictions. The hypothesis H_{1a} is thus confirmed. The coefficient for the environmental performance is positive and statistically significant at 1% level. Firms with better environmental performance tend to be associated with greater environmental disclosure. Consequently, H_{1b}, that predicted a negative relationship between environmental performance and environmental disclosure, is not confirmed.

Table 4- 6: Results of regression analysis for hypothesis H_2

	Environmental disclosure			
Variable	**Estimated coefficient**	**Standard error**	**p-value**	**VIF**
EP	0.176	0.061	0.004***	1.19
EI	3.660	1.732	0.036**	1.09
Size	0.498	0.223	0.027 **	1.09
Debt	1.233	3.335	0.712	1.29
Risk	0.079	0.061	0.201	1.07
ROA	2.677	6.857	0.697	1.14
Industrials	-1.216	1.442	0.400	1.79
Materials	1.739	1.613	0.282	1.50
Utilities	2.218	1.693	0.192	1.75
_cons	1.547	3.832	0.687	
p	0.000***			
r2	0.149			
N	210			

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$ Mean VIF = 1.31

Regression (2) was used to test the hypothesis H_2. This model includes environmental innovation and environmental performance as explanatory variables for environmental disclosure. A positive association between environmental innovation and environmental disclosure is expected. Results reported in Table 4-6 provide evidence that environmental innovation is a significantly and positively associated with environmental disclosure. Environmental innovation's coefficient is positive and statistically significant (p-value of 0.034). These results confirmed hypothesis H_2, environmental innovative firms will disclose more about their environmental performance.

Hypothesis H_3, concerning the moderation effect of environmental innovation, was tested using regression (3). The product of environmental performance and environmental innovation is introduced as an interaction term in regression. Results are reported in Table 4-7. Consistent with H_3, the interaction term is statistically significant ($p < 0.05$, two tailed), providing evidence of the moderating role played by environmental innovation on the relationship between environmental performance and environmental disclosure. The standardized coefficient of the interaction term is negative (-0,397), while the coefficients for environmental performance and environmental innovation are positive: 0,220 and 24,863 respectively. These statistically significant coefficients suggest that the level of environmental disclosure is positively associated with both environmental performance and environmental innovation. The negative interaction term shows an attenuation of the positive effect of environmental innovation on environmental disclosure as environmental performance increases.

For firms with no environmental innovation, the coefficient 0,220 represents the total effect of environmental performance on environmental disclosure (then EI=0). For environmental innovative firms, the total effect of environmental performance on environmental disclosure will be obtained by adding at the main effect the interaction effect of environmental performance and environmental innovation: 0,220 – 0,397*EI. As for environmentally innovative firms EI=1, the coefficient for the total effect of environmental performance on environmental disclosure become negative: -0,177.

Figure 4-3 represents the graphs of environmental disclosure as function of environmental performance for firms with no innovation versus environmentally innovative firms. Hence, our data suggest that the relationship between environmental performance and environmental disclosure will be different for innovative firms then for firms with no environmental innovation: a negative relationship was found for environmental innovative firms and a positive relationship for firms with no environmental innovation.

Table 4- 7: Results of regression analysis for hypothesis H_3

	Environmental disclosure			
Variable	**Estimated coefficient**	**Standard error**	**p-value**	**VIF**
EP	0.220	0.063	0.001***	1.19
EI	24.863	9.686	0.011**	1.09
Interaction EP*EI	-0.397	0.178	0.027**	
Size	0.498	0.221	0.025 **	1.09
Debt	1.624	3.308	0.624	1.29
Risk	0.087	0.061	0.154	1.07
ROA	1.333	6.817	0.845	1.14
Industrials	-1.048	1.430	0.464	1.79
Materials	1.892	1.599	0.238	1.50
Utilities	2.237	1.676	0.184	1.75
_cons	-0.935	3.955	0.813	
p	0.000***			
r2	0.170			
N	210			

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$ Mean VIF = 1.31

Our results suggest that environmental disclosure is determined by both environmental performance and environmental innovation. Figure 4-7 represents the graph of the interaction between environmental performance and environmental innovation. Non-innovative firms tend to increase environmental disclosure when their environmental performance increases. Environmentally innovative firms provide generally more environmental disclosure than non-innovative firms at low levels of environmental performance" but this disclosure gap tends to be mitigated as environmental performance increases.

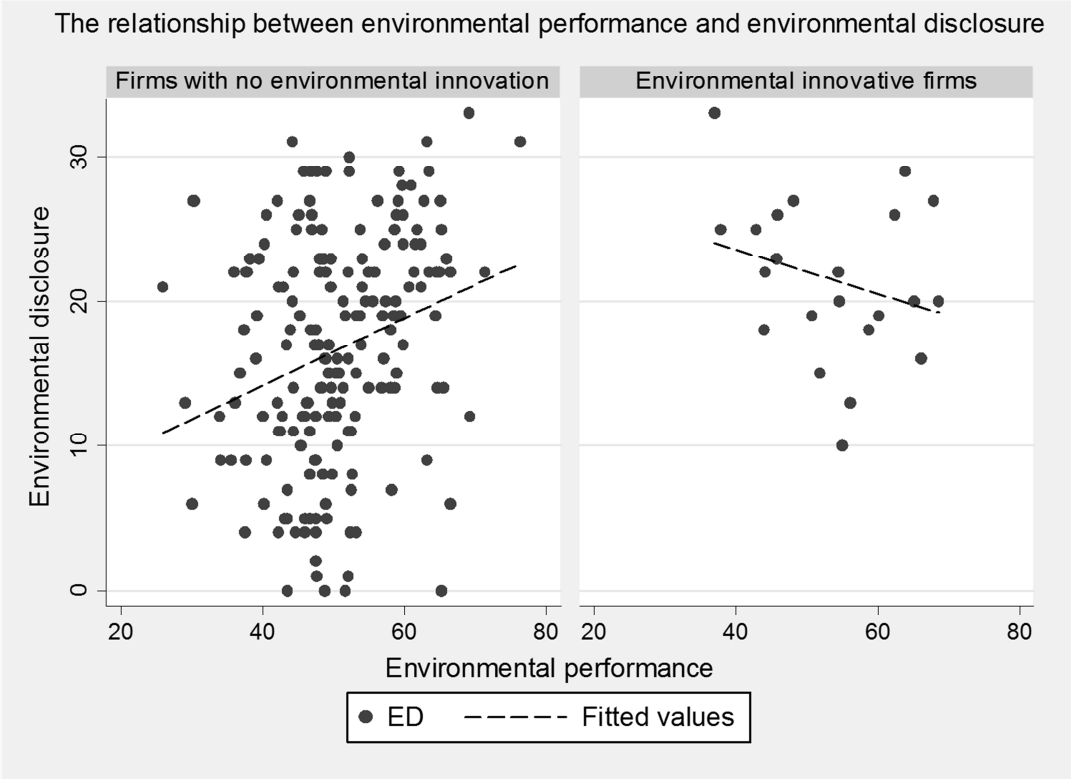

Figure 4- 6: Graphs of environmental disclosure as function of environmental disclosure for firms with no environmental innovation versus environmental innovative firms

Empirical results show that disclosure gap between environmentally innovative and non-innovative firms is completely absorbed when environmental performance reaches a high level. In our sample, this level corresponds to en environmental performance of 64.50. For innovative firms, there seems to be a substitution effect of determinants of environmental disclosure. At low level of environmental performance, environmentally innovative firms disclose more about their innovative strategy and action

plan to become better environmental performers. As they become better environmental performers, their environmental disclosure is more focused on performance elements.

In our sample, 9% of firms have a level of environmental performance higher than 64.50. That represents 19 firms: 15 firms are non-innovative and 4 are innovative firms.

The R-squared value varies from 0.13 for the regression (1) to 0.17 for regression (3). The final model explains 17% of the total variance of environmental disclosure. The introduction of environmental innovation as an explanatory variable increases the model's explanatory power, with the adjusted R-square value increasing from 0.096 for regression (1) to 0.128 for regression (3).

The results of the multicollinearity test are reported in Tables 4-4, 4-5 and 4-6. Collinearity between independent variables does not represent a problem as long as the variance inflation factor (VIF) is below 10 (Stevens, 1996). The VIF calculated for the three regression models do not exceed 1.5.

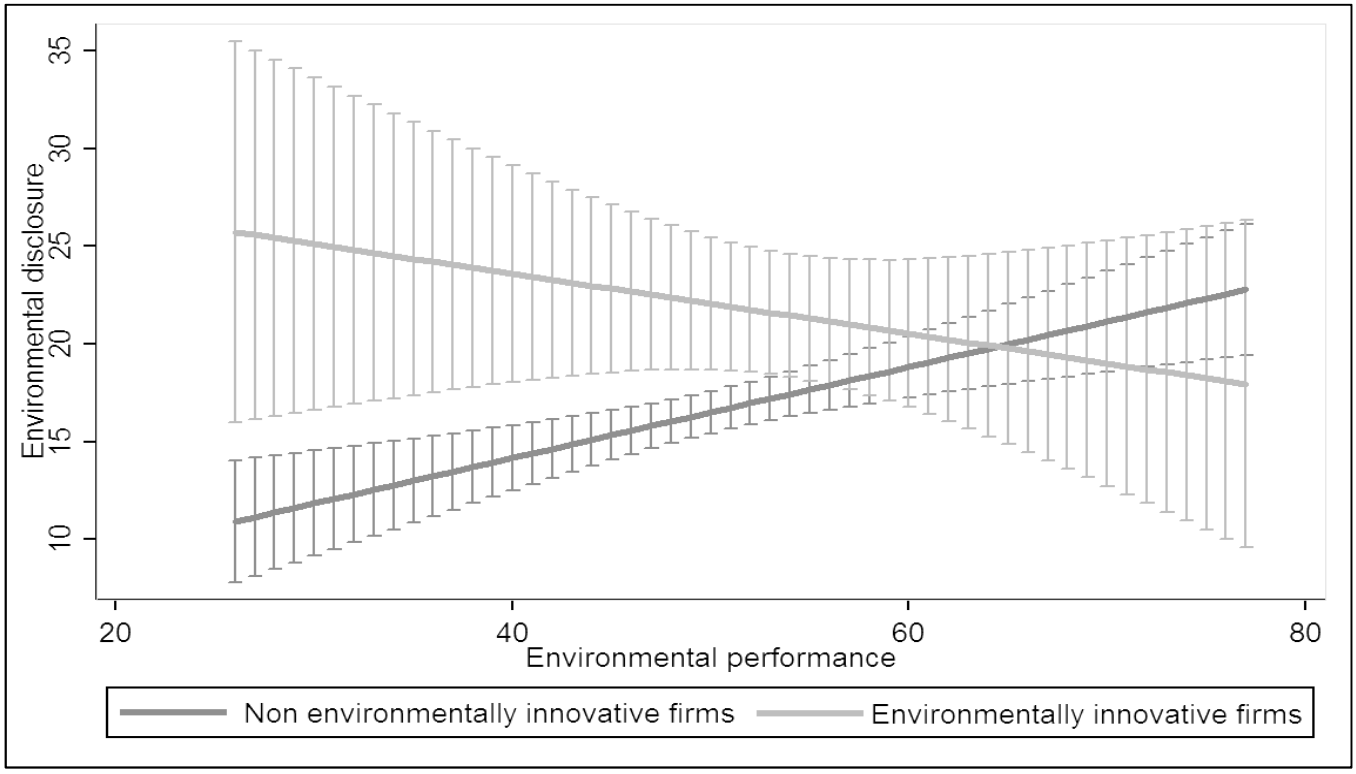

Figure 4- 7: Graph of interaction between environmental performance and environmental innovation

4.3. Sensitivity analysis

Sensitivity analysis was performed to check the robustness of our results. As our sample includes 210 firms from environmentally sensitive industries we tested our hypothesis without control for industry. Results of tests of hypothesis H_{1a} and H_{1b} are presented in Table 4-8. The coefficient of environmental performance is positive and statistically significant at 1% level.

Table 4- 8: Results of sensitivity analysis for hypothesis H_{1a} and H_{1b}

	Environmental disclosure			
Variable	**Estimated coefficient**	**Standard error**	**p-value**	**VIF**
EP	0.193	0.059	0.001***	1.12
Size	0.587	0.224	0.009**	1.07
Debt	1.940	3.195	0.544	1.14
Risk	0.094	0.062	0.134	1.06
ROA	0.840	6.774	0.901	1.07
_cons	0.187	3.820	0.961	
p	0.000***			
r2	0.099			
N	210			

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4-9 presents results of sensitivity analysis for hypothesis H_2. The coefficient for environmental performance and the coefficient for environmental innovation are positive and statistically significant.

Our conclusion of a positive and significant association between environmental performance, environmental innovation and environmental disclosure is not changed.

Results of sensitivity analysis for testing H_3 are presented in Table 4-10. The coefficient for the interaction term is also negative and statistically significant.

Thus, our conclusions do not change when we perform robustness check.

Table 4- 9: Results of sensitivity analysis for hypothesis H_2

	Environmental disclosure			
Variable	**Estimated coefficient**	**Standard error**	**p-value**	**VIF**
EP	0.180	0.059	(0.003)***	1.13
EI	3.679	1.725	(0.034)**	1.06
Size	0.543	0.223	(0.016) **	1.08
Debt	1.963	3.167	0.536	1.14
Risk	0.085	0.062	0.167	1.06
ROA	-0.337	6.739	0.960	1.08
_cons	0.946	3.804	0.804	
p	0.000***			
r2	0.120			
N	210			

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4- 10: Results of sensitivity analysis for hypothesis H_3

	Environmental disclosure			
Variable	**Estimated coefficient**	**Standard error**	**p-value**	**VIF**
EP	0.226	0.062	0.000***	1.13
EI	25.479	9.749	0.010**	1.06
Interaction EP*EI	-0.408	0.180	0.024**	
Size	0.540	0.221	0.015 **	1.08
Debt	2.439	3.142	0.439	1.14
Risk	0.095	0.061	0.125	1.08
ROA	-1.507	6.691	0.822	1.08
_cons	-1.590	3.927	0.686	
p	0.000***			
r2	0.142			
N	210			

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Chapter V: Discussion and conclusion

The new GRI guidelines for environmental disclosure include reliability as a guiding principle for integrated reporting. The reliability of environmental disclosure, as an accurate reflection of a firm's real environmental performance, is important to social responsible shareholders interested in social or green investments. This research investigates the reliability of environmental disclosure and concludes about the role played by environmental innovation on the environmental disclosure of a firm.

5.1. Conclusion

Prior research has attempted to assess the level of reliability of environmental disclosure by examining the relationship between environmental performance and environmental disclosure. Results are mixed. Several studies find a positive association (Al-Tuwaijri et al., 2004) (P. Clarkson et al., 2008); (Dawkins & Fraas, 2011), others a negative association (Hughes et al., 2001); (Patten, 2002); (C. Cho & Patten, 2007) (Cormier et al., 2011), or no association at all (Ingram & Frazier, 1980); (Wiseman, 1982) (Freedman & Wasley, 1990); (Fekrat et al., 1996) between environmental performance and environmental disclosure.

We tested competing predictions of this relationship from two different theoretical perspectives. Economic voluntary disclosure theory predicts a positive relationship between environmental performance and environmental disclosure: better environmental performers will have incentives to disclose more about their improved performance. Sociopolitical theories predicts opposite direction for the relationship between environmental performance and environmental disclosure. Worst

environmental performers will try to legitimate their environmental activities and they will disclose more.

Consistent with economic theories, our data provide evidence of a positive and statistically significant association between environmental performance and environmental disclosure. Better environmental performers tend to disclose more about their environmental performance to inform their stakeholders.

A possible explanation for these results is the general increase in the level and quality of environmental disclosure, the increasing awareness, and responsibility of firms regarding the environment, and the decreasing use of environmental disclosure as a tool to legitimize environmental activities and impact. (Rupley et al., 2012) also recently note the increased quality of environmental disclosure over time.

This increase in the quality of environmental disclosure also could have important consequences on the relationship between different variables explaining environmental disclosure. As (Combs et al., 2011) conclude, relationships between variables describing social phenomena are historically dependent and may vary over time.

Our findings also show that environmental innovation, including processes, techniques, systems and products designed to prevent or reduce pollution, is positive and significantly associated with environmental disclosure. At low levels of environmental performance, innovative firms tend to disclose about their innovations to reassure their stakeholders about their future environmental performance. When they do reach a high level of environmental performance, their disclosure is more focused on elements pertaining to their environmental performance. We conclude that environmental performance and environmental innovation act as substitutes in their relationship with environmental disclosure.

5.2. Contribution, limitations and research opportunities

This study is not free from limitations. First, all the tests were done in the U.S. context, due to availability of data. Other contexts could lead to different results. Second, although the methodology to assess the level of environmental disclosure is widely accepted among academics, it involves manual scoring which inevitably induces a risk of subjectivity. To reduce this risk, the data was collected by industry to insure a certain level of uniformity. Systematic recollection was performed to mitigate biases in scoring process. Also, our measure of innovation is limited to technological innovation. Other types of innovation could be considered in future studies. Finally, interaction between environmental performance and environmental innovation was tested for environmental 188 firms with no environmental innovation and only 22 environmental innovative firms. Future research could look at the reliability of environmental disclosure for a larger sample of environmental innovative firms or analyze the impact of environmental innovation on the relationship between environmental performance and environmental disclosure in a Canadian context, with different regulatory system, institutional investors and culture values.

This research investigates what really drives environmental performance. We extend prior research by considering the key role played by environmental innovation on the relationship between environmental performance and environmental disclosure.

These results provide new evidence of the substitution effect between environmental innovation and environmental performance in determining environmental disclosure. The positive influence of environmental innovation on both environmental performance and environmental disclosure should encourage managers to employ innovative environmental strategies. It could also encourage regulators

to provide incentives to organizations that innovate to obtain better environmental performance and disclosure. Other stakeholders, such as investors, analysts, and environmentalists, could add environmental innovation to their analyses to better evaluate and interpret a firm's environmental disclosure.

The results of this study should also motivate regulators to improve environmental regulation to guide firms toward innovative environmental strategies in order to obtain both improved environmental performance and better environmental disclosure and to fulfill the expectations of investors and other stakeholders.

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Appendix A: International standard ISO 14001 (actually in review)

ISO 14001:2004 specifies requirements for an environmental management system to enable an organization to develop and implement a policy and objectives which take into account legal requirements and other requirements to which the organization subscribes, and information about significant environmental aspects. It applies to those environmental aspects that the organization identifies as those which it can control and those which it can influence. It does not itself state specific environmental performance criteria.

ISO 14001:2004 is applicable to any organization that wishes to establish, implement, maintain and improve an environmental management system, to assure itself of conformity with its stated environmental policy, and to demonstrate conformity with ISO 14001:2004 by

a) making a self-determination and self-declaration, or

b) seeking confirmation of its conformance by parties having an interest in the organization, such as customers, or

c) seeking confirmation of its self-declaration by a party external to the organization, or

d) seeking certification/registration of its environmental management system by an external organization.

All the requirements in ISO 14001:2004 are intended to be incorporated into any environmental management system. The extent of the application will depend on factors such as the environmental policy of the organization, the nature of its activities, products and services and the location where and the conditions in which it functions.

Appendix B: Environmental disclosure grid

Expenditures and risks

- Investments
- Operation costs
- Future investments

- Future operating costs
- Financing for investments
- Environmental debts
- Risk provisions
- Risk litigation
- Provision for future expenditures

Compliance with laws and regulations

- Litigation present and potential
- Fines
- Orders to comply
- Corrective actions
- Incidents
- Future legislation and regulations

Pollution abatement

- Emission of pollutants

- Discharges

- Waste management
- Installation and process controls
- Compliance status or facilities
- Noise and odours

Sustainable development reporting

- Natural resource conservation
- Recycling
- Life cycle information

Land remediation and contamination

- Sites
- Remediation efforts
- Potential liability-remediation
- Implicit liability
- Spills: number, nature, reduction efforts

Environmental management

- Environmental policies or company concern for the environment
- Environmental management system
- Environmental auditing
- Goals and targets

- Awards
- Department, group, service assigned to the environment

- ISO 14001
- Involvement of the firm to develop environmental standards
- Involvement in environmental organizations: industry committees, etc.
- Joint environmental management projects with other firms

Rating scale

1: Item described in monetary, quantitative or qualitative terms.

0: Item not discussed.

Appendix C: Example of collected environmental disclosure score

Industry: Materials

Company name: *Air Products & Chemicals Inc.*

Scores for expenditures and risk

Investments	1
Operation costs	0
Future investments	1
Future operating costs	0
Financing for investments	0
Environmental debts	1
Risk provisions	0
Risk litigation	1
Provision for future expenditures	1
TOTAL: Expenditures and risk	**5**

Compliance with laws and regulations

Litigation, actual and potential	1
Fines	1
Orders to comply	0
Corrective actions	0
Incidents	0
Future legislation and regulations	1

TOTAL: Compliance with laws and regulations	**3**
Pollution abatement	
Emission of pollutants	1
Discharges	0
Waste management	1
Installation and process controls	1
Compliance status and facilities	1
Noise and odours	0
TOTAL: Pollution abatement	**4**
Sustainable development	
Natural resource conservation	1
Recycling	1
Life cycle information	0
TOTAL: Sustainable development	**2**
Land remediation and contamination	
Sites	1
Remediation efforts	1
Potential liability-remediation	1
Implicit liability	0
Spills (number, nature, reduction efforts)	1
TOTAL: land remediation and contamination	**4**

Environmental management

Environmental policies and company concern for the environment	1
Environmental management system	1
Environmental auditing	1
Goals and targets	1
Awards	1
Department, group, service assigned to the environment	1
ISO 14001	1
Involvement of the firm to develop environmental standards	0
Involvement in environmental organizations: industry, committees, etc.	1
Joint environmental management projects with other firms	0
TOTAL: Environmental management	**8**

TOTAL SCORE FOR ENVIRONMENTAL DISCLOSURE:	***26***

Information collected from:

http://media.corporate-ir.net/media_files/IROL/92/92444/air-products-ar2011-full.pdf

http://www.airproducts.com/~/media/Files/PDF/company/2011-sustainability-report-07-15-33649.pdf

http://www.airproducts.com/company/Sustainability/corporate-citizenship.aspx?_ga=1.248119758.890358190.1414955110

Appendix D: Environmental indicators – Sustainalytics

Impact and initiatives

- Resource use
    - Energy
    - Materials
    - Water
- Pollution control
    - Emissions and discharges
    - Waste management
    - Accidents, spills, other incidents
- Land use, biodiversity, and/or remediation
- Other impact initiatives

Regulatory compliance

- Environmental penalties over the last five years
- Number of convictions over the last five years
- Incidents of non-compliance

Exposure to environmental issues

- Potential environmental impact

Environmental impact of product/service

- Product/service with environmental benefits or reduced environmental impact

- Negative impact of product/service

Management Systems

- Formal environmental management system
- Environmental policy
- Certification
- Managerial structure and responsibility
- Environmental aspects identified
- Systems to measure and monitor environmental performance
- Audits
- Performance objectives and targets
- Employee training and communication
- Management review of environmental management system
- Environmental planning and impact assessment
- Sourcing practices
- Life-cycle analysis
- Systems/programs to manage environmental issues

Public reporting

- Substantial public environmental reporting
- The company's environmental reporting includes:
    - Its environmental policy and description of its environmental management system
    - Information on environmental programs and initiatives
    - Performance data

- Compliance data

Other environmental data

- Environmental liabilities
- Total environmental expenditures

Appendix E: IPC Green Inventory

List of environmentally sound technologies, as listed by United Nations Framework convention on Climate Change, in order to facilitate searches for patent information

BIO-FUELS		
. . Solid fuels	C10L 5/00, 5/40-5/48	C10L 5/00, 5/40-5/48
. . . Torrefaction of biomass	C10B 53/02 C10L 5/40, 9/00	C10B 53/02 C10L 5/40, 9/00
. . Liquid fuels	C10L 1/00, 1/02, 1/14	C10L 1/00, 1/02, 1/14
. . . Vegetable oils	C10L 1/02, 1/19	C10L 1/02, 1/19
. . . Biodiesel	C07C 67/00, 69/00 C10G C10L 1/02, 1/19 C11C 3/10 C12P 7/64	C07C 67/00, 69/00 C10G C10L 1/02, 1/19 C11C 3/10 C12P 7/64

. . . Bioethanol	C10L 1/02, 1/182 C12N 9/24 C12P 7/06-7/14	C10L 1/02, 1/182 C12N 9/24 C12P 7/06-7/14
. . Biogas	C02F 3/28, 11/04 C10L 3/00 C12M 1/107 C12P 5/02	C02F 3/28, 11/04 C10L 3/00 C12M 1/107 C12P 5/02
. . From genetically engineered organisms	C12N 1/13, 1/15, 1/21, 5/10, 15/00 A01H	C12N 1/13, 1/15, 1/21, 5/10, 15/00 A01H
. Integrated gasification combined cycle (IGCC)	C10L 3/00 F02C 3/28	C10L 3/00 F02C 3/28
. Fuel cells	H01M 4/86-4/98, 8/00-8/24, 12/00-12/08	H01M 4/86-4/98, 8/00-8/24, 12/00-12/08
. . Electrodes	H01M 4/86-4/98	H01M 4/86-4/98
. . . Inert electrodes with catalytic activity	H01M 4/86-4/98	H01M 4/86-4/98

. . Non-active parts	H01M 2/00-2/04 , 8/00-8/24	H01M 2/00-2/04 , 8/00-8/24
. . Within hybrid cells	H01M 12/00-12/08	H01M 12/00-12/08
. Pyrolysis or gasification of biomass	C10B 53/00 C10J	C10B 53/00 C10J
. Harnessing energy from manmade waste		
. . Agricultural waste	C10L 5/00	C10L 5/00
. . . Fuel from animal waste and crop residues	C10L 5/42, 5/44	C10L 5/42, 5/44
. . . Incinerators for field, garden or wood waste	F23G 7/00, 7/10	F23G 7/00, 7/10
. . Gasification	C10J 3/02, 3/46 F23B 90/00 F23G 5/027	C10J 3/02, 3/46 F23B 90/00 F23G 5/027
. . Chemical waste	B09B 3/00 F23G 7/00	B09B 3/00 F23G 7/00

. . Industrial waste	C10L 5/48 F23G 5/00, 7/00	C10L 5/48 F23G 5/00, 7/00
. . . Using top gas in blast furnaces to power pig-iron production	C21B 5/06	C21B 5/06
. . . Pulp liquors	D21C 11/00	D21C 11/00
. . . Anaerobic digestion of industrial waste	A62D 3/02 C02F 11/04, 11/14	A62D 3/02 C02F 11/04, 11/14
. . . Industrial wood waste	F23G 7/00, 7/10	F23G 7/00, 7/10
. . Hospital waste	B09B 3/00 F23G 5/00	B09B 3/00 F23G 5/00
. . Landfill gas	B09B	B09B
. . . Separation of components	B01D 53/02, 53/04, 53/047, 53/14, 53/22, 53/24	B01D 53/02, 53/04, 53/047, 53/14, 53/22, 53/24
. . Municipal waste	C10L 5/46	C10L 5/46

	F23G 5/00	F23G 5/00
. Hydro energy		
. . Water-power plants	E02B 9/00-9/06	E02B 9/00-9/06
. . . Tide or wave power plants	E02B 9/08	E02B 9/08
. . Machines or engines for liquids	F03B F03C	F03B F03C
. . . Using wave or tide energy	F03B 13/12-13/26	F03B 13/12-13/26
. . Regulating, controlling or safety means of machines or engines	F03B 15/00-15/22	F03B 15/00-15/22
. . Propulsion of marine vessels using energy derived from water movement	B63H 19/02, 19/04	B63H 19/02, 19/04
. Ocean thermal energy conversion (OTEC)	F03G 7/05	F03G 7/05
. Wind energy	F03D	F03D

. . Structural association of electric generator with mechanical driving motor	H02K 7/18	H02K 7/18
. . Structural aspects of wind turbines	B63B 35/00 E04H 12/00 F03D 11/04	B63B 35/00 E04H 12/00 F03D 11/04
. . Propulsion of vehicles using wind power	B60K 16/00	B60K 16/00
. . . Electric propulsion of vehicles using wind power	B60L 8/00	B60L 8/00
. . Propulsion of marine vessels by wind-powered motors	B63H 13/00	B63H 13/00
. Solar energy		
. . Photovoltaics (PV)		
. . . Devices adapted for the conversion of radiation energy into electrical energy	H01L 27/142, 31/00-31/078 H01G 9/20 H02N 6/00	H01L 27/142, 31/00-31/078 H01G 9/20 H02N 6/00

. . . . Using organic materials as the active part	H01L 27/30, 51/42-51/48	H01L 27/30, 51/42-51/48
. . . Assemblies of a plurality of solar cells	H01L 25/00, 25/03, 25/16, 25/18, 31/042	H01L 25/00, 25/03, 25/16, 25/18,
. . . Silicon; single-crystal growth	C01B 33/02 C23C 14/14, 16/24 C30B 29/06	C01B 33/02 C23C 14/14, 16/24 C30B 29/06
. . . Regulating to the maximum power available from solar cells	G05F 1/67	G05F 1/67
. . . Electric lighting devices with, or rechargeable with, solar cells	F21L 4/00 F21S 9/03	F21L 4/00 F21S 9/03
. . . Charging batteries	H02J 7/35	H02J 7/35
. . . Dye-sensitised solar cells (DSSC)	H01G 9/20 H01M 14/00	H01G 9/20 H01M 14/00
. . Use of solar heat	F24J 2/00-2/54	F24J 2/00-2/54

. . . For domestic hot water systems	F24D 17/00	F24D 17/00
. . . For space heating	F24D 3/00, 5/00, 11/00, 19/00	F24D 3/00, 5/00, 11/00, 19/00
. . . For swimming pools	F24J 2/42	F24J 2/42
. . . Solar updraft towers	F03D 1/04, 9/00, 11/04 F03G 6/00	F03D 1/04, 9/00, 11/04 F03G 6/00
. . . For treatment of water, waste water or sludge	C02F 1/14	C02F 1/14
. . . Gas turbine power plants using solar heat source	F02C 1/05	F02C 1/05
. . Hybrid solar thermal-PV systems	H01L 31/058	H01L 31/058
. . Propulsion of vehicles using solar power	B60K 16/00	B60K 16/00
. . . Electric propulsion of vehicles using solar power	B60L 8/00	B60L 8/00
. . Producing mechanical power from solar	F03G 6/00-6/06	F03G 6/00-6/06

energy		
. . Roof covering aspects of energy collecting devices	E04D 13/00, 13/18	E04D 13/00, 13/18
. . Steam generation using solar heat	F22B 1/00 F24J 1/00	F22B 1/00 F24J 1/00
. . Refrigeration or heat pump systems using solar energy	F25B 27/00	F25B 27/00
. . Use of solar energy for drying materials or objects	F26B 3/00, 3/28	F26B 3/00, 3/28
. . Solar concentrators	F24J 2/06 G02B 7/183	F24J 2/06 G02B 7/183
. . Solar ponds	F24J 2/04	F24J 2/04
. Geothermal energy		
. . Use of geothermal heat	F01K F24F 5/00	F01K F24F 5/00

	F24J 3/08 H02N 10/00 F25B 30/06	F24J 3/08 H02N 10/00 F25B 30/06
. . Production of mechanical power from geothermal energy	F03G 4/00-4/06, 7/04	F03G 4/00-4/06, 7/04
. Other production or use of heat, not derived from combustion, e.g. natural heat	F24J 1/00, 3/00, 3/06	F24J 1/00, 3/00, 3/06
. . Heat pumps in central heating systems using heat accumulated in storage masses	F24D 11/02	F24D 11/02
. . Heat pumps in other domestic- or space-heating systems	F24D 15/04	F24D 15/04
. . Heat pumps in domestic hot-water supply systems	F24D 17/02	F24D 17/02
. . Air or water heaters using heat pumps	F24H 4/00	F24H 4/00
. . Heat pumps	F25B 30/00	F25B 30/00

. Using waste heat		
. . To produce mechanical energy	F01K 27/00	F01K 27/00
. . Of combustion engines	F01K 23/06-23/10 F01N 5/00 F02G 5/00-5/04 F25B 27/02	F01K 23/06-23/10 F01N 5/00 F02G 5/00-5/04 F25B 27/02
. . Of steam engine plants	F01K 17/00, 23/04	F01K 17/00, 23/04
. . Of gas-turbine plants	F02C 6/18	F02C 6/18
. . As source of energy for refrigeration plants	F25B 27/02	F25B 27/02
. . For treatment of water, waste water or sewage	C02F 1/16	C02F 1/16
. . Recovery of waste heat in paper production	D21F 5/20	D21F 5/20
. . For steam generation by exploitation of the heat content of hot heat carriers	F22B 1/02	F22B 1/02
. . Recuperation of heat energy from waste	F23G 5/46	F23G 5/46

incineration		
. . Energy recovery in air conditioning	F24F 12/00	F24F 12/00
. . Arrangements for using waste heat from furnaces, kilns, ovens or retorts	F27D 17/00	F27D 17/00
. . Regenerative heat-exchange apparatus	F28D 17/00-20/00	F28D 17/00-20/00
. . Of gasification plants	C10J 3/86	C10J 3/86
. Devices for producing mechanical power from muscle energy	F03G 5/00-5/08	F03G 5/00-5/08
TRANSPORTATION		
. Vehicles in general		
. . Hybrid vehicles, e.g. Hybrid Electric Vehicles (HEVs)	B60K 6/00, 6/20	B60K 6/00, 6/20
. . . Control systems	B60W 20/00	B60W 20/00
. . . Gearings therefor	F16H 3/00-3/78, 48/00-48/30	F16H 3/00-3/78, 48/00-48/30

. . Brushless motors	H02K 29/08	H02K 29/08
. . Electromagnetic clutches	H02K 49/10	H02K 49/10
. . Regenerative braking systems	B60L 7/10-7/22	B60L 7/10-7/22
. . Electric propulsion with power supply from force of nature, e.g. sun, wind	B60L 8/00	B60L 8/00
. . Electric propulsion with power supply external to vehicle	B60L 9/00	B60L 9/00
. . . With power supply from fuel cells, e.g. for hydrogen vehicles	B60L 11/18	B60L 11/18
. . Combustion engines operating on gaseous fuels, e.g. hydrogen	F02B 43/00 F02M 21/02, 27/02	F02B 43/00 F02M 21/02, 27/02
. . Power supply from force of nature, e.g. sun, wind	B60K 16/00	B60K 16/00
. . Charging stations for electric vehicles	H02J 7/00	H02J 7/00
. Vehicles other than rail vehicles		
. . Drag reduction	B62D 35/00, 35/02 B63B 1/34-1/40	B62D 35/00, 35/02 B63B 1/34-1/40

. . Human-powered vehicle	B62K B62M 1/00, 3/00, 5/00, 6/00	B62K B62M 1/00, 3/00, 5/00, 6/00
. Rail vehicles	B61	B61
. . Drag reduction	B61D 17/02	B61D 17/02
. Marine vessel propulsion		
. . Propulsive devices directly acted on by wind	B63H 9/00	B63H 9/00
. . Propulsion by wind-powered motors	B63H 13/00	B63H 13/00
. . Propulsion using energy derived from water movement	B63H 19/02, 19/04	B63H 19/02, 19/04
. . Propulsion by muscle power	B63H 16/00	B63H 16/00
. . Propulsion derived from nuclear energy	B63H 21/18	B63H 21/18
. Cosmonautic vehicles using solar energy	B64G 1/44	B64G 1/44
ENERGY CONSERVATION		
. Storage of electrical energy	B60K 6/28 B60W 10/26 H01M 10/44-10/46	B60K 6/28 B60W 10/26 H01M 10/44-10/46

	H01G 9/155 H02J 3/28, 7/00, 15/00	H01G 9/155 H02J 3/28, 7/00, 15/00
. Power supply circuitry	H02J	H02J
. . With power saving modes	H02J 9/00	H02J 9/00
. Measurement of electricity consumption	B60L 3/00 G01R	B60L 3/00 G01R
. Storage of thermal energy	C09K 5/00 F24H 7/00 F28D 20/00, 20/02	C09K 5/00 F24H 7/00 F28D 20/00, 20/02
. Low energy lighting		
. . Electroluminescent light sources (e.g. LEDs, OLEDs, PLEDs)	F21K 99/00 F21L 4/02 H01L 33/00-33/64, 51/50 H05B 33/00	F21K 99/00 F21L 4/02 H01L 33/00-33/64, 51/50 H05B 33/00
. Thermal building insulation, in general	E04B 1/62, 1/74-1/80, 1/88, 1/90	E04B 1/62, 1/74-1/80, 1/88, 1/90

. . Insulating building elements	E04C 1/40, 1/41, 2/284-2/296	E04C 1/40, 1/41, 2/284-2/296
. . . For door or window openings	E06B 3/263	E06B 3/263
. . . For walls	E04B 2/00 E04F 13/08	E04B 2/00 E04F 13/08
. . . For floors	E04B 5/00 E04F 15/18	E04B 5/00 E04F 15/18
. . . For roofs	E04B 7/00 E04D 1/28, 3/35, 13/16	E04B 7/00 E04D 1/28, 3/35, 13/16
. . . For ceilings	E04B 9/00 E04F 13/08	E04B 9/00 E04F 13/08
. Recovering mechanical energy	F03G 7/08	F03G 7/08
. . Chargeable mechanical accumulators in vehicles	B60K 6/10, 6/30 B60L 11/16	B60K 6/10, 6/30 B60L 11/16
WASTE MANAGEMENT		
. Waste disposal	B09B B65F	B09B B65F
. Treatment of waste		

. . Disinfection or sterilisation	A61L 11/00	A61L 11/00
. . Treatment of hazardous or toxic waste	A62D 3/00, 101/00	A62D 3/00, 101/00
. . Treating radioactively contaminated material; decontamination arrangements therefor	G21F 9/00	G21F 9/00
. . Refuse separation	B03B 9/06	B03B 9/06
. . Reclamation of contaminated soil	B09C	B09C
. . Mechanical treatment of waste paper	D21B 1/08, 1/32	D21B 1/08, 1/32
. Consuming waste by combustion	F23G	F23G
. Reuse of waste materials		
. . Use of rubber waste in footwear	A43B 1/12, 21/14	A43B 1/12, 21/14
. . Manufacture of articles from waste metal particles	B22F 8/00	B22F 8/00
. . Production of hydraulic cements from waste materials	C04B 7/24-7/30	C04B 7/24-7/30
. . Use of waste materials as fillers for mortars, concrete	C04B 18/04-18/10	C04B 18/04-18/10
. . Production of fertilisers from waste or refuse	C05F	C05F

. . Recovery or working-up of waste materials	C08J 11/00-11/28 C09K 11/01 C11B 11/00, 13/00-13/04 C14C 3/32 C21B 3/04 C25C 1/00 D01F 13/00-13/04	C08J 11/00-11/28 C09K 11/01 C11B 11/00, 13/00-13/04 C14C 3/32 C21B 3/04 C25C 1/00 D01F 13/00-13/04
. . . Recovery of plastics materials from waste	B29B 17/00	B29B 17/00
. . . Disassembly of vehicles for recovery of salvageable parts	B62D 67/00	B62D 67/00
. . . Of polymers	C08J 11/04-11/28	C08J 11/04-11/28
. . . Production of liquid hydrocarbons from rubber waste	C10G 1/10	C10G 1/10
. . . Solid fuels derived from waste	C10L 5/46, 5/48	C10L 5/46, 5/48
. . . Obtaining metals from scrap	C22B 7/00-7/04, 19/30, 25/06	C22B 7/00-7/04, 19/30, 25/06
. . . Disintegrating fibrous materials for reuse	D01G 11/00	D01G 11/00
. . . Working-up waste paper to obtain cellulose	D21C 5/02	D21C 5/02

. . . Reclaiming salvageable components or material from electric discharge tubes or lamps	H01J 9/50, 9/52	H01J 9/50, 9/52
. . . Reclaiming serviceable parts of waste cells, batteries or accumulators	H01M 6/52, 10/54	H01M 6/52, 10/54
. Pollution control		
. . Carbon capture and storage	B01D 53/14, 53/22, 53/62 B65G 5/00 C01B 31/20 E21B 41/00, 43/16 E21F 17/16 F25J 3/02	B01D 53/14, 53/22, 53/62 B65G 5/00 C01B 31/20 E21B 41/00, 43/16 E21F 17/16 F25J 3/02
. . Air quality management		
. . . Treatment of waste gases	B01D 53/00-53/96	B01D 53/00-53/96
. . . . Exhaust apparatus for combustion engines with means for treating exhaust	F01N 3/00-3/38	F01N 3/00-3/38
. . . . Rendering exhaust gases innocuous	B01D 53/92 F02B 75/10	B01D 53/92 F02B 75/10
. . . . Removal of waste gases or dust in steel	C21C 5/38	C21C 5/38

production		
. . . . Combustion apparatus using recirculation of flue gases	C10B 21/18 F23B 80/02 F23C 9/00	C10B 21/18 F23B 80/02 F23C 9/00
. . . . Combustion of waste gases or noxious gases	F23G 7/06	F23G 7/06
. . . . Electrical control of exhaust gas treating apparatus	F01N 9/00	F01N 9/00
. . . Separating dispersed particles from gases or vapours	B01D 45/00-51/00 B03C 3/00	B01D 45/00-51/00 B03C 3/00
. . . . Dust removal from furnaces	C21B 7/22 C21C 5/38 F27B 1/18 F27B 15/12	C21B 7/22 C21C 5/38 F27B 1/18 F27B 15/12
. . . Use of additives in fuels or fires to reduce smoke or facilitate soot removal	C10L 10/02, 10/06 F23J 7/00	C10L 10/02, 10/06 F23J 7/00
. . . Arrangements of devices for treating smoke or fumes from combustion apparatus	F23J 15/00	F23J 15/00
. . . Dust-laying or dust-absorbing materials	C09K 3/22	C09K 3/22

. . . Pollution alarms	G08B 21/12	G08B 21/12
. . Control of water pollution		
. . . Treating waste-water or sewage	B63J 4/00 C02F	B63J 4/00 C02F
. . . . To produce fertilisers	C05F 7/00	C05F 7/00
. . . Materials for treating liquid pollutants	C09K 3/32	C09K 3/32
. . . Removing pollutants from open water	B63B 35/32 E02B 15/04	B63B 35/32 E02B 15/04
. . . Plumbing installations for waste water	E03C 1/12	E03C 1/12
. . . Management of sewage	C02F 1/00, 3/00, 9/00 E03F	C02F 1/00, 3/00, 9/00 E03F
. . Means for preventing radioactive contamination in the event of reactor leakage	G21C 13/10	G21C 13/10
AGRICULTURE / FORESTRY		
. Forestry techniques	A01G 23/00	A01G 23/00
. Alternative irrigation techniques	A01G 25/00	A01G 25/00

. Pesticide alternatives	A01N 25/00-65/00	A01N 25/00-65/00
. Soil improvement	C09K 17/00 E02D 3/00	C09K 17/00 E02D 3/00
. . Organic fertilisers derived from waste	C05F	C05F
ADMINISTRATIVE, REGULATORY OR DESIGN ASPECTS		
. Commuting, e.g., HOV, teleworking, etc.	G06Q G08G	G06Q G08G
. Carbon/emissions trading, e.g. pollution credits	G06Q	G06Q
. Static structure design	E04H 1/00	E04H 1/00
NUCLEAR POWER GENERATION		
. Nuclear engineering	G21	G21
. . Fusion reactors	G21B	G21B
. . Nuclear (fission) reactors	G21C	G21C
. . Nuclear power plant	G21D	G21D
. Gas turbine power plants using heat source of	F02C 1/05	F02C 1/05

nuclear origin