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ENVIRONMENTAL INNOVATIONS: EVIDENCE FROM BRAZILIAN MANUFACTURING FIRMS

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ABSTRACT

The increasing concern with environmental damage and climate change has highlighted the importance of environmental innovations (EI) as an alternative to current technological standards. This thesis aims to contribute to the analysis of the determinants of environmental innovation and also to the identification of the effects of the adoption of environmental innovations on labor demand and performance of Brazilian manufacturing firms.

Based on panel data between 1998 and 2008, the results obtained in Chapter 2 corroborate international evidence on the determinants of environmental innovation adoption. The environmental inducement hypothesis is verified, indicating that environmental regulation has an important role to influence the Brazilian firms in order to adopt both technical and organizational environmental innovations. Specifically related to developing countries innovative processes, our results confirm that foreign owned firms are significantly more likely to adopt "green" innovation, usually through capital embodied technology transfer and licensing agreements. The size of the firm and physical capital intensity are also important determinants of environmental innovation in Brazilian manufacturing firms.

In Chapter 3 we use a translog cost function approach and we analyze the impact of environmental innovations on employment shares and wage bill shares in Brazilian manufacturing industries. The results obtained indicate that environmental technologies are unskilled biased, favoring blue-collar positions and wages, relative to white-collar ones. The "green-collar" jobs deriving from the green technologies adopted are in many situations (especially in low and medium technological intensive industrial sectors) filled by blue-collar workers, trained with green skills and thus capable of dealing with environmental preservation challenges. On the other hand, organizational environmental innovations registered a negative impact in blue-collar employment and wage bill shares, reinforcing the skill biased organizational change hypothesis, as the white-collar workforce is better prepared to deal with increased uncertainty, multi-tasking activities and increased responsibility.

Concerning the effects of environmental innovation adoption on performance, Chapter 4 modeling strategy is based on a translog production function, due to its flexibility to represent different production structures, especially in the case of more than two factor inputs. The results indicate that both technical EI and organizational EI have positive impact on Brazilian manufacturing firms' value added. We analyze four different types of technical EI in order to consider different characteristics of each type of EI, including those that reduce resources consumption and those that reduce environmental negative externalities, traditionally understood as additional compliance costs. All the different types of EI tested registered positive correlation with value added change. Pollution abatement investment was also tested and indicated positive effects on value added, even if to a lesser extent.

RESUMO

A crescente preocupação com a degradação ambiental e variações climáticas trouxe à tona a importância de inovações ambientais (IA) como uma alternativa ao padrão tecnológico atual. Esta tese tem como objetivo contribuir para a análise dos determinantes da inovação ambiental e também para a identificação dos seus efeitos sobre a demanda por mão de obra e sobre o valor adicionado das indústrias de transformação brasileiras.

Utilizando dados de painel entre 1998 e 2008, os resultados obtidos no capítulo 2 corroboram a evidência internacional sobre os determinantes da adoção de inovações ambientais. A hipótese de viés ambiental é verificada, o que indica que a regulação ambiental apresenta um papel importante para influenciar as firmas brasileiras a adotar tanto inovações ambientais tecnológicas quanto organizacionais. Em relação especificamente ao processo inovativo em países em desenvolvimento, nossos resultados confirmam que empresas de capital estrangeiro têm maior probabilidade de adotar inovações "verdes", geralmente através de transferência tecnológica e acordos de licenciamento. O tamanho da firma e a intensidade de capital físico também são importantes determinantes da inovação ambiental nas indústrias de transformação brasileiras.

No capítulo 3 utilizamos uma abordagem baseada na função de custo translog e analisamos o impacto de inovações ambientais na participação de emprego e massa salarial nas indústrias brasileiras de manufatura. Os resultados obtidos indicam que as tecnologias ambientais são enviesadas para o trabalho não qualificado, favorecendo o emprego e salários de mão de obra menos qualificada (ou diretamente ligada à produção) em detrimento da mão de obra mais qualificada (ou não diretamente ligada à produção). Os empregos "verdes" derivados da adoção de tecnologias ambientais são, em muitos casos (especialmente nos setores de baixa ou média intensidade tecnológica), ocupados por trabalhadores de baixa qualificação treinados com habilidades "verdes" e, portanto, capacitados para lidar com os desafios da preservação do meio ambiente. Por outro lado, as inovações ambientais organizacionais registraram um impacto negativo na contratação e nos salários de mão de obra de baixa qualificação, reforçando a hipótese de mudança tecnológica enviesada para a qualificação, uma vez que a mão de obra qualificada é mais bem preparada para lidar com o aumento da incerteza, atividade multitarefas e aumento de responsabilidade.

Em relação aos efeitos da adoção de inovações ambientais no valor adicionado da empresa, no capítulo 4 adotamos como estratégia de modelagem uma função de produção translog, devido à sua flexibilidade para representar diferentes estruturas produtivas, especialmente no caso de mais de dois fatores de produção. Os resultados indicam que tanto as IA tecnológicas quanto as organizacionais apresentam impacto positivo sobre o valor adicionado das firmas brasileiras. Nós analisamos quatro tipos diferentes de IA tecnológicas com o intuito de considerar as diferentes características de cada tipo de IA, incluindo aquelas que reduzem o consumo de recursos e aquelas que reduzem as externalidades negativas sobre o meio ambiente, tradicionalmente entendidas como custos adicionais de conformidade à regulação ambiental vigente. Todos os diferentes tipos de IA testados registraram correlação positiva com variações no valor adicionado. Investimento em redução de poluição também foi testado e indicou efeito positive sobre o valor adicionado, ainda que em menor intensidade.

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1. Introduction

1.1 Motivation and thesis structure

The economic impacts of environmental degradation have become the focus of greater attention in recent decades. The aggravation of environmental problems associated with climate change and the possibility of depletion of basic natural resources has made both developed and developing countries seek (voluntarily or not) new ways to produce and consume.

In this scenario, the substitution or adaptation of current technological standards, towards environmental innovations, becomes an alternative to promote sustainable growth and to contribute to improve the quality of life of future generations.

This thesis aims to contribute to the literature on innovation and environmental economics, through the analysis of environmental innovation adoption by Brazilian manufacturing firms in three dimensions:

(1) the determinants of the adoption of environmental innovations, distinguishing between technical and organizational environmental innovation. We try to address the following questions, among others: a) Is the environmental inducement hypothesis verified in this case? b) What is the role of foreign ownership and international trade? c) Following the Schumpeterian approach, is firm size an important aspect?

(2) the effects of the adoption of environmental innovation on labor demand. Specifically: a) What is the effect of environmental innovations on the change of employment shares and wage bill shares? b) Is environmental innovation skill biased or not? Does it favor white collar jobs and wages or blue collar wages and positions? c) What is the relation between technical and organizational environmental innovations and their impact on labor markets?

(3) the impact of environmental innovation on the firm performance. The following questions are addressed: a) does environmental innovation represent additional compliance costs to the firms and consequently are

negatively correlated to changes on value added? b) are the impacts of environmental innovation that reduce resources consumption different from the impact of environmental innovations that reduce environmental negative externalities? c) what is the impact of organizational environmental innovations on value added change?

In order to answer these questions, we use a panel data approach based on PINTEC[1] and PIA[2] data between 1998 and 2008. We also consider the nuances of technology transfer, foreign ownership and international trade in developing countries like Brazil.

This thesis is organized in five chapters, including this one. Chapter two deals with the determinants of environmental innovations adoption – both technical and organizational EIs - in Brazilian manufacturing firms. Chapter three presents the effects of environmental innovations on skill demand and number of jobs creation. Chapter four, in turn, studies the impact of environmental innovations on firm performance. Finally, chapter five presents our final considerations about the determinants and effects of adopting environmental innovations in Brazilian manufacturing firms between 1998 and 2008.

This chapter is organized in four sections (besides this one): section 1.2 presents the definitions of environmental innovations; section 1.3 explains how environmental innovation is measured in the PINTEC survey; section 1.4 explains how pollution abatement investment is measured in PIA survey; section 1.5 discusses environmental policy instruments; and finally, section 1.6 presents a brief review on the Brazilian environmental legislation and explains how we constructed a proxy for the Brazilian environmental regulation stringency.

[1] Technological Innovation Survey, conducted by IBGE (Brazilian Institute of Geography and Statistics).

[2] Annual Industrial Firms Survey, also conducted by IBGE.

1.2 Environmental Innovations: definitions

The concept of environmental innovation is relatively new. This could be the explanation for several distinct definitions of environmental innovation. Also, many different terms have been used to refer to it: eco-innovation, green innovation, environmental innovation and sustainable innovation are mostly used as synonymous[3].

According to Kemp and Foxon (2007), eco-innovation was the first term to appear in the literature, in 1996, in the definition presented by Fussler and James (1996): "*new products and processes which provide customer and business value but significantly decrease environmental impacts*".

Another definition of eco-innovation, presented by Kemp and Pearson (2007), is "*the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organization (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives.*"

Related to green innovation, Driessen and Hillebrand (2002) propose that it "*does not have to be developed with the goal of reducing the environmental burden (...) It does however, yield significant environmental benefits*". Oltra and Saint Jean (2009) define environmental innovation "*as innovations that consist of new or modified processes, practices, systems and products which benefit the environment and so contribute to environmental sustainability*". And finally, sustainable innovation can be understood as a broader concept, which includes social aspects such as higher satisfaction of human needs and higher quality of life. (SCHIEDERIG *et al*, 2012)

In fact, the definition of environmental innovation (EI) is close to the conventional understanding of general innovation (or non-environmental innovation): "*implementation of new, or significantly improved, products, or processes, marketing methods, or organizational methods in business practices, workplace organization or external relations*" (OECD and Eurostat, 2005). The main difference between environmental innovation and general innovation is that EI is not an open-ended concept, in the sense that it is necessarily related to the reduction of environmental

[3] Schiederig *et al* (2012) presents an interesting and detailed survey on the concept and terminology of environmental innovation.

damage, regardless of whether or not the EI was intentionally developed with environmental purposes.

Therefore, the definition of environmental innovation adopted in this thesis is the definition suggested by the Organization for economic co-operation and development (OECD)[4] in 2009:

> (…) the implementation of new, or significantly improved, products (goods and services), processes, marketing methods, organizational structures and institutional arrangements which – with or without intent – lead to environmental improvements compared to relevant alternatives. (OECD, 2009:40)

The definition adopted emphasizes that environmental innovations not necessarily have to be developed intentionally to preserve the environment. Rather, it includes all innovations that produce some kind of environmental gain. Hence, all new processes that are more resource efficient can be considered as environmental innovations.

It is important to notice that we are going to use the term environmental innovation throughout the thesis but we understand that the terms eco-innovation, green innovation and environmental innovation can be used interchangeably.

According to the Oslo Manual[5] (OECD and Eurostat, 2005), environmental innovations can be classified in (see Figure 1): a) technical environmental innovations; and, b) organizational environmental innovations. Technical environmental innovations can be distinguished between process and product (or services) EIs and organizational EI refers to new management practices focusing on environmental issues (e.g. environmental management systems).

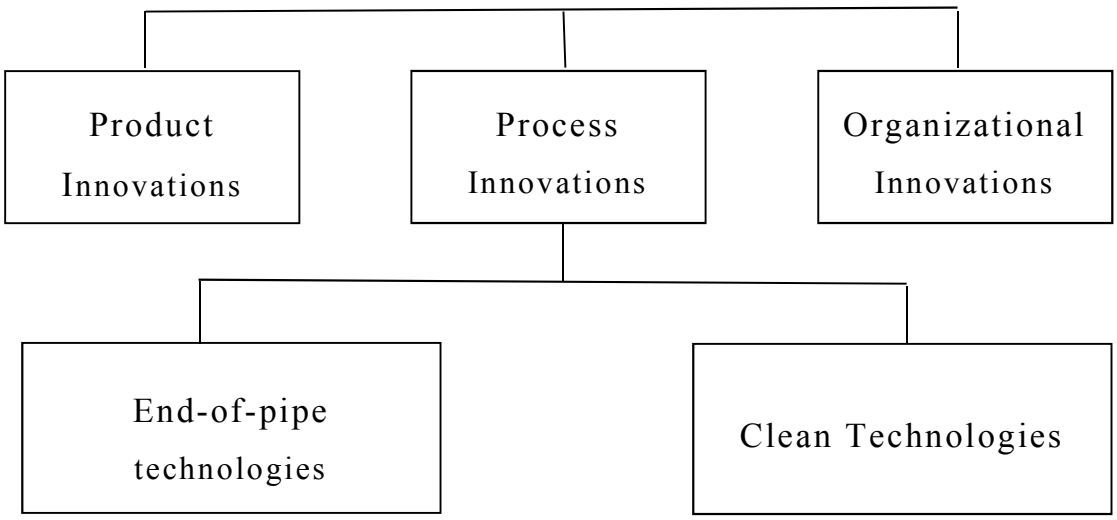
Specifically related to process EI, we have clean technologies and end-of-pipe technologies. End-of-pipe technologies reduce the emission of pollutants by adding supplementary measures to production processes, while clean technologies reduce the use of resources and/or reduce pollution generation through the use of cleaner inputs

[4] Indeed, OECD (2009) uses the term eco-innovation instead of environmental innovation. But, as pointed out by Rennings (2000), often eco-innovation is used as shorthand for environmental innovation, and thus we understand that these two concepts can be used interchangeably.

[5] OECD Guidelines for collecting and Interpreting Innovation data, (2005).

and cleaner production methods. We can understand end-of pipe technologies as additive solutions and clean technologies[6] as integrated and precautionary solutions.

Figure 1. Environmental Innovation typology



Source: Frondel *et al* (2007)

Therefore, clean technologies are seen as superior, both in terms of reducing environmental impacts and in economic terms, when compared to end-of-pipe technologies. However, the adoption of clean technologies requires greater coordination, integrated measures and organizational support. Examples of end-of-pipe technologies are incineration plants, wastewater treatment plants, sound absorbers, exhaust-gas cleaning equipment and air quality control equipment. Examples of clean technologies are the use of recycled materials, environmentally friendly processes (e.g., replacing organic solvents with water), modification of the combustion chamber design (integrated process), among others.

Finally, product EIs are products or services that give rise to low levels of environmental impact through its use and disposal, such as eco-houses, eco-buildings, phosphate-free detergents, water-based paints, environmental consulting, testing and engineering, etc.

[6] In 1989 the United Nations Environment Programme (UNEP) launched the "Cleaner production programme", to develop the use of clean technologies.

1.3 Environmental Innovation in the PINTEC survey

The data on environmental innovation used in this thesis is based on the Technological Innovation Survey (PINTEC). This survey is conducted by IBGE (Brazilian Institute of Geography and Statistics) and seeks to: a) construct sectorial, national and regional indicators of the technological innovation activity in Brazilian firms; b) construct national indicators of technological innovation in selected service companies (publishing, telecommunications and IT); and c) discover the extent to which research and development (R&D) expenditures are consistent with international recommendations in conceptual and methodological terms.

It is important to notice that each PINTEC survey refers to the preceding three years, (and thus is conducted every three years) following the Oslo Manual (OECD document establishing guidelines for collecting and interpreting data on industrial innovation) and the Community Innovation Survey (CIS) recommendation. Therefore, there are four PINTECs conducted to date:

- PINTEC 2008 - period 2006 - 2008;
- PINTEC 2005 - period 2003 - 2005;
- PINTEC 2003 - period 2001 - 2003; and,
- PINTEC 2000 – period 1998 - 2000.

Based on the OECD (2009) definition of environmental innovation presented in Section 1.1, we utilized the responses to the following questions in the PINTEC questionnaire, in order to construct the environmental innovation dummies:

- *What was the importance of the impact of product and process innovations implemented during the period between 2003 and 2005[7], related to:*

  - question 102: Raw material consumption reduction?
  1) high 2) medium 3) low 4) not relevant

[7] We used the PINTEC 2003 to illustrate the questions utilized.

- question 103: Energy consumption reduction?

1) high 2) medium 3) low 4) not relevant

- question 104: Water consumption reduction?

1) high 2) medium 3) low 4) not relevant

- question 105: Environmental impact reduction and aspects related to health and safety improvement?

1) high 2) medium 3) low 4) not relevant

- *During the period between 2001 and 2003, did the firm carried out any of the activities listed below?*

  - question 189: Implementation of advanced management techniques - including production, information and environmental?

  1) yes 2) no"

The questions 104 and 189 did not exist in PINTEC 2000 survey. In PINTEC 2008 questions 105 and 189 were modified to:

- question 105_B: Environmental impact reduction?

1) high 2) medium 3) low 4) not relevant

- question 189_B: Implementation of new environmental management techniques for effluent treatment waste reduction, CO_2, etc?

1) yes 2) no

Also PINTEC 2008 introduced a new question related to environmental innovation:

- *question 194 - Did the firm carry out any activity related to biotechnology for industrial biological effluent treatment?*

  1) yes 2) no

Based on the aforementioned questions, we constructed four environmental innovation dummies related to the period between 1998 and 2008, named as:

1) Environmental innovation - at least one: dummy variable that equals to one when the firm has answered high or medium impact for at least one of questions 102, 103, 104 or 105; zero otherwise.

2) Environmental innovation – all: dummy variable that equals to one when the firm has answered high or medium impact for all the questions 102, 103, 104 and 105; zero otherwise.

3) Environmental impact reduction and safety improvement: dummy variable that equals to one when the firm has answered high or medium impact for question 105; zero otherwise.

4) Environmental management techniques: dummy variable that equals to one when the firm has answered yes for question 189; zero otherwise.

Additionally, we also constructed two environmental dummies related only to the period between 2006 and 2008:

5) Environmental impact reduction: dummy variable that equals to one when the firm has answered high or medium impact for question 105_B; zero otherwise.

6) Biological effluent treatment: dummy variable that equals to one when the firm has answered yes for question 194; zero otherwise.

It is important to note that: a) in questions 102, 103, 104, 105, 105_B and 194 it is not possible to distinguish whether the innovation was in process or product; we only know that it was a technical innovation; b) question 189 and 189_B are related to organizational innovations; and, c) due to the modification in question 105 in the PINTEC 2008 survey, we considered also the question 106 (below) in PINTEC 2008 in order to harmonize the answers and construct the environmental dummies related to the

period between 1998 and 2008. The same procedure was adopted in relation to question 189, with the addition of question 188 below:

- question 106: Impact on aspects related to health and safety improvement?
1) high 2) medium 3) low 4) not relevant

- question 188: Implementation of advanced management techniques - including production and information?
1) yes 2) no

1.4 Pollution abatement investment in the PIA survey

Estimations using pollution abatement costs are very common in the US because of the existence of a detailed database provided by the Census Bureau's Pollution Abatement Costs and Expenditure Survey (PACE). In Brazil, a similar variable was calculated in the Annual Survey of Industrial Firms (PIA) in the years of 1997, 2002 and 2007[8].

The PIA survey is also conducted by IBGE, but differently from PINTEC survey, PIA survey is performed every year. The main objective of PIA survey is to identify the basic structural characteristics of industrial activity in Brazil and its changes over time, based on a sample of industrial firms.

In this thesis we use the pollution abatement investment variable calculated as a proxy to environmental innovation. The pollution abatement investment variable is equal to the percentage of investments spent in reducing or controlling emissions of pollutants that result from production process, or to attend environmental regulations. The measurement of this variable includes the acquisition of industrial machines that incorporate the design of clean technology, acquisition of other equipment and construction of treatment stations. It is important to note that the pollution abatement investment variable does not consider expenses resulting from the recovery of degraded

[8] We do not have any other information about this variable in other years, even from other research institutes.

areas and it considers only the acquisition of machinery and equipment with ate least one year of useful life.

1.5 Environmental Policy: Command and Control measures and Economic Instruments

A relevant factor for environmental innovation adoption refers to the characteristics of environmental policy. Environmental policy measures can be classified in two main groups: a) command and control; and b) economic instruments. Command and control refer to the imposition of measures that alter the behavior of pollutants by means of specific legislation, usually imposing technological or strict emission standards. On the other hand, economic instruments allow greater flexibility in terms of adequacy technology, time and production processes, in order to reduce the environmental impact. If well designed, economic instruments can "*encourage firms to undertake pollution control efforts that are in their own interests and that collectively meet policy goals.*" (JAFFE *et al*, 2003)

According to Almeida (1998) we can exemplify command and control measures as follows:

- standards for specific sources of pollution (e.g. sulfur dioxide);
- installation of pollution control equipment (e.g. filters);
- mandatory use of clean technologies once they are available;
- replacement of inputs;
- standards for products whose production process or final consumption entails some form of pollution (e.g., quantity of pesticides in agriculture and the prohibition of low energy efficiency cars production);
- ban or restriction of activities at certain times of the day or areas (e.g. traffic control in the city of São Paulo); and,
- natural resources control through the establishment of (non-tradable) extraction quotas (e.g. timber and fishing).

Although the definition of economic instruments is quite complex (as pointed out by OECD, 1989), some instruments are widely recognized in the literature, such as:

- rates and tariffs: e.g. in the case of certain pollutants, effluent charge per unit released into the environment - water, soil or air; payments for the costs of collective or public treatment of effluents; better prices for non-polluting products;
- subsidies: non-repayable financial assistance, offered to polluters that voluntarily implement measures to reduce their pollution levels; loans at below market rates offered to polluters that adopt amelioration measures and tax incentives; and,
- tradeable pollution permits- pollution rights and credits or emission reduction certificates (ERCs).

Environmental policies, such as "command and control", specify the method and sometimes the equipment in order to comply with regulation, and often impose technology standards that can only be met through end-of-pipe reduction measures. Command and control can also set performance standards based on uniform control target for firms, such as emissions per unit of output. Despite effectively reducing pollutant emissions, the imposition of technology or performance standards can be expensive and counterproductive. In turn, economic instruments do not inhibit the adoption of new technologies that could result in greater levels of pollution abatement. In fact, economic instruments can incentive firms to identify cheaper and cleaner technologies.

1.6 Brazilian Environmental Legislation

Even though some regulatory initiatives existed since the 1930s[9], Brazil only implemented an effective environmental policy in 1981, through the federal law N° 6938, which established the "*Environmental policy and environmental national system*". The main instruments included in this law (and applied until today) were: a) environmental quality standards; b) environmental zoning; c) evaluation of

[9] For example, the Water Code of 1934, the Act of Protection of Forests in 1965 and the Wildlife Protection Act of 1967.

environmental impacts; d) licensing and review of polluting or potentially polluting activities; e) national environmental information system; f) conservation units system. Before 1981 there were two important initiatives, the creation in 1973 of the Secretary of Environment (SEMA) at the federal level and at the state level the creation of the Environmental State Agency in the states of São Paulo (1968) and Rio de Janeiro (1975) [10].

One of the most important Brazilian environmental protection agencies, called CONAMA (National Council of Environment), was established in 1981 in accordance with law N° 6938. CONAMA main responsibility is to develop resolutions (linked to federal laws or not) stating the guidelines, technical norms, rules and standards related to environmental protection and sustainable use of environmental resources. In this sense, also IBAMA (Brazilian Institute of Environment and Renewable Natural Resources) and CNRH (National Council on Water Resources) are important federal environmental protection agencies. IBAMA was created in 1989 and among its main responsibilities are the evaluation of environmental impact, zoning, environmental licensing, the application of administrative penalties and environmental monitoring, especially regarding the prevention and control of deforestation and the use of wildlife, fisheries and forestry resources. CNRH was created in 1997 and it is responsible for the management of water resources in the country.

Table 1.1 presents a brief review on the main federal environmental programmes and institutions created between 1981 and 2008, classified according to the instrument utilized for their creation: federal laws, federal decrees, CONAMA's resolution and CNRH's resolution. Observing Table 1.1 we can see that in general terms the Brazilian environmental regulation has followed the evolution of international agreements and conventions, such as the United Nations Convention on Climate Change, among many others incorporated in federal laws. Besides that, the Ministry of Environment (MMA), in its current form, was established in 1992 and, in the period mentioned, there has been special attention to the mitigation of air and water pollution (including the control of industrial effluents) mainly through corrective measures.

[10] The Company of Environmental Sanitation Technology (CETESB) of São Paulo State was created in 1968 and the State Foundation of Environmental Engineering (FEEMA) in the State of Rio de Janeiro was created in 1975.

Table 1.1 Federal Environmental Legislation: Selected laws, decrees and resolutions by year of publication[(a)]

TOPIC	FEDERAL LEGISLATION		
INSTITUTIONS / AGENCIES	**Laws**	**Decrees**	**Conama[(b)] Resolution**
National Council of Environment (CONAMA)	1981		
Ministry of Urban Development and Environment		1985	
Brazilian Institute of Environment and Renewable Natural Resources (IBAMA)	1989		
Environment Secretary		1973	
Environment Ministry	1992		
Ministry of Environment and the Legal Amazon	1993		
National Council on Water Resources (CNRH)	1997		
International Convention for Combating Desertification		1998[(1)]	
United Nations Convention Framework on Climate Change		1998[(2)]	
Ministry of Environment (MMA)	1992		
National Water Agency (ANA)	2000		
POLICIES / PROGRAMMES	**Laws**	**Decrees**	**Conama[(b)] Resolution**
National Environmental Policy	1981[(3)]	1990	
National Fund for the Environment	1989	2000	
National Program for Control of Air Pollution (PRONAR)			1989 1990
National Policy on Desertification Control			1997
National Policy for Conservation and Rational Use of Energy	2001		
National Policy on Water Resources, National Water Resources Management System	1997		
Control Program for Air Pollution derived from Motor Vehicles (PROCONVE)			1986 1993 1994 2002 2008
National Policy for Sea Resources (PNRM)		2005	

Notes: (1) Consistent measures with Agenda 21; (2) It is based on definitions adopted by Agenda 21; (3) Do not mention any particular industry; (a) Except for institutions / agencies: legislation provides the year of their creation; (b) National Council of Environment; (c) National Council on Water Resources.

In Brazil, the control of pollution is decentralized to states, occurring through environmental state agencies subordinated to federal legislation. Specifically related to industrial pollutant activities – the focus of this thesis - , Seroa da Motta (2006) indicates that each state is responsible for its own territorial monitoring and usually firms can "*face two different types of legal sanctions: (i) administrative fines imposed by the Environmental State agencies; and, (ii) remediation and clean-up legal sanctions imposed by the judiciary.* Also, according to the environmental criminal law[11] established in 1998, manufacturing firms which: a) launch solid, liquid, gaseous, waste, oil or oily substances, in violation of the requirements established in laws or regulations; or b) fail to adopt, when required by the competent authority, precautionary measures in case of risk of serious or irreversible environmental damage, can be penalized with imprisonment of their legal representatives between one to five years.

[11] Federal Law N° 9605.

Given the complexity and disorganization of Brazilian environmental legislation, particularly at the state level, we conducted a detailed survey[12] (until 2008) on the laws, decrees, resolutions, ordinances and regulatory instructions specifically related to the industrial activity, of special interest in this thesis.

The survey was conducted both at federal and state levels, according to eight relevant topics: 1) creation of environmental agencies and institutions; 2) environmental policies and programs; 3) industrial activities; 4) inspections, monitoring and sanctions; 5) industrial effluents and waste; 6) funds; 7) economic instruments; and, 8) specific industries. The first, second, fourth and sixth topics are not exclusively related to industrial activities. As a result of this survey, we generated summary tables based on the aforementioned topics related to:

a) federal environmental legislation – Table 1.1 and Tables A.1.6, A.1.7 and A.1.8 (these last three Tables can be found in the appendices);

b) state environmental legislation – comparison of the 27 Brazilian states[13] – Tables 1.2, 1.3, 1.4 and Tables A.1.2, A.1.3, A.1.4 and A.1.5 (in the appendices). In these tables and annexes the name of the states were abbreviated. The states full name can be found in Table A.1.1 in the appendices.

Table 1.2 presents selected laws, decrees, resolutions, ordinances and normative instructions at the state level concerning industrial activities, inspections, monitoring and sanction measures across the Brazilian states.

Analyzing Table 1.2 we can note that environmental self-monitoring and voluntary inspections are still rare and concentrated in few states. On the other hand, administrative and criminal penalties are much disseminated, most of them following the federal environmental criminal law established in 1998.

[12] To the best of our knowledge this kind of survey is not yet existent in the Brazilian literature.

[13] We generated also one detailed table for each of the 27 Brazilian states. The tables for each Brazilian state can be obtained upon request.

Table 1.3 shows selected laws, decrees, resolutions, ordinances and normative instructions at the state level, related to industrial effluents and industrial waste disposal across the 27 different Brazilian states. Taking Table 1.3 as a whole, we notice that the Brazilian states located in the Southeast region of the country present more detailed regulations concerning industrial effluents and waste disposal, especially the state of Sao Paulo.

Environmental policy in Brazil is concentrated in command and control measures in detriment of economic instruments. We can observe this fact analyzing Table 1.4, which enumerates selected laws, decrees, resolutions, ordinances and normative instructions at the state level related to economic instruments, the most important being the "green" VAT[14] (value added tax).

[14] ICMS verde.

Table 1.2 - State environmental legislation: selected laws, decrees, resolutions, ordinances e regulatory instructions by year of publication - Industrial Activities

	Midwest					Northeast									North						Southeast				South		
INDUSTRIAL ACTIVITIES	**DF** *(b)*	**GO** *(e)*	**MT** *(b)*	**MS** *(e)*	**TO** *(g)*	**AL** *(b)*	**BA** *(f)*	**CE** *(g)*	**MA** *(c)*	**PB** *(b)*	**PE** *(f)*	**PI** *(d)*	**RN** *(d)*	**SE** *(d)*	**AC** *(d)*	**AP** *(d)*	**AM** *(f)*	**PA** *(e)*	**RO** *(c)*	**RR** *(b)*	**ES** *(g)*	**MG** *(f)*	**RJ** *(e)*	**SP** *(g)*	**PR** *(g)*	**RS** *(d)*	**SC** *(d)*
Industrial landfill																								1981			
Potentially polluting activities / Industrial Activities	1975	2002					2006		1993		2003 2007		2006	1979 1980 2008		1999 2006	1987 1997 2003 2006	2002 2004			1985 1992 1994 2004	1981 1990 2003 2004			1975 2008		2006 2008
Economic Ecological zoning										1993					1999 2000 2007 2008									2004 2005			
Industrial zoning / Industrial development				1981																				2002			
INSPECTION / MONITORING / SANCTIONS	**DF** *(b)*	**GO** *(e)*	**MT** *(b)*	**MS** *(e)*	**TO** *(g)*	**AL** *(b)*	**BA** *(f)*	**CE** *(g)*	**MA** *(c)*	**PB** *(b)*	**PE** *(f)*	**PI** *(d)*	**RN** *(d)*	**SE** *(d)*	**AC** *(d)*	**AP** *(d)*	**AM** *(f)*	**PA** *(e)*	**RO** *(c)*	**RR** *(b)*	**ES** *(g)*	**MG** *(f)*	**RJ** *(e)*	**SP** *(g)*	**PR** *(g)*	**RS** *(d)*	**SC** *(d)*
Environmental self-monitoring					2003																				2006 2008		
Environmental Audit																1999											
Independent Police Forestry and Watershed company						1989																					
Environmental Military Police / Environmental Company Police										1988		###		2005			2007 2008					1989 2007		1997			
Police station of repression of environmental crimes						1998										1997		1998 2001 2006									
Voluntary Inspection of Environment / Environmental Community Agent							2008									2004											
Strategy Group for Environmental Crimes Combat/ Strategic Planning for Inspection																	2008					2007					
Administrative and Criminal Penalties	1998	2001 2002		2007	2008	1992 1998		2007			2001 2002			1997							1999 2002	2000 2002 2004	2000			2002 2006	

NOTES: (b) includes only laws and decrees; (c) includes laws, decrees and ordinances; (d) includes laws, decrees and resolutions; (e) includes laws, decrees, resolutions and ordinances; (f) includes laws, decress, resolutions and normative instructions; (g) includes laws, decrees, resolutions, normative instructions and ordinances.

Table 1.3 - State environmental legislation: selected laws, decrees, resolutions, ordinances e regulatory instructions by year of publication - Industrial Effluents

INDUSTRIAL EFFLUENTS / INDUSTRIAL WASTE	Midwest					Northeast									North						Southeast				South		
	DF (b)	GO (e)	MT (b)	MS (e)	TO (g)	AL (b)	BA (f)	CE (g)	MA (c)	PB (b)	PE (f)	PI (d)	RN (d)	SE (d)	AC (d)	AP (d)	AM (f)	PA (e)	RO (c)	RR (b)	ES (g)	MG (f)	RJ (e)	SP (g)	PR (g)	RS (d)	SC (d)
Waste incinerators				2007																	2000						
Toxic waste																2000											
Biological treatment of industrial effluents and / or solid waste																								1984 2007			
Industrial Efluent:																											
- liquid and / or gas							1990	1996 2002						1979							2006 2007	1960 1981 1986 2002 2008	1969 1986	1984		2006	
- calcium / alkalinity																								1992			
- Clostridium perfringens																								2004			
- E. coli / dissolved oxygen																								1990			
- fluoride																								1987			
- phosphorus / nitrates and nitrites / organic nitrogen, ammonia / sulfide																								1978			
- fungi																								1988			
- Pseudomonas aeruginosa																								2002			
- Salmonella tiphimurium																								1991			
- selenium / arsenic / metals																								1995			
- soluble silica																								1993			
- toxicity																								1988 2001			
Gaseous effluent:																											
- ammonia / reduced sulfur																								1993			
- Lead / fluorides																								1995			
- free chlorine and hydrochloric acid																								1994			
- particulate matter		1980																						1989 1995			
- hydrogen sulfide																								1990			
- iron																								1989			
- flue gas - sulfur dioxide / sulfuric acid / nitrogen oxide							1979																	1992			

NOTES: (b) includes only laws and decrees; (c) includes laws, decrees and ordinances; (d) includes laws, decrees and resolutions; (e) includes laws, decrees, resolutions and ordinances; (f) includes laws, decress, resolutions and normative instructions; (g) includes laws, decrees, resolutions, normative instructions and ordinances.

Table 1.4 - State environmental legislation: selected laws, decrees, resolutions, ordinances e regulatory instructions by year of publication - Economic Instruments

ECONOMIC INSTRUMENTS	Midwest					Northeast									North						Southeast				South		
	DF *(b)*	**GO** *(e)*	**MT** *(b)*	**MS** *(e)*	**TO** *(g)*	**AL** *(b)*	**BA** *(f)*	**CE** *(g)*	**MA** *(c)*	**PB** *(b)*	**PE** *(f)*	**PI** *(d)*	**RN** *(d)*	**SE** *(d)*	**AC** *(d)*	**AP** *(d)*	**AM** *(f)*	**PA** *(e)*	**RO** *(c)*	**RR** *(b)*	**ES** *(g)*	**MG** *(f)*	**RJ** *(e)*	**SP** *(g)*	**PR** *(g)*	**RS** *(d)*	**SC** *(d)*
Green VAT / Eco VAT / Social Environmental VAT				2000 2001	2002						2000 2003	2008			2004						1997				2003 2004 2005		
Carbon Sequestration				2005																							
Forestry and Environmental Bonds - stock exchange							2006																				
Environmental Clearing House / Environmental Compensation				2005 2007	2004		2005	2003 2007						2006				2007			2000 2008	2006		2004		2004	

NOTES: (b) includes only laws and decrees; (c) includes laws, decrees and ordinances; (d) includes laws, decrees and resolutions; (e) includes laws, decrees, resolutions and ordinances; (f) includes laws, decress, resolutions and normative instructions; (g) includes laws, decrees, resolutions, normative instructions and ordinances.

Utilizing the number of laws, decrees, resolutions, ordinances and normative instructions presented in Tables 1.2, 1.3, 1.4 and Tables A.1.2, A.1.3 and A.1.4 (in the appendices), we construct a counting variable named "Environmental regulation".

The purpose of constructing this variable is to use it as a proxy to the stringency of the Brazilian environmental regulation in Chapter 2 and also to use it as an instrument for environmental innovation in Chapter 3 (due to simultaneity bias with employment and wages)[15].

Therefore the "Environmental regulation" variable was constructed as a counting variable that counts the number of laws, decrees, resolution, ordinances and instructions at the state level, for each Brazilian state based in three year intervals: 1995-1997, 1998-2000, 2000-2002 and 2003-2005. These three year interval periods precede each of the PINTEC's survey available so far: PINTEC 1998, 2001, 2003 and 2008 respectively.

We understand that the number of laws, decrees, resolutions, etc, per Brazilian state is not a strict measure of regulation stringency, but unfortunately it was not possible to evaluate regulation practical effectiveness.

[15] For more details see Chapter 2 and 3 respectively.

2. Determinants of Environmental Innovation in Brazilian Manufacturing Industries

2.1 Introduction

The economic impacts of environmental degradation have become the focus of greater attention in recent decades. The aggravation of environmental problems associated with climate change and the possibility of depletion of basic natural resources has made both developed and developing countries seek (voluntarily or not) new ways to produce and consume.

If on one hand economic growth can increase welfare, on the other hand there are many costs involved. Several authors have studied how to assess the costs of growth in relation to its benefits and how to incorporate these costs – including here environmental costs - in the theory of economic growth[16]. Besides growth macro models, empirical analysis of the relation between the environment and economic growth has focused on the inverted U-shaped relationship between per capita income and pollution (e.g. concentrations or emissions of air or water pollution), the so-called environmental Kuznets curve[17].

In this scenario, the substitution or adaptation of current technological standards, towards environmental innovations, becomes an alternative to promote sustainable growth and contribute to improve the quality of life of future generations[18].

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[16] To cite a few, Stokey (1998) states that the degradation of the environment generates an endogenous limit on growth that depends on the elasticity of the marginal utility of consumer goods and the level of productive capacity. Jones (2009) presents a systematic analysis of the conditions under which environmental degradation and other costs of economic growth would eliminate its benefits. Acemoglu *et al* (2012) propose an endogenous growth model with environmental constraints, limited resources and technologically driven change, and indicate different possibilities of optimal environmental policy.

[17] For more details on the environmental Kuznets curve (EKC) see Cole and Lucchesi (2013).

[18] There is a branch of the literature that studies possible rebound effects arising from environmental innovation adoption, for instance when the new "green" technology reduces the consumption of energy. Briefly explaining, as energy becomes more productive, its effective price decreases and the aggregate use of energy may increase. This increased consumption of energy can potentially offset any reduction in emissions resulting from the technique effect. For more details see Turner and Hanley (2011), Sorrell and Dimitropoulos (2008) or Greening *et al* (2000), among others.

As mentioned in Chapter one, we define environmental innovation according to the definition proposed by the Organization for Economic Co-operation and Development (OECD) in 2009. This definition emphasizes that environmental innovations not necessarily have to be developed intentionally to preserve the environment. Rather, it includes all innovations that produce some kind of environmental gain. In this Chapter, we will consider both: a) technical (product and process) environmental innovations - including the EI that reduces resources consumption and the EI that reduces environmental negative externalities; and, b) organizational environmental innovations[19].

The economic literature on innovation has extensively discussed the determinants of general (or non-environmental) innovations usually based on one of the three broad modeling approaches: Schumpeterian, induced innovation and evolutionary approach. When studying the determinants of environmental innovations, we must also consider the relationship between innovation and the characteristics of environmental regulation.

This chapter aims to contribute to this topic by investigating the determinants of technical environmental innovations and organizational environmental innovations adopted by Brazilian manufacturing firms. We use a panel data approach based on PINTEC[20] and PIA[21] data between 1998 and 2008. While the few existing studies on environmental innovation in Brazilian firms are based on cross section data, we use panel data, considering the existence of unobserved specific effects that may influence the firms' decision to adopt EI.

This chapter is organized in five sections (in addition to this one): section 2.2 presents a brief literature review of empirical studies on the determinants of environmental innovation, section 2.3 discusses the methodological approach used (Schumpeterian and induced innovation approaches), section 2.4 explains the data sources and data description, section 2.5 presents the econometric results and section 2.6 contains our final considerations.

[19] For more details on the definition and different types of EI see Chapter one.

[20] Technological Innovation Survey, conducted by IBGE (Brazilian Institute of Geography and Statistics).

[21] Annual Industrial Companies Survey, also conducted by IBGE.

2.2 Literature Review

There is a vast empirical literature on the firm-level determinants of environmental innovation adoption. In order to organize a brief literature review on this topic, it is interesting to distinguish these empirical studies according to the following criteria:

a) how they measure the adoption (or not) of environmental innovations;

b) how they measure the stringency of environmental legislation;

c) how they measure voluntary motivations to adopt environmental innovation, usually related to organizational environmental innovations (with or without formal certification);

d) if they analyze the relation between organizational environmental and technical environmental innovations adoption; and,

e) specifically related to process environmental innovations, if they are able to distinguish between end-of-pipe and clean technologies. As mentioned in Section 2.1, clean technologies are seen as superior when compared to end-of-pipe technologies, both in terms of reducing environmental impacts and also in economic terms.

Environmental innovation (EI) – either process, or product or organizational EI - is usually represented by a dummy variable (that equals to one when the firm has adopted EI or zero otherwise) or by the number of "green" patents granted by the firm. EI can be also measured by the R&D investment directed to environmental innovations.

Related to the stringency of environmental policy, we can point out two common proxies used in the literature: a) pollution abatement costs – related directly to environmental compliance, since pollution abatement cost are expected to increase when regulations are tightened; and, b) number of visits of government monitoring activities. Other alternatives can be: c) number and amount of environmental assessments (notifications) received by the firm; and, d) surveys on the environmental policy design, where respondents are asked about the stringency, flexibility and stability of environmental legislation, and also about the importance of economic instruments

versus command and control policies[22] (e.g World Economic Forum's Executive Opinion Survey).

We can distinguish two ways of considering voluntary motivation. The first manner consists in including different measures of voluntary motivations as explanatory variables to explain the adoption of technical – process or product - environmental innovations. In this case, a possible way to measure voluntary motivations is through the use of surveys on the general motivations to adopt EI, such as image improvement, cost saving, reduction of environmental incidents, social pressures, customer demand, voluntary or negotiated agreements between the firm and the government, where respondents are asked directly if they adopted EI voluntarily or not. It is important to notice that this kind of survey is not very common.

The second manner is to analyze the relevant incentives for a firm to adopt environmental organizational innovations, which usually consist in voluntary measures to reduce environmental damage due to the firm activities. In this case, the most common measures of organizational environmental innovation are the ISO 14001 certification[23] and the European Union Environmental Management and Auditing Scheme (EMAS), both related to international Environmental Management Systems (EMS) norms. The literature also considers managerial activities not related to EMS standards.

EMS are organizational changes towards environmental self-regulation that include environmental reports, monitoring of environmental performance based in "*management practices that integrate the environment into production decisions, identifying opportunities for pollution and waste reductions, and implementing plans to make continuous improvements in production methods and environmental performance*". (KHANNA and ATON, 2002). The ISO 14001 certification, in turn, is one of the most diffused forms of EMS and constitutes a voluntary organizational framework that details the procedures to manage the impacts of the firm activities on the environment and has an attempt to get ahead from the existing government regulations. The ISO 14001 certification requires third party certification and investigation.

[22] For more details on command and control measures and economic instruments see Chapter one.

[23] Sponsored by the International Organization for Standardization (ISO).

Finally, there is another branch of the literature that investigates if the adoption of EMS or other environmental management techniques improves the firms technical environmental performance. We are not going to explore this approach in this chapter. For more details see Khanna *et al* (2009), Ziegler and Nogareda (2009), Wagner (2009), Rennings *et al* (2006) and Anton *et al* (2004), among others.

Based on the concepts aforementioned, we present below a brief literature review on the firm-level determinants of EI. Frondel *et al* (2007) use a multinomial logit model applying a categorical variable to reflect three distinct unordered choices of EI: a) end-of-pipe technologies, b) clean technologies; and c) no implementation of EI. They use dummy variables to measure both the environmental regulation stringency and the impact of regulatory measures. The "policy stringency" variable equals to one if the respondent considers the environmental police stringent and equals to zero if he considers the policy moderately or not stringent. The "regulatory measures" variable equals to one if the firm declares that input bans, technology or performance standards were very important motives to adopt EI.

Based on 2003 data for seven OECD countries (Canada, France, Germany, Hungary, Japan, Norway and the US - totaling 4,186 observations), the authors indicate a positive and significant correlation between stringent environmental regulation and end-of-pipe technologies, while the correlation between stringent policy and clean technologies was not significant. They argue that this particular result can be explained by the fact that command and control was still the dominant environmental policy at that time, which usually "*impose technology standards that can only be met through end-of-pipe abatement measures*". The study also attempted to analyze voluntary motivations to adopt the aforementioned EIs. However the "voluntary or negotiated agreements" dummy variable was not significant in any of the cases. On the other hand, the "prevention of environmental incidents" (dummy variable) was significant and positively related with both end-of-pipe and clean technologies. Clean technologies, in turn, were favored by cost saving motivations (dummy variable) tending to be market-driven instead of regulation-driven.

Brunnermeier and Cohen (2003) studied the determinants of environmental innovation in the US manufacturing industries between 1983 and 1992. The authors used the number of successful environmental patent applications granted to the industry as a proxy to environmental innovation. They were interested in understanding how the

adoption of EI by the US industries responded to changes in pollution abatement expenditure (US$ million) and to changes in the number of air and water pollution related inspections, proxies to environmental policy stringency. They estimated four different models (fixed effects, poisson, negative binomial fixed effects and negative binomial random effects) and obtained robust results across them, concluding that there is a positive and significant relation between pollution abatement expenditures and the number of "green" patents granted by the firm. The coefficients on the number of inspections are insignificant and the explanation proposed by the authors is that this occurs because the number of inspections might be highly correlated to the pollution abatement variable. They also reported positive and highly significant coefficient in the value of industry shipments control variable (US$ million), indicating a positive relation between industry output and patenting activity.

Horbach *et al* (2012) tested whether different types of environmental innovation are driven by different determinants. Based on the German 2009 Community Innovation Survey (CIS) covering 7,061 firms in mining and quarrying, manufacturing, energy and water supply and service sectors, the authors defined twelve different types of EI according to the environmental impact caused by the EI. The first nine types are related to process EI: 1) reduction on the consumption of materials; 2) reduction on the consumption of energy; 3) reduction on the emission of CO_2; 4) reduction on the emission of other air pollutants; 5) reduction on water pollution; 6) reduction on soil pollution; 7) reduction on noise pollution; 8) replacement of hazardous substances; 9) recycling of waste, water or materials. The other three types are product EIs related to the after sale use of the product. All the different EIs were measured by dummy variables and the authors estimated a probit model. According to the results obtained, except for the EIs that impact on the reduction of material and energy consumption, present and future environmental regulation registered positive and significant correlation with the adoption of the other ten different types of EI. "Present regulations" and "future regulations" variables were measured as dummy variables related respectively to: a) the relevance of the fulfillment of laws and regulations; and, b) the anticipation of future regulations. The adoption of EMS (dummy variable) presented positive and significant correlation with all the different types of EI considered. Related to voluntary motivations, cost savings turned out to be an important determinant in the adoption of energy and material saving EI; also, the customer requirements coefficient was significant and positively correlated to product EI. Cost savings were measured by

a dummy variable that equals to one when the cost reduction was highly relevant to innovate. Customer requirements were also represented by a dummy variable that equals to one, according to the firm's perception of customer demand for EI.

Demirel and Kesidou (2011) used a dataset on 289 UK firms that responded the DEFRA[24] Government Survey of Environmental Protection Expenditure in 2005 and 2006. The study considers three different types of environmental innovation (all of them measured as dummy variables): a) end-of-pipe technologies, b) integrated cleaner production technologies, and, c) environmental R&D – defined as the "*use of R&D to generate new or improved products and processes with environmental benefits*". The authors estimated a Tobit model and investigated the impact of environmental regulation (command and control policy), environmental taxes (economic instrument), ISO 14001 certification and efficiency improvement on the firms' probability to innovate in order to preserve the environment. Both environmental regulation and environmental taxes variables are binary variables that assume the value one if each of them has been effective to the firms' decision to innovate. Efficiency improvement was measured as equipment upgrades (dummy variable that equals to one if the firm invested in environmental protection because of equipment upgrade) or cost savings (equals to total costs savings resulting from environmental improvements, measured in pounds sterling). The results of the study confirm that different types of EI have different determinants. End-of-pipe technologies are stimulated by environmental regulations (usually characterized by command and control measures), equipment upgrade motives and ISO 14001 certification. Clean technologies are mainly driven by efficiency improvement motive (equipment upgrade) and Environmental R&D is positively correlated with environmental regulations, cost saving motives and ISO 14001 certification. The study indicates that ISO 14001 certification is important to stimulate firms to invest in Environmental R&D. Environmental taxes, in turn, was not significant to any of the three types of EI considered. According to the authors, in the UK "*environmental taxes have not been frequently used as means of regulating pollution levels since environmental laws have historically been the preferred policy tool in this field*".

[24] Department for Environment, Food and Rural Affairs (DEFRA).

Using OLS fixed and random effects models, the panel study conducted by Del Rio *et al* (2011) with Spanish manufacturing industries in the period 2000-2006, confirmed the relevance of the stringency of environmental regulation and physical capital intensity to explain the investment in environmental technologies. The authors also stated that the determinants of EI are likely to differ between end-of-pipe and clean technologies adoption. In the study, EI is measured as the investment in environmental technologies to value added ratio and environmental regulation stringency is represented by the intensity of environmental protection expenditures to value added ratio. Physical capital intensity equals the investments in material assets to turnover ratio. Furthermore, export intensity (exports to turnover ratio) was negatively correlated with EI, indicating, according to the authors, that "*environmental protection is often done in sectors that are (or have been in the past) protected and highly regulated, such as energy.*"

Concerning the determinants of organizational environmental innovations adoption, Frondel *et al* (2008) estimated a probit model based on an OECD survey performed in 2003 with 899 firms in Germany. Their results indicate that EMS adoption (dummy variable) was positively correlated with the enhancement of corporate image (dummy variable), firms' size (number of employees) and internal forces such as corporate headquarters employees and shareholders pressure (dummy variable). It was also negatively correlated with cost savings motivations (dummy variable) "*probably because survey respondents expect EMS adoption to be costly*".

Cole *et al* (2006), using data from 400 Japanese firms in 1999 and OLS regression, identified the factors that influence the adoption of 13 different aspects of a firms' environmental management process. These aspects are related to two broad groups: a) the management and control of specific environmental problems (such as management of total CO_2, treatment of industrial waste, water pollution control, among others); and, b) the quality of the general structure and systems that firms employ to handle environmental issues (ISO 14001 certification, environmental accounting, among others). The 13 different aspects are scored and based on those scores the authors constructed an "overall environmental management performance" index which ranges between 48 and 70 (the higher the more sophisticated). The results obtained indicate that foreign direct investment (dummy variable), firms that export (dummy variable), physical capital intensity (capital stock per worker) and size of the firm (total employment) are significant and positively correlated with the overall management

performance of the firm. The interpretation given by the authors is that Japanese firms that embark on FDI in more regulated countries will raise standards in Japan, or other possibility is that multinationals owned firms are subject to closer national and international monitoring when compared to domestically owned. The exports variable indicates that a firm that exports receives more influence of international competition and monitoring encouraging, to have better environmental management practices. Firms intensive in capital tend to be more pollution intensive, and hence, are expected to adopt more stringent environmental management. And, finally, the structure and resources necessary to implement environmental management are more likely to be encountered in larger firms.

Similarly, Anton *et al* (2004) constructed an overall environmental management variable that counts the different environmental management practices (among 13 options) adopted by the firm. The authors use Poisson and quantile regression methods, to assess the comprehensiveness of environmental management for S&P 500 US firms, between 1994-95. Across all the different models estimated, the results indicate a positive correlation between "potentially responsible parties (PRPs)" and the adoption of comprehensive EMS. Firms are listed as PRPs if they had already been held liable for contamination caused by their hazardous waste streams. Also firms classified as "final goods" producers (dummy variable that equals to one when the firm is primarily selling products or services to the consumers) are in closer contact to consumers and hence fell greater pressure or benefit more from improving their environmental awareness. Therefore, the "final good" variable registered a positive and significant impact on comprehensive EMS. In the same direction, toxic releases (defined as the sum of on-site toxic releases and off-site transfers) are positively correlated to EMS since firms that register larger volumes of toxic releases are more likely to face social pressures from stakeholders or communities, in order to improve their environmental management practices.

Focusing on the determinants of EI in developing countries, Albornoz *et al* (2009)[25] suggested that foreign owned firms are highly and positively correlated with EMS adoption (dummy variable equal to one if the firm has adopted EMS) in Argentinian manufacturing industries. This highlights the importance of technology and

[25] The authors are especially interested in verifying the presence of environmental spillovers in the sense that foreign firms have been known to directly encourage the dissemination of environmental related knowledge and technologies.

management practices transfer from developed to developing countries. This result is consistent across all specifications adopted and, particularly, the baseline regression indicates that foreign-owned firms are nearly twice as likely as domestic firms to have implemented EMS. The authors used a logistic regression model based on 1,187 Argentinian firms, between 1998-2001 (INDEC[26] data).

Specifically related to studies on Brazilian manufacturing firms, Marta *et al* (2011) analyzed the determinants of pollution abatement investment (measured as log of total investment directed to reduce or prevent environmental damage) in 2007. The study uses OLS regressions on 8,218 Brazilian firms and concludes that the main determinants of pollution abatement investment are the size of the firm (total employees) and the firms' productivity (measured as industrial transformation value to employees ratio), both variables with positive signs. On the other hand, the coefficients that correspond to age of the firm (years of operation) and export (measured as a dummy variable) are significant and negative.

Queiroz (2011) used a probit model based on 2008 PINTEC data and analyzed the determinants of EI with high or medium impact on the reduction of environmental damage (dummy variable). The study suggests that cost saving impacts, market share expansion and adjustment to internal and/or external general market norms are positively correlated to the adoption of this particular type of EI.

Seroa da Motta (2006) used data from a research conducted by CNI (National Industry Confederation) in 1997 on "Environmental Management in Brazilian Industry", along with 325 medium and large firms. The author constructed an index of environmental practices adoption and used OLS regression to analyze its determinants. The results obtained indicate that the main determinants of environmental practices are the size of the firm (total employees), cost reduction motivation (dummy variable) and social pressures of NGOs and local communities (dummy variable).

Finally, Ferraz and Sero da Motta (2001), based on a 1996 PAEP[27] database on 10,070 firms located in São Paulo State, concluded that size, foreign ownership, export intensity and environmental notification increase the firm's probability to realize

[26] Institute of Statistics and Censuses in Argentina.

[27] Economic Activity Survey of São Paulo (PAEP) held by SEADE (State System for Data Analysis).

environmental investment (dummy variable). The authors utilized probit, probit instrumental variable and Heckman Probit regression models, and the results are consistent across the different models. Environmental investment is a dummy variable equal to one if the firm realizes either investment in cleaner inputs, investment in cleaner production processes or investment in waste treatment. Foreign ownership is a dummy variable, export intensity is measured as exports to total sales ratio, and environmental notification is the number of fees or notifications received by the firm between 1993-95, issued by CETESB[28], and also the number of CETESB agencies in the city where the company is located.

2.3 Schumpeterian and Induced Innovation Approach

Our modeling strategy is based on the traditional Schumpeterian approach complemented with the induced innovation hypothesis. The literature on the economics of innovation was originated with Schumpeter (1942) writings, which pointed out the central role of technological progress to economic growth. In determining firms' innovative activities, Schumpeter focused on the importance of firm size and market structure. In his argument, large firms with market power (concentrated markets or monopolist firms) would have advantages in innovating. Large firms usually deal in a lesser extent with financing problems since usually generate more stable internal funds.

Furthermore, large firms have greater ability to deal with risky R&D activities, counts on economies of scale in maintaining R&D laboratories, and in some circumstances, provide economies of scope because of their diversified nature. In the modeling strategy adopted in this chapter we used the number of total employees as a proxy to the firm's size. We also introduced physical capital intensity since usually those industries that are more intensive in capital generate greater volumes of pollution – and consequently face larger abatement costs - than those intensive on labor. According to Cole *et al* (2005) this fact occurs in part due to the positive relation between physical capital intensity and energy use, intensive in the combustion of fossil fuels (largely pollutants).

Market power, in turn, stimulates the firm to invest in innovative activities because it reduces rivalry and uncertainty associated with innovation process. Additionally, some

[28] Company of Environmental Sanitation Technology (CETESB) of São Paulo State.

form of market power (even temporary), deriving from innovations (e.g. patents) incentives firms to invent. Patents and other forms of intellectual property are possible solutions to appropriability problems. (COHEN, 2010)

Schumpeter also distinguished between three stages in the process of technological change: a) invention - the first step in developing a new technological process or product; b) innovation - when the invention is commercialized; it includes organizational innovation besides technological innovations; and, c) diffusion – corresponds to wider application of innovations.

Concerning innovation processes in developing countries - focus of analysis in this chapter, it is important to reinforce that in many situations it is difficult to differentiate between the effects of innovation and the diffusion stages. Conventionally, innovation and invention are assumed to be activities concentrated in developed countries, while developing countries concentrate the diffusion of new technologies embodied in capital goods purchased from more advanced economies. Indeed, technology transfer from developed to developing countries can occur through several channels such as multinational parents, international trade and licensing agreements. Multinational parents often transfer technology to their subsidiaries, although in many situations the technology transferred is mature or, in other words, is not the most updated. Concerning international trade, firms can import frontier technology embodied in capital goods or inputs and/or can export to buyers endowed with more advanced technologies and hence be in contact with new technologies. International trade also enhances international monitoring in relation to the firms' environmental practices (ALMEIDA and FERNANDES, 2008).

In this scenario, developing countries are seen simply as "borrowers" of technology from developed countries. However we understand that this interpretation of technology diffusion is misplaced. According to Bell and Pavitt (1997) the diffusion stage "*involves more than the acquisition of machinery or product designs and the assimilation of related operating know-how*". In fact, innovation usually continues in the diffusion process, through adaptation to particular uses and conditions in developing countries' firms. Besides adaptation, the new technologies can be improved in the post-adoption phase by incorporating incremental developments and modifications in accordance to continuing learning curves in industrial production. Thus technology diffusion leads to creative and complex incremental technological change.

Trying to address the importance of transferred technology by multinational parents we included the "foreign owned" variable in the model tested in this chapter. We also added "export intensity" intending to measure the impact of international trade on the firms' probability to adopt environmental innovations.

More recently, in addition to Schumpeterian traditional approach, the determinants of technological change and innovation adoption have been studied according to the induced innovation hypothesis[29]. The induced innovation approach (originated from Hicks (1932) ideas) states that economic motives influence the rate and direction in which the innovations are developed[30].

According to Acemoglu[31] (2002), the direction of technical change is determined endogenously by the interaction between relative prices, market size, the elasticity of substitution between the input factors, and innovation costs (relatively to current or "state" composition of R&D). The relative prices favor innovations directed at scarce factors; the market size favors innovations directed at abundant factors. In the case of the elasticity of substitution between the input factors, whenever the elasticity of substitution is low, the relative price effect is more powerful, and technological changes will be biased towards the scarce factor. On the contrary, when the elasticity of substitution is high, market size effect is more powerful and technological innovation will be directed at abundant factors.

Focusing on environmental innovations, both scarcity of natural resources and environmental regulation (implicitly or explicitly) lead to more expensive environmental inputs, changing relative prices, and thus, they can be understood as a possible explanation to technological change directed towards "green" technologies. In this sense, Newell *et al* (1999) proposed the *environmental inducement* concept, including *inducement by regulatory standards* in the induced innovation hypothesis,

[29] There is also the evolutionary approach, which views technological progress as an evolutionary process. In this approach firms engage in satisficing behavior, without requiring its optimization. We are not going to base our analysis on this approach. For more details on the evolutionary theory see Dosi and Nelson (2010) and Cohen (2010).

[30] For more details on biased technological change theories, see Chapter 3.

[31] Acemoglu's model is based in a CES production function and considers a scale effect (the growth rate of the economy increases as the population increases) and treats factor supplies as given (not considering their response to relative prices). For more details see Acemoglu (2002).

suggesting an important relation between environmental policy and technology change. According to Jaffe *et al* (2003) it is very difficult to test the environmental inducement hypothesis because it is not easy to measure the extent of inducement across firms: "*more generally, non-price regulatory constraints can fit with the inducement framework if they can be modeled as changing the shadow or implicit price that firms face emitting pollutants*". Since shadow price of pollution or environmental inputs are not easily observed, we must use proxies for them. Such proxies are generally related to environmental regulations characteristics, trying to measure its stringency, expenditures on pollution abatement or prices of polluting inputs (e.g. energy, carbon fuels). In this chapter we are going to use the Brazilian environmental legislation count variable as a proxy to the stringency of environmental regulation. As explained in Chapter one, the Brazilian environmental legislation variable considers the number of laws, decrees, resolutions, etc., per Brazilian State, in a three years interval period.

Porter and Van der Linde (1995) also stressed the role played by stringent environmental legislation on firms decision to adopt environmental innovations. The controversial Porter Hypothesis[32] (PH) suggests that well designed environmental regulation may spur innovation that, in turn, will partially, or more than fully, offset its initial compliance cost.

In order to facilitate PH analysis, we can disaggregate it into two component parts: a) the first component part refers to the relation between the stringency of environmental regulation and innovation adoption; and, b) the second part deals with the proposition that environmental innovation can more than offset its initial cost and subsequently increase the firm's business performance. In this chapter we are going to deal with the first part of PH. For considerations on the second part of PH see Chapter 4.

There are many critiques to PH, especially related to its second part. However, turning the attention to its first component part, we can mention as the main critique the difficulty to design well fitted, stringent and at the same time efficient environmental

[32] Jaffe and Palmer (1997) suggest three different interpretations to the Porter Hypothesis: 1) the narrow version (concerning more flexible regulation): "*certain types of environmental regulation stimulate innovation*", 2) the weak version: "*regulation will stimulate certain kinds of innovation*", and 3) the strong version: "*environmental regulation is a free lunch (or even a paid lunch), that is, regulation induces innovation whose benefits exceeds its costs, making the regulation socially desirable, even ignoring the environmental problems it was designed to solve*".

regulations. In particular, PH indicates that what it means by "*properly designed regulations*" favors the utilization of economic instruments in place of command and control policies[33]. Unfortunately, the Brazilian environmental legislation does not permit its discrimination in economic instruments and command and control policies, so in this case, we are also going to use the Brazilian environmental legislation variable as a proxy to test the stringency of environmental regulation in the PH sense.

So, the modeling strategy utilized in this chapter is based in the Schumpeterian and environmental inducement approaches presented along this section. Therefore, we estimated pooled OLS, fixed effects and logit regressions according to equation (1):

$$\mathbf{EI}_{it} = \beta_1(\text{EnvReg}_{it-1}) + \beta_2(\text{Size}_{it}) + \beta_3(\text{Export}_{it}) + \beta_4(\text{Foreign}_{it}) + \beta_5(\text{Capital}_{it}) + \delta_t + \mu_{it} \quad (1)$$

where:

$i = 1, 2, \ldots, N$ – cross section firms units (CNAE[34] 3 digit);

$t = 1, 2, \ldots, T$ – time period (years);

$\mathbf{EI}_{it}$ – set of environmental innovation dummies (at least one, all, environmental impact reduction and safety improvement, biological effluent treatment and environmental management techniques);

$EnvReg_{it-1}$ – lagged Brazilian environmental regulation count variable;

$Size_{it}$ – Size of the firm - proxied by total number of employees;

$Export_{it}$ – Export intensity - measured as exports to total sales ratio;

$Foreign_{it}$ – Foreign ownership - measured as a dummy variable that equals to one when the firm is owned by foreigners (more than 51% of capital) or zero otherwise;

$Capital_{it}$ – Physical capital intensity – measured as capital stock to total employees ratio;

[33] For more details on economic instruments and command and control policies, see Chapter one.

[34] National Classification of Economic Activities.

δ_t - time effects

β_1, β_2, β_3, β_4, β_5 - parameters to be estimated

μ_{it} – error term

It is important to notice that Brazilian environmental regulation is lagged in one period, since there is an interval between the law publication and the effective adoption of environmental innovations by the firm.

As a robustness test, we also tested the determinants of pollution abatement investment (in place of environmental innovation), using pooled OLS and fixed effects estimation methods. In this sense, we estimated equation (2) considering pollution abatement investment:

$$PAI_{it} = \beta_1(EnvReg_{it-1}) + \beta_2(Size_{it-1}) + \beta_3(Export_{it-1}) + \beta_4(Foreign_{it}) + \beta_5(Capital_{it-1}) + \delta_t + \mu_{it} \quad (2)$$

where,

PAI_{it} – pollution abatement investment – measured as a percentage of total investment.

In equation (2) all the explanatory variables are lagged (except foreign ownership) because, once again, there is a lag of time between the aforementioned variables and the decision to invest in pollution abatement. The foreign ownership is not lagged because the firms' capital origin does not change very frequently and thus we suppose that it is fixed along all the period considered (1997-2008).

In the pooled OLS and pooled logit regressions we also considered industry sector dummies and state dummies. In the OLS and logit fixed effects estimations it is not possible to control by industry and state characteristics because they are already included in the fixed effects.

2.4 Data sources and description

The data used in this chapter combine two different databases, both calculated by IBGE (Brazilian Institute of Geography and Statistics): a) PIA - Annual Survey of Industrial Companies, and, b) PINTEC -Technological Innovation Survey. PIA and PINTEC data are classified according to the Brazilian government's National Classification of Economic Activities – CNAE version 2.0. These microdata are confidential and the

access to them is possible only at IBGE´s secrecy room with previous authorization. All monetary values were corrected by IPA_OG[35] (wholesale price index) sectoral price index and are expressed in terms of 2008 values.

It is important to notice that, while PIA survey is conducted every year, PINTEC survey is conducted every three years, following the Oslo Manual (OECD document establishing guidelines for collecting and interpreting data on industrial innovation) and Community Innovation Survey (CIS) recommendation.

Unfortunately, according to the available data in Brazil, it is not possible to distinguish process EI between end-of-pipe technologies and clean technologies. Either, it is not possible to distinguish between EI adopted to comply with command and control measures or motivated by economic instruments.

In order to construct a panel data, we used the four PINTECs conducted until now: PINTEC 2000 (refers to the period between 1998 and 2000), PINTEC 2003 (between 2001 and 2003), PINTEC 2005 (between 2003 and 2005) and PINTEC 2008 (between 2006 and 2008) and merged the PINTEC's variables (environmental innovations and capital origin variables) with PIA's variables in the first year of PINTEC three year interval period corresponding to: 2006, 2003, 2001 and 1998. In this sense, we did the following merge between PINTEC and PIA (Table 2.1):

Table 2.1 - Panel database: data sources, measurement and merged periods

Data source:	**PINTEC[(a)]**	**PIA**
Variables:	environmental innovations, capital origin	firm size, physical capital intensity, export intensity
Measurement:	**level**	**level**
Periods:	(1998-2000) (2001-2003) (2003-2005) (2006-2008)	1998 2001 2003 2006

Note: (a) we refer to PINTEC's periods according to the year in which the survey was conducted (2000, 2003, 2005 and 2008). The exact definition should describe PINTEC's periods as three year interval period (1998-2000, 2001-2003, 2003-2005 and 2006-2008, respectively).

[35] Calculated by FGV - Getúlio Vargas Foundation.

The panel database covers 20 industrial sectors in 27 states. Observing Table 2.2 and Table 2.3 we can see the percentage of firms by industrial sectors and by Brazilian state[36]. The sectors of pulp and paper, nonmetallic minerals, oil and oil products, metallurgy, and chemicals are among the most polluting sectors considered in accordance with international literature[37] and the Brazilian Federal Law Nº 10.165.

Table 2.2 - Percentage of firms by industry sectors

	PINTEC year			
	2000	**2003**	**2005**	**2008**
number of obs	***7081***	***6737***	***8226***	***10850***
Food	18%	17%	19%	21%
Textile	11%	12%	11%	10%
Metallurgical	8%	8%	8%	8%
Vehicles and Others	7%	8%	8%	9%
Machinery and Equipment	7%	7%	6%	7%
Leather	6%	7%	8%	6%
Computer and Electronics	6%	7%	6%	6%
Rubber and Plastic	5%	5%	5%	5%
Chemical	5%	4%	4%	4%
Nonmetallic	5%	4%	5%	4%
Furniture	4%	4%	4%	4%
Pulp and Paper	3%	3%	3%	3%
Wood	3%	3%	3%	3%
Petrol	3%	2%	3%	3%
Print	3%	3%	3%	2%
Beverage	2%	2%	2%	2%
Pharmaceutical	2%	2%	2%	2%
Mining and Quarrying	2%	2%	2%	2%
Tobacco	1%	1%	1%	1%

Note: weighted by sampling frequency and firm size.

[36] In these tables and annexes the name of the states were abbreviated. The states' full name can be found in Annex 1.1.

[37] e.g. Albornoz et al (2009)

Table 2.3 - Percentage of firms by Brazilian state

state	PINTEC year				*state*	PINTEC year			
	2000	2003	2005	2008		2000	2003	2005	2008
Southeast region	***62%***	***62%***	***59%***	***60%***	***Midwest region***	***3%***	***2%***	***3%***	***3%***
ES	1%	1%	1%	1%	DF	0.3%	0.2%	0.2%	0.3%
MG	9%	9%	8%	9%	GO	1%	1%	1%	2%
RJ	8%	7%	6%	7%	MS	0.3%	0.2%	0.4%	0.3%
SP	43%	45%	43%	43%	MT	1%	1%	1%	0.5%
Northeast region	***10%***	***10%***	***10%***	***11%***	TO	0.0%	0.1%	0.1%	0.0%
AL	1%	2%	2%	2%	***North region***	***3%***	***2%***	***3%***	***3%***
BA	2%	2%	2%	2%	AC	0.04%	0.04%	0.04%	0.02%
CE	3%	3%	3%	3%	AM	1%	1%	2%	2%
MA	0.3%	0.2%	0.3%	0.3%	AP	0.02%	0.04%	0.02%	0.03%
PB	1%	1%	1%	1%	PA	1%	1%	1%	1%
PE	2%	2%	2%	2%	RO	0.2%	0.2%	0.3%	0.2%
PI	0.4%	0.2%	0.3%	0.2%	RR	0.00%	0.01%	0.01%	0.00%
RN	1%	0.5%	0.5%	1%	***South region***	***23%***	***23%***	***25%***	***23%***
SE	0.3%	0.3%	0.3%	0.3%	PR	6%	6%	7%	6%
					RS	10%	10%	9%	9%
					SC	8%	7%	9%	8%

Note: weighted by sampling frequency and firm size.

As mentioned in Chapter One, we considered as technical environmental innovation those product or process innovations that had high our medium impact in a) reducing the resources consumption; and b) reducing the environmental negative externalities, both a) and b) are defined as protecting the environment. As organizational environmental innovation we considered the adoption of environmental management techniques[38].

Based on PINTEC's data, we constructed two grouped dummy variables in each 3-year period covered by the survey. The first grouped dummy variable was constructed in order to represent those firms that had adopted at least one of the following four different types of technical EIs: a) EI with high or medium impact in reducing raw material consumption, b) EI with high or medium impact in reducing energy consumption, c) EI with high or medium impact in reducing water consumption and d) EI with high or medium impact in reducing environmental impact and improving safety requirements[39]. The second grouped dummy variable was constructed to measure those firms that have adopted all the four different EIs aforementioned.

[38] The adoption of environmental management techniques variable was not available in PINTEC 2000.

[39] It is not possible to distinguish between environmental and safety effects before PINTEC 2005. The question regarding this impact includes both effects in PINTEC's 2000, 2003 and 2005 questionnaires. Only in PINTEC 2008 questionnaire the environmental and safety effects were separated in two different questions.

Therefore, in the constructed panel database we have three technical environmental innovations - “EI - at least one”, “EI – all” and “Environmental impact reduction and/or safety improvement” - and one organizational environmental innovation - adoption of “Environmental management techniques”. In Table 2.4 is possible to observe the percentage of firms that adopted each type of EI:

Table 2.4 - Percentage of firms by type of Environmental Innovation

	ano PINTEC			
	2000	**2003**	**2005**	**2008**
number of obs.	**7081**	**6737**	**8226**	**10850**
Product or Process Innovation	65%	61%	68%	64%
EI - at least one	49%	38%	43%	41%
EI - all	13%	7%	8%	10%
Environmenal impact reduction and safety improvment	43%	32%	35%	30%
Environmental management techniques	.	35%	37%	50%

Note: weighted by sampling frequency and firm size.

Concerning the independent variables, we used: a) firm’s size variable - measured as log number of total employees; b) export intensity variable – measured as exports to total sales ratio; c) foreign ownership variable - a dummy variable equal to one in case of foreign ownership, zero otherwise; and, d) physical capital intensity variable – equals to log of capital stock to total employees ratio. We also used an environmental regulation variable, which is a variable that counts the number of environmental laws, decrees, etc, per Brazilian state, and intends to be a proxy to regulation stringency: the greater the number of laws, the greater the stringency of environmental regulation. The environmental regulation variable was measured in the preceding three year interval to each PINTEC survey (1995-1997; 1998-2000; 2000-2002 and 2003-2005 respectively). Table 2.5 presents the average of the independent variables by PINTEC year:

Table 2.5 - Explanatory variables - average by PINTEC year

	measurement	ano PINTEC 2000	2003	2005	2008
number of obs.		**7081**	**6737**	**8226**	**10850**
Environmental regulation	*number of laws, etc*	5.0	1.7	6.2	7.7
Size of the firm	*ln (number employees)*	6.3	6.3	6.4	6.6
Export intensity	*exports/total sales*	13%	15%	18%	17%
Foreign ownership	*dummy*	22%	22%	21%	23%
Physical capital intensity	*log(capital stock/total employees)*	10.9	10.8	10.7	10.7

Note: weighted by sampling frequency and firm size.

Table 2.6 presents the descriptive statistics[40] for the panel database (1998-2008) constructed:

Table 2.6 - Descriptive Statistics - Panel database

Variable	***Measurament***		***Number of obs.***	***Mean***	***Standard Deviation***
Dependent Variables:					
Environmental Innovation - at least one	*dummy variable*	*level*	32,894	0.43	0.49
Environmental Innovation - all	*dummy variable*	*level*	32,894	0.10	0.29
Environmental impact reduction and safety improvement	*dummy variable*	*level*	32,894	0.34	0.48
Environmental Management Techniques	*dummy variable*	*level*	25.813	0.41	0.49
Explanatory Variables:					
Environmental Regulation	*number of laws per state*	*3 year lagged*	32,894	5.3	4.2
Size of the Firm	*log (total employees)*	*level*	32,894	6.4	1.8
Export Intensity	*(exports/total sales) ratio*	*level*	32,894	0.16	0.25
Foreign Ownership	*dummy variable*	*level*	32,894	0.22	0.42
Physical Capital Intensity	*log (capital stock/total employees)*	*level*	32,894	10.8	1.8

Notes: Panel database considers PINTECs 2000, 2003, 2005 and 2008 merged to PIAs 1998, 2001, 2003 and 2006 respectively. All dummy variables were measured between a 3-year interval period (1998-2000; 2001-2003; 2003-2005 and 2006-2008) due to PINTEC's methodology. Size of the firm, export Intensity and physical capital intensity were measured in level, in the first year of each 3-year period: 2006, 2003, 2001 and 1998, respectively; and environmental regulation was measured in 3-year intervals, preceeding each PINTEC survey: 1995-1997; 1998-2000; 2000-2002 and 2003-2005. Environmental management techniques variable is not available in PINTEC 2000, fact that explains the number of observations being lower to this variable. All statistics are weighted by firms' size and sampling frequency.

[40] Maximum and minimum values of the variables presented in the table were not shown because it is forbidden to calculate such statistics when using IBGE's confidential data in secrecy room.

Besides the panel database, we also used a cross section sample based on PINTEC 2008 merged with PIA 2006. In this cross section sample we considered a different type of environmental innovation named "Biological effluent treatment". The biological effluent treatment variable was considered in a cross section basis because it was made available only in PINTEC 2008 survey.

Relative to the cross section database, we can observe its descriptive statistics in Table 2.7:

Table 2.7 - Descriptive Statistics - Cross Section database

Variable	*Measurament*		*Number of obs.*	*Mean*	*Standard Deviation*
Dependent Variable:					
Biological Effluent Treatment	*dummy variable*	*level*	10,850	0.05	0.22
Explanatory Variables:					
Environmental Regulation	*number of laws per state*	*3 year lagged*	10,850	7.7	4.7
Size of the Firm	*log (total employees)*	*level*	10,850	6.6	1.9
Export Intensity	*(exports/total sales) ratio*	*level*	10,850	0.17	0.25
Foreign Ownership	*dummy variable*	*level*	10,850	0.23	0.42
Physical Capital Intensity	*log (capital stock/total employees)*	*level*	10,850	10.7	1.9

Notes: Cross Section database considers PINTEC 2008 merged to PIA 2006. All dummy variables were measured between a three year interval period (2006-2008) due to PINTEC's methodology. Size of the firm, export Intensity and physical capital intensity were measured in level, in the first year of the three year interval period: 2006. Environmental regulation was measured in the 3-year interval period preceeding PINTEC 2008 survey: 2003-2005. All statistics are weighted by firms' size and sampling frequency.

Finally, a second panel database was created to analyze the determinants of pollution abatement investment effect, available in PIA 1997, 2002 and 2007 surveys. The pollution abatement investment variable is equal to the percentage of investments spent in reducing or controlling emissions of pollutants that result from production process, or to attend environmental regulations. The measurement of this variable includes the acquisition of industrial machines that incorporate the design of clean technology, acquisition of other equipment and construction of treatment stations (Table 2.8).

Table 2.8 - Pollution abatement investment by PIA year

	PIA year		
	1997	**2003**	**2007**
number of obs.	***6661***	***7149***	***11048***
Polution abatement investment (% total investment)	4.6%	6.2%	5.8%

Note: weighted by sampling frequency and firm size.

In this second panel database we considered lagged firm size, export intensity, physical capital intensity and environmental regulation, as can be observed in Table 2.9. Pollution abatement investment was measured in level and foreign ownership (assuming that capital origin does not change frequently) is measured in level, on a three year basis interval, according to PINTEC's methodology:

Table 2.9 - Pollution abatement panel database: data sources, measurement and merged periods

Data source:	**PINTEC**[(a)]	**PIA**
Variables:	capital origin	pollution abatement investment, firm size, export intensity and physical capital intensity
Measurement:	**level**	**lagged *t-1***
Periods:	2000[(b)] 2003 2008	1997 2002 2007

Notes: (a) we refer to PINTEC's periods according to the year in which the survey was conducted (2000, 2003 and 2008). The exact definition should describe PINTEC's periods as three year interval periods (1998-2000, 2001-2003 and 2006-2008, respectively). (b) capital origin was not available in PINTEC 1997, so we used the information availble for the period between 1998 and 2000, assuming that the capital origin was the same in the 1997-2000 period.

As mentioned in Section 2.3, all the explanatory variables are lagged (except foreign ownership), assuming that there is a lag of time between the aforementioned variables and the decision to invest in pollution abatement.

Table 2.10 presents the descriptive statistics for pollution abatement investment variable:

Table 2.10 - Descriptive Statistics - Pollution abatement database

Variable	*Measurament*		*Number of obs.*	*Mean*	*Standard Deviation*
Dependent Variable:					
Pollution abatement investment	*% total investment*	*level*	23,290	0.06	0.17
Explanatory Variables:					
Environmental Regulation	*number of laws per state*	*lagged*	23,290	2.1	2.0
Size of the Firm	*log (total employees)*	*lagged*	23,290	6.4	1.8
Export Intensity	*(exports/total sales) ratio*	*lagged*	23,290	0.15	0.24
Foreign Ownership	*dummy variable*	*lagged*	23,290	0.23	0.42
Physical Capital Intensity	*log (capital stock/total employees)*	*level*	23,290	10.8	1.7

Notes: Pollution abatment database considers PINTECs 2000, 2003 and 2008 merged to PIAs 1997, 2002 and 2007 respectively. Foreign ownership was measured between three year interval periods (1998-2000; 2001-2003; and 2006-2008) due to PINTEC's methodology. Size of the firm, Export Intensity, Physical capital intensity and Environmental regulation are one year lagged variables measured in 1997, 2002 and 2007, respectively. Pollution abatement investment was measured in level as contemporaneus variables: 1998, 2003 and 2008. All statistics are weighted by firms' size and sampling frequency.

2.5 Empirical Results

Tables 2.11 to 2.15 present the estimation results, related to the determinants of technical and organizational environmental innovations in Brazilian manufacturing firms, between 1998-2008. Table 2.16 presents the results for the determinants of pollution abatement investment between 1997-2007.

Related to the determinants of EI adoption, we estimate four different models, which can be verified in Tables 2.11, 2.12, 2.13 and 2.14: a) pooled OLS (columns 1 and 2), b) linear fixed effects (columns 3 and 4), c) pooled logit (columns 5 and 6) and d) logit fixed effects (columns 7 and 8). All the regressions are weighted by sampling frequency and establishment size[41]

The advantage of using fixed effects models (linear or logit) is that they control unobservable effects, avoiding possible omitted variable bias. In particular, logit and logit fixed effects models were utilized because of the binary characteristic of the dependent variable, as the logistic function is restrained to range between 0 and 1. Besides that, the main difference between linear OLS and nonlinear logit models is that

[41] The rationale for weighting by size (standard in skill biased technological change) is to give larger firms a bigger weight, just as we would do if aggregating to macro economy. Besides that, measurement error is worse for smaller firms, so this also helps in this dimension (CAROLI and VAN REENEN, 2001). In the logit and logit fixed effects models the weights were calculated as average weights per firm.

the linear model assumes that the regressors present constant marginal effects, while the logit model assumes diminishing partial effects. The marginal effects of the logit estimates (columns 5 and 6) and logit fixed effects estimates (columns 7 and 8) were calculated at the means of the independent variables, and are comparable with the OLS estimates.

In Tables 2.11, 2.12, 2.13 and 2.14, column (1) differs from column (2) - and analogously column (3) from (4) and column (5) from (6) – due to specification purposes. The first column of each model (columns 1, 3 and 5) includes only the environmental legislation count variable, while the second column of each model (columns 1, 4 and 6) includes the control variables. Additionally, dummy year variables (2003, 2005 and 2008) were included in all regressions. Besides that, 19 industry-specific dummies and 26 state dummies were included in the pooled OLS (columns 1 and 2) and logit models (columns 5 e 6). The complete estimation results (including the dummies for years, states and industry sector) can be observed in Appendices to chapter 2.

Table 2.11 shows the results of the estimation of the influence of each explanatory variable on the firms' probability to adopt at least one type of technical environmental innovation[42] (equation 1) - approximately 43% of the firms (mean of dependent variable). Taking Table 2.11 as a whole, we can observe that the estimates are consistent across the four different models. The same explanatory variables are significant in each model (with the same level of significance in most of the times) and also they have the same signal across the different models.

[42] As mentioned in Section 2.4, we utilized four different types of technical environmental innovations, defined as technical innovations that had medium or high impact on: a) the reduction of raw material consumption; b) reduction of energy consumption; c) reduction on water consumption; and, d) reduction of environmental impact and safety improvement.

Table 2.11: Determinants of Technical Environmental Innovation (at least one)

Dependent Variable: Environmental Innovation - at least one

	Pooled OLS		OLS Fixed Effects		Pooled Logit *marginal effects*		Logit Fixed Effects *marginal effects*	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Environmental Regulation	0.002*	0.004***	0.006***	0.006***	0.002***	0.003***	0.009***	0.009***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.0002)	(0.0003)	(0.0001)	(0.0001)
Size of the Firm		0.097***		0.023**		0.038		0.012***
		(0.002)		(0.012)		(0.0004)		(0.001)
Export Intensity		-0.063***		-0.129***		-0.078***		-0.126***
		(0.012)		(0.036)		(0.003)		(0.002)
Foreign Ownership		0.039***				0.028***		
		(0.007)				(0.002)		
Physical Capital Intensity		0.020***		0.006		0.028***		0.004***
		(0.002)		(0.008)		(0.0004)		(0.0004)
Year Dummies	yes	yes	yes	yes	yes	yes	yes	yes
Industrial Sector Dummies	yes	yes	no	no	yes	yes	no	no
State Dummies	yes	yes	no	no	yes	yes	no	no
Observations	*32,894*	*32,894*	*32,894*	*32,894*	*32.894*	*32.894*	*11.866*	*11.866*

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Notes: Estimation period is 1998-2008. All regressions weighted by the establishment size and sampling frequency. Pooled OLS (columns 1 and 2) and Logit (columns 5 e 6) regressions include 3 year dummies, 19 industrial sector dummies and 26 state dummies. OLS fixed effects (columns 3 e 4) and Logit fixed effects (columns 7 e 8) regressions include 3 year dummies. Environmental innovation - at least one is a dummy variable that equals to one when the firm has adopted at least one type of technical environmental innovation. Envrionmental regulation is a count variable that counts the number of laws, decress, etc, per Brazilian state. All monetary values were corrected by IPA (wholesale) price index and are expressed in terms of 2008 values.

The environmental regulation variable is highly significant and has a positive coefficient in all models, despite its small magnitude, ranging from 0.002 to 0.009. This means that one additional environmental law increases the firm's average probability to adopt at least one type of technical EI between 0.2 p.p. (percentage point) and 0.9 p.p. This result confirms the importance of the environmental regulation in influencing firms' probability to innovate in order to reduce environmental impact, in line with Horbach (2012), Demirel and Kesidou (2011), Del Rio (2011), Smita and Cohen (2003) and Frondel *et al* (2007) findings.

As expected, the size of the firm seems to be an important issue to innovate "green". This variable is also highly significant across the models and indicates that 1% increase in the number of employees would increase the average probability to innovate between 0.012 p.p. and 0.097 p.p.. This result is consistent with Smita and Cohen (2003), Marta *et al* (2011) and Ferraz and Seroa da Motta (2001).

In the same way, foreign ownership and physical capital intensity have a positive and significant influence in the firms' probability to adopt EI. As mentioned in Section 2.3, in developing countries, foreign ownership is frequently highlighted as of particular importance to technology convergence to that of high-income countries, especially due to capital embodied technology transfer. Being a foreign owned firm, instead of

domestically owned, increases the average probability of innovating green between 2.8 p.p. and 3.9 p.p. (columns 2 and 6 respectively). This result confirms Albarnoz *et al* (2009) and Ferraz and Seroa da Motta (2001) findings. In fact, in our analysis, foreign ownership variable registered the greater coefficient magnitude indicating the importance of technology transfer in increasing the average probability to adopt EI.

In turn, physical capital intensity coefficient is positive and highly significant, which suggests that industrial firms with greater number of machinery and equipment per employee have greater probability of introducing environmental innovation in their production processes or products. The idea behind this argument is that capital-intensive firms are usually more pollutant and hence tend to invest more in new technologies in order to reduce environmental damage. If physical capital intensity increases in 1%, the average probability of adopting green technologies will raise between 0.004 p.p. and 0.028 p.p., depending on the model analyzed. Cole *et al* (2006) and Del Rio (2011) also find positive coefficients on physical capital intensity.

On the other hand, the negative sign of the export intensity coefficient in all models, ranging from -0.063% to -0.129%, was opposite to the notion that competition in international markets tends to spur environmental innovations. Despite that, this result is in line with Marta *et al* (2001) and Del Rio *et al* (2011).

In order to verify the robustness of the estimates presented in Table 2.11, we realized the estimation of the determinants of other two technical EIs: a) "EI – all": dummy variable that equals one when the firm has adopted all the four different types of technical EI – Table 2.12; and, b) "Environmental impact reduction and safety improvement" - we isolated one of the four types of technical environmental innovation, the "environmental impact reduction and safety improvement", since it is directly related to environmental protection purposes – Table 2.13. As said before, the structure of Tables 2.12 and 2.13 are similar to that utilized in Table 2.11.

Table 2.12: Determinants of Technical Environmental Innovation (all)

Dependent Variable: Environmental Innovation - all

	Pooled OLS		OLS Fixed Effects		Pooled Logit *marginal effects*		Logit Fixed Effects *marginal effects*	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Environmental Regulation	0.001	0.002**	0.002***	0.002**	0.0004	0.0003	0.008***	0.003***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.0004)	(0.0004)	(0.0001)	(0.0001)
Size of the Firm		0.042***		-0.020***		0.030***		-0.061***
		(0.001)		(0.008)		(0.001)		(0.002)
Export Intensity		-0.092***		-0.028		-0.023***		-0.056***
		(0.007)		(0.024)		(0.005)		(0.003)
Foreign Ownership		0.047***				0.065***		
		(0.004)				(0.003)		
Physical Capital Intensity		0.011***		0.003		0.066***		0.029***
		(0.001)		(0.005)		(0.001)		(0.001)
Year Dummies	yes	yes	yes	yes	yes	yes	yes	yes
Industrial Sector Dummies	yes	yes	no	no	yes	yes	no	no
State Dummies	yes	yes	no	no	yes	yes	no	no
Observations	*32,894*	*32,894*	*32,894*	*32,894*	*32.894*	*32.894*	*2.678*	*2.678*

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Notes: Estimation period is 1998-2008. All regressions weighted by the establishment size and sampling frequency. Pooled OLS (columns 1 and 2) and Logit (columns 5 e 6) regressions include 3 year dummies, 19 industrial sector dummies and 26 state dummies. OLS fixed effects (columns 3 e 4) and Logit fixed effects (columns 7 e 8) regressions include 3 year dummies. Environmental innovation - all is a dummy variable that equals to one when the firm has adopted all types of technical environmental innovation. Envrionmental regulation is a count variable that counts the number of laws, decress, etc, per Brazilian state. All monetary values were corrected by IPA (wholesale) price index and are expressed in terms of 2008 values.

Interestingly, concerning the adoption of all types of technical EI (approximately 10% of the firms – mean of dependent variable), in Table 2.12, we observe that the magnitudes of the coefficients on Environmental regulation are approximately the same when compared to Table 2.11 results (adoption of at least one type of EI), ranging from 0,002 to 0,008. One possible interpretation to this fact is that the influence of regulation enforcement is related to meet the requirements of environmental protection, independent of the number of different types of EI adopted.

The firms' size variable registers mixed results. On pooled OLS regression (column 2) and Logit regression (column 6) the coefficient on Firm Size was positive, while on OLS fixed effects and logit fixed effects it was negative. Once again, contradicting the expectation, export intensity turned to be significant and negatively correlated to the adoption of all EIs. In opposition, the partial effects of being a foreign owned firm (6.5 p.p. - column 6) and of physical capital intensity (0.07 p.p. - column 6) are more than twice the magnitude when compared to the adoption of at least one environmental innovation (Table 2.11).

Table 2.13 presents the estimations results on the determinants of the adoption of a specific type of EI, focused on the reduction of environmental negative externalities, the

"Environmental impact reduction and safety improvement". The influence of environmental regulation to adopt environmental impact reduction and improvement safety innovation (approximately 34% of the firms – mean of dependent variable) are highly significant and positive, ranging between 0.2 p.p. and 0.8 p.p.. The interpretations of the control variables estimates are similar to those in Table 2.12.

Table 2.13: Determinants of Technical Environmental Innovation (env. impact reduction and safety)

Dependent Variable: Environmental Impact reduction and Safety improvement

	Pooled OLS		OLS Fixed Effects		Pooled Logit *marginal effects*		Logit Fixed Effects *marginal effects*	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Environmental Regulation	0.002*	0.003***	0.004***	0.004***	0.002***	0.004***	0.008***	0.007***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.0003)	(0.0003)	(0.0001)	(0.0001)
Size of the Firm		0.084***		0.001		0.011***		-0.014***
		(0.002)		(0.011)		(0.0004)		(0.0004)
Export Intensity		-0.073***		-0.105***		-0.089***		-0.100***
		(0.011)		(0.036)		(0.003)		(0.002)
Foreign Ownership		0.041***				0.031***		
		(0.007)				(0.002)		
Physical Capital Intensity		0.019***		0.006		0.034***		0.008***
		(0.002)		(0.008)		(0.0004)		(0.0004)
Year Dummies	yes	yes	yes	yes	yes	yes	yes	yes
Industrial Sector Dummies	yes	yes	no	no	yes	yes	no	no
State Dummies	yes	yes	no	no	yes	yes	no	no
Observations	*32,894*	*32,894*	*32,894*	*32,894*	*32.894*	*32.894*	*10.631*	*10.631*

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Notes: Estimation period is 1998-2008. All regressions weighted by the establishment size and sampling frequency. Pooled OLS (columns 1 and 2) and Logit (columns 5 e 6) regressions include 3 year dummies, 19 industrial sector dummies and 26 state dummies. OLS fixed effects (columns 3 e 4) and Logit fixed effects (columns 7 e 8) regressions include 3 year dummies. Environmental impact reduction and safety improvement is a dummy variable that equals to one when the firm has adopted this type of technical environmental innovation. Envrionmental regulation is a count variable that counts the number of laws, decress, etc, per Brazilian state. All monetary values were corrected by IPA (wholesale) price index and are expressed in terms of 2008 values.

The consistency of environmental regulation positive coefficients across the different types of EI and different models utilized is an important finding, and can be interpreted as reinforcement to the environmental inducement hypothesis. To a minor extent it also reinforces Porter's weak version (Porter and Van der Linde 1995). According to Porters' first component part, properly designed stringent environmental regulation would spur innovations. The second component part of Porter hypothesis will be analyzed in Chapter 4.

Organizational environmental innovations regression results can be observed in Table 2.14. Once again the coefficients of explanatory variables are consistent across the four models estimated. Observing the results, it is clear that environmental regulation is less important to influence the average probability of adopting organizational environmental

innovations, ranging from 0.02 p.p. to 0.5 p.p.. This finding is in line with the expected, since organizational innovations generally are voluntary measures adopted by the firm in order to complement technical EIs adopted.

The size of the firm and physical capital intensity coefficients are highly significant and positively correlated to organizational environmental innovation (as in Cole *et al* 2006). It is interesting to note that being a foreign owned firm increases the average probability of introducing organizational environmental innovations between 6.7 p.p.(column 2) and 7.4 p.p. (column 6), confirming that foreign owned firms are more likely to adopt organizational EI as pointed out by Albarnoz *et al* (2009).

Table 2.14: Determinants of Organizational Environmental Innovation

Dependent Variable: Environmental Management Techniques

	Pooled OLS		OLS Fixed Effects		Pooled Logit *marginal effects*		Logit Fixed Effects *marginal effects*	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Environmental Regulation	0.001	0.002	0.004**	0.004**	0.001***	0.001***	0.005***	0.0002***
	(0.001)	(0.001)	(0.002)	(0.002)	(0.0003)	(0.0003)	(0.0001)	(0.0001)
Size of the Firm		0.097***		0.065***		0.013***		0.002***
		(0.002)		(0.016)		(0.001)		(0.0001)
Export Intensity		-0.017		-0.001		-0.013***		0.001***
		(0.013)		(0.047)		(0.004)		(0.0001)
Foreign Ownership		0.067***				0.074***		
		(0.008)				(0.002)		
Physical Capital Intensity		0.017***		0.031***		0.033***		0.002***
		(0.002)		(0.010)		(0.001)		(0.0001)
Year Dummies	yes	yes	yes	yes	yes	yes	yes	yes
Industrial Sector Dummies	yes	yes	no	no	yes	yes	no	no
State Dummies	yes	yes	no	no	yes	yes	no	no
Observations	*25,813*	*25,813*	*25,813*	*25,813*	*25.813*	*25.813*	*7.449*	*7.449*

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Notes: Estimation period is 2001-2008. All regressions weighted by the establishment size and sampling frequency. Pooled OLS (columns 1 and 2) and Logit (columns 5 e 6) regressions include 3 year dummies, 19 industrial sector dummies and 26 state dummies. OLS fixed effects (columns 3 e 4) and Logit fixed effects (columns 7 e 8) regressions include 3 year dummies. Environmental Management technique is a dummy variable that equals to one when the firm has adopted this type of organizational environmental innovation. Envrionmental regulation is a count variable that counts the number of laws, decress, etc, per Brazilian state. All monetary values were corrected by IPA (wholesale) price index and are expressed in terms of 2008 values.

Tables 2.15 and 2.16 also present results from the estimation of cross section regressions based on 2008 PINTECs' survey (Table 2.15) and from the estimation of the determinants of pollution abatement expenditures (Table 2.16).

We opted to estimate cross section regressions because PINTEC 2008 introduced a new variable related to environmental innovation, the adoption of biological effluent treatment techniques. From the results in Table 2.15 we can see that environmental regulation stringency is significant and has a positive impact on the probability of

adopting biological effluent treatment. Surprisingly, if the number of environmental laws raises by one, the probability of adopting biological effluent treatment increases between 0.3 p.p. and 0.7 p.p.. The size of the firm (0.022 p.p.) and physical capital intensity (0.013 p.p.) remains highly significant and positively correlated to biological treatment. Foreign ownership and export intensity were not significant.

Table 2.15: Determinants of Technical EI - Cross Section

Dependent Variable: Biological Effluent Treatment

	OLS	
	(1)	(2)
Environmental Regulation	0.007***	0.003**
	(0.001)	(0.001)
Size of the Firm		0.022***
		(0.005)
Export Intensity		-0.034
		(0.032)
Foreign Ownership		-0.016
		(0.010)
Physical Capital Intensity		0.013***
		(0.003)
Industrial Sector Dummies	yes	yes
State Dummies	yes	yes
Observations	*10,850*	*10,850*

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Notes: Estimation period is 2008. All regressions are OLS weighted by the establishment size and sampling frequency. All regressions include 19 industrial sector, dummies and 26 state dummies. Biological Effluent Treatment is a dummy variable that equals to one when the firm has adopted this type of technical environmental innovation. Environmental regulation is a count variable that counts the number of laws, decress, etc, per Brazilian state.

Since the pollution abatement investment is available only in three years (1997, 2002 and 2007), we constructed a three-year panel. We decided to use the pollution abatement investment variable as a dependent variable, instead of an explanatory variable (proxy to the stringency of environmental regulation) because we assumed pollution abatement investment as a proxy to environmental innovation.

The results in Table 2.16 show that environmental regulation is also important to invest in pollution abatement, registering highly significant and positive coefficients. Physical capital intensity is positively correlated to pollution abatement investment. Interestingly, foreign ownership is negatively correlated to pollution abatement investment, suggesting that foreign owned firms tend to invest in more comprehensive solutions, in order to mitigate environmental damages, such as EIs.

Table 2.16: Determinants of Pollution abatement investment

Dependent Variable: Pollution abatement investment (%)

	Pooled OLS		OLS Fixed Effects	
	(1)	(2)	(3)	(4)
Environmental Regulation	0.002**	0.002**	0.003***	0.003***
	(0.001)	(0.001)	(0.001)	(0.001)
Size of the Firm		0.004***		-0.005
		(0.001)		(0.004)
Export Intensity		-0.0001		-0.0001
		(0.005)		(0.017)
Foreign Ownership		-0.012***		
		(0.003)		
Physical Capital Intensity		0.008***		0.007**
		(0.001)		(0.004)
Year Dummies	yes	yes	yes	yes
Industrial Sector Dummies	yes	yes	no	no
State Dummies	yes	yes	no	no
Observations	*23,290*	*23,290*	*23.290*	*23.290*

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Notes: Estimation period is 1997-2007. All regressions weighted by the establishment size and sampling frequency. Pooled OLS (columns 1 and 2) regressions include 2 year dummies, 19 industrial sector dummies and 26 state dummies. OLS fixed effects (columns 3 e 4) regressions include 2 year dummies. Pollution abatement investiment is measured as the percentage of total investment directed to pollution control. Envrionmental regulation is a count variable that counts the number of laws, decress, etc, per Brazilian state.

2.6 Final Considerations

The determinants to environmental innovation in Brazilian manufacturing firms were shown to be consistent with the empirical literature on the topic. Environmental regulation registered an important role to influence the firms to adopt both technical and organizational EIs, although organizational EI are usually introduced voluntarily. Usually organizational EI are complement to technical EI and hence they often occur together. Thus, the results obtained in relation to the environmental regulation role confirm the environmental inducement hypothesis (also, these results reinforce the Porters' weak version).

However, environmental regulation is only part of the story. It is important to emphasize that, according to industrial economics literature (based in a Schumpeterian approach), there are other important determinants which influence the firm's innovative activities. In line with this approach, our results indicate that firms' size and physical capital intensity are also important variables. Large firms have numerous advantages to develop innovations such as stable financing funds and greater ability to deal with risky R&D activities. In turn, high physical capital intensity is associated with greater volumes of pollution and hence large abatement pressure, stimulating EIs.

Specifically related to developing countries innovative processes, our results confirm that foreign owned firms are significantly more likely to innovate "green" through capital embodied technology transfer and licensing agreements. On the other hand, export intensity registered highly significant and negative coefficients, contradicting international trade role in enhancing international monitoring and promoting domestic firms contact with more advanced technologies. Despite that, this result is in line with Marta *et al* (2001) and Del Rio *et al* (2011).

Future research should test the complementary effect of organizational EI as a determinant of technological EI. Unfortunately the data available does not permit to distinguish between end-of-pipe and clean technologies.

It would also be interesting to investigate how technology sourcing affects environmental innovation adoption, since international licensing agreements play an important role in total patents granted in Brazil.

Finally, future research should consider the challenge to merge "green" patents INPI[43] data with PIA and PINTEC data. There are numerous difficulties concerning the utilization of the three databases. To cite a few, green patents classification is usually too embracing and it is very difficult to properly identify the patent depositor.

[43] Brazilian industrial property institute (INPI). Marta *et al* (2011) suggest a methodology to merge patents data to PIA and PINTEC data.

3. Environmental innovation, skill demand and relative wages in Brazilian manufacturing industry

3.1 Introduction

In most situations, technological innovations are not neutral. Hicks (1932) proposed the concept of factor-neutral technological change, referring to those innovations which preserve the marginal rates of transformation, for given inputs used in production process (when the labor and capital are the only two production factors, the ratio between labor and capital marginal products remains constant for a given capital labor ratio). However, in the last decades, data on relative wages and rental rate of capital in developed countries (especially in the US) tells a different story. This key fact has fostered both theoretical and empirical studies trying to explain why the wage rate has increased steadily in the US economy in the last 150 years while the rental rate of capital has remained approximately constant. Or, more recently, why has the return to skills (or schooling) been increasing since the 1960's (relatively to the unskilled labor wages), despite the major increase in the relative supply of skills in the same period. A common explanation to these facts is that technology progress over the century has been biased towards a particular production factor (see Griliches (1969) and Welch (1970), for empirical studies and Acemoglu (1998, 2002) for theoretical models; among others).

We can define biased technological changes, in opposition to neutral, when the innovation does not alter the marginal products of all factor inputs in the same proportion, but instead, it increases the marginal product of a particular input more than others (and in a permanent way). Thus, a technological change can be labor-biased (or capital saving) in the Hicksian sense when the marginal product of labor increases more than the capital marginal product for a given capital-labor ratio, and hence, rises the labor demand. Or, on the contrary, capital-biased (or labor saving) innovations occurs when the marginal product of capital rises more than that of labor, for a given capital labor ratio, increasing capital demand.

Once admitting that technological progress is not neutral (in the Hicksian sense), it would be interesting to understand in what direction these changes occur. Acemoglu (1998, 2002) proposes the assumption that new technologies are not factor-biased by nature, but by design. And more than that, economic motives influence the direction in

which the innovations are developed[44]. In Acemoglu's model[45] (based in a CES production function) the direction of technical change is determined endogenously by the interaction between relative prices, market size, the elasticity of substitution between the input factors, and innovations' costs (relatively to current or "state" composition of R&D). The relative prices favor innovations directed at scarce factors; the market size favors innovations directed at abundant factors. In the case of the elasticity of substitution between the input factors, whenever the elasticity of substitution is low, the relative price effect is more powerful, and technological changes will be biased towards the scarce factor; and vice-versa.

Particularly, the increase in skills (years of schooling defined as a proxy) return observed since the 1960's in the US and in some western European economies[46], despite the rise in the supply of high skilled workforce in the same period[47], originated an extensive literature based on the so-called "skill biased technological change hypothesis" or SBTC hypothesis (for a survey see Hornstein *et al* (2005)). In this approach, technological changes demand high-skilled (or with college degree) workers to promote its implementation while replacing activities that were usually carried out by unskilled workers. In this sense, these new technologies are complementary to skills and, therefore, favor the demand for high-skilled workers at the expense of the unskilled ones[48]. The resulting return to skills is determined by the "race" (to use Tinbergen's (1975) terminology) between the increase in the supply of skilled labors and the rise in its demand due to SBTC hypothesis.

In the last 30 years, the diffusion of information and communication technologies (ICT) while accelerating the rise in the demand for skilled labors has given room to the "ICT

[44] Alternatively, we can understand that advances in basic science are not profit motivated, only their commercial use are. (MOKYR, 1990 and BRESNAHAN and TRAJTENBERG, 1995; *apud* ACEMOGLU, 2002).

[45] The model considers a scale effect (the growth rate of the economy increases as the population increases) and treats factor supplies as given (not considering their response to relative prices). For more details see Acemoglu (2002).

[46] For a survey on European countries see Vivarelli (2012).

[47] According to Acemoglu (2010) this increase in the supply of skilled labors occurred in the US because of higher public investments in schooling and greater willingness of individuals to acquire schooling.

[48] According to Acemoglu (2002) technologies introduced by the Industrial Revolution were unskilled-biased: skilled artisans working in artisan shops were substituted by unskilled labor working in factories manufacturing the same artisan products.

polarization hypothesis" (Autor *et al* (2003), Goss and Manning (2007), Acemoglu and Autor (2010), Michaels *et al* (2010), among others) which introduces a more nuanced analysis (and empirical evidence) to the usual trend of substituting low-skilled by high-skilled workers. According to this hypothesis, the dominant ICT is a substitute for middle-skilled labor (decreasing its demand) and a complement with highly skilled labors (increasing its demand), leaving the demand for low-skilled workers little affected. This occurs predominantly because ICT replace routine activities carried out by middle-skilled workforce (comprising sales, office and administrative support, production, craft and repair, and operators among others) and complement non-routine analytic tasks that require workers with higher qualification (managerial, professional and technical occupations).

Since the 1990's, empirical literature on innovation has stressed the importance of organizational changes upon productivity and skills demand. The basic argument here is that in the last decades (especially after the dominance of ICT) firms' organizational forms have been characterized by less rigid hierarchies changing towards more flexible structures. These "new" organizational forms[49] are characterized by decentralization of decision making, employees being involved in a wider range of tasks and gaining more responsibility and work teams and quality circles which emerges as new working practices (PIVA *et al*, 2003).

All these changes in organizational structure favor the demand for skilled labors, as the higher skilled workforce is better prepared to deal with increased uncertainty, multi-tasking activities and increased responsibility. In other words, we can say that organizational changes are skill-biased, leading to the "skill biased organizational change hypothesis" (SBOC). It is important to notice that organizational innovations and technological innovations are complementary and often occur together, reinforcing positive impacts on a firm's performance. As stated by Caroli and Van Reenen (2001), "*Without the organizational and skills infrastructure, technology alone is not enough*".
Finally, recent climate change policies and other environmental policies (from 2000 on) have required more substantial policy responses towards both economic growth and mitigation of environmental damage, especially in developed countries. They seem to address a different relation between technological progress and skills demand in the

[49] For a survey on developed countries, see Caroli (2001).

labor market. To give an example, as part of Kyoto's international protocol (1997), developed countries have agreed with reduced greenhouse gas[50] emission targets applying to the periods of 2008-2012 and 2013-2020. These limiting emission targets result in different ways of producing and consuming. In this context, new technologies are committed to cleaner and low-carbon production processes, including all types of technological and/or organizational innovations which reduce environmental impacts, such as clean technologies, renewable energy, water, energy and raw material saving, environmental managing system (EMS), etc. According to Acemoglu (2009) – and as pointed out in Chapter 2 - we can apply Hicks (1932) factor-bias ideas (for instance the scarcity of natural resources) to explain technological progress towards environmental technologies.

This global environmental innovation wave, even though at different speeds in developed and developing countries, leads to specific skills demand in the labor market. Firms enrolled in reducing pollution externalities demand workers with appropriate skills to deal with the new "green" production environment, known as the *green-collar* jobs. Therefore, the relevant questions here are: What exactly is the definition of a green-collar job? Are environmental innovations skilled-biased? Are the green-collar jobs mainly occupied by high qualified or low qualified workers? There are many studies trying to size the green economy in terms of potential GDP growth and jobs creation (Fankhauser, *et al* (2008); OECD (2010), among others[51]). There is also a widespread belief (with no theoretical foundation) that climate change mitigation policies will foster economic growth, open new industrial sectors of investment (as renewable energies, energy efficiency, biomaterials, green buildings, etc), create millions of new "green" jobs and solve global economic recession arisen since December 2007 financial turmoil.

Nevertheless, it is very difficult to address the impacts of new technologies on production and labor market. Particularly in the event of the imminent "green" revolution net economic impact, we must consider those industries and occupations (probably related to high-carbon activities) that will suffer retraction, and also the costs

[50] Includes: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs).

[51] Including private institutes reports such as IER (2009) - Institute for Energy Research - and Muro *et al* (2011) (The Brookings Institute Report).

involved in the implementation of cleaner technologies. Focusing on the effects of environmental innovations on employment, it is important to understand what we mean by green jobs.

The concept of green-collar jobs can be very confusing and usually differ from one study to another. For instance, jobs created in the promising renewable energy sector can be both green jobs and "traditional" (or non-green) jobs in a wide spectrum of activities as manufacturing, installation, maintenance, operations, transportation, etc. (MORRISS *et al* 2009; PEARCE and STILWELL 2009). In this chapter we will adopt the definition proposed in the UNEP's 2008 report (United Nations Environment Programme – 2008 report):

> We define green jobs as work in agricultural, manufacturing, research and development (R&D), administrative, and service activities that contribute substantially to preserving or restoring environmental quality. Specifically, but not exclusively, this includes jobs that help to protect ecosystems and biodiversity; reduce energy, materials, and water consumption through high-efficiency strategies; de-carbonize the economy; and minimize or altogether avoid generation of all forms of waste and pollution. (UNEP, 2008: 3)

To summarize, we understand green-collar jobs as those occupations that: a) reduce consumption of energy, raw materials and/or water; b) limit greenhouse gas emissions or any other pollutant gas emissions; c) minimize waste and pollution (including industrial effluents or solid waste); and, d) protect and restore ecosystems. This definition includes both new occupations and existing jobs that demand new "green" skills. It does not consider recycling activities, nuclear power jobs, or even the broader (and part of a social justice agenda) concept of decent jobs[52] (many times attached to green jobs): "*good jobs which offer adequate wages, safe working conditions, job security, reasonable career prospects, and worker rights. People's livelihoods and sense of dignity are bound up tightly with their jobs"* (UNEP, 2008: 4).

[52] Or according to ILO's (International Labor Organization) definition, "Decent work sums up the aspirations of people in their working lives. It involves opportunities for work that is productive and delivers a fair income, security in the workplace and social protection for families, better prospects for personal development and social integration, freedom for people to express their concerns, organize and participate in the decisions that affect their lives and equality of opportunity and treatment for all women and men".

Using years of schooling as a proxy to skills[53], green-collar jobs can range from low-skilled to high-skilled positions, like PhD's working in solar panels and high tech polymer inks industry or trained high schools employees working directly in the production process. Despite this, nascent literature on green-collar jobs treats them mainly as a "*blue collar job that has been upgraded to address the environmental challenges*" (APOLLO ALIANCE, 2008), or, "*Though they can be found in all income brackets and industries, including public and community organizations, the majority are blue-collar jobs with a sustainable edge*" (DURNING and LANGSTONE, 2009), or even, "*Many of the positions are similar to skilled, blue-collar jobs, such as electricians, welders, carpenters, etc. The difference is they apply these skills to green industries.*" (GREEN and DANE, 2010).

Either SBTC, ICT polarization or SBOC hypotheses are well supported by substantial and consistent evidence in developed countries such as the US and the UK. In developing countries or low and medium high tech countries (including here some European countries) the evidence is not so clear[54]. To explain this fact we can point out two main reasons. As mentioned in Chapter 2, most process and product innovations in developing countries are implemented through "embodied technological change", meaning that new technologies are incorporated through the importation of intermediate and capital goods from the developed countries (in detriment of R&D local development)[55]. In this context, trade liberalization and foreign direct investment[56]

[53] Usually low-skilled workers education ranges from no schooling to primary education (approximately between 0 and 4 years of schooling), middle-skilled have lower and/or upper secondary education (around 5 and 11 years) and skilled workers have at least university degree (11 or more years of schooling). For more details on the definitions of primary and secondary education see Unesco's International Standard Classification of Education (ISCED-97).

[54] For empirical studies on SBTC and ICT evidence in Brazil see Giovannetti and Menezes-Filho (2006), Basant *et al* (2006) and Menezes-Filho and Rodrigues Jr. (2003).

[55] The hypothesis of embodied technological change is part of a broaden hypothesis called "skill-enhancing trade hypothesis" (SET). For evidence on SET hypothesis in Brazilian manufacturing firms see Araújo *et al* (2011) and Fajnzylber and Fernandes (2009).

[56] In opposition to SET hypothesis (see note 12), Heckscher-Ohlin model states that each country specializes in producing goods intensive in their abundant factor. Hence, developing countries trading with skill-abundant developed countries should specialize in producing goods that are unskilled-labor intensive, increasing relative unskilled labor demand. As explained by Vivarelli (2012) "if Heckscher-Ohlin model's assumption of homogeneous production function and identical technologies between countries is relaxed, then international openness may facilitate technology diffusion from industrialized

accelerate the flow of technology transfer and induce the introduction of skilled intensive ones, increasing the demand for skilled workers. So, even in the cases when the imported machineries and intermediate inputs are "mature" or, in other words, are not the most updated ones, the developing countries are following the richer economies technological change path, thus presenting lagged effects on labor market. On the other hand, using only two categories to distinguish the workforce skills (white-collars and blue-collars) in developing countries can be very limiting and many times affect the analysis of innovations impacts on labor market. This occurs because the variability of schooling in the unskilled group (blue-skilled) can be very large in developing countries. (VIVARELLI, 2012; GIOVANETTI and MENEZES-FILHO, 2006).

Based on the concepts of green-collar jobs, skilled and organizational-biased technological changes and the specificities of technological transfer that surrounds developing countries, in this chapter we aim to contribute to the literature of labor markets impacts of environmental innovations. We do so by investigating the relation between environmental innovations, skills demand and relative wages in Brazilian manufacturing firms. Using a panel data approach we verify whether the new "green" technological and organizational innovations, applied in the Brazilian industries, are skilled-biased or not; and the subsequent overall impact over white-collar and blue-collar relative wages. In this sense, this chapter is divided in five sections (in addition to this one): section 3.2 presents a brief literature review of empirical studies on this matter, section 3.3 discusses the methodological approach utilized (the translog cost function approach), section 3.4 explains the data sources and data description, section 3.5 presents the econometric results and section 3.6 contains our final considerations.

3.2 Literature Review

Empirical evidence concerning the effects of environmental innovations on the relative demand or wages of different categories of workers, e.g. skilled, middle-skilled or unskilled labors, is still scarce (known as the qualitative impacts). Most of the empirical firm-level literature focuses on the quantitative impact of "green technologies" in

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to developing countries, implying that trade and technology changes are complement rather than alternative mechanisms".

detriment of the qualitative impacts. By quantitative impact we understand changes on the overall number of employees demanded by the firms, independently of their skills characteristics. On the other hand, many of these quantitative studies distinguish between the impact of process and product environmental innovations and, related to environmental process innovations, the comparison between clean and end of pipe technologies effects[57]. Remarkably, end of pipe technologies seem to disfavor employment, while clean technologies lead to jobs creation. In the same direction, environmental product innovations have positive effects on employment figures.

Starting with studies concerning the effects of environmental process innovations on labor market, Getzner (2002) deals with the impacts of five different types of clean technologies (water waste and sewage, waste management technologies, materials reduction, air emission and energy conservation) on employment and skill demand. This study is based on a survey[58] of 407 firms in five European countries (Austria, Germany, Netherlands, Spain and Sweden) in 1999. The estimations were calculated using a probit model and two dependent dummy variables: a) the number of employees (equals to one when the number of jobs has increased in the period, or zero otherwise) and, b) qualification (equals to one if there was an increase in the demand for high skilled labors in the period, or zero otherwise). The results showed that any of the five clean technologies mentioned registered significant impacts on the number of employees. On the other hand, waste management technologies (deals with the reduction and treatment of industrial waste) indicated a negative effect on qualifications, meaning that the introduction of waste technologies leads to lower qualifications.

Specifically related to environmental product innovations, we can point out Horbach (2007) and Cainelli *et al* (2007) studies. Horbach (2007) analyses their influence on quantitative employment changes from 2003 to 2005 in 904 environmental sector firms in Germany. The author defines as environmental firms those that produce goods or services which prevent environmental damages in different fields, such as air and water pollution, waste disposal, recycling, noise abatement, removal of hazardous waste,

[57] For more details on clean technologies and end-of-pie technologies see Chapter one.

[58] The survey was part of a broader research program and was sent to the firms through EMAS (EU Eco-Management and Audit Scheme) and ISO (international standard for environmental management systems) programs in order to select firms that had adopted clean technologies. Therefore the results of this study cannot be generalized without further qualifications.

environmental R&D and others. The employment variable was measured as a dummy variable that equals to one when there was a positive change on the firm's number of employees (between 2003-2005), and zero when there was a negative or neutral change on employment (in the same period). The environmental product innovation was measured as a dummy variable that equals one if the firm has adopted the mentioned kind of innovation, or zero otherwise, between 2002 and 2004. The study uses a probit model and shows that environmental product innovation presents a significantly and positive impact on employment change.

In turn, Cainelli *et al* (2007) exploit a dataset of 773 Italian service firms based on CIS and SEA (Service of Enterprise Account) data. According to the authors, because of potential selections bias, they used a Heckman two stage model to estimate the impact of innovations - adopted (during the period of 1993-1995) strategically to develop services and/or products with lower environmental impact - on employment changes between 1995 and 1998. Their findings indicate a negative effect of environmental product innovations (measured as a dummy variable) on employment growth, which according to the authors, go in line with the SBTC hypothesis, since the negative impact results from a net effect between the destruction of low skilled jobs and high skilled job creation.

Analyzing both process – differentiated in clean and end of pipe technologies - and product environmental innovations, Horbach and Rennings (2012) examine their impact on employment changes between 2006 and 2008. The database utilized in the study combine 2009 German CIS[59] (7,061 firms - manufacturing and service sectors) and ZEW[60] Survey (2,952 firms). The dependent variable is defined as a dummy variable that equals to one when the firm has increased the number of employees between 2006 and 2008, or equals to zero when the firm has decreased or maintained constant its' number of employees. According to the authors, environmental process innovations which reduce energy, material consumption and CO_2 emissions are classified as clean technologies and environmental process innovations which reduce other air pollutant emissions (not CO_2) and water pollutant emissions are mainly dominated by end-of-pipe

[59] European Community Innovation Surveys.

[60] Centre for European Economic Research.

technologies (such as new air emissions filter, for instance)[61]. The results obtained show that material and energy environmental innovation has a positive and significant impact on 2006-08 employment changes, while air and water emission environmental innovation has a negative effect on employment change, indicating that clean technologies favors jobs creation in opposition to end-of-pipe technologies. The effects of environmental product innovations were not significant in all specifications adopted.

Including the analysis of environmental organizational innovations, Rennings and Zwick (2001) carried out a telephone survey, in the year of 2000, covering 1,594 firms (industry, manufacturing and services sectors)[62] in Germany, Italy, Switzerland, UK and Netherlands. All the firms included in the survey have introduced at least one environmental innovation (it could be process innovation – either end of pipe or clean technologies -, product innovation or organizational innovation) in the three preceding years. Their methodology estimates only impacts on the sign of employment changes. The dependent variable equals to one - if the firm has increased long-term employment (for more than one year)-, equals to two - if the firm has decreased employment - or equals to three - in the case of no changes in the firm's employment. They use a multinomial logit regression to detect the differences between the firm's probability to increase or decrease employment. The results show that environmental product innovation (dummy variable) has a positive and significant impact on the probability of number of jobs growth, while end-of-pipe technologies increase the probability of job losses. Neither environmental process innovations[63] (clean technologies) nor environmental organizational innovations registered significant impact on employment.

[61]The author also distinguishes between environmental innovations that reduce soil and noise pollution, emission of dangerous substances and recycling. But it is not clear if these environmental process innovations represent clean or end-of-pipe technologies, so we decided not to comment these results.

[62] Mining, agriculture and public administration firms were not included in the survey.

[63] We suppose that the environmental process innovation variable refers to clean technologies in opposition to the end-of pipe technologies variable.

3.3 Translog Cost Function Approach

The translog cost function (Christensen and Greene, 1976; Berman *et al*, 1993) is a flexible functional form that does not place a priori restrictions on the production technology (and hence on substitution possibilities among production factors or scales of economies) and, thus, allows testing the non-neutrality of technological changes (or more specifically, the non-neutrality of environmental innovations, the focus of attention in this study). For the purposes of this chapter, we consider a translog cost function with only two variable inputs (white-collar and blue-collar labor) and one quasi-fixed input (capital):

$$\ln(C) = \alpha_0 + \beta_1 \ln(Y) + \Sigma_f \beta_f \ln(W_f) + \beta_3 \ln(K) + \tfrac{1}{2} \beta_{11} (\ln Y)^2 + \Sigma_f \beta_{1f} (\ln Y)(\ln W_f) + \beta_{13} (\ln Y)(\ln K) + \tfrac{1}{2} \Sigma_f \Sigma_j \beta_{fj} (\ln W_f)(\ln W_j) + \Sigma_f \beta_{3f} (\ln K)(\ln W_f) + \tfrac{1}{2} \beta_{33} (\ln K)^2 \quad \textbf{(1)}$$

where:

C – total cost;

Y – value added;

f, j = skill groups (white-collar and blue-collar labor);

W_f – labor wage rate of the skill group *f*;

K – capital stock;

α, β - parameters to be estimated

The translog cost function regularity conditions are:

(a) continuity – the translog cost function must be continuous and twice differentiable;

(b) symmetry – requires that the translog cost function second cross derivatives are symmetric: $\beta_{fj} = \beta_{jf}$

(c) linear homogeneity in prices - total cost increases proportionally when all factor prices increase proportionally, for a fixed level of output, which implies:

$$\Sigma_f \beta_f = 1 \text{ and } \Sigma_j \beta_{fj} = \Sigma_f \beta_{fj} = \Sigma_f \beta_{1f} = \Sigma_f \beta_{3f} = 0$$

(d) monotonicity in prices and outputs - monotonicity in outputs requires positive marginal costs ($\partial C/\partial Y>0$) and monotonicity in prices ($\partial C/\partial W_f>0$) requires that total costs increase as input prices increase.

(e) concavity in prices - requires that the corresponding bordered Hessian matrix of the first and second order partial derivatives be negative semi-definite.

It is important to notice that we use occupation as a proxy to workers skills groups, according to PIA's[64] available data, corresponding to: blue collar employees (directly related to production) as the unskilled labor group and white-collar employees (not directly related to production) as the skilled labor group.

Shepard's lemma in the logarithmic form states that:

$$\partial \ln C/\partial \ln w_f = (\partial C/\partial w_f)*(w_f/C)$$

where $\partial C/\partial W_f = x_f$, w_f is input *f* price and x_f is the optimal quantity of input *f*, given cost minimization. Following cost minimization procedures and using Shephard's lemma we obtain cost share equations of the form:

$$S_f = \alpha_f + \beta_{1f}\ln(Y) + \Sigma_j \beta_{fj} \ln(W_j) + \beta_{3f}\ln(K) \qquad \textbf{(2)}$$

where:

S_f = wage bill share of skill group *f*

Assuming homogeneity of degree one in prices, as mentioned above, we have $\Sigma_j \beta_{fj} = \Sigma_f \beta_{fj}$, and we can rewrite equation (2) as:

$$S_f = \alpha_f + \beta_{1f}\ln(Y) + \beta_2 \ln(W_f/W_j) + \beta_{3f}\ln(K) \qquad \textbf{(3)}$$

Since we are interested in the impact of environmental innovations on the change in wage bill shares and employment shares, we estimate equation (3) in long differenced

[64] Annual Survey of Industrial Companies calculated by the Brazilian Institute of Geography and Statistics (IBGE).

form (three year differences), augmented with an environmental innovation dummy (EI). We consider that three year periods represent plausible time intervals to verify the effects of environmental innovation on wage bill and employment shares.

In the modeling specification adopted in this chapter, we do not impose constant returns to scale restriction (which implies that $\beta_{1f} = -\beta_{3f}$). Besides that, the assumption that wages tend to move in accordance to economy performance implies that the relative wages term ($\beta_2 \ln(W_f/W_j)$) is likely to be endogenous. Thus, the relative wage terms were replaced by time dummies (δ_t), which capture common macroeconomic shocks[65]. Consequently, wage bill shares (and employment shares[66]) are estimated in a panel data approach, with *i* indexing the firms units, *t* as index to years and *f* indexing skill groups, as:

$$\Delta_3 S_{fit} = \beta_{of} + \beta_{1f}\Delta_3 \ln(Y_{it}) + \beta_{3f}\Delta_3 \ln(K_{it}) + \beta_4(EI_{it}) + \beta_5 \mathbf{X}_{it} + \beta_6 \mathbf{Z}_i + \delta_t + \mu_{it} \qquad \textbf{(4)}$$

where:

$i = 1, 2, \ldots, N$ – cross section firms units (CNAE[67] 3 digit);

$t = 1, 2, \ldots, T$ – time period (years);

Δ_3= three year differences;

$\Delta_3 S_{fit}$ = three year differences of wage bill share of skill group *f*;

EI_{it} = dummy for environmental technical innovation (equals to one when the firm has adopted an environmental technical innovation during the three year interval period or zero otherwise);

$\mathbf{X}_{it}$ is a set of extended control variables (size of the firm, foreign ownership and export intensity);

$\mathbf{Z}_i$ is a set of 19 industry sector dummies and 26 state dummies;

δ_t = time effects;

[65] Caroli and Van Reenen (2001).replace relative wages by time dummies.

[66] Employment shares are estimated in a similar way to wage bill shares.

[67] National Classification of Economic Activities.

μ_{it} = error term.

Importantly enough, the flexibility of the translog functional form allows testing the non-neutrality of technological change by verifying the significance and sign of the coefficient on environmental innovation variable (β_{4f}). The hypothesis of non-neutrality will be verified in the case of $\beta_{4f} \neq 0$, and the complementarity hypothesis (or EI biased towards an specific skill group) when $\beta_4 > 0$.

One can argue that environmental innovations are likely to be endogenous because of simultaneity bias with employment and wages. Therefore, we estimate equation (4) using Instrumental Variable (IV) method (two stage least square), instrumenting the environmental innovation dummy with Environmental Legislation, a count variable corresponding to the number of laws, decrees, etc in the Brazilian environmental legislation, discriminated by each of the 27 Brazilian states, and assumed to be exogenous and correlated to environmental innovation.

We also present the estimation equation (5) below including the complementary role played by environmental organizational innovations (EOI) and the interaction between environmental technical innovation (EI) and environmental organizational innovation (EOI):

$$\Delta_3 S_{fit} = \beta_{of} + \beta_{1f}\Delta_3 \ln(Y_{it}) + \beta_{3f}\Delta_3 \ln(K_{it}) + \beta_{4f}(EI_{it}) + \beta_5(EOI_{it}) + \beta_6(EI_{it} * EOI_{it}) + \beta_7 \mathbf{X}_{it} + \beta_8 \mathbf{Z}_i + \delta_t + \mu_{it} \quad \textbf{(5)}$$

where:

EOI_{it} is a dummy for environmental organizational innovation that equals to one when the firm has adopted this type of environmental innovation during the three year interval period, or zero otherwise.

The sign and magnitude of the complementary role played by environmental organizational innovation can be verified analyzing $\beta_5 + \beta_6$.

3.4 Data sources and description

The data used in this chapter covers the period of 1998 to 2008, 20 Brazilian industrial sectors and combine two different databases, both calculated by IBGE (Brazilian Institute of Geography and Statistics): a) PIA (Annual Survey of Industrial Companies), and b) PINTEC (Technological Innovation Survey) and classified according to the Brazilian government's National Classification of Economic Activities – CNAE version 2.0. All monetary values are measured as 2008 values and were corrected by IPA-OG (wholesale price index, calculated by Getúlio Vargas Foundation) sectorial price index.

It is important to notice that, while PIA survey is conducted every year, PINTEC survey is conducted every three years following Oslo Manual (OECD document establishing guidelines for collecting and interpreting data on industrial innovation) and Community Innovation Survey (CIS) recommendation.

In order to construct a panel data, we used the four available PINTECs: PINTEC 2000 (refers to the period between 1998 and 2000), PINTEC 2003 (between 2001 and 2003), PINTEC 2005 (between 2003 and 2005) and PINTEC 2008 (between 2006 and 2008) and merged the PINTEC's variables (environmental innovations and capital origin variables) with: i) PIA three year difference variables (capital stock[68], wage bill share and employment share); and, ii) PIA's variables in the first year of PINTEC three year period interval (extended control variables) to account possible effects since the beginning of the period. Summarizing, we did the following merge between PINTEC and PIA surveys (Table 3.1):

Table 3.1 - Panel database: data sources, measurement and merged periods

Data source:	**PINTEC**	**PIA**	**PIA**
Variables:	environmental innovation dummies, foreign owned capital	value added, capital stock, wage bill share, employment share	extended control variables
Measurement:	**level**	**3 year difference**	**level**
Periods:	2000 2003 2005 2008	(1998-2000) (2001-2003) (2003-2005) (2006-2008)	1998 2001 2003 2006

[68] We used the methodology developed by IPEA to calculate the capital stock of the firms. For more details see ALVES. P and SILVA, A. M. (2008).

The dependent variables are measured as three year difference in blue-collar wage bill share (blue collar wage bill to total wage bill ratio) and blue-collar employment share (number of blue collar employees to total employees ratio)[69] (Table 3.2).

Table 3.2 - Blue-collar wage bill share and employment share - average by PINTEC year

		PINTEC year			
	measurement	**2000**	**2003**	**2005**	**2008**
number of obs.		***6693***	***6272***	***7642***	***9956***
Blue-collar Wage bill share	*3 year difference*	0.6%	-0.9%	0.3%	-0.2%
Blue-collar employment share	*3 year difference*	0.7%	-0.8%	-0.1%	-0.2%

Note: weighted by sampling frequency and firm size.

The proportion of blue-collar employees on total employees by PIA year can be observed in Table 3.3:

Table 3.3 - Blue-collar employment share by PIA year

		PIA year			
	measurement	**1998**	**2001**	**2003**	**2006**
Blue-collar employment share	*% total employees*	75%	76%	76%	77%

Note: weighted by sampling frequency and firm size.

As mentioned in Chapter one, we considered as technical environmental innovations (EI) those product or process innovations that had high our medium impact in preserving the environment, and as environmental organizational innovation, the adoption of environmental management techniques[70].

Based on PINTEC's data, we constructed a grouped dummy variable (named "EI - at least one"), in each 3-year period covered by the survey, in order to represent those firms that had adopted at least one of the following four different types of EIs: a) high or medium impact in reducing raw material consumption, b) high or medium impact in reducing energy consumption, c) high or medium impact in reducing water

[69] We also estimated the regressions considering white-collar employment and wage bill shares.

[70] The adoption of environmental management techniques variable was not available in PINTEC 2000.

consumption[71], and, d) high or medium impact in reducing environmental impact and/or improving safety requirements[72].

Therefore, in the constructed panel database we have one grouped environmental technical innovations ("EI - at least one") and one environmental organizational innovation (adoption of "Environmental management techniques") (Table 3.4):

Table 3.4 - Percentage of firms by type of Environmental Innovation

		PINTEC year			
	measurement	**2000**	**2003**	**2005**	**2008**
number of obs.		**6693**	**6272**	**7642**	**9956**
EI - at least one	*dummy*	50%	39%	44%	42%
Environmental management techniques	*dummy*	.	35%	37%	51%

Note: weighted by sampling frequency and firm size.

As basic control variables we used three year difference PIA data (as presented in Table 3.1) on value added (measured as industrial value transformation[73]) and capital stock, 19 dummies for industrial sectors and 26 dummies for Brazilian states. As extended controls (also presented in Table 3.1) we used PIA level data on size of the firm (number of employees), export intensity (measured as export/net sales ratio) and foreign ownership (dummy variable that equals to one when the firm's capital control is foreign owned – at least 51%, or zero otherwise).

In order to measure the severity of the Brazilian environmental legislation, we constructed a count variable that considers the number of laws, decrees, etc., per state of Brazil in every 3 years that preceded each PINTEC survey. Accordingly, the Environmental Legislation variable (as explained in Chapter one) counts the number of environmental laws, decrees, etc., in the periods of: 1995-1997; 1998-2000; 2000-2002 and 2003-2005, corresponding to PINTEC 2000, 2003, 2005 and 2008 data, respectively. The main purpose of constructing the environmental legislation variable was to use it as an instrument to environmental innovation because of simultaneity bias between employment and wage bill shares.

[71] The reduction on water consumption variable was not available in PINTEC 2000.

[72] It is not possible to distinguish between environmental and safety effects except in PINTEC 2008. The question regarding this impact includes both effects in PINTEC's 2000, 2003 and 2005 questionnaires. Only in PINTEC 2008 questionnaire the environmental and safety effects were separated in two different questions.

[73] Defined as: gross value of industrial operations – cost of industrial operations.

Table 3.5 presents the descriptive statistics[74] for the panel database (1998-2008) constructed:

Table 3.5 - Descriptive Statistics - Panel database

Variable	*Measurament*		*Number of obs.*	*Mean*	*Standard Deviation*
Dependent Variables:					
Δ_3 Wage bill share - blue collar	*(Blue collar wages/Total employees wages) ratio*	*3 year difference*	30,563	-0.001	0.167
Δ_3 Employment share - blue collar	*(Blue collar number of employees/Total employees) ratio*	*3 year difference*	30,563	-0.001	0.144
Environmental Innovation dummies:					
Environmental Innovation - at least one	*dummy variable*	*level*	30,563	0.44	0.49
Environmental Management techniques	*dummy variable*	*level*	23,870	0.42	0.49
Basic Controls:					
Δ_3 log Value Added	*log (Industrial transformation value)*	*3 year difference*	30,563	-0.02	1.05
Δ_3 log Capital Stock	*log (capital stock)*	*3 year difference*	30,563	0.24	0.48
Extended Controls:					
Size of the Firm	*log (total employees)*	*level*	30,563	6.48	1.77
Export Intensity	*(exports/total sales) ratio*	*level*	30,563	0.16	0.24
Foreign Ownership	*dummy variable*	*level*	30,563	0.23	0.41
Instrument Variable:					
Environmental Legislation	*number of laws, etc, per state*	*level*	30,563	5.31	4.24

Notes: Panel database considers PINTECs 2000, 2003, 2005 and 2008 merged to PIAs 1998, 2001, 2003 and 2006 variables are measured between a 3 year interval period (2006-2008; 2003-2005; 2001-2003 and 1998-2000) due to PINTEC's methodology. Environmental regulation, Size of the firm and Export Intensity are measured in level, in the first year of each 3 year period: 2006, 2003, 2001 and 1998, respectively, and the variables in 3 year differences were measured as differences between 2006-2008, 2003-2005, 2001-2003 and 1998-2000. Environmental management techniques is not available in PINTEC 2000, fact that explains why the number of observations is lower in this case. The maximum and minimum statistics were not presented because it is not allowed to calculate such statistics when using IBGE's confidential data.

Besides the panel database, we also used a cross section sample based on PINTEC 2008 merged to PIA 2006. In this cross section sample we had the possibility to consider the Biological Effluent Treatment variable, only available in PINTEC 2008 survey. Relative to the cross section database, we can observe its descriptive statistics in Table 3.6:

[74] Maximum and minimum values were not presented as it is not allowed to calculate such statistics when using IBGE's confidential data in secrecy room.

Table 3.6 - Descriptive Statistics for Cross Section - 2008

Variable	*Measurament*		*Number of obs.*	*Mean*	*Standard Deviation*
Dependent Variables:					
Δ_3 Wage bill share - blue collar	*(Blue collar wages/Total employees wages) ratio*	*3 year difference*	9,956	-0.002	0.162
Δ_3 Employment share - blue collar	*(Blue collar number of employees/Total employees) ratio*	*3 year difference*	9,956	-0.002	0.137
Environmental Innovation dummy:					
Biological Effluent Treatment	*dummy variable*	*level*	9,956	0.06	0.22
Basic Controls:					
Δ_3 log Value Added	*log (industrial transformation value)*	*3 year difference*	9,956	0.04	0.82
Δ_3 log Capital Stock	*log (capital stock)*	*3 year difference*	9,956	0.29	0.49
Extended Controls:					
Size of the Firm	*log (total employees)*	*level*	9,956	6.68	1.88
Export Intensity	*(exports/total sales) ratio*	*level*	9,956	0.18	0.25
Foreign Ownership	*dummy variable*	*level*	9,956	0.24	0.42

Notes: The Cross Section sample refers to PINTEC 2008 merged to PIA 2006. All dummy variables were measured between 3 year interval period (2006-2008) due to PINTEC 2008 methodology. Environmental regulation, Size of the firm and Export Intensity were measured in level, in 2006 (the first year of the 3 year period), and the variables in 3 year differences were measured as differences between 2006-2008. The maximum and minimum statistics were not presented because it is not allowed to calculate such statistics in the IBGE secrecy room.

3.5 Econometric Results

As pointed out in Sections 3.1 and 3.2, the expected impacts of the adoption of environmental technical innovations on labor markets are not clear. In terms of the number of "green collar" jobs creation, we must distinguish between the need for a completely new set of "green skills", versus the possibility of training the existent workforce that actually presents traditional skills. It seems that this decision depends on the firm´s sector of activity and its technological intensity. When the firm belongs to traditional low technology intensity[75] manufacturing sectors, like Food, Beverage, Textile, Paper, etc, in many cases, specialized low and middle skilled blue-collar employees with "green" capabilities, will meet the firm "green-skills" needs. On the other hand, in the high technology intensity sectors, like Pharmaceuticals and

[75] OECD classifies the economic sectors by its technological intensity in four groups based on the firm´s R&D expenditures to value added (or sales) ratio: 1) low intensity, 2) medium-low intensity, 3) medium-high intensity and 4) high intensity.

Electronics, higher skilled white-collar occupations[76] will need a broader and more specific set of new "green skills".

In particular, in developing countries like Brazil, international technology transfer plays, as said in Chapter 2, an important role in determining the level of green skills demanded by the firms. In other words, in those cases where the new green technology adopted was developed in a foreign owned multinational firm and transferred to subsidiaries, embodied in new capital goods imported by local firms or acquired through license agreements with more advanced economies, the demand for green skills tends to favor low and middle skilled blue-collar occupations and only in a minor extent favors high skilled white collar positions.

In turn, organizational innovations - in this study represented by the adoption of environmental management techniques - often occur together with technical innovations and are expected to be a complement to white-collars occupations, like managers with more green oriented managerial capabilities, awareness and new perspectives to respond to the changes taking place in the realm of their responsibilities (OECD, UNEP 2008).

Starting with the impact on employment shares, Table 3.4 reports the results for estimating the effects of environmental technical innovation in the employment share of blue-collar occupations (following equation (4)). The adoption of environmental innovation (dummy variable) indicates whether the firm has introduced this kind of technological change between the years of 2006-2008, 2003-2005, 2001-2003 and 1998-2000[77], corresponding to the three years period covered by each PINTEC survey. Accordingly, changes in blue-collar shares occupations are measured in long (three year) differences between 2006-2008, 2003-2005, 2001-2003 and 1998-2000. Columns (1) and (2) present the OLS regressions results and columns (3) and (4) present the IV regressions results, estimated by 2SLS, where environmental innovation is instrumented

[76] It is important to note that when using occupation as a proxy to labor skills, blue-collar workers are mainly defined as low and middle-skilled positions and white-collar workers are predominantly defined as high skilled positions.

[77] In fact, the environmental management technique was made available from PINTEC 2003 on, so this variable was measured in long (three year) difference between: 2006-2008, 2003-2005 and 2001-2003, not including the difference between 1998-2000. This fact explains why regressions in columns (3), (4), (7) and (8) presents 23,873 number of observations instead of 30,568 observations in regressions in columns (1), (2), (5) and (6) that do not include the environmental management technique variable.

by the environmental regulation variable, both regressions methods being weighted by the establishment size and sampling frequency[78].

Also, there are specification differences between Columns (1) and (2) (and similarly between columns (3) and (4)). The first and third columns consider only the basic controls: three year differences in log value added (proxied by the value of industrial transformation), three year differences in log capital stock, 3 year dummies, 19 industrial sector dummies and 26 state dummies. In turn, the second and fourth columns add extended controls to columns (1) and (3): the firm size (log total employees), export intensity (exports/total sales) and the origin of capital control (if foreign or not – dummy variable). These extended controls are measured in level, in the first year of each period of difference, that is, 2006, 2003, 2001 and 1998. The complete estimation results (including the dummies for years, states and industry sector) can be observed in Appendices to chapter 3.

[78] Standard in SBTC (skill biased technological change) literature. The rationale for weighting by size is to give larger firms a bigger weight just as we would do if aggregating to macro economy. Also sampling frequency and/or measurement errors are worse for smaller firms, then helps in this dimension too (CAROLI and VAN REENEN, 2001).

Table 3.7: Changes in Employment Shares - Effects of Technical El

Dependent Variable - Three year difference in Employment Share off:				
	Blue-Collar			
	(1)	(2)	(3)	(4)
	OLS	OLS	IV	IV
Environmental Innovation - at least one	0.002	0.004**	0.219	0.138
	(0.002)	(0.002)	(0.179)	(0.101)
Basic Controls:				
Δ_3 log Value Added	0.004***	0.004***	0.00001	0.002
	(0.001)	(0.001)	(0.003)	(0.002)
Δ_3 log Capital Stock	0.001	0.001	-0.002	-0.003
	(0.002)	(0.002)	(0.003)	(0.003)
Extended Controls:				
Size of the firm		-0.001		-0.015
		(0.001)		(0.011)
Export Intensity		-0.009**		-0.001
		(0.004)		(0.007)
Foreign Capital Control		-0.003		-0.010*
		(0.002)		(0.006)
Year Dummies	yes	yes	yes	yes
Industry Sector Dummies	yes	yes	yes	yes
State Dummies	yes	yes	yes	yes
Number of Observations	*30,563*	*30,563*	*30,563*	*30,563*
Environmental Legislation (first stage)			*0.003***	*0.004****
			(0.001)	*(0.001)*
F-stat for excluded instrument in the first stage			*4.26*	*11.62*

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Notes: Estimation period is 1998-2008. All regressions weighted by the establishment size and sampling frequency and includes 3 year dummies, 19 industrial sector dummies and 26 state dummies. Environmental innovation - at least one is a dummy variable that equals to one when the firm has innovated. In columns (3) and (4) Environmental Innovation was instrumented by Environmental Legislation count variable; IV regressions estimated by 2SLS. All changes are in three year differences: 2008-2006, 2005-2003, 2003-2001 and 2000-1998. Environmental Legislation (first stage) presents the environmental legislation coefficient (and standard errors in parenthesis) in the first stage regression; F-stat for excluded instruments tests the relevance of the instrument. All monetary values were corrected by IPA (wholesale) price index and are expressed in terms of 2008 values.

Analyzing Table 3.7 results, we can see that that environmental innovation favors blue-collar jobs creation (column 2): adopting at least one type of environmental innovation increases the average blue-collar employment share in 0.4 pp (percentage points). Value added positive coefficient presented to be very significant to explain variations in blue-collar employment shares (columns 1 and 2), while export intensity is also significant and registered negative sign (column 2) contradicting the positive effect presented in environmental innovation coefficient.

In columns (3) and (4) we have the estimates for the IV regressions. The difficulty to find convincing instruments for technology is well known in the literature (Machin and Van Reenen 1998). In this study we investigate the possibility of using Environmental Legislation assuming that it is a valid instrument (or uncorrelated with the error term). We can observe that, although significant in the Environmental Innovation reduced

form (with positive coefficients – 0.003 and 0.004 - and 5% of significance – columns 3 and 4 respectively), the F statistic for excluded instrument presented in column (3) indicates that Environmental Legislation is a weak instrument. And more than that, the coefficients of Environmental Innovation is not significant in column (4), despite the first stage F statistic of excluded instrument being bigger than 10.

As we know, when the relevance of the instrument is weak, the estimation becomes less precise, standard errors rise and t statistics get smaller in comparison to OLS results. Reinforcing this result, standard errors in columns (3) and (4) are many times larger than those of OLS regressions (columns 1 and 2).

One possible explanation for this fact concerns the quality of the instrument: the Environmental Legislation variable does not vary across industries or firms. As explained in Section 3.4, Environmental Legislation is measured as the number of laws, decrees, etc, by Brazilian state varying across states and over time, but it does not consider the different specificities between the different industry sectors (or firms)[79]. Unfortunately the available data on Brazilian environmental legislation does not permit its discrimination by industry sector.

Turning to the adoption of environmental organizational innovations, environmental management technique, as a complementary explanation for changes in skills demand (equation 5), is included in Table 3.8. Columns (1) and (2) show that Environmental Innovation coefficient is positive and significant, reinforcing the unskilled biased pattern presented in Table 3.7. When a firm adopts at least one type of environmental innovation, the average share of blue collar employees increases between 0.5 and 0.7 pp. At the same time, Environmental Management Techniques coefficients, despite insignificants, present negative sign, consistent with skilled biased organizational change hypothesis. The interaction dummy between environmental innovation and environmental management technique added in column (2) is also insignificant. Once again value added and export intensity are significant with positive and negative signs, respectively.

Table 3.8: Changes in Employment Shares: Effects of Technical and Organizational Environmental Innovations

Dependent Variable - Three year difference in Employment Share off:		
	Blue-Collar	
	(3)	(4)
	OLS	OLS
A. Environmental Innovation - at least one	0.007***	0.005*
	(0.002)	(0.003)
B. Environmental Management Techniques	-0.001	-0.002
	(0.002)	(0.003)
Interaction between: **A*B**		0.003
		(0.004)
Basic Controls:		
Δ_3 log Value Added	0.005***	0.005***
	(0.001)	(0.001)
Δ_3 log Capital Stock	0.001	0.001
	(0.002)	(0.002)
Extended Controls:		
Size of the firm	-0.001	-0.001*
	(0.001)	(0.001)
Export Intensity	-0.008*	-0.008*
	(0.004)	(0.004)
Foreign Capital Control	0.001	0.001
	(0.003)	(0.003)
Year Dummies	yes	yes
Industry Sector Dummies	yes	yes
State Dummies	yes	yes
Number of Observations	*23,870*	*23,870*

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Notes: Estimation period is 2000-2008. All regressions weighted by the establishment size and sampling frequency and includes 2 year dummies, 19 industrial sector dummies and 26 state dummies. Environmental innovation - at least one is a dummy variable that equals to one when the firm has innovated. All changes are in three year differences: 2008-2006, 2005-2003 and 2003-2001. All monetary values were corrected by IPA (wholesale) price index and are expressed in terms of 2008 values.

Since the Brazilian manufacturing firms are concentrated in traditional sectors characterized by low intensity and mixed low-medium intensity technology (approximately 52% and 21%, respectively - see Table 3.9), it is possible to conclude that the "green-collar" jobs created are in essence blue-collar jobs that have been upgraded to address the environmental challenges.

Table 3.9 - Industry Sectors by technological Intensity[1]

	PINTEC year:			
	2000	**2003**	**2005**	**2008**
Low Intensity:				
Food	18%	17%	18%	20%
Beverage	2%	2%	2%	2%
Tobacco	1%	1%	1%	1%
Textile	11%	12%	12%	11%
Leather	6%	7%	7%	6%
Wood	3%	3%	4%	3%
Pulp and Paper	3%	3%	3%	3%
Print	3%	3%	3%	2%
Furniture	4%	4%	4%	4%
Total	*51%*	*52%*	*52%*	*52%*
Medium/Low intensity:				
Extractive Industry	2%	2%	2%	2%
Oil	3%	2%	2%	2%
Rubber and Plastic	5%	5%	5%	5%
Non Metallic	5%	4%	5%	4%
Metallurgy	8%	8%	8%	8%
Total	*23%*	*21%*	*21%*	*22%*
Medium/High intensity:				
Machinery and Equipmets	7%	7%	6%	7%
Vehicles	6%	7%	8%	8%
Chemical	5%	4%	4%	4%
Total	*19%*	*19%*	*19%*	*19%*
High intensity:				
Pharmaceutical	2%	2%	2%	1%
Eletronics and Computer	6%	7%	6%	6%
Total	*8%*	*9%*	*8%*	*8%*

Source: PINTEC/IBGE; data weighted bt establisment size and sample frequency.

1/ OECD's classification

Indeed, this result is in accordance to PIA's blue-collar occupations definition, which includes "green skills":

> Number of employees paid directly by the firm, effectively occupied in activities related to the production of industrial goods and services: maintenance and repair of equipment, utilities (treated water, compressed air, steam and cold for industrial purposes) and direct support to industrial production (quality control, industrial projects and *treatment of pollutants*). (PIA, 2010)

In opposition to PIA's white-collar jobs definition:

> Number of employees paid directly by the firm, engaged in indirect activities that give support to industrial production: the administrative activities of security, cleaning, accounting, management control, and

the commercial activities of non-industrial services, transportation, construction, etc." (PIA, 2010)

Nevertheless, the demand for blue-collar workers apparently has grown more rapidly than its corresponding labor supply since they are proportionally better paid than the white-collar workers. Table 3.10 holds these results (similar in structure and columns specifications to Table 3.7):

Table 3.10: Changes in Wage Bill Shares - Effects of Tecnical El

Dependent Variable - Three year difference in Wage Bill Share off:				
	Blue-Collar			
	(1)	(2)	(3)	(4)
	OLS	OLS	IV	IV
Environmental Innovation - at least one	0.0002	0.004**	0.136	0.077
	(0.002)	(0.002)	(0.180)	(0.111)
Basic Controls:				
Δ_3 log Value Added	0.005***	0.005***	0.003	0.004**
	(0.001)	(0.001)	(0.003)	(0.002)
Δ_3 log Capital Stock	-0.0003	-0.001	-0.002	-0.003
	(0.002)	(0.002)	(0.003)	(0.003)
Extended Controls:				
Size of the firm		-0.003***		-0.010
		(0.001)		(0.012)
Export Intensity		-0.009**		-0.005
		(0.005)		(0.008)
Foreign Capital Control		-0.007***		-0.011*
		(0.003)		(0.007)
Year Dummies	yes	yes	yes	yes
Industry Sector Dummies	yes	yes	yes	yes
State Dummies	yes	yes	yes	yes
Number of Observations	*30,563*	*30,563*	*30,563*	*30,563*

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Notes: Estimation period is 1998-2008. All regressions weighted by the establishment size and sampling frequency and includes 3 year dummies, 19 industrial sector dummies and 26 state dummies. Environmental innovation - at least one is a dummy variable that equals to one when the firm has innovated. In columns (3) and (4) Environmental Innovation was instrumented by Environmental Legislation count variable; IV regressions estimated by 2SLS. All changes are in three year differences: 2008-2006, 2005-2003, 2003-2001 and 2000-1998. Environmental Legislation (first stage) and F-stat for excluded instruments are the same as presented in Table 3.1. All monetary values were corrected by IPA (wholesale) price index and are expressed in terms of 2008 values.

It is clear from Table 3.10 that the introduction of environmental innovations in the firm is associated with a positive effect on wage bill share of blue-collar workers, significant at 5% in column (2). When a firm adopts at least one type of environmental innovation, the average share of blue collar employees increases 0.4 pp. All the results for 2SLS first stage regressions presented in Table 3.7 are the same in this case. So, as we can see in Columns (3) and (4), the instrument presents weak relevance in explaining the variations of blue-collar wage bill share. Despite that, Environmental Innovation

coefficient is positive, many times larger than OLS coefficients (columns 1 and 2) and also with much larger standard errors, consequence of the instrument being weak. Interestingly, the firm size and foreign ownership are highly significant in explaining variations on the blue-collar wage bill shares. Both have negative coefficients, indicating that, in large and foreign owned firms, changes on white-collar salaries were higher relative to blue-collar employees between 1998 and 2008.

Table 3.11 introduces the effects of environmental management techniques on the change in the wage bill shares of blue-collar occupations (equation 5) and also when interacting with the adoption of environmental management techniques (column 2). Accordingly to the results presented in Table 3.11, environmental management techniques present a negative and highly significant effect (between -0.7 and -1.3 pp) on the blue-collar wage bill share (columns 1 and 2), favoring the SBOC hypothesis. The interaction dummy between organizational and technical green innovations shows a positive and significant coefficient effect (1.3 pp) on blue-collar wage bill share (column 2) revealing the prevalence of the unskilled biased hypothesis developed in this study in those firms that have adopted both technical and organizational EI.

Table 3.11: Changes in Wage Bill Shares - Effects of Technical and Organizational EI

Dependent Variable - Three year difference in Wage Bill Share off:		
	Blue-Collar	
	(1)	(2)
	OLS	OLS
A. Environmental Innovation - at least one	0.010***	0.004
	(0.002)	(0.003)
B. Environmental Management Techniques	-0.007***	-0.013***
	(0.003)	(0.003)
Interaction between: **A*B**		0.013***
		(0.005)
Basic Controls:		
Δ_3 log Value Added	0.007***	0.007***
	(0.001)	(0.001)
Δ_3 log Capital Stock	-0.002	-0.002
	(0.002)	(0.002)
Extended Controls:		
Size of the firm	-0.003***	-0.003***
	(0.001)	(0.001)
Export Intensity	-0.011**	-0.010**
	(0.005)	(0.005)
Foreign Capital Control	0.001	0.001
	(0.003)	(0.003)
Year Dummies	yes	yes
Industry Sector Dummies	yes	yes
State Dummies	yes	yes
Number of Observations	*23,870*	*23,870*

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Notes: Estimation period is 2001-2008. All regressions weighted by the establishment size and sampling frequency and includes 2 year dummies, 19 industrial sector dummies and 26 state dummies. Environmental innovation - at least one is a dummy variable that equals to one when the firm has innovated. All changes are in three year differences: 2008-2006, 2005-2003 and 2003-2001. All monetary values were corrected by IPA (wholesale) price index and are expressed in terms of 2008 values.

Finally, we realized a robustness check through the estimation of cross section regressions based on 2008 PINTECs' survey. In PINTEC 2008 it was introduced a new variable related to environmental innovation: the adoption (or not) of biological effluent treatment techniques by the firm. Therefore, the cross section regressions estimate the impact of this specific kind of environmental innovation on blue-collar employment and wage bill shares. The corresponding results can be checked on Table 3.12:

Table 3.12: Cross Section - PINTEC 2008 - Effects of Biological Effluent Treatment

Dependent Variable - (2008-2006) Change in employment and wage bill share off:	*Blue-Collar*	
	employment share	*wage bill share*
	(1)	(2)
A. Biological Effluent Treatment	0.054***	0.048**
	(0.020)	(0.024)
B. Environmental Management Techniques	0.005	-0.003
	(0.003)	(0.004)
Interaction between: **A*B** (dummy)	-0.070***	-0.093***
	(0.021)	(0.025)
Basic Controls:		
Δ_3 log Value Added	0.007***	0.011***
	(0.002)	(0.002)
Δ_3 log Physical Capital Intensity	-0.002	-0.006*
	(0.003)	(0.003)
Extended Controls:		
Size of the company	0.003***	0.005***
	(0.001)	(0.001)
Export Intensity	-0.029***	-0.050***
	(0.007)	(0.008)
Foreign Capital Control	-0.012***	-0.017***
	(0.004)	(0.005)
Industry Sector Dummies	yes	yes
State Dummies	yes	yes
Number of Observations	*9,956*	*9.956*

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Notes: All regressions are OLS regressions weighted by the establishment size and sampling frequency and include 19 industrial sector dummies and 26 state dummies. Biological Effluent Treatment and Environmental Management Techniqtes are dummy variables that equals to one when the firm has adopte the mentioned innovation. All changes are in three year differences between 2008-2006. All monetary valu are expressed in terms of 2008 values.

According to the results presented in Table 3.12, the partial effects of adopting Biological Effluent Treatment on the change in blue-collar employment (5.4 pp) and wage bill shares (4.8 pp) remain positive and with greater magnitudes when compared to the positive impact of environmental technical innovation in the panel study. Surprisingly, the coefficients on environmental management techniques were positive (despite insignificant) and the coefficients on the interaction dummy were negative. This indicates that, in the cases where firms have adopt both Biological Effluent Treatment and Environmental Management Techniques, there is a decrease in blue-collar employment (-1.6 pp) and wages (-4.5 pp) relatively to white collars employees. The analysis for firm size and foreign owned firms is the same as for Table 3.10.

3.6 Conclusion

The increasing concern with environmental damage and climate change has highlighted the importance of new "green" technologies and their effect on labor markets. Recent empirical studies investigate the effect of environmental innovations on employment (as number of jobs creation) in developed countries (especially in European countries). But there is a lack of qualitative analysis concerning the impact of these "green" innovations on skills demand and relative wages in the same manner as conducted by SBTC or SBOC literature. Even worse, as far as we know, there is an absence of studies concerning potential impacts on developing countries, in many cases known to be rich in natural resources and hence important locations to be environmentally preserved[80].

In this sense, this Chapter aims to contribute to this topic, by analyzing the impact of technical and organizational environmental innovations on employment shares and wage bill shares in Brazilian manufacturing industries. The results obtained here indicate that environmental technologies are unskilled biased favoring both blue-collar positions and wages, relative to white-collar ones.

One possible explanation to this fact is that "green-collar" jobs requirements, deriving from the green technologies adoption, are in many situations (especially in low and medium technological intensive industrial sectors) filled by blue-collar workers, trained with green skills and thus capable to deal with the environmental preservation challenges.

On the other hand, organizational environmental innovations, like the adoption of environmental management techniques, were shown in this study to have a negative impact in blue-collar employment and wage bill shares, reinforcing the skill biased organizational change hypothesis. In other words, changes on organizational structure favor the demand for white-collar labors as the higher skilled workforce is better

[80] This argument does not consider the discussion about the effect of the rising purchasing power and consumption of middle and low classes in some developing countries. The process of developing poor countries leads to higher production and consumption, and subsequent impact on the environment. This fact does not invalidate our argument that it is important to preserve the environment in developing countries. There must be a balance between economic growth, entrance of new individuals in the consumer market and environmental quality. In this scenario, clean technologies can be of great value.

prepared to deal with increased uncertainty, multi-tasking activities and increased responsibility.

Future research should consider more nuanced skills groups (including middle-skilled labors, for instance) in order to obtain more specific results on the effects of environmental innovation on labor market. This is especially important in developing countries like Brazil, in which the variability of schooling in the unskilled group (blue-skilled) can be very large.

Another possible future research development is to deepen the analysis concerning the "skill enhancing trade hypothesis" relative to environmental innovations in developing countries, focusing on the role played by foreign direct investments, embodied technologies and technology sourcing.

4. Environmental innovation and performance in Brazilian firms

4.1 Introduction

Environmental innovations (EIs) have been seen as additional costs to firms, since they are usually associated with compliance procedures to environmental regulations and/or strict emission standards. In this sense, EIs have been understood in a different way from general or non-environmental innovations. In particular, this negative impact on the firm's performance probably could be verified in the case of adoption of end-of-pipe technologies, but it is not so obvious in the case of adoption of clean technologies, environmental management techniques or "green" products innovation.

Alternatively, we can understand pollution externality as a manifestation of economic waste which involves unnecessary or incomplete utilization of resources (Porter and Van der Linde, 1995). This interpretation leads to the possibility of EIs that enhance productivity (in a dynamic perspective), instead of only representing additional costs.

There is also another conventional belief, that environmental innovations do not fully overcome their additional costs and consequently introduce an effect of crowding-out more profitable non-EI innovations (Popp and Newell ,2009 and Marin, 2012).

In order to contribute to this discussion, we use a translog production function to assess the relation between EIs and firm's performance. This chapter presents the estimations of product, process and organizational environmental innovations' impacts on the performance of Brazilian manufacturing firms in a panel data approach between 1998 and 2008. In opposition to most of empirical studies in this topic, we do not concentrate our analysis in the role played by the stringency of environmental regulation. We do not focus on the possible crowding-out effect aforementioned either. Instead, we focus on the direct effect of environmental innovation output on firm's performance, as (unfortunately) the available data does not permit to distinguish between voluntary and compliance motivated EIs.

This chapter is organized as follows: section 4.2 presents a literature review on recent empirical firm or industry level studies that investigate the relationship between EI and productivity or EI and financial performance of firms; section 4.3 discusses the empirical methodology adopted; section 4.4 explains data sources and gives a statistical

description of the data used; section 4.5 focuses on the estimation results; and finally, section 4.6 presents final considerations.

4.2 Literature Review

First of all, in order to analyze the relationship between innovation and firm's performance, it is important to distinguish between innovation inputs and innovation outputs. As pointed out by Crépon *et al* (1998), "*…it is not innovation input (R&D) but innovation output that increases productivity. Firms invest in research in order to develop process and product innovations, which in turn may contribute to their productivity and other economic performances".*

In this sense, innovation inputs are related to the activities that are required in order to innovate, whereas innovation output refers to the effective use of innovations in production activities. Usually, innovation inputs are measured as R&D expenses or R&D intensity (R&D expenses to sales ratio) and innovation output can be measured as the number of patents (a partial and indirect measure), and dummies that indicate whether the firm has introduced process or product innovations over the preceding years (a more direct measure). In the case of product innovations, innovation output can be measured as the share of the firm's innovative sales.

It is well known that most econometric studies concerning aggregate data or industry level data finds a positive and large effect of R&D (innovation input) on productivity. Moreover, evidence based on firm level data and general, non-environmental, innovation outputs indicates mixed results[81]. According to Hall's (2011) survey on 25 recent studies, which attempted to estimate the relationship between firm-level productivity and innovation, the results differ between process and product innovations. Generally, product innovation presents a significant and positive impact on productivity, while process innovations indicate a more ambiguous effect, mostly due to the difficulties to measure its quantity impact.

[81] Including studies concerning the Brazilian manufacturing firms such as Raffo, Lhuillery and Miotti (2008), De Negri *et al* (2007), Goedhuys (2007) and Correa *et al* (2005). For the impact of ICT on Brazilian firms revenue see Basant *et al*, (2006).

Focusing on environmental innovations, object of analysis of this study, we find that the economic literature gives little attention to the effects of environmental innovations on productivity or financial performance of firms, when compared to non-environmental innovation empirical research. The analysis of the impacts of environmental innovation on productivity has been predominantly developed indirectly, by studies attempting to assess the validity of the controversial Porter Hypothesis (Porter and van der Linde, 1995).

There are as many interpretations of Porter's hypothesis (PH) as studies of its validity[82], but to give a simple definition, we can describe it as the relation between the stringency of environmental regulation, environmental innovation adoption and firm's (international) competitiveness. Porter suggests that well designed environmental regulation may spur innovation that, in turn, will partially, or even fully, offset its initial compliance cost. This hypothesis has been criticized[83] mainly in relation to: a) its implication that firms systematically overlook opportunities to innovate, in order to both improve their environmental performance and enhance their competitiveness; and, b) the difficulty to design well fitted, stringent and at the same time efficient environmental regulations[84]. (AMBEC *et al*, 2011; WAGNER, 2003).

On the other hand, those who support PH argue that imperfect competition or market imperfections (such as incomplete information, spillover in knowledge, and learning by doing), validate the possibility of innovations that reduce environmental damage and at the same time, increase the firm's performance. Spillovers in knowledge, for instance, lead to underinvestment in R&D since the firm's investment in R&D is typically shared with its competitors and in this case, market power can generate situations where firms enjoy first-mover advantages. (LANOIE et al 2011; WAGNER, 2003)

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[82] Jaffe and Palmer 1997 suggest three different interpretations to the Porter Hypothesis: 1) the narrow version (concerning more flexible regulation): "*certain types of environmental regulation stimulate innovation*", 2) the weak version: "*regulation will stimulate certain kinds of innovation*", and 3) the strong version: "*environmental regulation is a free lunch (or even a paid lunch), that is, regulation induces innovation whose benefits exceeds its costs, making the regulation socially desirable, even ignoring the environmental problems it was designed to solve*".

[83] For more details about this critiques see for instance Jaffe and Palmer, 1997 and Jaffe *et al*, 1995.

[84] There is another common critique, which states that Porter and Van der Linde (1995) have based their hypothesis in several (anecdotal) case studies that do not provide a general assessment of the impact of environmental regulation on innovative activity or performance.

In order to test Porter's Hypothesis empirical and theoretical validity, many authors have disaggregated PH usually into two components parts. The first component part refers to the relation between the stringency of environmental regulation and innovation adoption. The second part deals with the proposition that environmental innovation can more than offset its initial cost and subsequently increase the firm's business performance (measured as profitability or productivity). This second part is the focus of attention in this chapter (for considerations on the first part of PH see Chapter 2).

There is also a third approach to PH, which assumes that properly designed regulations (such as economic instruments in place of command, and control policies) will improve the firm's (or sometimes the country's) international competitiveness. It is important to notice that different measures of competitiveness – net exports, overall trade flows, plant location decisions - lead to different results (for a survey see Jaffe *et al* 1995).

Therefore, firm-level empirical tests of the second part of PH shows that there is no overall consensus in the relationship between environmental innovation outputs and business performance. We briefly comment below some of the recent studies on this topic.

Marin (2012) utilizes an extended Cobb Douglas production function to verify how the number of environmental patents applications (environmental technology defined by OECD[85], renewable energy technology, and waste and pollution management) per employee affects labor productivity (value added per employee) in Italian manufacturing firms. The study concludes that environmental innovations have little positive impact on productivity (in comparison to the effects of non-environmental innovation) or slightly reduce it when considering the full sample or 5,694 firms between 2000 and 2007. Doran and Ryan (2012) also compare the impact of environmental and non-environmental innovations on firm's performance. The authors use a knowledge augmented production function and Community Innovation Survey (CIS) 2006-08 data on 2,181 Ireland firms to assess the impact of EI and non-EI, measured as dummy variables, on the firms' turnover per employee. The results of Doran and Ryan's (2012) estimations indicate that firms which adopt EI have higher levels of turnover per employee than firms that introduce non-EI.

[85] For more details see OECD 2011.

Rexhäuser and Rammer (2011), in turn, distinguish between environmental Innovations (EIs) that directly reduce resources consumption (energy or material) from EIs that reduce environmental externalities without increasing resources efficiency. The study focuses on CIS German firm level data in 2009 and estimates the impacts of these two types of EI (measured as dummy variables) on the firm's profitability (pre-tax return as a share in total sales). Rexhäuser and Rammer (2011) conclude that EIs that improve resources efficiency have positive and significant impact on profitability, while EIs that only reduce environmental damage have negative impact.

Lanoie *et al* (2008) tests the impact of the change in pollution control investment to total costs ratio on the rate of growth of total factor productivity (TFP - measured by the Törnqvist index) for Québec (Canada) manufacturing industries in the period of 1985 and 1994. They use contemporaneous and lagged change in pollution control investment ratio and find that the coefficient on the contemporaneous variable is significant and negative, and the coefficient on lagged 2 or 3 years variables is significant and positive, indicating that the compliance costs at first reduces TFP growth, then, after two or three year cycle, leads to increase in TFP.

Not directly related to PH test validity, Soltmann et al (2013) exploit panel data over 30 years (1980 to 2009) on 7,920 manufacturing industries in 12 OECD countries (Austria, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, Sweden, Switzerland, UK and the United States). The authors use an augmented Cobb Douglas production function and fixed effects methods to regress green patent stock (calculated using the perpetual inventory method) on total value added (proxy for output). In their study, green patents follow the OECD definition[86] that comprises pollution control, water pollution control, solid waste management and renewable energy. They find an U-shaped relationship between the intensity of green patents (or more properly green inventions – patent families) and productivity; in other words, for most industries, an increasing level of green patents affects negatively productivity. The turning point is considerably high (3014 patents), which implies that only few industries, with very large stock of green patents, are more likely to present positive effect on productivity.

[86] For more details see OECD 2011.

Related to the Brazilian manufacturing industries, Podcameni and Queiroz (2011) use a probit model on 2001-03 PINTEC's[87] data to estimate the impact of EI (dummy variable) on the firm's competitiveness. In the study, competitiveness is measured as a dummy variable that equals to one when the firm declares that had maintained or expanded its market share and/or opened new markets. The results found by the authors indicate that the adoption of environmental innovations has no direct effect on the competitiveness of innovative firms.

4.3 Empirical methodology

The choice of a functional form is dependent on the purpose of the particular analysis. In this chapter it was interesting to have a functional form that imposed relatively few restrictions on the production technology. In this sense, the modeling strategy was based in a translog production function[88], widely applied to production analysis, due to its flexibility to represent different production structures, especially in the case of more than two factor inputs. The translog production function can be approximated by a second-order Taylor series expansion of an arbitrary twice differentiable function[89], property that diminishes the required maintained restrictions to test structural hypothesis. This means that, unlike the Cobb Douglas or CES production functions, the technology associated to the translog production function does not impose a priori restrictions on the values of partial elasticities of substitution or the returns to scale. On the other hand, it does not assume strong separability[90], as do CES or Cobb Douglas production functions (CORBO and MELLER, 1979).

A translog production function with *j*-input variables can be written in terms of logarithms as:

[87] Technological Innovation Survey conducted by IBGE.

[88] For more details see Christensen, L. R., Jorgenson, D. W. and L. J. Lau (1973).

[89] This approximation is local in nature, the global approximation properties of translog functional forms are usually unknown. (Tzouvelekas, 2000). This implies that the translog form does not satisfy monotonicity and quasi-concavity globally.

[90] The translog production function is strongly separable when $\beta_{jk} = 0$, for all *j, k.*

$$\ln(Y_i) = \beta_0 + \Sigma_{j=1}^{J} \beta_j \ln(x_{ji}) + \tfrac{1}{2} \Sigma_{j=1}^{J} \Sigma_{k=1}^{J} \beta_{jk} \ln(x_{ji}) \ln(x_{ki}) \quad \textbf{(1)}$$

where:

i = 1, 2, ..., N – cross section firms units;

j,k = 1, 2, …, J – inputs;

Y_{it} – output of the *ith* firm;

x_{jit} - *jth* input of the *ith* firm;

β_0, β_j, β_{jk} are the parameters to be estimated.

To estimate function (1) it is necessary to satisfy three theoretical restrictions (TZOUVELEKAS, 2000):

(a) *symmetry* – requires that $\beta_{jk}=\beta_{kj}$ for all $j \neq k$ (Young's theorem of integrable functions);

(b) *monotonicity* – requires that the marginal products (MP) of all inputs are positive. For instance, the MP of the Blue collar input should be:

$$MP_{ji} = \partial Y_i/\partial x_{ji} = (Y_i/x_{ji})*(\ln(Y_i)/\partial \ln(x_{ji})) = (Y_i/x_{ji}) * (\beta_j + \Sigma_{k=1}^{J} \beta_{jk} \ln x_{ki}) > 0 \quad \textbf{(2)}$$

(c) *diminishing marginal productivities* – the marginal products should also be decreasing in inputs or, alternatively, the convexity of the isoquants of the translog production function requires that the corresponding bordered Hessian matrix of the first and second order partial derivatives be negative semi-definite, which implies that its diagonal elements ($\partial^2 Y_i/\partial x^2_{ji}$) are non-positive.

For the purposes of this chapter, we considered a translog production function with three inputs in a panel context:

$$Ln(Y_{it}) = \beta_0 + \beta_1 \ln(L^S_{it}) + \beta_2 \ln(L^{US}_{it}) + \beta_3 \ln(K_{it}) + \tfrac{1}{2} \beta_{11} (\ln L^S_{it})^2 + \beta_{12} (\ln L^{US}_{it}) (\ln L^S_{it}) + \beta_{23} (\ln L^{US}_{it}) (\ln K_{it}) + \tfrac{1}{2} \beta_{22} (\ln L^{US}_{it})^2 + \beta_{13} (\ln L^S_{it}) (\ln K_{it}) + \tfrac{1}{2} \beta_{33} (\ln K_{it})^2 \quad \textbf{(3)}$$

where:

$i = 1, 2, ..., N$ – cross section firms units (CNAE[91] 3 digit);

$t = 1, 2, ..., T$ – time period (years);

Y_{it} – Value added - industrial value transformation of the ith firm in the t^{ih} period;

L^{US}_{it} – unskilled labor - number of blue collar employees of the ith firm in the t^{ih} period;

L^{S}_{it} – skilled labor - number of white collar employees of the ith firm in the t^{ih} period;

K_{it} – capital stock of the ith firm in the t^{ih} period;

β - parameters to be estimated

It should be noted that workers skills were proxied by their occupation in the firm according to: a) blue collar employees - directly related to production, and b) white collar employees – not directly related to production.

Since we are interested in the impact of environmental innovations on the change in firm productivity, we estimated equation (3) in long differenced form (three year differences), augmented with an environmental innovation dummy. We consider that 3-year periods are plausible time intervals to verify the effects of environmental innovation on firm's performance[92]:

$$\Delta_3 Y_{it} = \beta_0 + \beta_1(EI_{it}) + \beta_2\Delta_3\ln(K_{it}) + \beta_3\Delta_3\ln(L^{s}_{it}) + \beta_4\Delta_3\ln(L^{US}_{it}) + \beta_5\mathbf{X}_{it} + \delta_t + \mu_i \quad \textbf{(4)}$$

where:

Δ_3= three year differences;

EI_{it} = dummy for environmental technical innovation (equals to one when the firm has adopted an environmental technical innovation during the three year interval period or zero otherwise);

[91] National Classification of Economic Activities.

[92] And also long differences can contribute to reduce the impact of measurement errors.

$\mathbf{X}_{it}$ is a set of basic control variables (includes 19 industry sector dummies and 26 state dummies) and extended control variables (size of the firm, foreign ownership and export intensity);

δ_t= time effects;

μ_{it}= error term.

It is important to notice that equation (4) estimates the impact of environmental innovation on the change on firm performance. Equation (4) does not estimate the effect of EI on firm's productivity, usually measured as labor productivity (e.g., value added to employees ratio) or total factor productivity. Besides that, due to more simplicity in analyzing the estimation results, equation (4) suppressed the interaction terms between the quasi-fixed factors. However, we also estimated equation (4) considering the mentioned interactions, where the results are very similar and can be observed in Tables A.4.5 to Table A.4.8 in the Appendices to Chapter 4.

We are especially interested in the sign and significance of β_1. The hypothesis of profitable EIs will be verified in the case of $\beta_1 > 0$.

We also present the estimation of models, equation (5), which include (a) the complementary role played by environmental organizational innovation (EOI) and (b) the interaction between environmental technical innovation (EI) and environmental organizational innovation (EOI). As mentioned in Chapter 3, organizational innovations and technological innovations are complementary and often occur together, reinforcing positive impacts on a firm's performance (or negative impacts in the case of lack of organizational change). Equation (5) is described below:

$$\Delta_3 Y_{it} = \beta_0 + \beta_1(EI_{it}) + \beta_2(EOI_{it}) + \beta_3(EI_{it}*EOI_{it}) + \beta_2\Delta_3\ln(K_{it}) + \beta_3\Delta_3\ln(L^{s}_{it}) + \beta_4\Delta_3\ln(L^{US}_{it}) + \beta_5\mathbf{X}_{it} + \delta_t + \mu_{it} \quad \textbf{(5)}$$

where:

EOI_{it} is a dummy for environmental organizational innovation, equal to one if the firm has adopted an environmental organizational innovation during the 3-year interval period, or zero otherwise.

In equation (5) the complementarity role of organizational EI can be verified when $\beta_2>0$.

Finally, as a robustness test, we considered the effect of pollution abatement investment (available in 1997, 2002 and 2007 PIA survey), in place of environmental innovation, on changes in firms' performance. In this sense, the estimated equation (6) considering pollution abatement investment is:

$$\Delta Y_{it} = \beta_0 + \beta_1(PAI_{it-1}) + \beta_2\Delta\ln(K_{it}) + \beta_3\Delta\ln(L^{s}_{it}) + \beta_4\Delta\ln(L^{US}_{it}) + \beta_5\mathbf{Z}_{it} + \beta_6\mathbf{X}_{it-1} + \delta_t + \mu_{it} \quad \textbf{(6)}$$

where:

Δ= first differences;

PAI_{t-1} is lagged pollution abatement investment;

$\mathbf{Z}_{it}$ is a set of other basic control variables (19 industry sector dummies and 26 state dummies) and one extended control variable measured in *t* (foreign ownership).

$\mathbf{X}_{it-1}$ is a set of extended control variables lagged in *t-1* (size of the firm and export intensity).

Equation (6) posits that changes in value added are affected by lagged pollution abatement investment, and it corresponding lagged firm's size and export intensity. The rationale to use lagged variables is that it is necessary some time interval to the aforementioned variables impact value added. In our estimation we consider that one year is an appropriate time interval. We are especially interested in the sign and significance of β_1, in order to verify the impact of pollution abatement investments on value added.

4.4 Data sources and description

The data used in this chapter cover the period of 1998 to 2008, 20 Brazilian industrial sectors, and combine two different databases, both calculated by IBGE (Brazilian Institute of Geography and Statistics): a) PIA - Annual Survey of Industrial Companies, and, b) PINTEC Technological Innovation Survey. PIA and PINTEC data are classified according to the Brazilian Government's National Classification of Economic Activities – CNAE version 2.0. All monetary values were corrected by IPA_OG[93] (wholesale price index) sectoral price index and are expressed in terms of 2008 values.

It is important to notice that, while PIA survey is conducted every year, PINTEC survey is conducted every three years, following the Oslo Manual (OECD document establishing guidelines for collecting and interpreting data on industrial innovation) and the Community Innovation Survey (CIS) recommendation.

In order to construct a panel data, we used the four PINTECs conducted until now: PINTEC 2000 (refers to the period between 1998 and 2000), PINTEC 2003 (between 2001 and 2003), PINTEC 2005 (between 2003 and 2005) and PINTEC 2008 (between 2006 and 2008) and merged the PINTEC's variables (environmental innovations and capital origin variables) with: i) PIA three year difference variables (capital stock and number of employees); and, ii) PIA's variables in the first year of PINTEC three year period interval (extended control variables). In this sense, we did the following merge between PINTEC and PIA (Table 4.1):

[93] Calculated by Getúlio Vargas Foundation.

Table 4.1 - Panel database: data sources, measurement and merged periods

Data source:	PINTEC[(a)]	PIA	PIA
Variables:	environmental innovation, capital origin	value added capital stock, blue and white collar employees	extended controls
Measurement:	**level**	**3 year difference**	**level**
Periods:	2000 2003 2005 2008	(1998-2000) (2001-2003) (2003-2005) (2006-2008)	1998 2001 2003 2006

Notes: (a) we refer to PINTEC's periods according to the year in which the survey has been conducted 2000, 2003, 2005 and 2008). The exact definition must describe PINTEC's periods as three year interval period (1998-2000, 2001-2003, 2003-2005 and 2006-2008, respectively).

As mentioned in Chapter one, we considered as environmental technical innovations (EI) those product or process innovations that had high our medium impact in preserving the environment, and as environmental organizational innovation the adoption of environmental management techniques[94].

Based on PINTEC's data, we constructed two grouped dummy variables, in each 3-year period covered by the survey. The first grouped dummy variable was constructed in order to represent those firms that had adopted at least one of the following four different types of EIs: a) high or medium impact in reducing raw material consumption, b) high or medium impact in reducing energy consumption, c) high or medium impact in reducing water consumption and d) high or medium impact in reducing environmental impact and/or improving safety requirements[95]. The second grouped dummy variable was constructed to measure those firms that have adopted all four different EIs aforementioned.

Therefore, in the constructed panel database we have three environmental technical innovations - "EI - at least one", "EI – all" and "Environmental impact reduction and/or safety improvement" - and one environmental organizational innovation - adoption of "Environmental management techniques".

[94] The adoption of environmental management techniques variable was not available in PINTEC 2000.

[95] It is not possible to distinguish between environmental and safety effects until PINTEC 2005. The question regarding this impact includes both effects in PINTEC's 2000, 2003 and 2005 questionnaires. Only in PINTEC 2008 questionnaire the environmental and safety effects were separated in two different questions.

As basic control variables we used 3-year difference PIA (as presented in Table 4.1) data on value added (measured as industrial value transformation[96]), capital stock, blue-collar and white-collar number of employees, 19 industry sectors dummies and 26 Brazilian state dummies. As extended controls (also presented in Table 4.1) we used PIA level data on size of the firm (number of employees), foreign ownership dummy and export intensity (measured as export/net sales ratio).

Table 4.2 presents the descriptive statistics[97] for the panel database (1998-2008) constructed:

Table 4.2 - Descriptive Statistics - Panel database

Variable	*Measurament*		*Number of obs.*	*Mean*	*Standard Deviation*
Dependent Variable:					
Δ_3 log Value Added	*log (industrial transformation value)*	*3 year difference*	26,979	-0.02	1.02
Environmental Variables:					
Environmental Innovation - at least one	*dummy variable*	*level*	26,979	0.45	0.49
Environmental Innovation - all	*dummy variable*	*level*	26,979	0.11	0.30
Environmental impact reduction and safety improvement	*dummy variable*	*level*	26,979	0.37	0.48
Environmental Management Techniques	*dummy variable*	*level*	20,823	0.44	0.49
Basic Controls:					
Δ_3 White Collar Employees	*log (number of white collar employees)*	*3 year difference*	26,979	0.034	0.69
Δ_3 Blue Collar Employees	*log (number of blue collar employees)*	*3 year difference*	26,979	0.013	0.48
Δ_3 Capital Stock	*log (capital stock)*	*3 year difference*	26,979	0.238	0.45
Extended Controls:					
Size of the Firm	*log (total employees)*	*level*	26,979	6.61	1.74
Export Intensity	*exports/total sales ratio*	*level*	26,979	0.17	0.25
Foreign Ownership	*dummy variable*	*level*	26,979	0.24	0.43

Notes: Panel database considers PINTECs 2000, 2003, 2005 and 2008 merged to PIAs 1998, 2001, 2003 and 2006 respectively. All dummy variables were measured between a 3 year interval period (1998-2000; 2001-2003; 2003-2005 and 2006-2008) due to PINTEC's methodology. Size of the firm and Export Intensity were measured in level, in the first year of each 3 year period: 2006, 2003, 2001 and 1998, respectively; and the variables in 3 year differences were measured as differences between 1998-2000, 2001-2003, 2003-2005 and 2006-2008. Environmental management techniques variable is not available in PINTEC 2000, fact that explains the number of observations being lower to this variable. All statistics are weighted by firms' size and sampling frequency.

[96] Defined as gross value of industrial operations less cost of industrial operations.

[97] Maximum and minimum values of variables in the table were not presented because IBGE does not permit their calculation when using IBGE's confidential data.

Besides the panel database, we also used a cross section sample based on PINTEC 2008 merged to PIA 2006. In this cross section sample we constructed another grouped dummy variable, this time to represent the adoption of biological effluent treatment and/or product or process innovations that had high or medium impact in reducing environmental impact. This grouped dummy variable was named "Environmental impact and/or Biological effluent treatment". It was constructed in a cross section basis because: a) the biological effluent treatment variable was available only in PINTEC 2008 survey, and, b) in PINTEC 2008 the reduction on environmental impact variable was separated from the improvement in safety effect, allowing for the separate analysis of the environmental aspect.

Relative to the cross section database, we can observe its descriptive statistics in Table 4.3:

Table 4.3 - Descriptive Statistics for Cross Section database - 2008

Variable	*Measurament*		*Number of obs.*	*Mean*	*Standard Deviation*
Dependent Variable:					
Δ_3 log Value Added	*log (industrial transformation value)*	*3 year difference*	8,542	0.046	0.78
Environmental Innovation Dummy:					
Environmental Impact reduction AND/OR Biological Effluent Treatment	*dummy variable*	*level*	8,542	0.41	0.49
Basic Controls:					
Δ_3 White Collar Employees	*log number of white collar employees*	*3 year difference*	8,542	0.07	0.69
Δ_3 Blue Collar Employees	*log number of blue collar employees*	*3 year difference*	8,542	0.04	0.51
Δ_3 Capital Stock	*log (capital stock)*	*3 year difference*	8,542	0.28	0.46
Extended Controls:					
Size of the Firm	*log (total employees)*	*level*	8,542	6.84	1.84
Export Intensity	*exports/total sales ratio*	*level*	8,542	0.19	0.25
Foreign Ownership	*dummy variable*	*level*	8,542	0.26	0.44

Notes: The Cross Section sample refers to PINTEC 2008 merged to PIA 2006. All dummy variables were measured between a 3 year interval period (2006-2008) due to PINTEC's methodology. Size of the firm and Export Intensity were measured in level, in the first year of the 3 year period: 2006; and the variables in 3 year differences were measured as differences between 2006-2008. All statistics are weighted by firms' size and sampling frequency.

Finally, a second panel database was created to analyze the pollution abatement investment effect, available only in PIA 1997, 2002 and 2007 surveys. The pollution abatement investment variable equals the percentage of investments spent in reducing or

controlling emissions of pollutants that result from production process, or to attend environmental regulations. The measurement of this variable includes the acquisition of industrial machines that incorporate the design of clean technology, acquisition of other equipment and construction of treatment stations.

In this second panel database we considered the first differences of value added, capital stock, blue and white collar number of employees and lagged pollution abatement investment, firm size and export intensity, according to Table 4.4:

Table 4.4 - Pollution abatement panel database: data sources, measurement and merged periods

Data source:	**PINTEC**[(a)]	**PIA**	**PIA**
Variables:	foreign capital control	value added, capital stock, number of blue and white collar employees	pollution abatement investment, firm size and export intensity
Measurement:	**level**	**first difference**	**lagged *t-1***
Periods:	2000[(b)] 2003 2008	(1997-1998) (2002-2003) (2007-2008)	1997 2002 2007

Notes: (a) we refer to PINTEC's periods according to the year in which the survey has been conducted (2000, 2003 and 2008). The exact definition must describe PINTEC's periods as three year interval period (1998-2000, 2001-2003 and 2006-2008, respectively). (b) despite PINTEC 2000 refers to the period between 1998 and 2000, we assume that the capital origin was the same in the 1997-2000 period once this information is not available to 1997.

Table 4.5 presents the descriptive statistics for pollution abatement investment variable:

Table 4.5 - Descriptive Statistics - Pollution Abatement Investment database

Variable	*Measurament*		*Number of obs.*	*Mean*	*Standard Deviation*
Dependent Variable:					
Δ_3 log Value Added	*log (industrial transformation value)*	*3 year difference*	20,875	0.006	0.897
Environmental Variables:					
Pollution Abatement Investment	*% investment*	*level*	20,875	0.06	0.16
Environmental Management Techniques	*dummy variable*	*level*	14,791	0.46	0.49
Basic Controls:					
Δ_3 White Collar Employees	*log (number of white collar employees)*	*3 year difference*	20,875	0.0005	0.59
Δ_3 Blue Collar Employees	*log (number of blue collar employees)*	*3 year difference*	20,875	-0.034	0.39
Δ_3 Capital Stock	*log (capital stock)*	*3 year difference*	20,875	0.13	0.35
Extended Controls:					
Size of the Firm	*log (total employees)*	*level*	20,875	6.64	1.77
Export Intensity	*exports/total sales ratio*	*level*	20,875	0.16	0.24
Foreign Ownership	*dummy variable*	*level*	20,875	0.24	0.43

Notes: Pollution abatment database considers PINTECs 2000, 2003 and 2008 merged to PIAs 1997, 2002 and 2007 respectively. All dummy variables were measured between a 3 year interval period (1998-2000; 2001-2003; 2003-2005 and 2006-2008) due to PINTEC's methodology. Size of the firm and Export Intensity were measured in level, in the first year of each 3 year period: 2006, 2003, 2001 and 1998, respectively; and the variables in 3 year differences were measured as differences between 1998-2000, 2001-2003, 2003-2005 and 2006-2008. Environmental management techniques variable is not available in PINTEC 2000, fact that explains the number of observations being lower to this variable. All statistics are weighted by firms' size and sampling frequency.

4.5 Results

The effects of environmental innovation adoption on firm's performance (measured as three year differences in the log of industrial value transformation) can be seen in Table 4.6 (equation 4). Columns (1) and (2) present the effects of the adoption of at least one environmental technical innovation[98] and columns (3) and (4) present the estimated effects of adopting all four different types of environmental technical innovations, between 1998 and 2008.

The difference between column (1) and column (2) – likewise the difference between column (3) and column (4) – are the distinct set of control variables applied in each of them. First we consider only basic controls - in columns (1) and (3): change in log white-collar number of employees, change in log blue-collar workers and change in log

[98] As mentioned in section 4.4, there are four different types of environmental technical innovations (dummy variables): a) high or medium impact in reducing raw material consumption, b) high or medium impact in reducing energy consumption, c) high or medium impact in reducing water consumption and d) high or medium impact in reducing environmental impact and/or improving safety requirements.

capital stock. Second, extended controls are included in columns (2) and (4): size of the firm (log total employees), export intensity (exports/total sales ratio) and foreign owned capital (dummy variable that equals to one when the majority of the firm´s capital is controlled by foreigners, and equals to zero otherwise). The basic controls were measured in three year differences (2006-2008, 2003-2005, 2001-2003 and 1998-2000) and the extended controls were measured at level, in the first year of each of the three year period: 2006, 2003, 2001 and 1998. The regressions presented in Table 4.6 are OLS estimations weighted by the establishment size and sampling frequency[99] and include 3-year dummies, 19 industrial sector dummies and 26 state dummies. The complete estimation results (including the dummies for years, states and industry sector) can be observed in Appendices to chapter 4.

Table 4.6: Changes in Value added - Effects of Technical Environmental Innovation
Dependent Variable - Three year difference in Value Added

	Δ_3 log Value Added			
	(1)	(2)	(3)	(4)
A. Environmental Innovation - at least one	0.064***	0.059***		
	(0.012)	(0.013)		
B. Environmental Innovation - all			0.051**	0.034
			(0.020)	(0.021)
Basic Controls:				
Δ_3 log White-collar employees	0.193***	0.194***	0.193***	0.194***
	(0.009)	(0.009)	(0.009)	(0.009)
Δ_3 log Blue-collar employees	0.437***	0.437***	0.438***	0.439***
	(0.013)	(0.013)	(0.013)	(0.013)
Δ_3 log Capital Stock	0.120***	0.123***	0.122***	0.125***
	(0.013)	(0.014)	(0.013)	(0.014)
Extended Controls:				
Size of the firm		0.006		0.011**
		(0.005)		(0.004)
Export Intensity		-0.140***		-0.141***
		(0.028)		(0.028)
Foreign Ownership		0.025		0.027
		(0.017)		(0.017)
Observations	*26,979*	*26,979*	*26,979*	*26,979*
R-squared	0.078	0.079	0.077	0.078

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Notes: Estimation period is 1998-2008. All regressions weighted by the establishment size and sampling frequency and include 3 year dummies, 19 industrial sector dummies and 26 state dummies. Environmental innovation - at least one (columns 1 and 2) and Environmental innovation - all (columns 3 and 4) are dummy variables that equal to one when the firm has adopted at least one type of environmental innovation and all types of environmental innovations, respectively. All changes are in three year differences: 2008-2006, 2005-2003, 2003-2001 and 2000-1998. All monetary values were corrected by IPA (wholesale) price index and are expressed in terms of 2008 values.

[99] As said in Chapter 3, this procedure is standard in SBTC (skill biased technological change) literature. The rationale for weighting by size is to give larger firms a bigger weight, just as we would do if aggregating to macro economy. Also, sampling frequency and/or measurement errors are worse for smaller firms (CAROLI and VAN REENEN, 2001).

Taking Table 4.6 as a whole, it is clear that EI – at least one and EI - all are positively correlated with the productivity of the firm. The introduction of at least one type of environmental innovation (columns 1 and 2) increases the firm's performance in approximately 6%, and the adoption of all the four different types of environmental innovation (columns 3 and 4) increases value added in 5%, both on a three year basis.

The complementary role played by environmental organizational innovations (dummy variable that equals one if the firm has adopted environmental management techniques and equals zero otherwise) is introduced in Table 4.7:

Table 4.7: Changes in Value Added - Effects of Technical and Organizational Environmental Innovations

Dependent Variable - Three year difference in Value Added				
	Δ_3 log Value Added			
	(1)	(2)	(3)	(4)
A. Environmental Innovation - at least one	0.041***	0.043**		
	(0.014)	(0.018)		
B. Environmental Innovation - all			0.050**	0.099*
			(0.022)	(0.053)
C. Environmental Management Techniques	0.026*	0.027	0.032**	0.035**
	(0.014)	(0.018)	(0.014)	(0.014)
Interaction between: **A*C**		-0.003		
		(0.026)		
Interaction between: **B*C**				-0.059
				(0.058)
Basic Controls:				
Δ_3 log White-collar employees	0.183***	0.183***	0.183***	0.183***
	(0.009)	(0.009)	(0.009)	(0.009)
Δ_3 log Blue-collar employees	0.449***	0.449***	0.451***	0.450***
	(0.013)	(0.013)	(0.013)	(0.013)
Δ_3 log Capital Stock	0.113***	0.113***	0.114***	0.114***
	(0.013)	(0.013)	(0.013)	(0.013)
Extended Controls:				
Size of the firm	-0.005	-0.005	-0.004	-0.004
	(0.005)	(0.005)	(0.005)	(0.005)
Export Intensity	-0.205***	-0.205***	-0.202***	-0.203***
	(0.028)	(0.028)	(0.028)	(0.028)
Foreign Ownership	0.019	0.019	0.017	0.018
	(0.017)	(0.017)	(0.017)	(0.017)
Year Dummies	yes	yes	yes	yes
Industry Sector Dummies	yes	yes	yes	yes
State Dummies	yes	yes	yes	yes
Observations	*20,823*	*20,823*	*20,823*	*20,823*

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Notes: Estimation period is 2001-2008. All regressions are weighted by the establishment size and sampling frequency and include 2 year dummies, 19 industrial sector dummies and 26 state dummies. Environmental innovation - at least one (columns 1 and 2) and Environmental innovation - all (columns 3 and 4) are dummy variables that equal to one when the firm has adopted at least one type of environmental innovation and all types of environmental innovations, respectively. All changes are in three year differences: 2008-2006, 2005-2003 and 2003-2001. All monetary values were corrected by IPA (wholesale) price index and are expressed in terms of 2008 values.

Similarly to table 4.6, in table 4.7 columns (1) and (2) consider the effect of EI – at least one combined to environmental organizational innovations and columns (3) and (4) present the effects of environmental innovation – all combined with environmental organizational innovations. Table 4.7 indicates that adoption of environmental organizational innovations (EOI) is complementary to environmental technical innovations (EI), with greater impact on value added when the firm has adopted all the environmental innovations types (columns 3 and 4). The interaction between the two types of EI and EOI was insignificant. The significance and signs of the basic and extended control variables are similar to those presented in Table 4.6.

Focusing on the positive effects of EI on value added change, shown in tables 4.6 and 4.7, it could be argued that this positive result is related to the reduction in resources consumption that is characteristic in three of the four environmental innovation types included in the EI grouped dummies. The three EIs that lead to resources consumption reduction are those innovations with high or medium impact on the reduction of: a) raw material consumption, b) energy consumption reduction, and c) water consumption reduction. But, contradicting this argument, when we consider the impact of the fourth type of EI on its own (namely, high or medium impact in reducing environmental damage and/or improving safety), it is possible to observe that the effect on value added remains positive, despite the fact that this type of EI concerns the reduction of environmental externalities and usually imposes additional (compliance) costs to the firm. This result can be seen in Table 4.8:

Table 4.8: Changes in Value Added - Effects of Environmental Impact Reduction and Organizational Environmental Innovation

Dependent Variable - Three year difference in Value Added				
	Δ_3 log Value Added			
	(1)	(2)	(3)	(4)
D. Environmental Impact reduction and safety improvement	0.063***	0.058***	0.049***	0.043**
	(0.013)	(0.014)	(0.014)	(0.021)
C. Environmental Management Techniques			0.024*	0.020
			(0.014)	(0.017)
Interaction between: **D*C**				0.012
				(0.028)
Observations	*26,979*	*26,979*	*20,823*	*20,823*

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Notes: Basic and extended controls not presented in this table. Estimation period is 1998-2008. All regressions are OLS weighted by the establishment size and sampling frequency and include 3 year dummies, 19 industrial sector dummies and 26 state dummies. Environmental impact reduction and safety improvement and Environmental management techniques are dummy variables that equal to one when the firm has adopted each type of innovation, respectively. Columns (1) and (2) considers the effects of D on value added and columns (3) and (4) considers the impact of D and C on value added.

According to Table 4.8, reducing the environmental impacts and/or improving safety has a positive effect of approximately 4% to 6% in value added change (columns 1 to 4), while the effect of environmental management techniques is significant and positive (2%) in column (3) and the interaction between technical and organizational environmental innovation (column 4) is not significant. The number of observations is lower in columns (3) and (4) because the environmental management techniques variable is available only from PINTEC 2003 on.

This result is particularly important because in some sense it reinforces the so-called Porter Hypothesis (Porter and Van der Linde, 1995). In other words, once the firm has decided to introduce an environmental innovation[100], the results presented in Table 4.8 go in line with Porter's (second component part or strong version[101]) argument. Porter's strong version hypothesis says that pollution is usually a waste of resources, so eliminating pollution (partially or totally) through e.g. new green technologies (or market based instruments) can offset the additional costs imposed by the pollution abatement strategy and consequently enhance firm's profits and competitiveness.

[100] We are not considering here the stringency of environmental policy in order to influence the firm to adopt environmental innovations, central in Porter hypothesis. This analysis can be seen in Chapter 2.

[101] For more details see Palmer et al 1997.

In the same direction, the adoption of biological effluents treatment and/or environmental impact[102] reduction (grouped dummy variable) favors the 2006-2008 change in value added as can be seen analyzing the OLS cross section regressions' results presented in Table 4.9.

Table 4.9: Changes in Value Added: Cross Section - PINTEC 2008

Dependent Variable: (2008-2006) Change in value added:

	Δ_3 log Value Added			
	(1)	(2)	(3)	(4)
E. Environ. Impact AND/OR Biological Effluent Treatment	0.035**	0.040**	0.032*	0.070**
	(0.017)	(0.018)	(0.019)	(0.030)
C. Environmental Management Techniques			0.026	0.045**
			(0.018)	(0.022)
Interaction between: **E * C**				-0.060
				(0.037)
Basic Controls:				
Δ_3 log White-collar employees	0.172***	0.173***	0.172***	0.172***
	(0.011)	(0.011)	(0.011)	(0.011)
Δ_3 log Blue-collar employees	0.455***	0.451***	0.451***	0.450***
	(0.016)	(0.016)	(0.016)	(0.016)
Δ_3 log Capital Stock	0.100***	0.104***	0.103***	0.104***
	(0.017)	(0.017)	(0.017)	(0.017)
Extended Controls:				
Size of the firm		0.0003	-0.001	-0.0003
		(0.006)	(0.006)	(0.006)
Export Intensity		-0.156***	-0.156***	-0.157***
		(0.038)	(0.038)	(0.038)
Foreign Capital Control		0.025	0.024	0.023
		(0.022)	(0.022)	(0.022)
Industry Sector Dummies	yes	yes	yes	yes
State Dummies	yes	yes	yes	yes
Observations	*8,542*	*8,542*	*8,542*	*8,542*

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Notes: All regressions are OLS regressions weighted by the establishment size and sampling frequency and include 19 industrial sector dummies and 26 state dummies. Biological Effluent Treatment and Environmental Management Techniques are dummy variables that are equal to one when the firm has adopted the corresponding innovation. All changes are in three year differences

[102] In PINTEC 2008 the reduction on environmental impact was separated from the improvement in safety effect, making possible to analyze the environmental aspect separately.

Table 4.9 shows that the introduction of more specific environmental innovations still have a positive effect on value added change, ranging from 3% to 7% and once again reinforcing the Porter's hypothesis (columns 1 to 4). Environmental management techniques adoption was significant and registered positive effect (4.5%) on value added in column (4). In turn, influences of basic and extended controls are similar to those on the panel analysis in Table 4.7.

Finally, a robustness check is presented in Table 4.10, using the percentage of pollution abatement investment in place of environmental innovations as explanatory variable. As mentioned in Section 4.4, the percentage of pollution abatement investment is available only in 1997, 2002 and 2007 PIA's survey. All the regressions in Table 4.10 are estimated using OLS weighted by the sampling frequency and establishment size. Columns (1) and (2) consider the effects of pollution abatement investment and columns (3) and (4) add the role played by organizational environmental innovation. The number of observations is lower in columns (3) and (4) because the environmental management techniques variable is available only from PINTEC 2003 on.

Table 4.10: Effects of Pollution Abatement Investment and Organizational Environmental Innovation

Dependent Variable - First difference in Value Added				
	Δ log Value Added			
	(1)	(2)	(3)	(4)
F. Pollution Abatement Investment (%)	0.089**	0.082**	0.059	0.042
	(0.037)	(0.037)	(0.037)	(0.051)
C. Environ. Management Techniques			0.031**	0.029*
			(0.014)	(0.015)
Interaction between: **F*C**				0.036
				(0.075)
Basic Controls:				
Δ log White-collar employees	0.157***	0.157***	0.132***	0.132***
	(0.011)	(0.011)	(0.011)	(0.011)
Δ log Blue-collar employees	0.401***	0.403***	0.414***	0.414***
	(0.016)	(0.016)	(0.016)	(0.016)
Δ log Capital Stock	0.082***	0.082***	0.083***	0.083***
	(0.018)	(0.018)	(0.018)	(0.018)
Extended Controls:				
Size of the firm		0.016***	0.010**	0.010**
		(0.004)	(0.005)	(0.005)
Export Intensity		-0.094***	-0.126***	-0.126***
		(0.029)	(0.030)	(0.030)
Foreign Ownership		0.006	0.003	0.003
		(0.017)	(0.018)	(0.018)
Year Dummies	yes	yes	yes	yes
Industry Sector Dummies	yes	yes	yes	yes
State Dummies	yes	yes	yes	yes
Observations	*20,875*	*20,875*	*14,791*	*14,791*

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Notes: Estimation period is 1997-2008. All regressions are weighted by the establishment size an sampling frequency and include 2 year dummies, 19 industrial sector dummies and 26 state dummies. Pollution abatement investiment is measured as a percentage of total investment. Environmental management techniques (columns 3 and 4) are dummy variables that are equal to c when the firm has adopted this type of innovation and equal to zero otherwise. All changes are in first differences: 1997-1998, 2002-2003 and 2007-2008. All monetary values are corrected by IPA (wholesale) price index and are expressed in terms of 2008 values.

Table 4.10 results are not so robust. Columns (1) and (2) show a positive correlation between investment in pollution abatement, at 5% of significance, while in columns (3) and (4) this correlation is no longer significant. The inclusion of the environmental management techniques variable in columns (3) and (4) has absorbed the importance of pollution abatement investment.

4.6 Conclusion

The positive impact of non-environmental innovations on value added or productivity is well supported by consistent empirical evidence based on aggregate data or industry level data. Environmental innovations, in turn, are associated with compliance

procedures to environmental regulations, which represent additional costs to the firms and lead to negative impacts on value added or crowding-out effects on more profitable non-environmental innovations.

Alternatively, pollution externalities can be understood as inefficiencies in production process, giving room to the adoption of new "green" technologies, which will enhance the business performance.

We contribute to this discussion in this chapter, by analyzing the effects of technical environmental innovations and organizational environmental innovations on Brazilian manufacturing industries performance. We use firm-level data in a panel approach, covering 20 industrial sectors from 1998 to 2008.

The results obtained here indicate that both technical EI and organizational EI have positive impact on value added. We analyzed four different types of technical EI (in grouped dummies and individually) in order to consider different characteristics of each type of EI. Specifically, environmental innovations can be distinguished in two broad groups: those that reduce resources consumption and those that reduce environmental negative externalities, traditionally understood as additional compliance costs.

Regarding the last group, the EIs named "environmental impact reduction and/or safety improvement" and "environmental impact reduction and/or biological effluent treatment" registered positive effects on the firm's performance. This result is particularly important because it reinforces the Porter Hypothesis (Porter and Van der Linde, 1995) strong version which states that pollution elimination (partially or totally) can lead to offset the additional costs imposed by the pollution abatement strategy and consequently enhance firms' profits and competitiveness. Pollution abatement investment was also tested and indicated positive effects on value added, even if to a lesser extent.

Future research on this topic should consider the effects of EIs on productivity indicators such as turnover per employee or total factor productivity growth. It would be also interesting to distinguish between the impacts of clean technologies versus end-of-pipe technologies or distinguish between the effects of voluntary EIs from compliance motivated EIs on firm's productivity or profitability. Unfortunately, Brazilian micro data available until now do not permit this kind of detailing.

5. Concluding remarks

5.1 General results

This thesis focused on the analysis of environmental innovation adoption by Brazilian manufacturing firms in three different aspects: its determinants, its effects on skills demand, relative wages and employment creation, and its impacts on the firm's performance. In this sense, we presented an overall analysis on environmental innovation, incipient in Brazil until now.

Regarding the environmental innovation determinants, the results obtained indicated that they were consistent with international empirical evidence on the topic. Environmental regulation stringency and foreign ownership were the most important influences in stimulating the firm to innovate "green". Additionally the size of the firm and physical capital intensity were also positively correlated to EI.

Once the firm has adopted environmental innovations, it would be interesting to understand their effects on labor market. To do so, we studied the impact of technical and organizational environmental innovations on employment shares and wage bill shares in Brazilian manufacturing industries and concluded that:

a) technical EI are unskilled biased, favoring blue-collar positions and wages, relative to white-collar ones, indicating that "green-collar" jobs are in many situations filled by blue-collar workers, trained with green skills and thus capable of dealing with the environmental preservation challenges;

b) organizational EI have a negative impact in blue-collar employment and wage bill shares, reinforcing the skill biased organizational change hypothesis.

Finally, both the EI that reduces resources consumption and the EI that reduces environmental negative externalities (usually understood as compliance costs) registered positive impact on firms' value added. Organizational EI, in turn, are also positively correlated to changes on value added.

5.2 Main results and policy implications

We can distinguish two possible policy implications arising from the results described in the above section:

(1) stringent environmental regulations – measured here as the number of laws, decrees, resolutions etc., per Brazilian state – can play an important role in stimulating the adoption of "green" technologies and environmental management techniques. Unfortunately, it was not possible to distinguish between end-of-pipe or clean technologies adoption, since the data available so far does not permit this distinction. This differentiation would be important to direct environmental policy objectives.

(2) it is possible to adopt environmental innovations that reduce environmental negative externalities and, at the same time, have positive impacts on the firm performance. This result indicates that environmental policy design (combination of command and control, and economic instruments) is important also in this dimension. Once again it would have been interesting to distinguish between end-of-pipe and clean technologies effects on the firms' value added

5.3 Future research

We can consider three avenues for future research:

(1) Regarding the determinants of EI - it would be interesting to investigate how technology sourcing affects environmental innovation adoption, especially in developing countries, since technology transfer plays an important role in technological progress in those countries. Concerning the Brazilian manufacturing firms, future research should consider using "green" patents as a proxy to environmental innovation. There are many difficulties related to the proper definition of green patents and proper identification of the patent depositor.

(2) Regarding the impact of EI on labor market – specifically related to the Brazilian manufacturing industries, future research should consider more nuanced skill groups (e.g. including middle-skilled labors) in order to obtain more specific results on the effects of environmental innovation on labor market. This is especially important in

developing countries like Brazil, in which the variability of schooling in the unskilled group (blue-collars) can be very large.

(3) Regarding the impact of EI on the firm's performance – concerning the Brazilian manufacturing industries, future research on this topic should consider the effects of EIs on productivity indicators such as turnover per employee or total factor productivity growth. It would be also interesting to distinguish between the impacts of clean technologies versus end-of-pipe technologies on firm's productivity or profitability.

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APPENDICES

APPENDICES TO CHAPTER ONE

Table A.1.1 - Brazilian states abbreviation and macro regions

Midwest		**North**	
DF	Destrito Federal	**AC**	Acre
GO	Goiás	**AP**	Amapá
MT	Mato Grosso	**AM**	Amazonas
MS	Mato Grosso do Sul	**PA**	Pará
TO	Tocantins	**RO**	Rondonia
Northeast		**RR**	Roraima
AL	Alagoas	**Southeast**	
BA	Bahia	**ES**	Espírito Santo
CE	Ceará	**MG**	Minas Gerais
MA	Maranhão	**RJ**	Rio de Janeiro
PB	Paraíba	**SP**	São Paulo
PE	Pernambuco	**South**	
PI	Piauí	**PR**	Paraná
RN	Rio Grande do Norte	**RS**	Rio Grande do Sul
SE	Sergipe	**SC**	Santa Catarina

Table A.1.2 - State environmental legislation: selected laws, decrees, resolutions, ordinances e regulatory instructions by year of publication - Institutions

INSTITUTIONS / AGENCIES by year of creation:	Midwest					Northeast									North						Southeast				South		
	DF *(b)*	**GO** *(e)*	**MT** *(b)*	**MS** *(e)*	**TO** *(g)*	**AL** *(b)*	**BA** *(f)*	**CE** *(g)*	**MA** *(c)*	**PB** *(b)*	**PE** *(f)*	**PI** *(d)*	**RN** *(d)*	**SE** *(d)*	**AC** *(d)*	**AP** *(d)*	**AM** *(f)*	**PA** *(e)*	**RO** *(c)*	**RR** *(b)*	**ES** *(g)*	**MG** *(f)*	**RJ** *(e)*	**SP** *(g)*	**PR** *(g)*	**RS** *(d)*	**SC** *(d)*
Environmental State Institute / Environmental State Agency / Environmental State Secretary / Environmental State Council	2007	1995 1999		2001	1996 2007	1978 1985 1986 1988 1989 1991 2000 2002 2003 2005	1973	1987 2001	1979 1981 1991	1997	1976 1994 1997	1987 1993 1995[5]	1997 1999	1978 1979	1986 1992 2003	1990 1996	1996 2005	1988 1990	1993 1997	1992	1987 1994 2002[3]	1987	1975 1987[6] 1987 2007	1968 1983 1986	1992 1992 1996[4]	1994 1995	1991
State System of Environment, Science and Technology					2005				1979 1987				2000 2004 2006	2005	1992	1994	1996		1993	1996 1997 2000 2001						1981 1994	
Water Agency/ State Council for Water Resources/ Integrated Water Resources Management	2001	2003		2002 2002	1988	1997 1998 1999			2004 2005	1996 1997 2001 2005[1]	1997 2003	2002 2007	1996 1997 2002	1995 1997 2000	2002 2003		1997 2001 2007	2001 2001	2002		1997	1987	1999 1999	1991 1991 2005	2000	1994 1995 2000 2001	1985 1993
State Council for Energy Policy/ Alcohol																						1979 1996 2003[2]		2002			
State Council for Animal Protection/ Fishery Agency						1978										2007											
Mineral Resources Development Company										1978																	
State System of Forestry/ Management System of the Atlantic Forest / State Council on Forestry								1988							2001 2001			1988						2006 2007	2008		

NOTES: (b) includes only laws and decrees; (c) includes laws, decrees and ordinances; (d) includes laws, decrees and resolutions; (e) includes laws, decrees, resolutions and ordinances; (f) includes laws, decress, resolutions and normative instructions; (g) includes laws, decrees, resolutions, normative instructions and ordinances.

(1) in 2001 was created AAGISA Agency (Water, Sanitation and Irrigation Agency of Paraíba State) and in 2005 was established EFSA (Executive Agency for Water Management in the State of Paraíba).

(2) in 1996 was ceated CEEn (State Council of Energy) and in 2003 was established the CONER (State Council of Energy).

(3) in 1994 was created IEMA (State Environmental Institute) and in 2003 it incorporated water resources: IEMA - State Institute for the Environment and Water Resources.

(4) in 1992 was established the SEMA (Secretary of State for the Environment)and in 1996 it incorporated the water resources: SEMA - State Secretary for the Environment and Water Resources.

(5) the state Department of Environment, Science and Technology and Urban Development was established in 1987 and in 1995 was created SEMAR (Department of Environment and Water Resources of the State of Piauí).

(6) FEEMA (State Foundation of Environmental Engineering) was created in 1975 and in 1987 was established CONEMA (State Council of the Environment).

Table A.1.3 - State environmental legislation: selected laws, decrees, resolutions, ordinances e regulatory instructions by year of publication - Policies

POLICIES / PROGRAMMES	Midwest					Northeast									North						Southeast				South		
	DF (b)	GO (e)	MT (b)	MS (e)	TO (g)	AL (b)	BA (f)	CE (g)	MA (c)	PB (b)	PE (f)	PI (d)	RN (d)	SE (d)	AC (d)	AP (d)	AM (f)	PA (e)	RO (c)	RR (b)	ES (g)	MG (f)	RJ (e)	SP (g)	PR (g)	RS (d)	SC (d)
Environment State Policy	1989 1990	1978 1979	1995	1980 2005	1991 1994	1979	2001 2006 2008	1987	1980 1992 1993	1981 1990 1999 2000	1977 1978 1983 1987	1996	2004 2006	2006	1994	1994 1998	1982 2005	1995 1996 2002	1993 1997	1994	1988	1977 1979 1981 1998 2007	1975 1985	1976 1997 2002 2004 2005 2006 2007		2000 2002 2003	1981
Solid Waste	1993	2002		2000 2001				2001 2002			2001 2002 2006			1979 2006		2001			2002			1981	2002 2008	2003 2006 2007	1999 2001 2002 2007 2008	1993 2003	
Standards for air quality / Air pollution							1980	1996 2007			1991			1979								1981	1967		2002 2006	2000	
Water Resources / Pollution		1991		2002	2002	1997 2001	1995 2005		2004 2005	1996 2006 2007	1996 1997 1997 2003 2005	2000	1996 1997	1979 1995 2002	2002 2003	2002	1997 2004 2007	1994 2001 2002 2008	2002		1997	1994 1999 2000 2001 2002 2005 2006 2007	1999	1970 1991 1994	1974 1999		1994
Agenda 21											2003					1998						2008	1997				
Climate Change State Policy / Policy to Combat Desertification		2008			2008			2008									2007 2008										
Forestry Policy		1995	2005 2006		1999	1996	1994 1997 2004 2005	1995 1996	2006	1994	1995	2000				2002		2002 2006	2002		1996						
Recycling Materials	1996			2003							2001	2008				2008		2006	2003								
"Bolsa Floresta" Program																	2007										
Energy Saving Program																						1997					
Waste Reduction Program																							1992				
Green Label / Eco Label / Stamp of forestry origin / Environmental certification																1997		1999			1998	2002	1991				

NOTES: (b) includes only laws and decrees; (c) includes laws, decrees and ordinances; (d) includes laws, decrees and resolutions; (e) includes laws, decrees, resolutions and ordinances; (f) includes laws, decress, resolutions and normative instructions; (g) includes laws, decrees, resolutions, normative instructions and ordinances.

Table A.1.4 - State environmental legislation: selected laws, decrees, resolutions, ordinances e regulatory instructions by year of publication - Funds

FUNDS	Midwest					Northeast									North						Southeast				South		
	DF *(b)*	**GO** *(e)*	**MT** *(b)*	**MS** *(e)*	**TO** *(g)*	**AL** *(b)*	**BA** *(f)*	**CE** *(g)*	**MA** *(c)*	**PB** *(b)*	**PE** *(f)*	**PI** *(d)*	**RN** *(d)*	**SE** *(d)*	**AC** *(d)*	**AP** *(d)*	**AM** *(f)*	**PA** *(e)*	**RO** *(c)*	**RR** *(b)*	**ES** *(g)*	**MG** *(f)*	**RJ** *(e)*	**SP** *(g)*	**PR** *(g)*	**RS** *(d)*	**SC** *(d)*
State Forest Fund						1989									2001				1993								
State Fund for the Prevention and Control of Pollution / State Fund for the Environment / Environment Agency		1976 1989							1992		1999	1988 1996 2004		2004		1994	1990	1995	1993		1979 1999	1987 1988 1997 2003 2006	1986	2002	1999 2008	1990 1998	
Water Resources State Fund						2002	2007			1997			1998	1997 2000 2002	2001				2002		2008	1999 2000 2005	2001	1991		1989 1995	1998

NOTES: (b) includes only laws and decrees; (c) includes laws, decrees and ordinances; (d) includes laws, decrees and resolutions; (e) includes laws, decrees, resolutions and ordinances; (f) includes laws, decress, resolutions and normative instructions; (g) includes laws, decrees, resolutions, normative instructions and ordinances.

Table A.1.5 - State environmental legislation: selected laws, decrees, resolutions, ordinances e regulatory instructions by year of publication - Specific Industries

SPECIFIC INDUSTRIES	Midwest					Northeast									North						Southeast				South		
	DF (b)	GO (e)	MT (b)	MS (e)	TO (g)	AL (b)	BA (f)	CE (g)	MA (c)	PB (b)	PE (f)	PI (d)	RN (d)	SE (d)	AC (d)	AP (d)	AM (f)	PA (e)	RO (c)	RR (b)	ES (g)	MG (f)	RJ (e)	SP (g)	PR (g)	RS (d)	SC (d)
Food																						2003		1993			
Beverage																					2005						
Biodiesel				2007																		2006	2005				
Rubber / Natural raw Rubber															1999						2005						
Ozone Layer (GHG)						1988								1989					1989		1988 1994		1991 1995				
Coal production																		2002	2006						2007		
Chloro Chemical / Chloro-Alkali (7)						1985 1985																	1995				
Construction - Amianto / Asbestos / Concrete				2001							2004												2001		1995 2002 2005		2008
Leather Goods																						2003					
Detergents																									1985 2005		
Ascarel																							1999				
Pharmaceutical																								1993 2001			
Lead smelting																									2008		
Insecticides - Methyl Isocyanate																							1984				
Metallurgy																					2005						
Batteries		2002		2001 2006				1999								2000	1999						1993 1998 2000		1999	1998 2008	
Oil / Natural Gas / Diesel																			1997 2002		2005 2006	2007	1991				
Tyres / Pneumatics																1994 2005								2002	1999 2002		
Steel Industry				2008																		1993 2001 2008					
Chemicals										1991						1993											
Sugar, alcohol, spirits											2007											1986 2004	1985	2008			
Textile																						2001					
Paints / Solvents																					1995						
Vehicles	2004					2004 2005		1995 1996									2000										

NOTES: (b) includes only laws and decrees; (c) includes laws, decrees and ordinances; (d) includes laws, decrees and resolutions; (e) includes laws, decrees, resolutions and ordinances; (f) includes laws, decress, resolutions and normative instructions; (g) includes laws, decrees, resolutions, normative instructions and ordinances.
(7) pulp and paper, chemical, aluminum, construction, petrochemical, textile, metallurgy, detergents, among others.

Table A.1.6 - Federal Environmental Legislation: Selected laws, decrees, resolutions and instructions by year of publication - Industrial Activities

TOPIC	FEDERAL LEGISLATION			
INSPECTION / SANCTIONS	**Laws**	**Decrees**	**Conama[b] Resolution**	**IBAMA[d] Instruction**
Criminal and Administrative Penalties derived from harmful conduct and activities to the environment	1998	1999 2008		2003
Control and Supervision Environmental Rate; Annual Report on Environmental Activities	2000			
INDUSTRIAL ACTIVITIES	**Laws**	**Decrees**	**Conama[b] Resolution**	**IBAMA[d] Instruction**
Control of pollution caused by industrial activities		1975		
Industrial zoning in the critical areas of pollution	1980			
Location of new industries of high pollution potential			1984	
Criteria and standards for noise emissions from industrial activities.			1990	
Ecological Zoning (ZEE)		2002		
EFFLUENTS / INDUSTRIAL WASTE	**Laws**	**Decrees**	**Conama[b] Resolution**	**IBAMA[d] Instruction**
Effluents from alcohol distilleries			1984	
Appropiate Collection and disposal of used or contaminated lubricant oil			1993 2005	
Launch of oil and other harmful or dangerous substances in waters under national jurisdiction	2000[4]	2002 2003	2000	
Procedures and criteria for the operation of thermal treatment of waste			2002[5]	
Products registration intended for remediation			2002[6]	
Industrial Solid Waste National Inventory			2002[7]	
Classification of water bodies and definition of standards for effluent discharge			2005[8] 2006 2008	
Maximum emission limits for air pollutants from stationary sources			2006[9]	

NOTES: (b) National Council of Environment; (d) Brazilian Institute of Environment and Renewable Natural Resources.

(4) Violations determined according to: a) Marpol 73/78: International Convention for the Prevention of Pollution caused by Ships, b) CLC/69: International Convention on Civil Responsability for Damage Caused by Oil Pollution.

(5) Waste: materials or substances that are useless or not capable of economic use, resulting from industrial activities.

(6) Remediator: product, made by microorganisms or not, for the recovery of contaminated environments and ecosystems, effluent treatment

(7) industrial solid waste: any waste in solid, semi-solid, gaseous (when contained) or liquid estates, resulting from industrial activities, whose characteristics make it impossible to be launched in the public sewer or water bodies or require technicall

(8) It also establishes maximum amounts of arsenic, barium, boron, cadmium, lead, cyanide, copper, chrome, tin, iron, fluoride, manganese, mercury, nickel. nitrogen, silver, selenium, sulfeno, zinc, chloroform, dichloroethene, phenolic, carbon tetrachlori

(9) derives from the process of: generating heat from external combustion of fuel oil, natural gas, sugar cane bagasse and wood products; generating electricity, oil refineries, manufacturing cellulose, secondary smelting of lead, primary aluminum industry, glass melting furnaces, portland cement industry, fertilizer, phosphoric acid, sulfuric acid and nitric integrated steel and semi-integrated and pelletizing iron ore.

Table A.1.7 - Federal Environmental Legislation: Selected laws, decrees, resolutions and ordinances by year of publication - Wastes

TOPIC	FEDERAL LEGISLATION				
HAZARDOUS WASTE	**Laws**	**Decrees**	**Conama[b] Resolution**	**IBAMA Ordinance**	**MS[e] Ordinance**
Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (Basel/1989)		1993	1996 1998		
Prohibits the import of hazardous wastes - Class I - national territory			1994[10] 1998		
OZONE LAYER	**Laws**	**Decrees**	**Conama[b] Resolution**	**IBAMA Ordinance**	**MS[e] Ordinance**
Prohibits the manufacture of cosmetics, toiletries, perfumes and sanitizing products containing GHG propellants.					1988
Specifies the group of substances chlorofluorocarbons - GHGs					1989[11]
Approves the Vienna Convention of 1985 for the Protection of the Ozone Layer and the Montreal Protocol of 1987 on substances that deplete the Ozone Layer.		1989[12] 1990		2007[13]	
Promulgates adjustments to the Montreal Protocol occurred in the 2nd Meeting (London, 1990)		1991[14] 1992 1998[15]			
Amendments to the Montreal Protocol adopted at the 4th Meeting (Copenhagen, 1992).		1996			
Controlled substances (GHGs and SDOs)			1995[16] 2000[17]	1995[18] 2004	
Botlling of gases that deplete the Ozone Layer			2003		
RADIOACTIVE REJECTS / NUCLEAR ACTIVITY	**Laws**	**Decrees**	**Conama[b] Resolution**	**IBAMA Ordinance**	**MS[e] Ordinance**
Civil responsibility for nuclear damages and criminal responsibility for acts related to nuclear activities	1977				
Deposits of radioactive waste	2001				
Requires prior consent of CNEN (National Nuclear Energy Commission) for any import or export of radioactive material			1994		

NOTES: (b) National Council of Environment; (e) Health Ministry.

(10) Hazardous Waste - Class I: those that fall into any category contained in Annex 1A, 1B and 1C (Annex I of the Basel Convention and Annexes A and B of NBR-10.004/87, respectively), unless do not hold any of the characteristics described in Annex 2 (Annex III of the Basel Convention), as well as those who, although not listed in the Annexes cited, show any of the characteristics described in Annex 2.

(11) Montreal Protocol (1987) Annex A substances are the GHGs and Halonium.

(12) Substances in Annex A (GHGs and Halonium), B (GHGs, carbon tetrachloride and methyl chloroform), C (transitional substances) of the Montreal Protocol (1987).

(13) Imports relating to Annex C, Group I of Hydrochlorofluorocarbons - HCFCs and blends containing HCFCs

(14) Goals for reducing the use of substances in Annex A (GHGs and Halonium).

(15) Includes Annexes B (CFCs, carbon tetrachloride and methyl chloroform) and C (transitional substances).

(16) Prohibition of the usage of substances in Annex A (GHGs and Halonium) and B (GHGs, carbon tetrachloride and methyl chloroform) of the Montreal Protocol. Includes the following products: fire fighting facilities, central air conditioning systems, refrigeration plants with compressors whose capacity is equal to or greater than 100 HP, and use as propellant in aerosols

(17) Prohibition of substances in Annexes A and B of the Montreal Protocol.

(18) controlled substances are those listed in Annex A (GHGs and Halonium), B (CFCs, carbon tetrachloride and methyl chloroform), C (transitional substances) and E (methyl bromide) of the Montreal Protocol.

Table A.1.8 - Federal Environmental Legislation: Selected laws, decrees, resolutions, instructions and ordinances by year of publication - Specific Industries

TOPIC	FEDERAL LEGISLATION					
SPECIFIC INDUSTRIES	**Laws**	**Decrees**	**Conama[b] Resolution**	**CNRH[c] Resolution**	**IBAMA[d] Instruction**	**IBAMA Ordinance**
Water Code	1934					
Managing groundwater			2008	2001 2002 2008		
Rules, guidelines and general criteria for the practice of direct non-potable reuse water				2005[19]		
Fertilizer, lime, inoculants, stimulants or biofertilizers	1980 1989	2004			1996[20]	
Pneumatics Import			1999 2002		2002	
Construction / asbestos	1995		2002 2004			
Production of non-biodegradable detergents	1985					
Phosphorus ilevel n detergent powder			2005			
Mandatory use of stamp noise, as an indication of the sound power level, in electrical house appliances.			1994			
Metallic mercury		1989				1995
Mining Code		1940 1967				
Special arrangements for exploration and exploitation of minerals	1978					
Plan Usage of Water in Mining (PUA)					2002 2005	
Oil / Natural Gas / Diesel			2006 2007			
Maximum vehicles soot emissions, specifications for commercial diesel oil and implementation of the schedule for Improvement of the Diesel			1997 1998 2003			
Import of scrap lead in the form of automotive batteries			2002			
Environmentally appropriate final disposal of batteries			1999 2008			
Batteries import					2000	
Maximum levels of lead, cadmium and mercury in batteries			2008			
Pollution from Motor Vehicles	1993		1984 1995 1996 1998 2002 2003			
Emission of hydrocarbons and aldehydes in the exhaust of automotive vehicles			1989 1993 1995			
Maximum levels of noise with the vehicle stopped and accelerating			1993 1995 1996 1997 1998 2000			
Catalytic converters intended o replacement			2001			

NOTES: (b) National Council of Environment; (c) National Council on Water Resources; (d) Brazilian Institute of Environment and Renewable Natural Resources. (19) Water and wastewater reuse: sewage, waste water, effluent from buildings, industries, agriculture and agribusiness, processed or not. (20) Registration and evaluation of the potential environmental hazard of pesticides.

APPENDICES TO CHAPTER TWO

Table A.2.1: Determinants of Technical Environmental Innovation

Dependent Variable: Environmental Innovation - at least one

	Pooled OLS		OLS Fixed Effects	
	(1)	(2)	(3)	(4)
Environmental Regulation	0.002*	0.004***	0.006***	0.006***
	(0.001)	(0.001)	(0.001)	(0.001)
Size of the Firm		0.097***		0.023**
		(0.002)		(0.012)
Export Intensity		-0.063***		-0.129***
		(0.012)		(0.036)
Foreign Ownership		0.039***		
		(0.007)		
Physical Capital Intensity		0.020***		0.006
		(0.002)		(0.008)
year dummy:				
year 2003	-0.101***	-0.0981***	-0.107***	-0.108***
	(0.00884)	(0.00825)	(0.0102)	(0.0104)
year 2005	-0.0605***	-0.0648***	-0.0834***	-0.0819***
	(0.00783)	(0.00733)	(0.00911)	(0.00985)
year 2008	-0.0959***	-0.117***	-0.142***	-0.146***
	(0.00814)	(0.00763)	(0.00973)	(0.0117)
Industry dummy:				
MinQuar.	0.179*	0.0853		
	(0.101)	(0.0945)		
Food	0.361***	0.192**		
	(0.0996)	(0.0930)		
Beverage	0.358***	0.184*		
	(0.101)	(0.0943)		
Tobacco	0.479***	0.238**		
	(0.104)	(0.0973)		
Textile	0.208**	0.184**		
	(0.0997)	(0.0930)		
Leather	0.311***	0.210**		
	(0.100)	(0.0934)		
Wood	0.221**	0.226**		
	(0.101)	(0.0941)		
PulpPaper	0.352***	0.276***		
	(0.101)	(0.0939)		
Print	0.165	0.119		
	(0.101)	(0.0939)		
Petrol	0.550***	0.262***		
	(0.101)	(0.0940)		

	Pooled OLS		OLS Fixed Effects	
	(1)	(2)	(3)	(4)
Chemical	0.472***	0.388***		
	(0.100)	(0.0934)		
Pharmac.	0.418***	0.312***		
	(0.101)	(0.0945)		
RubPlastic	0.297***	0.279***		
	(0.100)	(0.0934)		
NonMet	0.267***	0.248***		
	(0.100)	(0.0935)		
Metal	0.371***	0.293***		
	(0.0998)	(0.0931)		
CompElect	0.413***	0.315***		
	(0.0999)	(0.0932)		
MachEquip	0.406***	0.334***		
	(0.0999)	(0.0932)		
VeichOth	0.576***	0.361***		
	(0.0998)	(0.0932)		
Furniture	0.286***	0.317***		
	(0.100)	(0.0935)		
State dummy:				
AC	-0.235	-0.0575		
	(0.153)	(0.143)		
AL	-0.0592	-0.135***		
	(0.0553)	(0.0517)		
AM	0.0134	-0.0613		
	(0.0551)	(0.0514)		
AP	0.118	0.149		
	(0.177)	(0.165)		
BA	-0.0146	-0.0278		
	(0.0544)	(0.0507)		
CE	0.117**	0.0182		
	(0.0533)	(0.0497)		
ES	0.0142	0.0200		
	(0.0563)	(0.0525)		
GO	-0.0487	0.00784		
	(0.0556)	(0.0519)		
MA	-0.198***	-0.118*		
	(0.0733)	(0.0684)		

	Pooled OLS		OLS Fixed Effects	
	(1)	(2)	(3)	(4)
MG	-0.0335	-0.0620		
	(0.0530)	(0.0495)		
MS	-0.212***	-0.114*		
	(0.0701)	(0.0654)		
MT	-0.173***	-0.0863		
	(0.0625)	(0.0583)		
PA	-0.0489	-0.0102		
	(0.0579)	(0.0540)		
PB	-0.148**	-0.0844		
	(0.0616)	(0.0575)		
PE	-0.143***	-0.151***		
	(0.0546)	(0.0509)		
PI	-0.0807	-0.00965		
	(0.0715)	(0.0667)		
PR	-0.0359	-0.0310		
	(0.0522)	(0.0487)		
RJ	0.0147	-0.0912*		
	(0.0520)	(0.0486)		
RN	-0.00428	-0.0550		
	(0.0624)	(0.0582)		
RO	-0.150*	-0.0467		
	(0.0775)	(0.0723)		
RR	0.342	0.552		
	(0.397)	(0.370)		
RS	0.0190	0.0245		
	(0.0518)	(0.0483)		
SC	0.163***	0.0838*		
	(0.0518)	(0.0484)		
SE	0.00498	0.0347		
	(0.0701)	(0.0654)		
SP	-0.0172	-0.0770		
	(0.0514)	(0.0480)		
TO	-0.133	0.0459		
	(0.114)	(0.106)		
Constant	0.128	-0.567***	0.480***	0.288**
	(0.112)	(0.105)	(0.0093)	(0.133)
Observations	*32,894*	*32,894*	*32,894*	*32,894*
R-squared	0.063	0.185	0.624	0.624

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table A.2.2: Determinants of Technical Environmental Innovation

Dependent Variable: Environmental Innovation - all

	Pooled OLS		OLS Fixed Effects	
	(1)	(2)	(3)	(4)
Environmental Regulation	0.001	0.002**	0.002***	0.002**
	(0.001)	(0.001)	(0.001)	(0.001)
Size of the Firm		0.042***		-0.020***
		(0.001)		(0.008)
Export Intensity		-0.092***		-0.028
		(0.007)		(0.024)
Foreign Ownership		0.047***		
		(0.004)		
Physical Capital Intensity		0.011***		0.003
		(0.001)		(0.005)
year dummy:				
year 2003	0.0492**	-0.0466***	-0.0566***	-0.0566***
	(0.00528)	(0.00508)	(0.00670)	(0.00682)
year 2005	0.0522**	-0.0501***	-0.0633***	-0.0611***
	(0.00467)	(0.00451)	(0.00600)	(0.00648)
year 2008	0.0318**	-0.0380***	-0.0459***	-0.0401***
	(0.00486)	(0.00469)	(0.00640)	(0.00773)
Industry dummy:				
MinQuar.	0.00931	-0.00803		
	(0.0604)	(0.0581)		
Food	0.0709	0.0152		
	(0.0594)	(0.0572)		
Beverage	0.0962	0.0234		
	(0.0603)	(0.0580)		
Tobacco	0.130**	0.0381		
	(0.0622)	(0.0599)		
Textile	0.0433	0.0458		
	(0.0595)	(0.0572)		
Leather	0.107*	0.0901		
	(0.0597)	(0.0574)		
Wood	0.0265	0.0616		
	(0.0601)	(0.0579)		
PulpPaper	0.0645	0.0432		
	(0.0600)	(0.0577)		
Print	0.0174	0.00611		
	(0.0600)	(0.0577)		
Petrol	0.277***	0.168***		
	(0.0600)	(0.0578)		

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

	Pooled OLS		OLS Fixed Effects	
	(1)	(2)	(3)	(4)
Chemical	0.105*	0.0712		
	(0.0597)	(0.0575)		
Pharmac.	0.0238	-0.0216		
	(0.0604)	(0.0581)		
RubPlastic	0.0423	0.0412		
	(0.0597)	(0.0574)		
NonMet	0.0255	0.0283		
	(0.0598)	(0.0575)		
Metal	0.0758	0.0558		
	(0.0595)	(0.0573)		
CompElect	0.0677	0.0303		
	(0.0596)	(0.0573)		
MachEquip.	0.138**	0.115**		
	(0.0596)	(0.0573)		
VeichOth	0.200***	0.114**		
	(0.0596)	(0.0573)		
Furniture	0.0422	0.0728		
	(0.0598)	(0.0575)		
State dummy:				
AC	-0.0206	0.0511		
	(0.0914)	(0.0878)		
AL	0.0476	0.0370		
	(0.0330)	(0.0318)		
AM	0.0759**	0.0363		
	(0.0329)	(0.0316)		
AP	-0.0140	0.0227		
	(0.105)	(0.101)		
BA	0.0232	0.0207		
	(0.0324)	(0.0312)		
CE	0.203***	0.165***		
	(0.0318)	(0.0306)		
ES	0.0579*	0.0647**		
	(0.0336)	(0.0323)		
GO	0.00828	0.0333		
	(0.0332)	(0.0319)		
MA	-0.00872	0.0321		
	(0.0437)	(0.0420)		
MG	0.00203	-0.0113		
	(0.0316)	(0.0304)		

	Pooled OLS		OLS Fixed Effects	
	(1)	(2)	(3)	(4)
MS	-0.00857	0.0360		
	(0.0418)	(0.0402)		
MT	-0.00946	0.0270		
	(0.0373)	(0.0359)		
PA	0.0250	0.0505		
	(0.0345)	(0.0332)		
PB	0.00290	0.0347		
	(0.0367)	(0.0353)		
PE	0.0127	0.0129		
	(0.0326)	(0.0313)		
PI	-0.0567	-0.0222		
	(0.0427)	(0.0410)		
PR	0.0195	0.0216		
	(0.0312)	(0.0300)		
RJ	0.0863***	0.0384		
	(0.0311)	(0.0299)		
RN	0.0269	0.00619		
	(0.0372)	(0.0358)		
RO	0.0105	0.0602		
	(0.0463)	(0.0445)		
RR	-0.00204	0.0987		
	(0.237)	(0.227)		
RS	0.0198	0.0282		
	(0.0309)	(0.0297)		
SC	0.0697**	0.0434		
	(0.0309)	(0.0298)		
SE	-0.0138	-0.00144		
	(0.0418)	(0.0402)		
SP	0.0408	0.0120		
	(0.0307)	(0.0295)		
TO	-0.0189	0.0572		
	(0.0678)	(0.0652)		
Constant	-0.00224	-0.335***	0.126***	0.222**
	(0.0667)	(0.0648)	(0.00614)	(0.0875)
Observations	*32,894*	*32,894*	*32,894*	*32,894*
R-squared	0.057	0.129	0.540	0.540

Table A.2.3: Determinants of Technical Environmental Innovation

Dependent Variable: Environmental Impact reduction and Safety improvement

	Pooled OLS		OLS Fixed Effects	
	(1)	(2)	(3)	(4)
Environmental Regulation	0.002*	0.003***	0.004***	0.004***
	(0.001)	(0.001)	(0.001)	(0.001)
Size of the Firm		0.084***		0.001
		(0.002)		(0.011)
Export Intensity		-0.073***		-0.105***
		(0.011)		(0.036)
Foreign Ownership		0.041***		
		(0.007)		
Physical Capital Intensity		0.019***		0.006
		(0.002)		(0.008)
year dummy:				
year 2003	-0.102***	-0.0987***	-0.116***	-0.116***
	(0.00847)	(0.00801)	(0.0101)	(0.0103)
year 2005	-0.0848***	-0.0871***	-0.105***	-0.103***
	(0.00750)	(0.00712)	(0.00906)	(0.00979)
year 2008	-0.143***	-0.159***	-0.172***	-0.171***
	(0.00780)	(0.00740)	(0.00967)	(0.0117)
Industry dummy:				
MinQuar.	0.159	0.0808		
	(0.0970)	(0.0917)		
Food	0.299***	0.156*		
	(0.0954)	(0.0902)		
Beverage	0.235**	0.0821		
	(0.0968)	(0.0915)		
Tobacco	0.368***	0.162*		
	(0.0998)	(0.0944)		
Textile	0.128	0.108		
	(0.0955)	(0.0903)		
Leather	0.251***	0.172*		
	(0.0958)	(0.0906)		
Wood	0.154	0.165*		
	(0.0965)	(0.0913)		
PulpPaper	0.251***	0.185**		
	(0.0963)	(0.0911)		
Print	0.102	0.0621		
	(0.0964)	(0.0911)		
Petrol	0.513***	0.264***		
	(0.0963)	(0.0913)		

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

	Pooled OLS		OLS Fixed Effects	
	(1)	(2)	(3)	(4)
Chemical	0.412***	0.337***		
	(0.0959)	(0.0907)		
Pharmac.	0.368***	0.274***		
	(0.0970)	(0.0917)		
RubPlastic	0.201**	0.185**		
	(0.0959)	(0.0906)		
NonMet	0.194**	0.178**		
	(0.0960)	(0.0907)		
Metal	0.283***	0.216**		
	(0.0956)	(0.0904)		
CompElect	0.274***	0.188**		
	(0.0958)	(0.0905)		
MachEquip.	0.334***	0.272***		
	(0.0957)	(0.0904)		
VeichOth	0.483***	0.297***		
	(0.0956)	(0.0904)		
Furniture	0.207**	0.237***		
	(0.0961)	(0.0908)		
State dummy:				
AC	-0.0707	0.0829		
	(0.147)	(0.139)		
AL	0.0893*	0.0311		
	(0.0530)	(0.0502)		
AM	0.152***	0.0850*		
	(0.0528)	(0.0499)		
AP	0.299*	0.331**		
	(0.169)	(0.160)		
BA	0.112**	0.102**		
	(0.0521)	(0.0492)		
CE	0.226***	0.143***		
	(0.0511)	(0.0483)		
ES	0.135**	0.142***		
	(0.0539)	(0.0510)		
GO	0.0432	0.0931*		
	(0.0533)	(0.0504)		
MA	-0.0383	0.0332		
	(0.0702)	(0.0663)		
MG	0.0612	0.0370		
	(0.0508)	(0.0480)		

	Pooled OLS		OLS Fixed Effects	
	(1)	(2)	(3)	(4)
MS	-0.109	-0.0226		
	(0.0671)	(0.0634)		
MT	-0.0296	0.0456		
	(0.0599)	(0.0566)		
PA	0.0985*	0.135***		
	(0.0555)	(0.0524)		
PB	-0.0256	0.0318		
	(0.0590)	(0.0558)		
PE	-0.0200	-0.0252		
	(0.0523)	(0.0494)		
PI	0.0213	0.0854		
	(0.0685)	(0.0648)		
PR	0.0864*	0.0913*		
	(0.0500)	(0.0473)		
RJ	0.119**	0.0269		
	(0.0499)	(0.0471)		
RN	0.118**	0.0764		
	(0.0598)	(0.0565)		
RO	-0.00947	0.0828		
	(0.0743)	(0.0702)		
RR	0.272	0.459		
	(0.380)	(0.359)		
RS	0.127**	0.133***		
	(0.0496)	(0.0469)		
SC	0.233***	0.167***		
	(0.0497)	(0.0470)		
SE	0.0967	0.124*		
	(0.0672)	(0.0635)		
SP	0.0740	0.0218		
	(0.0493)	(0.0466)		
TO	-0.0460	0.111		
	(0.109)	(0.103)		
Constant	0.0450	-0.578***	0.425***	0.370***
	(0.107)	(0.102)	(0.00927)	(0.132)
Observations	*32,894*	*32,894*	*32,894*	*32,894*
R-squared	0.067	0.167	0.597	0.597

Table A.2.4: Determinants of Organizational Environmental Innovation

Dependent Variable: Environmental Management Techniques

	Pooled OLS		OLS Fixed Effects	
	(1)	(2)	(3)	(4)
Environmental Regulation	0.001	0.002	0.004**	0.004**
	(0.001)	(0.001)	(0.002)	(0.002)
Size of the Firm		0.097***		0.065***
		(0.002)		(0.016)
Export Intensity		-0.017		-0.001
		(0.013)		(0.047)
Foreign Ownership		0.067***		
		(0.008)		
Physical Capital Intensity		0.017***		0.031***
		(0.002)		(0.010)
year dummy:				
year 2005	0.00668	0.00306	-0.0214*	-0.0295**
	(0.00986)	(0.00912)	(0.0120)	(0.0123)
year 2008	0.133***	0.114***	0.0879***	0.0615***
	(0.0111)	(0.0103)	(0.0140)	(0.0154)
Industry dummy:				
MinQuar.	0.227**	0.107		
	(0.110)	(0.102)		
Food	0.392***	0.203**		
	(0.108)	(0.100)		
Beverage	0.508***	0.319***		
	(0.110)	(0.102)		
Tobacco	0.548***	0.267**		
	(0.114)	(0.106)		
Textile	0.165	0.136		
	(0.109)	(0.100)		
Leather	0.262**	0.147		
	(0.109)	(0.101)		
Wood	0.243**	0.221**		
	(0.110)	(0.102)		
PulpPaper	0.387***	0.307***		
	(0.109)	(0.101)		
Print	0.178	0.131		
	(0.110)	(0.101)		
Petrol	0.593***	0.311***		
	(0.110)	(0.102)		

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

	Pooled OLS		OLS Fixed Effects	
	(1)	(2)	(3)	(4)
Chemical	0.428***	0.339***		
	(0.109)	(0.101)		
Pharmac.	0.417***	0.296***		
	(0.110)	(0.102)		
RubPlastic	0.225**	0.201**		
	(0.109)	(0.101)		
NonMet	0.278**	0.253**		
	(0.109)	(0.101)		
Metal	0.385***	0.295***		
	(0.109)	(0.100)		
CompElect	0.318***	0.204**		
	(0.109)	(0.101)		
MachEquip.	0.319***	0.231**		
	(0.109)	(0.101)		
VeichOth	0.519***	0.273***		
	(0.109)	(0.101)		
Furniture	0.186*	0.206**		
	(0.109)	(0.101)		
State dummy:				
AC	-0.0725	0.108		
	(0.174)	(0.161)		
AL	0.175***	0.0859		
	(0.0630)	(0.0584)		
AM	0.176***	0.103*		
	(0.0630)	(0.0582)		
AP	-0.00285	-0.0108		
	(0.188)	(0.174)		
BA	0.0759	0.0550		
	(0.0622)	(0.0576)		
CE	0.115*	0.00155		
	(0.0612)	(0.0566)		
ES	0.100	0.114*		
	(0.0641)	(0.0593)		
GO	-0.00430	0.0674		
	(0.0636)	(0.0588)		
MA	-0.119	-0.0356		
	(0.0844)	(0.0781)		

	Pooled OLS		OLS Fixed Effects	
	(1)	(2)	(3)	(4)
MG	0.0586	0.0421		
	(0.0618)	(0.0571)		
MS	-0.0636	0.0416		
	(0.0800)	(0.0740)		
MT	-0.0656	0.0241		
	(0.0714)	(0.0660)		
PA	0.00750	0.0492		
	(0.0659)	(0.0610)		
PB	-0.0523	0.0181		
	(0.0704)	(0.0651)		
PE	-0.0468	-0.0452		
	(0.0629)	(0.0582)		
PI	0.0861	0.161**		
	(0.0834)	(0.0772)		
PR	0.0152	0.0259		
	(0.0603)	(0.0557)		
RJ	0.101*	0.00160		
	(0.0600)	(0.0555)		
RN	-0.155**	-0.217***		
	(0.0716)	(0.0662)		
RO	-0.0690	0.0361		
	(0.0858)	(0.0793)		
RR	0.173	0.385		
	(0.389)	(0.360)		
RS	0.0290	0.0382		
	(0.0597)	(0.0552)		
SC	0.197***	0.117**		
	(0.0596)	(0.0551)		
SE	-0.0958	-0.0548		
	(0.0794)	(0.0734)		
SP	0.0543	-0.00270		
	(0.0593)	(0.0548)		
TO	-0.211*	-0.0215		
	(0.120)	(0.111)		
Constant	-0.0472	-0.709***	0.366***	-0.370**
	(0.123)	(0.115)	(0.00684)	(0.173)
Observation	*25,813*	*25,813*	*25,813*	*25,813*
R-squared	0.085	0.218	0.655	0.656

Table A.2.5: Determinants of Technical EI - Cross Section

Dependent Variable: Biological Effluent Treatment

	OLS	
	(1)	(2)
Environmental Regulation	0.007***	0.003**
	(0.001)	(0.001)
Size of the Firm		0.022***
		(0.005)
Export Intensity		-0.034
		(0.032)
Foreign Ownership		-0.016
		(0.010)
Physical Capital Intensity		0.013***
		(0.003)
Industry dummy:		
MinQuar.	0.0276	-0.0352
	(0.0245)	(0.0496)
Food	0.125***	0.0562
	(0.0176)	(0.0379)
Beverage	0.175***	0.105**
	(0.0402)	(0.0494)
Tobacco	0.0478**	-0.00574
	(0.0212)	(0.0436)
Textile	0.0953***	0.0733*
	(0.0235)	(0.0387)
Leather	0.0937***	0.0598
	(0.0245)	(0.0437)
Wood	0.0783***	0.0593
	(0.0215)	(0.0506)
PulpPaper	0.0911***	0.0437
	(0.0142)	(0.0308)
Print	0.0576***	0.0179
	(0.00781)	(0.0185)
Petrol	0.417	0.310
	(0.254)	(0.229)
Chemical	0.0837***	0.0410**
	(0.00739)	(0.0158)

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

	OLS	
	(1)	(2)
Pharmac.	0.0984***	0.0489***
	(0.00534)	(0.0156)
RubPlastic	0.0843***	0.0536
	(0.0251)	(0.0376)
NonMet	0.0587***	0.0310
	(0.0173)	(0.0355)
Metal	0.0998***	0.0577**
	(0.0205)	(0.0245)
CompElect	0.0758***	0.0379*
	(0.00810)	(0.0212)
MachEquip.	0.117***	0.0836***
	(0.0240)	(0.0216)
VeichOth	0.0810***	0.0136
	(0.0114)	(0.0251)
Furniture	0.0786***	0.0665
	(0.0254)	(0.0398)
State dummy:		
AC		
AL	0.0697***	-0.00433
	(0.0100)	(0.0237)
AM	0.00384	-0.0711***
	(0.0153)	(0.0136)
AP	-0.0136***	-0.0482***
	(0.00469)	(0.00848)
BA	0.0116	-0.0545***
	(0.0103)	(0.0128)
CE	0.0128	-0.0801***
	(0.00986)	(0.0177)
ES	-0.0208***	-0.0529***
	(0.00430)	(0.00590)
GO	0.0240**	-0.0293
	(0.0105)	(0.0175)
MA	-0.0776*	-0.115**
	(0.0451)	(0.0421)

	OLS	
	(1)	(2)
MG	0.00966	-0.0625***
	(0.0139)	(0.0159)
MS	-0.0250***	-0.0297***
	(0.00644)	(0.00558)
MT	-0.0465	-0.0669**
	(0.0293)	(0.0284)
PA	0.00399	-0.0362***
	(0.00495)	(0.00759)
PB	0.0482***	-0.00135
	(0.0130)	(0.0174)
PE	0.0635***	0.0442***
	(0.0108)	(0.0132)
PI	-0.0361	-0.0739*
	(0.0396)	(0.0384)
PR	-0.0406***	-0.0676***
	(0.00597)	(0.00908)
RJ	0.127***	0.0475
	(0.0279)	(0.0302)
RN	0.0145	-0.0677***
	(0.00912)	(0.0127)
RO	0.00195	-0.0169*
	(0.00597)	(0.00892)
RR	0.0254**	-0.0230*
	(0.0114)	(0.0130)
RS	0.0523***	-0.0305*
	(0.0104)	(0.0153)
SC	0.0887***	0.0325***
	(0.0100)	(0.0109)
SE	-0.0247***	-0.0539***
	(0.00516)	(0.00751)
SP	0.0112	0.00408
	(0.00963)	(0.00945)
TO	0.0428*	0.0304
	(0.0214)	(0.0211)
Constant	-0.115***	-0.266***
	(0.0228)	(0.0610)
Observations	*10,850*	*10,850*
R-squared	0.099	0.143

Table A.2.6: Determinants of Pollution abatement investment

Dependent Variable: Pollution abatement investment (%)

	Pooled OLS		OLS Fixed Effects	
	(1)	(2)	(3)	(4)
Environmental Regulation	0.002**	0.002**	0.003***	0.003***
	(0.001)	(0.001)	(0.001)	(0.001)
Size of the Firm		0.004***		-0.005
		(0.001)		(0.004)
Export Intensity		-0.0001		-0.0001
		(0.005)		(0.017)
Foreign Ownership		-0.012***		
		(0.003)		
Physical Capital Intensity		0.008***		0.007**
		(0.001)		(0.004)
year dummy:				
year 2002	0.0138***	0.0139***	0.012**	0.010**
	(0.00376)	(0.00375)	(0.005)	(0.005)
year 2007	0.00890***	0.00937***	0.007	0.004
	(0.00311)	(0.00311)	0.004	(0.005)
Industry dummy:				
MinQuar.	-0.0689	-0.0902		
	(0.0558)	(0.0556)		
Food	-0.0869	-0.104*		
	(0.0554)	(0.0552)		
Beverage	-0.0649	-0.0851		
	(0.0558)	(0.0556)		
Tobacco	-0.113**	-0.129**		
	(0.0567)	(0.0565)		
Textile	-0.0934*	-0.100*		
	(0.0554)	(0.0552)		
Leather	-0.107*	-0.115**		
	(0.0555)	(0.0553)		
Wood	-0.0792	-0.0885		
	(0.0557)	(0.0555)		
PulpPaper	-0.0680	-0.0869		
	(0.0556)	(0.0554)		
Print	-0.0987*	-0.111**		
	(0.0557)	(0.0555)		
Petrol	-0.0362	-0.0710		
	(0.0556)	(0.0555)		

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

	Pooled OLS		OLS Fixed Effects	
	(1)	(2)	(3)	(4)
Chemical	-0.0683	-0.0822		
	(0.0555)	(0.0553)		
Pharmac.	-0.0966*	-0.109*		
	(0.0559)	(0.0556)		
RubPlastic	-0.0973*	-0.108*		
	(0.0555)	(0.0553)		
NonMet	-0.0853	-0.0962*		
	(0.0555)	(0.0553)		
Metal	-0.0588	-0.0736		
	(0.0554)	(0.0552)		
CompElect	-0.103*	-0.112**		
	(0.0555)	(0.0553)		
MachEquip.	-0.0991*	-0.107*		
	(0.0555)	(0.0552)		
VeichOth	-0.0700	-0.0882		
	(0.0554)	(0.0552)		
Furniture	-0.0936*	-0.0954*		
	(0.0556)	(0.0554)		
State dummy:				
AC	-0.00406	0.0189		
	(0.0605)	(0.0602)		
AL	-0.0428*	-0.0429*		
	(0.0229)	(0.0228)		
AM	0.00979	0.00729		
	(0.0226)	(0.0226)		
AP	0.171**	0.169**		
	(0.0748)	(0.0745)		
BA	0.00255	0.00619		
	(0.0224)	(0.0223)		
CE	0.00117	0.00220		
	(0.0220)	(0.0220)		
ES	-0.0165	-0.0120		
	(0.0233)	(0.0232)		
GO	0.00245	0.0101		
	(0.0228)	(0.0227)		
MA	-0.0166	-0.00746		
	(0.0290)	(0.0289)		

	Pooled OLS		OLS Fixed Effects	
	(1)	(2)	(3)	(4)
MG	0.0162	0.0208		
	(0.0218)	(0.0217)		
MS	0.0252	0.0360		
	(0.0293)	(0.0292)		
MT	0.0237	0.0347		
	(0.0255)	(0.0254)		
PA	0.00965	0.0159		
	(0.0238)	(0.0237)		
PB	0.00251	0.0123		
	(0.0251)	(0.0250)		
PE	-0.00486	0.00157		
	(0.0222)	(0.0222)		
PI	0.0918***	0.103***		
	(0.0288)	(0.0287)		
PR	-0.00549	-0.000164		
	(0.0215)	(0.0214)		
RJ	0.0339	0.0310		
	(0.0214)	(0.0214)		
RN	-0.0180	-0.0141		
	(0.0251)	(0.0250)		
RO	-0.0101	0.00523		
	(0.0333)	(0.0332)		
RR	-0.0543	-0.0237		
	(0.193)	(0.192)		
RS	0.00472	0.00785		
	(0.0214)	(0.0213)		
SC	0.00607	0.00666		
	(0.0214)	(0.0213)		
SE	0.00335	0.0127		
	(0.0286)	(0.0285)		
SP	-0.00315	-0.00157		
	(0.0211)	(0.0211)		
TO	-0.0411	-0.0176		
	(0.0508)	(0.0506)		
Constant	0.124**	0.0249	0.042***	.0053317
	(0.0592)	(0.0594)	(0.003)	.0517943
Observation	*23,290*	*23,290*	*23.290*	*23.290*
R-squared	0.023	0.031	0.6325	0.6329

APPENDICES TO CHAPTER 3

Table A.3.1: Changes in Employment Shares - Effects of Technical Environmental Innovation - Complete results

Dependent Variable - Three year difference in Employment Share off Blue-collar

explanatory variables	*Blue-Collar*			
	(1)	(2)	(3)	(4)
	OLS	OLS	IV	IV
Environmental Innovation - at least one	0.0024	0.0041**	0.219	0.138
	(0.0017)	(0.0018)	(0.179)	(0.101)
Basic Controls:				
Δ_3 log Value Added	0.0039***	0.0039***	0.00001	0.0017
	(0.0008)	(0.0008)	(0.0034)	(0.0019)
Δ_3 log Capital Stock	0.0009	0.0008	-0.0021	-0.0025
	(0.0017)	(0.0017)	(0.0032)	(0.0031)
Extended Controls:				
Size of the firm		-0.0008		-0.0149
		(0.0006)		(0.0107)
Export Intensity		-0.0089**		-0.0010
		(0.0039)		(0.0074)
Foreign Capital Control		-0.0029		-0.0101*
		(0.0023)		(0.0059)
Number of Observations	*30,563*	*30,563*	*30,563*	*30,563*
Environmental Legislation (first stage)			*0.003***	*0.004****
			(0.0013)	*(0.0012)*
F-stat for excluded instrument in the first stage			*4.26*	*11.62*
Year dummies:				
year 2003	-0.0149***	-0.0146***	0.0098	0.0008
	(0.0025)	(0.0025)	(0.0206)	(0.0120)
year 2005	-0.0088***	-0.0082***	0.0054	0.0013
	(0.0024)	(0.0024)	(0.0120)	(0.0077)
year 2008	-0.0090***	-0.0083***	0.0121	0.0080
	(0.0023)	(0.0023)	(0.0176)	(0.0126)
Industry Sector dummies:				
MinQuar.	0.0395	0.0414	0.0027	0.0241
	(0.0340)	(0.0340)	(0.0517)	(0.0391)
Food	0.0302	0.0317	-0.0477	0.0018
	(0.0335)	(0.0335)	(0.0764)	(0.0428)
Beverage	-0.0047	-0.0049	-0.0801	-0.0347
	(0.0339)	(0.0339)	(0.0749)	(0.0432)
Tobacco	0.0090	0.0156	-0.0962	-0.0205
	(0.0348)	(0.0348)	(0.0967)	(0.0467)
Textile	0.0229	0.0221	-0.0202	-0.0051
	(0.0335)	(0.0335)	(0.0546)	(0.0418)
Leather	0.0238	0.0255	-0.0427	-0.0041
	(0.0336)	(0.0337)	(0.0687)	(0.0428)
Wood	0.0279	0.0298	-0.0209	-0.0058
	(0.0339)	(0.0339)	(0.0580)	(0.0456)

explanatory variables (cont.)	*Blue-Collar*			
	(1)	(2)	(3)	(4)
	OLS	OLS	IV	IV
PulpPaper	0.0275	0.0273	-0.0468	-0.0167
	(0.0338)	(0.0338)	(0.0741)	(0.0495)
Print	0.0536	0.0524	0.0158	0.0290
	(0.0338)	(0.0339)	(0.0521)	(0.0407)
Petrol	0.0581*	0.0591*	-0.0596	0.0160
	(0.0338)	(0.0338)	(0.106)	(0.0491)
Chemical	0.0338	0.0338	-0.0666	-0.0241
	(0.0337)	(0.0337)	(0.0926)	(0.0571)
Pharmac.	0.0269	0.0271	-0.0605	-0.0191
	(0.0340)	(0.0340)	(0.0834)	(0.0508)
RubPlastic	0.0266	0.0255	-0.0372	-0.0176
	(0.0337)	(0.0337)	(0.0670)	(0.0490)
NonMet	0.0335	0.0327	-0.0222	-0.00598
	(0.0337)	(0.0337)	(0.0619)	(0.0468)
Metal	0.0269	0.0273	-0.0510	-0.0170
	(0.0336)	(0.0336)	(0.0764)	(0.0495)
CompElect	0.0271	0.0279	-0.0592	-0.0170
	(0.0336)	(0.0336)	(0.0823)	(0.0499)
MachEquip.	0.0270	0.0276	-0.0600	-0.0208
	(0.0336)	(0.0336)	(0.0828)	(0.0517)
VeichOth	0.0307	0.0334	-0.0905	-0.0183
	(0.0336)	(0.0336)	(0.108)	(0.0535)
Furniture	0.0215	0.0207	-0.0405	-0.0252
	(0.0337)	(0.0337)	(0.0659)	(0.0505)
State dummies:				
AC	0.00242	0.00104	0.0554	0.0153
	(0.0575)	(0.0575)	(0.0833)	(0.0632)
AL	-0.0500***	-0.0461***	-0.0332	-0.0249
	(0.0175)	(0.0175)	(0.0257)	(0.0249)
AM	-0.0337*	-0.0322*	-0.0315	-0.0228
	(0.0174)	(0.0174)	(0.0216)	(0.0202)
AP	0.128**	0.131**	0.109	0.110*
	(0.0536)	(0.0536)	(0.0680)	(0.0602)
BA	-0.0158	-0.0143	-0.0083	-0.0071
	(0.0172)	(0.0172)	(0.0222)	(0.0194)
CE	-0.0174	-0.0159	-0.0441	-0.0182
	(0.0169)	(0.0169)	(0.0304)	(0.0184)
ES	-0.0274	-0.0260	-0.0256	-0.0268
	(0.0178)	(0.0178)	(0.0220)	(0.0193)
GO	-0.0275	-0.0279	-0.0140	-0.0270
	(0.0176)	(0.0176)	(0.0245)	(0.0191)

explanatory variables (cont.)	*Blue-Collar*			
	(1)	(2)	(3)	(4)
	OLS	OLS	IV	IV
MA	0.0122	0.0128	0.0637	0.0334
	(0.0229)	(0.0229)	(0.0510)	(0.0294)
MG	-0.0194	-0.0180	-0.0115	-0.0103
	(0.0164)	(0.0164)	(0.0213)	(0.0187)
MS	-0.0682***	-0.0677***	-0.0188	-0.0502*
	(0.0221)	(0.0221)	(0.0490)	(0.0274)
MT	-0.0264	-0.0266	0.0143	-0.0132
	(0.0198)	(0.0198)	(0.0415)	(0.0238)
PA	-0.0102	-0.0084	0.00537	-0.0041
	(0.0183)	(0.0183)	(0.0260)	(0.0201)
PB	-0.0213	-0.0204	0.0169	-0.00421
	(0.0195)	(0.0195)	(0.0396)	(0.0244)
PE	-0.0424**	-0.0410**	-0.0068	-0.0183
	(0.0171)	(0.0171)	(0.0362)	(0.0253)
PI	-0.0186	-0.0179	0.0086	-0.00851
	(0.0225)	(0.0225)	(0.0357)	(0.0254)
PR	-0.0177	-0.0168	-0.0061	-0.0106
	(0.0165)	(0.0165)	(0.0225)	(0.0185)
RJ	-0.0165	-0.0146	-0.0161	-0.0007
	(0.0165)	(0.0165)	(0.0203)	(0.0207)
RN	-0.0157	-0.0146	-0.0101	-0.0019
	(0.0197)	(0.0197)	(0.0247)	(0.0234)
RO	-0.0081	-0.0079	0.0268	-3.09e-05
	(0.0248)	(0.0248)	(0.0420)	(0.0275)
RR	0.140	0.139	0.0612	0.0638
	(0.124)	(0.124)	(0.167)	(0.146)
RS	-0.0265	-0.0253	-0.0257	-0.0266
	(0.0164)	(0.0164)	(0.0203)	(0.0178)
SC	-0.0245	-0.0222	-0.0549*	-0.0286
	(0.0164)	(0.0164)	(0.0322)	(0.0185)
SE	0.0277	0.0274	0.0302	0.0260
	(0.0221)	(0.0221)	(0.0273)	(0.0239)
SP	-0.0192	-0.0175	-0.0134	-0.0069
	(0.0162)	(0.0162)	(0.0206)	(0.0193)
TO	-0.0252	-0.0269	0.0087	-0.0260
	(0.0351)	(0.0351)	(0.0516)	(0.0380)
Constant	-0.0016	0.0023	-0.0389	0.0566
	(0.0372)	(0.0373)	(0.0552)	(0.0578)
R-squared	0.009	0.010	-0.513	-0.164

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table A.3.2: Changes in Employment Shares: Effects of Technical and Organizational Environmental Innovations

Dependent Variable - Three year difference in Employment Share off Blue-collar

	Blue-Collar		***explanatory variables (cont.)***	***Blue-Collar***		***explanatory variables (cont.)***	***Blue-Collar***	
	(3)	(4)		(3)	(4)		(3)	(4)
	OLS	OLS		OLS	OLS		OLS	OLS
A. Environmental Innovation - at least one	0.0066***	0.0054*	PulpPaper	0.0336	0.0337	GO	-0.0265	-0.0265
	(0.0021)	(0.0028)		(0.0380)	(0.0380)		(0.0202)	(0.0202)
B. Environmental Management Techniques	-0.0009	-0.0021	Print	0.0468	0.0469	MA	0.0084	0.0081
	(0.0022)	(0.0028)		(0.0381)	(0.0381)		(0.0265)	(0.0265)
Interaction between: **A*B**		0.0026	Petrol	0.0462	0.0464	MG	-0.0183	-0.0185
		(0.004)		(0.0381)	(0.0381)		(0.0189)	(0.0189)
Basic Controls:			Chemical	0.0433	0.0435	MS	-0.0654***	-0.0656***
Δ_3 log Value Added	0.0046***	0.0046***		(0.0379)	(0.0379)		(0.0252)	(0.0252)
	(0.001)	(0.001)	Pharmac.	0.0311	0.0312	MT	-0.0280	-0.0282
Δ_3 log Capital Stock	0.0005	0.0005		(0.0382)	(0.0382)		(0.0226)	(0.0226)
	(0.0019)	(0.0019)	RubPlastic	0.0339	0.0341	PA	-0.0160	-0.0162
Extended Controls:				(0.0379)	(0.0379)		(0.0209)	(0.0209)
Size of the firm	-0.0011	-0.0011*	NonMet	0.0421	0.0422	PB	-0.0358	-0.0360
	(0.0007)	(0.0007)		(0.0379)	(0.0379)		(0.0223)	(0.0224)
Export Intensity	-0.0077*	-0.0077*	Metal	0.0368	0.0370	PE	-0.0350*	-0.0350*
	(0.0043)	(0.0043)		(0.0378)	(0.0378)		(0.0198)	(0.0198)
Foreign Capital Control	0.0008	0.0008	CompElect	0.0390	0.0392	PI	-0.0122	-0.0123
	(0.0026)	(0.0026)		(0.0378)	(0.0378)		(0.0264)	(0.0264)
Number of Observations	23,870	23,870	MachEquip.	0.0328	0.0329	PR	-0.0244	-0.0245
Year Dummies:				(0.0378)	(0.0378)		(0.0190)	(0.0190)
year 2005	0.0065***	0.0065***	VeichOth	0.0431	0.0432	RJ	-0.0224	-0.0226
	(0.0023)	(0.0023)		(0.0378)	(0.0378)		(0.0190)	(0.0190)
year 2008	0.0064***	0.0064***	Furniture	0.0283	0.0284	RN	-0.0150	-0.0150
	(0.0023)	(0.0023)		(0.0379)	(0.0379)		(0.0228)	(0.0228)
Industry sector dummies:			***State dummies:***			RO	0.0062	0.00602
MinQuar.	0.0516	0.0519	AC	0.0007	0.0003		(0.0277)	(0.0277)
	(0.0382)	(0.0382)		(0.0613)	(0.0613)	RR	0.136	0.135
Food	0.0406	0.0408	AL	-0.0717***	-0.0719***		(0.122)	(0.122)
	(0.0377)	(0.0377)		(0.0200)	(0.0200)	RS	-0.0297	-0.0298
Beverage	0.0099	0.0102	AM	-0.0493**	-0.0495**		(0.0190)	(0.0190)
	(0.0382)	(0.0382)		(0.0200)	(0.0200)	SC	-0.0246	-0.0248
Tobacco	0.0344	0.0347	AP	0.156***	0.156***		(0.0190)	(0.0190)
	(0.0393)	(0.0393)		(0.0572)	(0.0572)	SE	0.0396	0.0395
Textile	0.0307	0.0308	BA	-0.0191	-0.0193		(0.0251)	(0.0251)
	(0.0377)	(0.0377)		(0.0198)	(0.0198)	SP	-0.0199	-0.0200
Leather	0.0330	0.0331	CE	-0.0191	-0.0192		(0.0187)	(0.0187)
	(0.0379)	(0.0379)		(0.0195)	(0.0195)	TO	-0.0555	-0.0558
Wood	0.0385	0.0385	ES	-0.0322	-0.0322		(0.0372)	(0.0372)
	(0.0381)	(0.0381)		(0.0203)	(0.0203)	Constant	-0.0163	-0.0158
							(0.0422)	(0.0422)
						R-squared	0.010	0.010

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table A.3.3: Changes in Wage Bill Shares - Effects of Technical Environmental Innovation

Dependent Variable - Three year difference in Wage Bill Share off Blue-collar

	Blue-Collar			
	(1)	(2)	(3)	(4)
	OLS	OLS	IV	IV
Environmental Innovation - at least one	0.0002	0.0043**	0.136	0.0768
	(0.002)	(0.0021)	(0.180)	(0.111)
Basic Controls:				
Δ_3 log Value Added	0.0054***	0.0053***	0.0029	0.0042**
	(0.0009)	(0.0009)	(0.0034)	(0.0020)
Δ_3 log Capital Stock	-0.0003	-0.0007	-0.0022	-0.0025
	(0.002)	(0.002)	(0.0032)	(0.0034)
Extended Controls:				
Size of the firm		-0.0026***		-0.0102
		(0.0007)		(0.0117)
Export Intensity		-0.0093**		-0.0049
		(0.0045)		(0.0081)
Foreign Capital Control		-0.0070***		-0.0109*
		(0.0027)		(0.0065)
Number of Observations	*30,563*	*30,563*	*30,563*	*30,563*
Environmental Legislation (first stage)			*0.003***	*0.004****
			(0.0013)	*(0.0012)*
F-stat for excluded instrument			*4.26*	*11.62*
Year dummies:				
year 2003	-0.0154***	-0.0147***	0.0002	-0.0064
	(0.0028)	(0.0028)	(0.0208)	(0.0130)
year 2005	-0.0037	-0.0028	0.0052	0.0024
	(0.0028)	(0.0028)	(0.0121)	(0.0084)
year 2008	-0.0085***	-0.0070***	0.0047	0.0018
	(0.0027)	(0.0027)	(0.0178)	(0.0138)
Industry Sector dummies:				
MinQuar.	0.0480	0.0495	0.0249	0.0401
	(0.0394)	(0.0394)	(0.0522)	(0.0426)
Food	0.0394	0.0416	-0.0095	0.0254
	(0.0389)	(0.0389)	(0.0771)	(0.0467)
Beverage	-0.0017	-0.0014	-0.0490	-0.0176
	(0.0394)	(0.0394)	(0.0756)	(0.0471)
Tobacco	0.0191	0.0302	-0.0469	0.0106
	(0.0404)	(0.0404)	(0.0976)	(0.0509)
Textile	0.0366	0.0339	0.0095	0.0192
	(0.0389)	(0.0389)	(0.0551)	(0.0456)
Leather	0.0369	0.0383	-0.0048	0.0223
	(0.0390)	(0.0391)	(0.0694)	(0.0467)
Wood	0.0356	0.0356	0.0050	0.0162
	(0.0393)	(0.0393)	(0.0585)	(0.0498)

explanatory variables (cont.)	Blue-Collar			
	(1)	(2)	(3)	(4)
	OLS	OLS	IV	IV
PulpPaper	0.0388	0.0369	-0.0079	0.0131
	(0.0392)	(0.0392)	(0.0748)	(0.0540)
Print	0.0629	0.0599	0.0392	0.0472
	(0.0393)	(0.0393)	(0.0526)	(0.0444)
Petrol	0.0612	0.0632	-0.0127	0.0399
	(0.0392)	(0.0392)	(0.107)	(0.0535)
Chemical	0.0401	0.0391	-0.0229	0.0077
	(0.0391)	(0.0390)	(0.0934)	(0.0623)
Pharmac.	0.0345	0.0344	-0.0204	0.0093
	(0.0394)	(0.0394)	(0.0841)	(0.0554)
RubPlastic	0.0362	0.0330	-0.0039	0.0096
	(0.0391)	(0.0390)	(0.0676)	(0.0534)
NonMet	0.0426	0.0396	0.0077	0.0186
	(0.0391)	(0.0391)	(0.0625)	(0.0511)
Metal	0.0360	0.0352	-0.0129	0.0112
	(0.0390)	(0.0390)	(0.0771)	(0.0540)
CompElect	0.0369	0.0377	-0.0173	0.0133
	(0.0390)	(0.0390)	(0.0831)	(0.0544)
MachEquip.	0.0347	0.0349	-0.0198	0.0086
	(0.0390)	(0.0390)	(0.0835)	(0.0564)
VeichOth	0.0408	0.0455	-0.0353	0.0174
	(0.0390)	(0.0390)	(0.109)	(0.0584)
Furniture	0.0366	0.0330	-0.0022	0.0082
	(0.0391)	(0.0391)	(0.0665)	(0.0550)
State dummies:				
AC	0.0188	0.0156	0.0520	0.0234
	(0.0668)	(0.0667)	(0.0841)	(0.0689)
AL	-0.0469**	-0.0409**	-0.0364	-0.0294
	(0.0203)	(0.0203)	(0.0259)	(0.0272)
AM	-0.0431**	-0.0398**	-0.0418*	-0.0346
	(0.0202)	(0.0202)	(0.0218)	(0.0220)
AP	0.0964	0.0987	0.0842	0.0874
	(0.0622)	(0.0622)	(0.0687)	(0.0656)
BA	-0.0248	-0.0223	-0.0200	-0.0184
	(0.0200)	(0.0200)	(0.0224)	(0.0212)
CE	-0.0257	-0.0223	-0.0424	-0.0236
	(0.0196)	(0.0196)	(0.0306)	(0.0201)
ES	-0.0279	-0.0262	-0.0268	-0.0267
	(0.0206)	(0.0206)	(0.0222)	(0.0210)
GO	-0.0324	-0.0337*	-0.0239	-0.0332
	(0.0205)	(0.0205)	(0.0247)	(0.0208)

explanatory variables (cont.)	Blue-Collar			
	(1)	(2)	(3)	(4)
	OLS	OLS	IV	IV
MA	0.0116	0.0115	0.0439	0.0226
	(0.0266)	(0.0266)	(0.0515)	(0.0320)
MG	-0.0217	-0.0192	-0.0168	-0.0150
	(0.0190)	(0.0190)	(0.0214)	(0.0204)
MS	-0.0720***	-0.0721***	-0.0410	-0.0626**
	(0.0256)	(0.0256)	(0.0495)	(0.0299)
MT	-0.0337	-0.0348	-0.0082	-0.0275
	(0.0230)	(0.0230)	(0.0419)	(0.0259)
PA	-0.0060	-0.0040	0.0038	-0.0017
	(0.0213)	(0.0213)	(0.0263)	(0.0220)
PB	-0.0181	-0.0173	0.0059	-0.0085
	(0.0226)	(0.0226)	(0.0399)	(0.0266)
PE	-0.0450**	-0.0427**	-0.0226	-0.0303
	(0.0199)	(0.0199)	(0.0365)	(0.0276)
PI	-0.0246	-0.0243	-0.0076	-0.0191
	(0.0261)	(0.0261)	(0.0360)	(0.0277)
PR	-0.0169	-0.0155	-0.0095	-0.0121
	(0.0192)	(0.0191)	(0.0227)	(0.0202)
RJ	-0.0107	-0.0064	-0.0104	0.0012
	(0.0191)	(0.0191)	(0.0205)	(0.0226)
RN	0.0194	0.0220	0.0228	0.0288
	(0.0229)	(0.0228)	(0.0250)	(0.0255)
RO	-0.0251	-0.0260	-0.0032	-0.0217
	(0.0288)	(0.0288)	(0.0424)	(0.0300)
RR	0.223	0.218	0.174	0.177
	(0.144)	(0.144)	(0.168)	(0.160)
RS	-0.0276	-0.0263	-0.0271	-0.0270
	(0.0190)	(0.0190)	(0.0205)	(0.0194)
SC	-0.0301	-0.0260	-0.0492	-0.0295
	(0.0191)	(0.0191)	(0.0325)	(0.0201)
SE	0.0299	0.0293	0.0315	0.0285
	(0.0256)	(0.0256)	(0.0276)	(0.0261)
SP	-0.0203	-0.0168	-0.0167	-0.0110
	(0.0188)	(0.0188)	(0.0208)	(0.0210)
TO	-0.0052	-0.0092	0.0161	-0.0087
	(0.0407)	(0.0407)	(0.0520)	(0.0415)
Constant	-0.0095	0.0048	-0.0329	0.0343
	(0.0432)	(0.0433)	(0.0557)	(0.0630)
R-squared	0.008	0.010	-0.144	-0.028

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table A.3.4: Changes in Wage Bill Shares - Effects of Technical and Organizational Environmental Innovations

Dependent Variable - Three year difference in Employment Share off Blue-collar

	Blue-Collar (1) OLS	*Blue-Collar* (2) OLS
A. Environmental Innovation - at least one	0.0101***	0.0044
	(0.0024)	(0.0032)
B. Environmental Management Techniques	-0.0073***	-0.0129***
	(0.0025)	(0.0033)
Interaction between: **A*B**		0.0126***
		(0.0047)
Basic Controls:		
Δ_3 log Value Added	0.0065***	0.0066***
	(0.0012)	(0.0012)
Δ_3 log Capital Stock	-0.0016	-0.0016
	(0.0022)	(0.0022)
Extended Controls:		
Size of the firm	-0.0027***	-0.0028***
	(0.0008)	(0.0008)
Export Intensity	-0.0106**	-0.0103**
	(0.005)	(0.005)
Foreign Capital Control	0.0005	0.0005
	(0.003)	(0.003)
Number of Observations	*23,870*	*23,870*
Year dummies:		
year 2005	0.0118***	0.0120***
	(0.0027)	(0.0027)
year 2008	0.0084***	0.0087***
	(0.0027)	(0.0027)
Industry Sector Dummy:		
MinQuar.	0.0504	0.0516
	(0.0446)	(0.0446)
Food	0.0407	0.0416
	(0.0440)	(0.0440)
Beverage	-0.0039	-0.0028
	(0.0445)	(0.0445)
Tobacco	0.0568	0.0579
	(0.0458)	(0.0458)
Textile	0.0294	0.0300
	(0.0440)	(0.0440)
Leather	0.0339	0.0344
	(0.0441)	(0.0441)
Wood	0.0328	0.0333
	(0.0444)	(0.0444)

explanatory variables (cont.)	*Blue-Collar* (1) OLS	*Blue-Collar* (2) OLS
PulpPaper	0.0320	0.0327
	(0.0443)	(0.0443)
Print	0.0429	0.0435
	(0.0444)	(0.0444)
Petrol	0.0397	0.0403
	(0.0444)	(0.0444)
Chemical	0.0424	0.0431
	(0.0441)	(0.0441)
Pharmac.	0.0275	0.0281
	(0.0446)	(0.0446)
RubPlastic	0.0280	0.0287
	(0.0441)	(0.0441)
NonMet	0.0362	0.0368
	(0.0442)	(0.0442)
Metal	0.0351	0.0356
	(0.0440)	(0.0440)
CompElect	0.0346	0.0357
	(0.0441)	(0.0441)
MachEquip.	0.0289	0.0296
	(0.0441)	(0.0440)
VeichOth	0.0430	0.0436
	(0.0440)	(0.0440)
Furniture	0.0292	0.0300
	(0.0442)	(0.0442)
State dummies:		
AC	-0.0072	-0.0093
	(0.0714)	(0.0714)
AL	-0.0844***	-0.0853***
	(0.0233)	(0.0233)
AM	-0.0637***	-0.0645***
	(0.0233)	(0.0233)
AP	0.0916	0.0895
	(0.0667)	(0.0667)
BA	-0.0385*	-0.0396*
	(0.0231)	(0.0231)
CE	-0.0414*	-0.0422*
	(0.0227)	(0.0227)
ES	-0.0487**	-0.0491**
	(0.0237)	(0.0237)

explanatory variables (cont.)	*Blue-Collar* (1) OLS	*Blue-Collar* (2) OLS
GO	-0.0495**	-0.0497**
	(0.0236)	(0.0236)
MA	-0.0243	-0.0257
	(0.0309)	(0.0309)
MG	-0.0358	-0.0365*
	(0.0221)	(0.0221)
MS	-0.0816***	-0.0821***
	(0.0294)	(0.0294)
MT	-0.0570**	-0.0579**
	(0.0264)	(0.0264)
PA	-0.0289	-0.0297
	(0.0244)	(0.0244)
PB	-0.0433*	-0.0444*
	(0.0261)	(0.0261)
PE	-0.0550**	-0.0550**
	(0.0230)	(0.0230)
PI	-0.0516*	-0.0523*
	(0.0308)	(0.0308)
PR	-0.0395*	-0.0401*
	(0.0222)	(0.0222)
RJ	-0.0359	-0.0371*
	(0.0222)	(0.0222)
RN	-0.0009	-0.0009
	(0.0265)	(0.0265)
RO	-0.0239	-0.0250
	(0.0323)	(0.0322)
RR	0.202	0.200
	(0.143)	(0.143)
RS	-0.0474**	-0.0481**
	(0.0221)	(0.0221)
SC	-0.0408*	-0.0420*
	(0.0221)	(0.0221)
SE	0.0329	0.0326
	(0.0293)	(0.0293)
SP	-0.0359*	-0.0365*
	(0.0218)	(0.0218)
TO	-0.0512	-0.0526
	(0.0434)	(0.0434)
Constant	0.0129	0.0151
	(0.0492)	(0.0492)
R-squared	0.011	0.011

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table A.3.5: Cross Section - PINTEC 2008 - Effects of Biological Effluent Treatment - Complete Results

Dependent Variable - (2008-2006) Change in employment and wage bill share off Blue-collar

	Blue-Collar	
	employment share	*wage bill share*
	(1)	(2)
A. Biological Effluent Treatment	0.0544***	0.0476**
	(0.0203)	(0.024)
B. Environmental Management Techniques	0.0048	-0.0027
	(0.003)	(0.0036)
Interaction between: **A*B** (dummy)	-0.0699***	-0.0929***
	(0.0213)	(0.0252)
Basic Controls:		
Δ_3 log Value Added	0.007***	0.0105***
	(0.0017)	(0.002)
Δ_3 log Physical Capital Intensity	-0.002	-0.0063*
	(0.0028)	(0.0033)
Extended Controls:		
Size of the company	0.0027***	0.0045***
	(0.001)	(0.0012)
Export Intensity	-0.0286***	-0.0499***
	(0.0066)	(0.0078)
Foreign Capital Control	-0.0115***	-0.0167***
	(0.0038)	(0.0045)
Number of Observations	*9,956*	*9,956*
Industry Sector dummies:		
MinQuar.	-0.140	-0.3616
	(0.315)	(0.3733)
Food	-0.173	-0.4052
	(0.315)	(0.3731)
Beverage	-0.166	-0.3965
	(0.315)	(0.3732)
Tobacco	-0.184	-0.3694
	(0.315)	(0.3737)
Textile	-0.174	-0.4127
	(0.315)	(0.3731)
Leather	-0.182	-0.4168
	(0.315)	(0.3732)
Wood	-0.164	-0.3950
	(0.315)	(0.3733)
PulpPaper	-0.174	-0.4064
	(0.315)	(0.3732)
Print	-0.190	-0.4143
	(0.315)	(0.3735)

explanatory variables (cont.)	*Blue-Collar*	
	employment share	*wage bill*
	(1)	(2)
Petrol	-0.136	-0.3796
	(0.315)	(0.3733)
Chemical	-0.142	-0.3819
	(0.315)	(0.3732)
Pharmac.	-0.191	-0.4126
	(0.315)	(0.3733)
RubPlastic	-0.171	-0.4084
	(0.315)	(0.3732)
NonMet	-0.169	-0.4080
	(0.315)	(0.3732)
Metal	-0.168	-0.4033
	(0.315)	(0.3731)
CompElect	-0.165	-0.4134
	(0.315)	(0.3731)
MachEquip.	-0.152	-0.3876
	(0.315)	(0.3731)
VeichOth	-0.161	-0.3967
	(0.315)	(0.3731)
Furniture	-0.175	-0.4053
	(0.315)	(0.3732)
State dummies:		
AC	(omitted)	(omitted)
AL	-0.0388	-0.0684
	(0.0979)	(0.1160)
AM	-0.0610	-0.1079
	(0.0979)	(0.1160)
AP	-0.0159	-0.0599
	(0.127)	(0.1499)
BA	0.000680	-0.0394
	(0.0978)	(0.1159)
CE	0.00176	-0.0538
	(0.0978)	(0.1158)
ES	-0.0116	-0.0560
	(0.0981)	(0.1162)
GO	0.00359	-0.0374
	(0.0980)	(0.1161)

explanatory variables (cont.)	*Blue-Collar*	
	employment share	*wage bill share*
	(1)	(2)
MA	0.0296	-0.0476
	(0.101)	(0.1196)
MG	-0.00620	-0.0478
	(0.0975)	(0.1155)
MS	-0.0343	-0.0729
	(0.101)	(0.1201)
MT	-0.00327	-0.0943
	(0.0992)	(0.1175)
PA	0.0109	-0.0374
	(0.0981)	(0.1163)
PB	-0.0179	-0.0498
	(0.0992)	(0.1176)
PE	-0.0111	-0.0504
	(0.0978)	(0.1159)
PI	0.0270	-0.0078
	(0.102)	(0.1204)
PR	-0.0105	-0.0528
	(0.0975)	(0.1155)
RJ	-0.00570	-0.0576
	(0.0976)	(0.1156)
RN	-0.00650	-0.0164
	(0.0990)	(0.1173)
RO	0.1000	-0.0105
	(0.103)	(0.1221)
RR	-0.0274	-0.0743
	(0.101)	(0.1199)
RS	-0.0159	-0.0654
	(0.0975)	(0.1155)
SC	-0.00837	-0.0539
	(0.0975)	(0.1155)
SE	0.0476	-0.0020
	(0.101)	(0.1191)
SP	0.00458	-0.0421
	(0.0974)	(0.1154)
TO	-0.0108	0.0037
	(0.118)	(0.1397)
Constant	0.157	0.4377
	(0.330)	(0.3905)
R-squared	0.024	0.024

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

APPENDICES TO CHAPTER 4

Table A.4.1: Changes in Value added - Effects of Technical Environmental Innovation

Dependent Variable - Three year difference in Value Added

explanatory variables	Δ_3 log Value Added (1)	(2)	(3)	(4)
A. Environmental Innovation - at least one	0.0635***	0.0591***		
	(0.0124)	(0.0132)		
B. Environmental Innovation - all			0.0507**	0.0339
			(0.0201)	(0.0209)
Basic Controls:				
Δ_3 log White-collar employees	0.193***	0.194***	0.193***	0.194***
	(0.0088)	(0.0088)	(0.0088)	(0.0088)
Δ_3 log Blue-collar employees	0.437***	0.437***	0.438***	0.439***
	(0.0126)	(0.0126)	(0.0126)	(0.0126)
Δ_3 log Capital Stock	0.120***	0.123***	0.122***	0.125***
	(0.0134)	(0.0135)	(0.0134)	(0.0135)
Extended Controls:				
Size of the firm		0.0063		0.0110**
		(0.0045)		(0.0044)
Export Intensity		-0.140***		-0.141***
		(0.0283)		(0.0283)
Foreign Ownership		0.0254		0.0268
		(0.0166)		(0.0166)
Observations	*26,979*	*26,979*	*26,979*	*26,979*
Year dummies:				
year 2003	0.0351**	0.0377**	0.0307*	0.0326*
	(0.0177)	(0.0177)	(0.0177)	(0.0177)
year 2005	0.0959***	0.103***	0.0945***	0.100***
	(0.0173)	(0.0174)	(0.0174)	(0.0174)
year 2008	0.102***	0.106***	0.0979***	0.0999***
	(0.0170)	(0.0171)	(0.0169)	(0.0170)
Industry Sector dummies:				
MinQuar.	0.188	0.240	0.201	0.250
	(0.252)	(0.252)	(0.252)	(0.252)
Food	0.201	0.230	0.223	0.246
	(0.249)	(0.249)	(0.249)	(0.249)
Beverage	0.228	0.231	0.248	0.246
	(0.252)	(0.252)	(0.252)	(0.252)
Tobacco	0.342	0.390	0.369	0.408
	(0.258)	(0.258)	(0.258)	(0.258)
Textile	0.274	0.295	0.288	0.308
	(0.249)	(0.249)	(0.249)	(0.249)
Leather	0.253	0.298	0.271	0.312
	(0.250)	(0.250)	(0.250)	(0.250)
Wood	0.160	0.229	0.177	0.246
	(0.252)	(0.252)	(0.252)	(0.252)

explanatory var. (cont.)	Δ_3 log Value Added (1)	(2)	(3)	(4)
PulpPaper	0.205	0.231	0.227	0.251
	(0.251)	(0.251)	(0.251)	(0.251)
Print	0.152	0.167	0.166	0.180
	(0.251)	(0.251)	(0.251)	(0.251)
Petrol	0.0990	0.119	0.122	0.134
	(0.251)	(0.251)	(0.251)	(0.251)
Chemical	0.226	0.241	0.253	0.267
	(0.250)	(0.250)	(0.250)	(0.250)
Pharmac.	0.303	0.312	0.330	0.336
	(0.252)	(0.252)	(0.252)	(0.252)
RubPlastic	0.198	0.215	0.218	0.235
	(0.250)	(0.250)	(0.250)	(0.250)
NonMet	0.271	0.296	0.290	0.314
	(0.250)	(0.250)	(0.250)	(0.250)
Metal	0.210	0.241	0.232	0.261
	(0.249)	(0.249)	(0.249)	(0.249)
CompElect	0.230	0.248	0.256	0.270
	(0.250)	(0.249)	(0.250)	(0.249)
MachEquip.	0.263	0.285	0.284	0.306
	(0.249)	(0.249)	(0.250)	(0.249)
VeichOth	0.294	0.318	0.322	0.339
	(0.249)	(0.249)	(0.249)	(0.249)
Furniture	0.172	0.204	0.191	0.225
	(0.250)	(0.250)	(0.250)	(0.250)
State dummies:				
AC	0.733	0.728	0.721	0.724
	(0.480)	(0.479)	(0.480)	(0.480)
AL	0.0940	0.135	0.0867	0.125
	(0.127)	(0.127)	(0.127)	(0.127)
AM	0.0583	0.0529	0.0532	0.0469
	(0.126)	(0.126)	(0.126)	(0.126)
AP	0.184	0.246	0.192	0.256
	(0.393)	(0.393)	(0.394)	(0.394)
BA	0.0418	0.0529	0.0384	0.0492
	(0.125)	(0.125)	(0.125)	(0.125)
CE	0.0826	0.0846	0.0790	0.0797
	(0.123)	(0.123)	(0.123)	(0.123)
ES	0.0704	0.0868	0.0667	0.0846
	(0.130)	(0.130)	(0.130)	(0.130)
GO	-0.0045	-0.0027	-0.0089	-0.0042
	(0.128)	(0.128)	(0.128)	(0.128)

explanatory var. (cont.)	Δ_3 log Value Added (1)	(2)	(3)	(4)
MA	0.113	0.128	0.0979	0.118
	(0.166)	(0.166)	(0.166)	(0.166)
MG	0.151	0.155	0.149	0.152
	(0.119)	(0.119)	(0.119)	(0.119)
MS	0.237	0.248	0.223	0.240
	(0.167)	(0.167)	(0.167)	(0.167)
MT	-0.0219	-0.0201	-0.0353	-0.0284
	(0.148)	(0.148)	(0.148)	(0.148)
PA	0.110	0.137	0.105	0.134
	(0.134)	(0.134)	(0.134)	(0.134)
PB	-0.125	-0.112	-0.137	-0.120
	(0.142)	(0.142)	(0.142)	(0.142)
PE	0.136	0.145	0.125	0.134
	(0.124)	(0.124)	(0.124)	(0.124)
PI	0.175	0.185	0.168	0.181
	(0.165)	(0.165)	(0.165)	(0.165)
PR	0.0919	0.0959	0.0872	0.0921
	(0.120)	(0.120)	(0.120)	(0.120)
RJ	0.153	0.151	0.148	0.144
	(0.120)	(0.120)	(0.120)	(0.120)
RN	0.181	0.179	0.179	0.174
	(0.143)	(0.143)	(0.143)	(0.143)
RO	-0.0364	-0.0228	-0.0473	-0.0283
	(0.184)	(0.184)	(0.184)	(0.184)
RR	0.578	0.594	0.622	0.643
	(1.641)	(1.641)	(1.642)	(1.641)
RS	0.0619	0.0788	0.0607	0.0786
	(0.119)	(0.119)	(0.119)	(0.119)
SC	0.131	0.147	0.137	0.150
	(0.120)	(0.120)	(0.120)	(0.120)
SE	0.0380	0.0352	0.0396	0.0380
	(0.163)	(0.163)	(0.163)	(0.163)
SP	0.0899	0.0915	0.0858	0.0863
	(0.118)	(0.118)	(0.118)	(0.118)
TO	-0.0265	-0.0303	-0.0375	-0.0331
	(0.252)	(0.252)	(0.253)	(0.253)
Constant	-0.473*	-0.532*	-0.466*	-0.550**
	(0.275)	(0.276)	(0.275)	(0.276)
R-squared	0.078	0.079	0.077	0.078

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table A.4.2: Changes in Value Added - Effects of Technical and Organizational Environmental Innovations
Dependent Variable - Three year difference in Value Added

explanatory variables	Δ_3 log (1)	(2)	(3)	(4)
A. Environmental Innovation - at least one	0.0413***	0.0425**		
	(0.0136)	(0.0181)		
B. Environmental Innovation - all			0.0499**	0.0988*
			(0.0224)	(0.0529)
C. Environmental Management Techniques	0.0262*	0.0274	0.0318**	0.0347**
	(0.0139)	(0.0183)	(0.0137)	(0.0140)
Interaction between: **A*C**		-0.0027		
		(0.0261)		
Interaction between: **B*C**				-0.0593
				(0.0580)
Basic Controls:				
Δ_3 log White-collar employees	0.183***	0.183***	0.183***	0.183***
	(0.0087)	(0.0087)	(0.0087)	(0.0087)
Δ_3 log Blue-collar employees	0.449***	0.449***	0.451***	0.450***
	(0.0126)	(0.0126)	(0.0126)	(0.0126)
Δ_3 log Capital Stock	0.113***	0.113***	0.114***	0.114***
	(0.0132)	(0.0132)	(0.0132)	(0.0132)
Extended Controls:				
Size of the firm	-0.0052	-0.0051	-0.0040	-0.0039
	(0.0045)	(0.0045)	(0.0045)	(0.0045)
Export Intensity	-0.205***	-0.205***	-0.202***	-0.203***
	(0.0278)	(0.0278)	(0.0279)	(0.0279)
Foreign Ownership	0.0188	0.0188	0.0173	0.0175
	(0.0166)	(0.0166)	(0.0167)	(0.0167)
Observations	*20,823*	*20,823*	*20,823*	*20,823*
Year dummies:				
year 2005	0.0686***	0.0685***	0.0703***	0.0695***
	(0.0151)	(0.0151)	(0.0151)	(0.0151)
year 2008	0.0722***	0.0721***	0.0705***	0.0695***
	(0.0149)	(0.0149)	(0.0149)	(0.0149)
Industry Sector dummies:				
MinQuar.	0.176	0.175	0.183	0.182
	(0.258)	(0.258)	(0.258)	(0.258)
Food	0.241	0.241	0.251	0.250
	(0.254)	(0.254)	(0.254)	(0.254)
Beverage	0.225	0.225	0.233	0.233
	(0.257)	(0.257)	(0.257)	(0.257)
Tobacco	0.322	0.322	0.328	0.324
	(0.264)	(0.264)	(0.264)	(0.264)
Textile	0.242	0.242	0.251	0.250
	(0.255)	(0.255)	(0.255)	(0.255)
Leather	0.249	0.249	0.256	0.256
	(0.255)	(0.255)	(0.255)	(0.255)

explanatory var. (cont.)	Δ_3 log (1)	(2)	(3)	(4)
Wood	0.152	0.152	0.161	0.161
	(0.257)	(0.257)	(0.257)	(0.257)
PulpPaper	0.254	0.253	0.265	0.264
	(0.256)	(0.256)	(0.256)	(0.256)
Print	0.307	0.307	0.316	0.315
	(0.257)	(0.257)	(0.257)	(0.257)
Petrol	0.0442	0.0440	0.0425	0.0447
	(0.257)	(0.257)	(0.257)	(0.257)
Chemical	0.200	0.200	0.215	0.214
	(0.255)	(0.255)	(0.255)	(0.255)
Pharmac.	0.287	0.287	0.302	0.300
	(0.258)	(0.258)	(0.258)	(0.258)
RubPlastic	0.195	0.195	0.207	0.206
	(0.255)	(0.255)	(0.255)	(0.255)
NonMet	0.264	0.264	0.275	0.274
	(0.256)	(0.256)	(0.256)	(0.256)
Metal	0.198	0.198	0.210	0.209
	(0.255)	(0.255)	(0.255)	(0.255)
CompElect	0.201	0.201	0.215	0.213
	(0.255)	(0.255)	(0.255)	(0.255)
MachEquip.	0.274	0.274	0.284	0.284
	(0.255)	(0.255)	(0.255)	(0.255)
VeichOth	0.290	0.289	0.300	0.301
	(0.255)	(0.255)	(0.255)	(0.255)
Furniture	0.140	0.140	0.152	0.151
	(0.256)	(0.256)	(0.256)	(0.256)
State dummies:				
AC	0.502	0.502	0.493	0.494
	(0.471)	(0.471)	(0.471)	(0.471)
AL	-0.0603	-0.0601	-0.0743	-0.0737
	(0.131)	(0.131)	(0.131)	(0.131)
AM	-0.185	-0.185	-0.197	-0.196
	(0.130)	(0.130)	(0.130)	(0.130)
AP	0.130	0.130	0.127	0.128
	(0.378)	(0.378)	(0.378)	(0.378)
BA	-0.170	-0.170	-0.178	-0.177
	(0.130)	(0.130)	(0.130)	(0.130)
CE	-0.151	-0.151	-0.167	-0.166
	(0.127)	(0.127)	(0.128)	(0.128)
ES	-0.211	-0.211	-0.221*	-0.221*
	(0.134)	(0.134)	(0.134)	(0.134)
GO	-0.244*	-0.244*	-0.253*	-0.252*
	(0.133)	(0.133)	(0.133)	(0.133)

explanatory var. (cont.)	Δ_3 log Value Added (1)	(2)	(3)	(4)
MA	-0.208	-0.208	-0.219	-0.218
	(0.173)	(0.173)	(0.173)	(0.173)
MG	-0.0656	-0.0655	-0.0738	-0.0735
	(0.124)	(0.124)	(0.124)	(0.124)
MS	-0.0807	-0.0806	-0.0912	-0.0911
	(0.172)	(0.172)	(0.172)	(0.172)
MT	-0.204	-0.204	-0.215	-0.214
	(0.151)	(0.151)	(0.151)	(0.151)
PA	-0.100	-0.0999	-0.109	-0.107
	(0.137)	(0.137)	(0.137)	(0.137)
PB	-0.279*	-0.278*	-0.290**	-0.289**
	(0.147)	(0.147)	(0.147)	(0.147)
PE	-0.0347	-0.0347	-0.0470	-0.0460
	(0.129)	(0.129)	(0.129)	(0.129)
PI	-0.0929	-0.0927	-0.105	-0.105
	(0.174)	(0.174)	(0.174)	(0.174)
PR	-0.0950	-0.0949	-0.104	-0.104
	(0.125)	(0.125)	(0.125)	(0.125)
RJ	-0.0652	-0.0650	-0.0780	-0.0766
	(0.125)	(0.125)	(0.125)	(0.125)
RN	-0.0552	-0.0552	-0.0604	-0.0590
	(0.149)	(0.149)	(0.149)	(0.149)
RO	-0.258	-0.258	-0.269	-0.268
	(0.183)	(0.183)	(0.183)	(0.183)
RR	0.193	0.192	0.218	0.219
	(1.439)	(1.440)	(1.440)	(1.440)
RS	-0.149	-0.149	-0.157	-0.157
	(0.124)	(0.124)	(0.124)	(0.124)
SC	-0.0869	-0.0866	-0.0936	-0.0927
	(0.124)	(0.124)	(0.124)	(0.124)
SE	-0.172	-0.172	-0.176	-0.176
	(0.167)	(0.167)	(0.167)	(0.167)
SP	-0.120	-0.120	-0.130	-0.130
	(0.123)	(0.123)	(0.123)	(0.123)
TO	0.342	0.342	0.334	0.335
	(0.240)	(0.240)	(0.240)	(0.240)
Constant	-0.166	-0.166	-0.164	-0.165
	(0.283)	(0.283)	(0.283)	(0.283)
R-squared	0.102	0.102	0.102	0.102

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table A.4.3: Changes in Value Added: Cross Section - PINTEC 2008

Dependent Variable: (2008-2006) Change in value added:

explanatory variables	Δ_3 log Value Added (1)	(2)	(3)	(4)
E. Environ. Impact AND/OR Biological Effluent Treatment	0.0354**	0.0404**	0.0323*	0.0695**
	(0.0166)	(0.0179)	(0.0188)	(0.0298)
C. Environmental Management Techniques			0.0256	0.0451**
			(0.0180)	(0.0216)
Interaction between: **E * C**				-0.0600
				(0.0372)
Basic Controls:				
Δ_3 log White-collar employees	0.172***	0.173***	0.172***	0.172***
	(0.0114)	(0.0114)	(0.0114)	(0.0114)
Δ_3 log Blue-collar employees	0.455***	0.451***	0.451***	0.450***
	(0.0158)	(0.0159)	(0.0159)	(0.0159)
Δ_3 log Capital Stock	0.100***	0.104***	0.103***	0.104***
	(0.0174)	(0.0174)	(0.0174)	(0.0174)
Extended Controls:				
Size of the firm		0.0003	-0.0013	-0.0003
		(0.0058)	(0.0059)	(0.0059)
Export Intensity		-0.156***	-0.156***	-0.157***
		(0.0376)	(0.0376)	(0.0376)
Foreign Capital Control		0.0246	0.0242	0.0229
		(0.0216)	(0.0216)	(0.0216)
Observations	*8,542*	*8,542*	*8,542*	*8,542*
Industry Sector dummies:				
MinQuar.	-0.169	-0.178	-0.181	-0.183
	(0.118)	(0.119)	(0.119)	(0.119)
Food	-0.100	-0.129	-0.136	-0.138
	(0.103)	(0.105)	(0.105)	(0.105)
Beverage	0.0236	-0.0494	-0.0583	-0.0574
	(0.114)	(0.116)	(0.116)	(0.116)
Tobacco				
Textile	-0.0422	-0.0948	-0.100	-0.101
	(0.105)	(0.107)	(0.108)	(0.108)
Leather	-0.0465	-0.0741	-0.0814	-0.0788
	(0.107)	(0.108)	(0.108)	(0.108)
Wood	-0.132	-0.128	-0.135	-0.135
	(0.114)	(0.115)	(0.116)	(0.116)
PulpPaper	-0.0307	-0.0757	-0.0841	-0.0847
	(0.110)	(0.112)	(0.112)	(0.112)

explanatory var. (cont.)	Δ_3 log Value Added (1)	(2)	(3)	(4)
Print	-0.311***	-0.340***	-0.349***	-0.351***
	(0.111)	(0.114)	(0.114)	(0.114)
Petrol	0.0167	-0.0433	-0.0523	-0.0517
	(0.108)	(0.110)	(0.110)	(0.110)
Chemical	-0.0974	-0.159	-0.168	-0.168
	(0.118)	(0.119)	(0.119)	(0.119)
Pharmac.	0.0515	-0.00785	-0.0138	-0.0152
	(0.107)	(0.109)	(0.109)	(0.109)
RubPlastic	0.0253	-0.0223	-0.0299	-0.0304
	(0.109)	(0.111)	(0.111)	(0.111)
NonMet	-0.0147	-0.0560	-0.0648	-0.0661
	(0.105)	(0.107)	(0.107)	(0.107)
Metal	-0.00242	-0.0554	-0.0617	-0.0627
	(0.106)	(0.108)	(0.108)	(0.108)
CompElect	0.0576	0.00879	0.00143	0.00104
	(0.106)	(0.107)	(0.107)	(0.107)
MachEquip.	0.0854	0.0460	0.0389	0.0389
	(0.105)	(0.106)	(0.106)	(0.106)
VeichOth	-0.0627	-0.104	-0.110	-0.110
	(0.110)	(0.112)	(0.112)	(0.112)
Furniture	-0.343	-0.277	-0.264	-0.257
	(0.789)	(0.788)	(0.788)	(0.788)
State dummies:				
AC	-0.638	-0.644	-0.639	-0.636
	(0.789)	(0.788)	(0.788)	(0.788)
AL	-1.043	-1.008	-0.988	-0.994
	(0.944)	(0.943)	(0.943)	(0.943)
AM	-0.557	-0.541	-0.536	-0.528
	(0.789)	(0.788)	(0.788)	(0.788)
AP	-0.476	-0.472	-0.466	-0.462
	(0.788)	(0.788)	(0.788)	(0.787)
BA	-0.570	-0.556	-0.549	-0.549
	(0.790)	(0.789)	(0.789)	(0.789)
CE	-0.597	-0.599	-0.593	-0.590
	(0.789)	(0.789)	(0.789)	(0.788)
ES	-0.658	-0.644	-0.630	-0.623
	(0.801)	(0.800)	(0.800)	(0.800)
GO	-0.460	-0.457	-0.452	-0.447
	(0.787)	(0.786)	(0.786)	(0.786)

explanatory var. (cont.)	Δ_3 log Value Added (1)	(2)	(3)	(4)
MA	-0.653	-0.629	-0.620	-0.613
	(0.806)	(0.805)	(0.805)	(0.805)
MG	-0.590	-0.587	-0.581	-0.577
	(0.795)	(0.794)	(0.794)	(0.794)
MS	-0.440	-0.413	-0.404	-0.398
	(0.791)	(0.790)	(0.790)	(0.790)
MT	-0.596	-0.589	-0.581	-0.573
	(0.794)	(0.794)	(0.794)	(0.793)
PA	-0.349	-0.344	-0.339	-0.337
	(0.788)	(0.788)	(0.788)	(0.788)
PB	-0.359	-0.363	-0.362	-0.360
	(0.805)	(0.804)	(0.804)	(0.804)
PE	-0.416	-0.412	-0.405	-0.401
	(0.787)	(0.787)	(0.787)	(0.787)
PI	-0.417	-0.410	-0.403	-0.397
	(0.787)	(0.787)	(0.787)	(0.787)
PR	-0.181	-0.175	-0.161	-0.155
	(0.793)	(0.793)	(0.793)	(0.793)
RJ	-0.524	-0.485	-0.482	-0.481
	(0.811)	(0.810)	(0.810)	(0.810)
RN	-0.286	-0.282	-0.273	-0.268
	(0.803)	(0.802)	(0.802)	(0.802)
RO	-0.453	-0.434	-0.429	-0.426
	(0.787)	(0.786)	(0.786)	(0.786)
RR	-0.428	-0.406	-0.400	-0.394
	(0.787)	(0.787)	(0.786)	(0.786)
RS	-0.249	-0.257	-0.248	-0.240
	(0.800)	(0.799)	(0.799)	(0.799)
SC	-0.466	-0.460	-0.453	-0.449
	(0.787)	(0.786)	(0.786)	(0.786)
SE	-0.458	-0.477	-0.468	-0.456
	(0.868)	(0.867)	(0.867)	(0.867)
SP	-0.0272	-0.0886	-0.0962	-0.0942
	(0.136)	(0.138)	(0.138)	(0.138)
TO	0.465	0.515	0.516	0.500
	(0.793)	(0.793)	(0.793)	(0.793)
R-squared	0.148	0.150	0.150	0.150

Table A.4.4: Effects of Pollution Abatement Investment and Organizational Environmental Innovation

Dependent Variable - First difference in Value Added

explanatory variables	Δ log Value Added			
	(1)	(2)	(3)	(4)
F. Pollution Abatement Investment (%)	0.0891**	0.0819**	0.0592	0.0424
	(0.0370)	(0.0371)	(0.0374)	(0.0511)
C. Environ. Management Techniques			0.0310**	0.0287*
			(0.0144)	(0.0151)
Interaction between: **F*C**				0.0359
				(0.0747)
Basic Controls:				
Δ log White-collar employees	0.157***	0.157***	0.132***	0.132***
	(0.0105)	(0.0105)	(0.0113)	(0.0113)
Δ log Blue-collar employees	0.401***	0.403***	0.414***	0.414***
	(0.0155)	(0.0155)	(0.0160)	(0.0160)
Δ log Capital Stock	0.0818***	0.0824***	0.0831***	0.0830***
	(0.0177)	(0.0177)	(0.0180)	(0.0180)
Extended Controls:				
Size of the firm		0.0157***	0.0099**	0.0098**
		(0.0043)	(0.0047)	(0.0047)
Export Intensity		-0.0940***	-0.126***	-0.126***
		(0.0291)	(0.0303)	(0.0304)
Foreign Ownership		0.0059	0.0029	0.0030
		(0.0168)	(0.0177)	(0.0177)
Observations	*20,875*	*20,875*	*14,791*	*14,791*
Year dummies:				
year 2002	0.0615***	0.0644***		
	(0.0157)	(0.0158)		
year 2007	0.0149	0.0133	-0.0552***	-0.0551***
	(0.0150)	(0.0150)	(0.0131)	(0.0131)
Industry Sector dummies:				
MinQuar.	-0.145	-0.132	-0.137	-0.140
	(0.338)	(0.338)	(0.323)	(0.323)
Food	-0.00188	-0.0110	0.0530	0.0500
	(0.336)	(0.336)	(0.320)	(0.320)
Beverage	-0.0499	-0.0723	-0.0769	-0.0801
	(0.338)	(0.338)	(0.323)	(0.323)
Tobacco	0.0575	0.0604	0.120	0.117
	(0.343)	(0.343)	(0.329)	(0.329)
Textile	-0.0216	-0.0233	-0.0427	-0.0459
	(0.336)	(0.336)	(0.320)	(0.320)
Leather	-0.122	-0.121	-0.132	-0.135
	(0.337)	(0.337)	(0.321)	(0.321)
Wood	-0.166	-0.132	-0.102	-0.106
	(0.338)	(0.338)	(0.323)	(0.323)

explanatory var. (cont.)	Δ log Value Added			
	(1)	(2)	(3)	(4)
PulpPaper	-0.00543	-0.00469	0.00386	0.00019
	(0.337)	(0.337)	(0.322)	(0.322)
Print	0.0418	0.0360	0.0814	0.0780
	(0.338)	(0.338)	(0.323)	(0.323)
Petrol	0.0471	0.0187	0.0490	0.0459
	(0.337)	(0.337)	(0.322)	(0.322)
Chemical	-0.0811	-0.0844	-0.0596	-0.0627
	(0.337)	(0.336)	(0.321)	(0.321)
Pharmac.	-0.0602	-0.0691	-0.0480	-0.0511
	(0.338)	(0.338)	(0.323)	(0.323)
RubPlastic	-0.102	-0.101	-0.0580	-0.0616
	(0.337)	(0.336)	(0.321)	(0.321)
NonMet	-0.0468	-0.0409	-0.0391	-0.0425
	(0.337)	(0.337)	(0.321)	(0.321)
Metal	-0.0571	-0.0545	-0.0289	-0.0327
	(0.336)	(0.336)	(0.320)	(0.320)
CompElect	-0.0506	-0.0562	-0.0226	-0.0261
	(0.336)	(0.336)	(0.321)	(0.321)
MachEquip.	-0.0131	-0.0154	0.0275	0.0242
	(0.336)	(0.336)	(0.320)	(0.321)
VeichOth	-0.0164	-0.0314	-0.0231	-0.0267
	(0.336)	(0.336)	(0.320)	(0.320)
Furniture	-0.180	-0.169	-0.109	-0.113
	(0.337)	(0.337)	(0.321)	(0.321)
State dummies:				
AC	0.348	0.377	0.239	0.240
	(0.401)	(0.401)	(0.464)	(0.464)
AL	-0.298**	-0.288**	-0.225*	-0.225*
	(0.123)	(0.123)	(0.134)	(0.134)
AM	-0.310**	-0.319***	-0.377***	-0.377***
	(0.123)	(0.123)	(0.134)	(0.134)
AP	-0.408	-0.361	-0.533	-0.529
	(0.409)	(0.409)	(0.406)	(0.406)
BA	-0.323***	-0.318***	-0.339**	-0.339**
	(0.122)	(0.122)	(0.133)	(0.133)
CE	-0.291**	-0.300**	-0.341***	-0.340***
	(0.120)	(0.120)	(0.131)	(0.131)
ES	-0.290**	-0.277**	-0.369***	-0.369***
	(0.127)	(0.127)	(0.137)	(0.137)
GO	-0.347***	-0.343***	-0.453***	-0.453***
	(0.124)	(0.124)	(0.135)	(0.135)

explanatory var. (cont.)	Δ log Value Added			
	(1)	(2)	(3)	(4)
MA	-0.153	-0.135	-0.0715	-0.0715
	(0.160)	(0.160)	(0.175)	(0.175)
MG	-0.338***	-0.337***	-0.368***	-0.369***
	(0.115)	(0.115)	(0.127)	(0.127)
MS	-0.455***	-0.435***	-0.353*	-0.353*
	(0.166)	(0.166)	(0.183)	(0.183)
MT	-0.133	-0.123	-0.339**	-0.339**
	(0.143)	(0.143)	(0.159)	(0.159)
PA	-0.278**	-0.257**	-0.322**	-0.321**
	(0.131)	(0.131)	(0.141)	(0.141)
PB	-0.422***	-0.407***	-0.209	-0.209
	(0.139)	(0.139)	(0.154)	(0.154)
PE	-0.162	-0.157	-0.175	-0.176
	(0.120)	(0.120)	(0.132)	(0.132)
PI	-0.164	-0.154	-0.327*	-0.326*
	(0.159)	(0.159)	(0.184)	(0.184)
PR	-0.207*	-0.204*	-0.221*	-0.221*
	(0.116)	(0.116)	(0.127)	(0.127)
RJ	-0.241**	-0.253**	-0.286**	-0.287**
	(0.116)	(0.116)	(0.127)	(0.127)
RN	-0.141	-0.154	-0.312**	-0.313**
	(0.139)	(0.139)	(0.151)	(0.151)
RO	-0.204	-0.189	-0.341*	-0.341*
	(0.199)	(0.199)	(0.204)	(0.204)
RR	-1.075	-0.971	-1.020	-1.021
	(3.161)	(3.160)	(2.787)	(2.787)
RS	-0.319***	-0.307***	-0.353***	-0.354***
	(0.115)	(0.115)	(0.127)	(0.127)
SC	-0.299***	-0.300***	-0.358***	-0.358***
	(0.116)	(0.116)	(0.127)	(0.127)
SE	-0.303*	-0.302*	-0.213	-0.213
	(0.161)	(0.161)	(0.173)	(0.173)
SP	-0.276**	-0.278**	-0.316**	-0.316**
	(0.114)	(0.114)	(0.125)	(0.125)
TO	-0.146	-0.131	-0.248	-0.250
	(0.289)	(0.289)	(0.284)	(0.284)
Constant	0.301	0.214	0.324	0.329
	(0.354)	(0.355)	(0.344)	(0.344)
R-squared	0.048	0.049	0.063	0.063

Table A.4.5: Changes in Value added - Effects of Technical EI - Complete

Dependent Variable - Three year difference in Value Added				
	Δ_3 log Value Added			
VARIABLES	OLS	OLS	OLS	OLS
A. Environmental Innovation - at least one	0.0579***	0.0531***		
	(0.0125)	(0.0132)		
B. Environmental Innovation - all			0.0557***	0.0411**
			(0.0201)	(0.0209)
Δ_3 log White-collar employees	0.191***	0.193***	0.197***	0.202***
	(0.0675)	(0.0677)	(0.0675)	(0.0677)
Δ_3 log Blue-collar employees	0.545***	0.544***	0.541***	0.548***
	(0.0793)	(0.0801)	(0.0794)	(0.0801)
Δ_3 log Capital Stock	0.123*	0.117*	0.0940	0.107
	(0.0625)	(0.0657)	(0.0621)	(0.0657)
Size of the firm		0.00712		0.0105**
		(0.00479)		(0.00472)
Export Intensity		-0.136***		-0.137***
		(0.0283)		(0.0283)
Foreign Ownership		0.0173		0.0179
		(0.0166)		(0.0167)
(Δ_3 log Capital Stock)^2	0.000233	0.000482	0.00110	0.000929
	(0.00272)	(0.00275)	(0.00271)	(0.00275)
(Δ_3 log White-collar employees)^2	0.0209***	0.0210***	0.0209***	0.0211***
	(0.00420)	(0.00420)	(0.00420)	(0.00420)
(Δ_3 log Blue-collar employees)^2	0.0532***	0.0527***	0.0530***	0.0530***
	(0.00576)	(0.00579)	(0.00576)	(0.00579)
(Δ_3 log White-collar employees)*(Δ_3 log Blue-collar employees)	-0.0910***	-0.0906***	-0.0926***	-0.0918***
	(0.00717)	(0.00717)	(0.00717)	(0.00718)
(Δ_3 log Capital Stock)*(Δ_3 log White-collar employees)	0.0201***	0.0199***	0.0203***	0.0197***
	(0.00541)	(0.00543)	(0.00542)	(0.00543)
(Δ_3 log Capital Stock)*(Δ_3 log Blue-collar employees)	-0.0164**	-0.0161**	-0.0156**	-0.0162**
	(0.00644)	(0.00652)	(0.00644)	(0.00653)

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table A.4.5: Changes in Value added - Effects of Technical EI - Complete *(cont.)*

Dependent Variable - Three year difference in Value Added

VARIABLES	Δ_3 log Value Added (1)	(2)	(3)	(4)
year 2003	0.0323*	0.0347**	0.0291*	0.0310*
	(0.0177)	(0.0177)	(0.0177)	(0.0177)
year 2005	0.0916***	0.0979***	0.0911***	0.0965***
	(0.0173)	(0.0174)	(0.0173)	(0.0174)
year 2008	0.0996***	0.103***	0.0955***	0.0977***
	(0.0169)	(0.0170)	(0.0169)	(0.0170)
MinQuar.	0.139	0.186	0.149	0.195
	(0.251)	(0.252)	(0.251)	(0.252)
Food	0.144	0.169	0.161	0.182
	(0.248)	(0.248)	(0.248)	(0.248)
Beverage	0.182	0.181	0.197	0.194
	(0.251)	(0.251)	(0.251)	(0.251)
Tobacco	0.299	0.347	0.320	0.362
	(0.257)	(0.257)	(0.257)	(0.257)
Textile	0.228	0.245	0.239	0.256
	(0.248)	(0.248)	(0.248)	(0.248)
Leather	0.205	0.244	0.219	0.255
	(0.249)	(0.249)	(0.249)	(0.249)
Wood	0.119	0.183	0.133	0.197
	(0.251)	(0.251)	(0.251)	(0.251)
PulpPaper	0.151	0.173	0.168	0.190
	(0.250)	(0.250)	(0.250)	(0.250)
Print	0.106	0.116	0.117	0.127
	(0.251)	(0.251)	(0.251)	(0.251)
Petrol	0.0553	0.0685	0.0692	0.0790
	(0.250)	(0.250)	(0.250)	(0.250)
Chemical	0.172	0.186	0.194	0.208
	(0.249)	(0.249)	(0.249)	(0.249)
Pharmac.	0.253	0.260	0.275	0.281
	(0.251)	(0.251)	(0.251)	(0.251)
RubPlastic	0.148	0.162	0.164	0.179
	(0.249)	(0.249)	(0.249)	(0.249)
NonMet	0.224	0.244	0.238	0.260
.	(0.249)	(0.249)	(0.249)	(0.249)
Metal	0.156	0.183	0.174	0.200
	(0.248)	(0.248)	(0.248)	(0.248)
CompElect	0.176	0.192	0.197	0.211
	(0.249)	(0.249)	(0.249)	(0.249)
MachEquip.	0.212	0.233	0.229	0.249
	(0.249)	(0.249)	(0.249)	(0.249)
VeichOth	0.244	0.266	0.266	0.284
	(0.249)	(0.248)	(0.249)	(0.249)
Furniture	0.116	0.145	0.132	0.162
	(0.249)	(0.250)	(0.250)	(0.250)
AC	0.852*	0.848*	0.845*	0.847*
	(0.478)	(0.478)	(0.478)	(0.478)
AL	0.112	0.150	0.104	0.141
	(0.126)	(0.127)	(0.126)	(0.127)
AM	0.0517	0.0478	0.0451	0.0416
	(0.126)	(0.126)	(0.126)	(0.126)

VARIABLES (cont)	Δ_3 log Value Added (1)	(2)	(3)	(4)
AP	0.226	0.287	0.231	0.293
	(0.392)	(0.392)	(0.392)	(0.392)
BA	0.0543	0.0658	0.0509	0.0626
	(0.125)	(0.125)	(0.125)	(0.125)
CE	0.0912	0.0926	0.0850	0.0866
	(0.123)	(0.123)	(0.123)	(0.123)
ES	0.0662	0.0832	0.0621	0.0805
	(0.130)	(0.130)	(0.130)	(0.130)
GO	-0.00779	-0.00545	-0.0113	-0.00699
	(0.128)	(0.128)	(0.128)	(0.128)
MA	0.128	0.143	0.115	0.134
	(0.166)	(0.166)	(0.166)	(0.166)
MG	0.148	0.152	0.145	0.150
	(0.119)	(0.119)	(0.119)	(0.119)
MS	0.236	0.249	0.224	0.241
	(0.166)	(0.166)	(0.166)	(0.166)
MT	-0.00231	0.000654	-0.0142	-0.00732
	(0.147)	(0.147)	(0.147)	(0.147)
PA	0.0961	0.123	0.0903	0.120
	(0.133)	(0.133)	(0.133)	(0.134)
PB	-0.120	-0.106	-0.131	-0.113
	(0.142)	(0.142)	(0.142)	(0.142)
PE	0.124	0.133	0.113	0.123
	(0.124)	(0.124)	(0.124)	(0.124)
PI	0.174	0.186	0.170	0.183
	(0.164)	(0.164)	(0.164)	(0.164)
PR	0.0879	0.0929	0.0828	0.0889
	(0.120)	(0.120)	(0.120)	(0.120)
RJ	0.148	0.146	0.141	0.139
	(0.119)	(0.119)	(0.119)	(0.119)
RN	0.170	0.168	0.168	0.164
	(0.143)	(0.143)	(0.143)	(0.143)
RO	-0.0175	-0.00294	-0.0271	-0.00865
	(0.183)	(0.183)	(0.183)	(0.183)
RR	0.418	0.437	0.457	0.479
	(1.636)	(1.635)	(1.636)	(1.635)
RS	0.0552	0.0721	0.0533	0.0713
	(0.119)	(0.119)	(0.119)	(0.119)
SC	0.129	0.144	0.132	0.146
	(0.119)	(0.119)	(0.119)	(0.119)
SE	0.0311	0.0289	0.0324	0.0313
	(0.162)	(0.162)	(0.162)	(0.162)
SP	0.0816	0.0845	0.0764	0.0793
	(0.117)	(0.117)	(0.117)	(0.117)
TO	0.0182	0.0162	0.0111	0.0146
	(0.252)	(0.252)	(0.252)	(0.252)
Constant	-0.410	-0.469*	-0.401	-0.481*
	(0.274)	(0.275)	(0.274)	(0.275)
Observation	*26,979*	*26,979*	*26,979*	*26,979*
R-squared	0.085	0.086	0.084	0.085

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table A.4.6: Changes in Value Added - Effects of Technical and Organizational EI - Complete

Dependent Variable - Three year difference in Value Added				
	Δ_3 log Value Added			
VARIABLES	(1)	(2)	(3)	(4)
A. Environmental Innovation - at least one	0.0388***	0.0392**		
	(0.0135)	(0.0181)		
B. Environmental Innovation - all			0.0621***	0.0948*
			(0.0225)	(0.0527)
C. Environmental Management Tecniques	0.0243	0.0245	0.0339*	0.0381**
	(0.0178)	(0.0224)	(0.0175)	(0.0178)
Interaction between: **A*C**		-0.000643		
		(0.0348)		
Interaction between: **B*C**				-0.109
				(0.0863)
Δ_3 log White-collar employees	0.197***	0.197***	0.204***	0.204***
	(0.0662)	(0.0662)	(0.0662)	(0.0662)
Δ_3 log Blue-collar employees	0.390***	0.390***	0.388***	0.389***
	(0.0761)	(0.0762)	(0.0762)	(0.0762)
Δ_3 log Capital Stock	0.0366	0.0367	0.0252	0.0265
	(0.0626)	(0.0626)	(0.0627)	(0.0628)
Size of the firm	-0.00765	-0.00764	-0.00742	-0.00728
	(0.00484)	(0.00485)	(0.00483)	(0.00483)
Export Intensity	-0.205***	-0.205***	-0.201***	-0.202***
	(0.0278)	(0.0278)	(0.0279)	(0.0279)
Foreign Ownership	0.0145	0.0145	0.0125	0.0126
	(0.0166)	(0.0166)	(0.0167)	(0.0167)
(Δ_3 log Capital Stock)^2	0.00111	0.00111	0.00151	0.00147
	(0.00262)	(0.00262)	(0.00262)	(0.00262)
(Δ_3 log White-collar employees)^2	0.0230***	0.0230***	0.0230***	0.0230***
	(0.00417)	(0.00417)	(0.00417)	(0.00417)
(Δ_3 log Blue-collar employees)^2	0.0466***	0.0466***	0.0467***	0.0467***
	(0.00566)	(0.00566)	(0.00566)	(0.00566)
(Δ_3 log White-collar employees)*(Δ_3 log Blue-collar	-0.0847***	-0.0847***	-0.0857***	-0.0856***
	(0.00711)	(0.00711)	(0.00711)	(0.00711)
(Δ_3 log Capital Stock)*(Δ_3 log White-collar employees)	0.0163***	0.0163***	0.0161***	0.0162***
	(0.00534)	(0.00535)	(0.00534)	(0.00535)
(Δ_3 log Capital Stock)*(Δ_3 log Blue-collar employees)	-0.00438	-0.00438	-0.00407	-0.00413
	(0.00620)	(0.00620)	(0.00621)	(0.00621)

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table A.4.6: Changes in Value Added - Effects of Technical and Organizational EI - Complete (cont.)

Dependent Variable - Three year difference in Value Added

	Δ_3 log Value Added					Δ_3 log Value Added			
VARIABLES	(1)	(2)	(3)	(4)	VARIABLES *(cont.)*	(1)	(2)	(3)	(4)
year 2005	0.0668***	0.0668***	0.0684***	0.0679***	AM	-0.196	-0.196	-0.208	-0.207
	(0.0151)	(0.0151)	(0.0151)	(0.0151)		(0.130)	(0.130)	(0.130)	(0.130)
year 2008	0.0710***	0.0710***	0.0694***	0.0687***	AP	0.172	0.172	0.169	0.169
	(0.0148)	(0.0148)	(0.0148)	(0.0148)		(0.376)	(0.376)	(0.376)	(0.376)
MinQuar.	0.125	0.125	0.133	0.132	BA	-0.171	-0.171	-0.179	-0.178
	(0.257)	(0.257)	(0.257)	(0.257)		(0.129)	(0.129)	(0.129)	(0.129)
Food	0.189	0.189	0.198	0.197	CE	-0.145	-0.145	-0.163	-0.163
	(0.254)	(0.254)	(0.254)	(0.254)		(0.127)	(0.127)	(0.127)	(0.127)
Beverage	0.190	0.190	0.197	0.197	ES	-0.215	-0.215	-0.227*	-0.226*
	(0.256)	(0.256)	(0.256)	(0.256)		(0.133)	(0.133)	(0.133)	(0.133)
Tobacco	0.287	0.287	0.292	0.289	GO	-0.248*	-0.247*	-0.256*	-0.256*
	(0.263)	(0.263)	(0.263)	(0.263)		(0.132)	(0.132)	(0.132)	(0.132)
Textile	0.204	0.204	0.212	0.211	MA	-0.204	-0.204	-0.215	-0.215
	(0.254)	(0.254)	(0.254)	(0.254)		(0.172)	(0.172)	(0.172)	(0.172)
Leather	0.209	0.208	0.214	0.214	MG	-0.0695	-0.0694	-0.0777	-0.0775
	(0.255)	(0.255)	(0.255)	(0.255)		(0.124)	(0.124)	(0.124)	(0.124)
Wood	0.119	0.119	0.127	0.127	MS	-0.0882	-0.0882	-0.0996	-0.0995
	(0.256)	(0.256)	(0.256)	(0.256)		(0.171)	(0.171)	(0.171)	(0.171)
PulpPaper	0.207	0.207	0.217	0.216	MT	-0.183	-0.183	-0.195	-0.194
	(0.255)	(0.255)	(0.255)	(0.255)		(0.151)	(0.151)	(0.151)	(0.151)
Print	0.258	0.258	0.266	0.265	PA	-0.116	-0.116	-0.125	-0.124
	(0.256)	(0.256)	(0.256)	(0.256)		(0.137)	(0.137)	(0.137)	(0.137)
Petrol	0.000565	0.000507	-0.00554	-0.00398	PB	-0.279*	-0.279*	-0.291**	-0.291**
	(0.256)	(0.256)	(0.256)	(0.256)		(0.146)	(0.146)	(0.146)	(0.146)
Chemical	0.155	0.155	0.168	0.167	PE	-0.0470	-0.0469	-0.0593	-0.0586
	(0.255)	(0.255)	(0.255)	(0.255)		(0.129)	(0.129)	(0.129)	(0.129)
Pharmac.	0.241	0.241	0.255	0.254	PI	-0.101	-0.101	-0.112	-0.112
	(0.257)	(0.257)	(0.257)	(0.257)		(0.173)	(0.173)	(0.173)	(0.173)
RubPlastic	0.152	0.152	0.163	0.162	PR	-0.101	-0.100	-0.110	-0.110
	(0.254)	(0.254)	(0.254)	(0.254)		(0.124)	(0.124)	(0.124)	(0.124)
NonMet	0.224	0.224	0.233	0.233	RJ	-0.0698	-0.0697	-0.0832	-0.0822
	(0.255)	(0.255)	(0.255)	(0.255)		(0.124)	(0.124)	(0.124)	(0.124)
Metal	0.151	0.151	0.162	0.161	RN	-0.0685	-0.0685	-0.0730	-0.0720
	(0.254)	(0.254)	(0.254)	(0.254)		(0.148)	(0.148)	(0.148)	(0.148)
CompElect	0.156	0.155	0.168	0.167	RO	-0.237	-0.237	-0.249	-0.249
	(0.254)	(0.254)	(0.254)	(0.254)		(0.182)	(0.182)	(0.182)	(0.182)
MachEquip.	0.231	0.231	0.239	0.239	RR	0.0366	0.0364	0.0557	0.0574
	(0.254)	(0.254)	(0.254)	(0.254)		(1.434)	(1.434)	(1.434)	(1.434)
VeichOth	0.244	0.244	0.253	0.253	RS	-0.154	-0.154	-0.163	-0.163
	(0.254)	(0.254)	(0.254)	(0.254)		(0.124)	(0.124)	(0.124)	(0.124)
Furniture	0.0918	0.0917	0.102	0.102	SC	-0.0923	-0.0922	-0.0999	-0.0993
	(0.255)	(0.255)	(0.255)	(0.255)		(0.124)	(0.124)	(0.124)	(0.124)
AC	0.626	0.626	0.619	0.619	Constant	-0.0978	-0.0980	-0.0894	-0.0905
	(0.470)	(0.470)	(0.470)	(0.470)		(0.282)	(0.282)	(0.282)	(0.282)
AL	-0.0462	-0.0462	-0.0601	-0.0597	*Observations*	*20,823*	*20,823*	*20,823*	*20,823*
	(0.130)	(0.130)	(0.130)	(0.130)	R-squared	0.110	0.110	0.110	0.110

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table A.4.7: Changes in Value Added: Cross Section - PINTEC 2008 - Complete

Dependent Variable: (2008-2006) Change in value added:				
explanatory variables	Δ_3 log Value Added			
	(1)	(2)	(3)	(4)
E. Environ. Impact AND/OR Biological Effluent Treatment	0.0397**	0.0426**	0.0327*	0.0663**
	(0.0167)	(0.0178)	(0.0187)	(0.0296)
C. Environmental Management Techniques			0.0311*	0.0485**
			(0.0178)	(0.0215)
Interaction between: **E * C**				-0.0540
				(0.0369)
Δ_3 log White-collar employees	0.0532	0.0394	0.0409	0.0376
	(0.0859)	(0.0861)	(0.0861)	(0.0861)
Δ_3 log Blue-collar employees	0.366***	0.345***	0.345***	0.342***
	(0.104)	(0.106)	(0.106)	(0.106)
Δ_3 log Capital Stock	0.241***	0.205**	0.209***	0.212***
	(0.0760)	(0.0800)	(0.0801)	(0.0801)
Size of the firm		0.000976	-0.000701	0.000213
		(0.00635)	(0.00643)	(0.00646)
Export Intensity		-0.136***	-0.136***	-0.137***
		(0.0375)	(0.0375)	(0.0375)
Foreign Ownership		0.00467	0.00382	0.00274
		(0.0216)	(0.0216)	(0.0216)
(Δ_3 log Capital Stock)^2	-0.00403	-0.00326	-0.00334	-0.00349
	(0.00355)	(0.00357)	(0.00357)	(0.00358)
(Δ_3 log White-collar employees)^2	0.0382***	0.0376***	0.0378***	0.0375***
	(0.00530)	(0.00532)	(0.00531)	(0.00532)
(Δ_3 log Blue-collar employees)^2	0.0650***	0.0626***	0.0632***	0.0631***
	(0.00751)	(0.00757)	(0.00758)	(0.00758)
(Δ_3 log White-collar employees)*(Δ_3 log Blue-collar employees)	-0.0767***	-0.0759***	-0.0759***	-0.0758***
	(0.00898)	(0.00898)	(0.00898)	(0.00898)
(Δ_3 log Capital Stock)*(Δ_3 log White-collar employees)	0.0139**	0.0147**	0.0145**	0.0148**
	(0.00699)	(0.00701)	(0.00701)	(0.00702)
(Δ_3 log Capital Stock)*(Δ_3 log Blue-collar employees)	-0.0171*	-0.0148	-0.0152*	-0.0151*
	(0.00884)	(0.00903)	(0.00904)	(0.00904)

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table A.4.7: Changes in Value Added: Cross Section - PINTEC 2008 - Complete *(cont.)*

Dependent Variable: (2008-2006) Change in value ac

explanatory variables	Δ_3 log Value Added (1)	(2)	(3)	(4)
MinQuar.	-0.247**	-0.268**	-0.272**	-0.273**
	(0.117)	(0.118)	(0.118)	(0.118)
Food	-0.150	-0.190*	-0.198*	-0.200*
	(0.102)	(0.104)	(0.104)	(0.104)
Beverage	-0.0365	-0.110	-0.121	-0.120
	(0.113)	(0.115)	(0.115)	(0.115)
Tobacco				
Textile	-0.101	-0.158	-0.165	-0.165
	(0.104)	(0.107)	(0.107)	(0.107)
Leather	-0.119	-0.155	-0.165	-0.162
	(0.106)	(0.108)	(0.108)	(0.108)
Wood	-0.183	-0.191*	-0.200*	-0.200*
	(0.113)	(0.115)	(0.115)	(0.115)
PulpPaper	-0.0920	-0.143	-0.153	-0.153
	(0.109)	(0.111)	(0.111)	(0.111)
Print	-0.344***	-0.390***	-0.400***	-0.402***
	(0.111)	(0.113)	(0.113)	(0.113)
Petrol	-0.0330	-0.0915	-0.102	-0.102
	(0.107)	(0.109)	(0.109)	(0.109)
Chemical	-0.171	-0.231*	-0.242**	-0.242**
	(0.117)	(0.118)	(0.119)	(0.119)
Pharmac.	-0.00391	-0.0641	-0.0712	-0.0722
	(0.106)	(0.108)	(0.108)	(0.108)
RubPlastic	-0.0249	-0.0772	-0.0863	-0.0865
	(0.109)	(0.110)	(0.111)	(0.111)
NonMet	-0.0804	-0.126	-0.137	-0.138
	(0.104)	(0.106)	(0.106)	(0.106)
Metal	-0.0685	-0.121	-0.129	-0.129
	(0.106)	(0.107)	(0.107)	(0.107)
CompElect	-0.00666	-0.0550	-0.0640	-0.0642
	(0.105)	(0.106)	(0.106)	(0.106)
MachEquip.	0.0140	-0.0255	-0.0342	-0.0340
	(0.104)	(0.105)	(0.105)	(0.105)
VeichOth	-0.127	-0.174	-0.181	-0.181
	(0.109)	(0.111)	(0.111)	(0.111)
Furniture	-0.314	0.771	0.764	0.775
	(0.781)	(0.519)	(0.519)	(0.519)
AC	-0.640	0.389	0.372	0.380
	(0.781)	(0.519)	(0.519)	(0.519)
AL	-1.062			
	(0.935)			
AM	-0.567	0.480	0.462	0.474
	(0.781)	(0.519)	(0.519)	(0.519)
AP	-0.462	0.571	0.556	0.564
	(0.781)	(0.518)	(0.518)	(0.518)

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.

explanat. var. (cont.)	Δ_3 log Value Added (1)	(2)	(3)	(4)
BA	-0.569	0.478	0.463	0.468
	(0.782)	(0.521)	(0.521)	(0.521)
CE	-0.614	0.418	0.402	0.408
	(0.782)	(0.520)	(0.520)	(0.520)
ES	-0.679	0.365	0.358	0.369
	(0.793)	(0.537)	(0.537)	(0.537)
GO	-0.465	0.572	0.555	0.564
	(0.780)	(0.517)	(0.517)	(0.517)
MA	-0.671	0.385	0.372	0.383
	(0.798)	(0.545)	(0.545)	(0.545)
MG	-0.560	0.477	0.461	0.469
	(0.787)	(0.528)	(0.528)	(0.528)
MS	-0.455	0.601	0.588	0.598
	(0.783)	(0.521)	(0.521)	(0.521)
MT	-0.604	0.435	0.421	0.433
	(0.787)	(0.528)	(0.528)	(0.528)
PA	-0.397	0.642	0.624	0.631
	(0.781)	(0.519)	(0.519)	(0.519)
PB	-0.389	0.642	0.620	0.626
	(0.797)	(0.543)	(0.543)	(0.543)
PE	-0.429	0.608	0.593	0.601
	(0.780)	(0.517)	(0.517)	(0.517)
PI	-0.427	0.610	0.595	0.605
	(0.780)	(0.517)	(0.517)	(0.517)
PR	-0.248	0.792	0.784	0.794
	(0.786)	(0.526)	(0.526)	(0.526)
RJ	-0.456	0.612	0.592	0.597
	(0.803)	(0.551)	(0.551)	(0.551)
RN	-0.299	0.735	0.723	0.732
	(0.795)	(0.540)	(0.540)	(0.540)
RO	-0.459	0.589	0.573	0.579
	(0.780)	(0.517)	(0.517)	(0.517)
RR	-0.437	0.611	0.595	0.605
	(0.780)	(0.517)	(0.517)	(0.517)
RS	-0.285	0.741	0.727	0.739
	(0.792)	(0.536)	(0.536)	(0.536)
SC	-0.467	0.572	0.558	0.566
	(0.779)	(0.516)	(0.516)	(0.516)
SE	-0.516	0.503	0.490	0.506
	(0.860)	(0.631)	(0.631)	(0.631)
SP	-0.0960	-0.159	-0.168	-0.166
	(0.135)	(0.137)	(0.137)	(0.137)
TO		1.035	1.012	1.017
		(0.934)	(0.934)	(0.934)
Constant	0.532	-0.449	-0.426	-0.445
	(0.786)	(0.527)	(0.527)	(0.527)
Observations	8,542	8,542	8,542	8,542
R-squared	0.165	0.166	0.166	0.167

Table A.4.8: Effects of Pollution Abatement Investment and Organizational EI - Complete

Dependent Variable - First difference in Value Added				
VARIABLES	Δ log Value Added			
	(1)	(2)	(3)	(4)
F. Pollution Abatement Investment (%)	0.0780**	0.0724*	0.0523	0.0336
	(0.0370)	(0.0370)	(0.0373)	(0.0510)
C. Environ. Management Techniques			0.0269*	0.0244
			(0.0144)	(0.0151)
Interaction between: **F*C**				0.0401
				(0.0746)
Δ_3 log White-collar employees	0.401***	0.405***	0.322***	0.323***
	(0.0836)	(0.0837)	(0.0826)	(0.0826)
Δ_3 log Blue-collar employees	0.156	0.167*	0.245***	0.244***
	(0.0954)	(0.0956)	(0.0942)	(0.0942)
Δ_3 log Capital Stock	-0.151*	-0.0949	-0.191**	-0.191**
	(0.0829)	(0.0855)	(0.0899)	(0.0900)
Size of the firm		0.0146***	0.00659	0.00652
		(0.00448)	(0.00486)	(0.00486)
Export Intensity		-0.0892***	-0.124***	-0.123***
		(0.0291)	(0.0303)	(0.0303)
Foreign Ownership		0.00316	-0.000129	-6.91e-05
		(0.0168)	(0.0177)	(0.0177)
$(\Delta_3$ log Capital Stock$)^2$	0.00635*	0.00502	0.00779**	0.00778**
	(0.00346)	(0.00349)	(0.00375)	(0.00375)
$(\Delta_3$ log White-collar employees$)^2$	0.0338***	0.0342***	0.0257***	0.0258***
	(0.00469)	(0.00470)	(0.00487)	(0.00487)
$(\Delta_3$ log Blue-collar employees$)^2$	0.0317***	0.0334***	0.0278***	0.0277***
	(0.00641)	(0.00644)	(0.00650)	(0.00651)
$(\Delta_3$ log White-collar employees$)*(\Delta_3$ log Blue-collar employees$)$	-0.0671***	-0.0657***	-0.0608***	-0.0608***
	(0.00781)	(0.00782)	(0.00786)	(0.00786)
$(\Delta_3$ log Capital Stock$)*(\Delta_3$ log White-collar employees$)$	-0.00861	-0.00946	-0.00286	-0.00296
	(0.00669)	(0.00671)	(0.00662)	(0.00663)
$(\Delta_3$ log Capital Stock$)*(\Delta_3$ log Blue-collar employees$)$	0.0124	0.0105	0.00883	0.00893
	(0.00775)	(0.00779)	(0.00767)	(0.00767)

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table A.4.8: Effects of Pollution Abatement Investment and Organizational EI - Complete *(cont.)*
Dependent Variable - First difference in Value Added

VARIABLES	Δ log Value Added			
	(1)	(2)	(3)	(4)
year 2002	0.0543***	0.0563***		
	(0.0158)	(0.0158)		
year 2007	0.00463	0.00307	-0.0570***	-0.0568***
	(0.0150)	(0.0151)	(0.0131)	(0.0131)
MinQuar.	-0.170	-0.157	-0.151	-0.155
	(0.337)	(0.338)	(0.322)	(0.322)
Food	-0.0201	-0.0268	0.0409	0.0375
	(0.335)	(0.335)	(0.319)	(0.319)
Beverage	-0.0715	-0.0911	-0.0927	-0.0962
	(0.337)	(0.337)	(0.322)	(0.322)
Tobacco	0.0382	0.0444	0.115	0.112
	(0.342)	(0.342)	(0.328)	(0.328)
Textile	-0.0339	-0.0368	-0.0440	-0.0475
	(0.335)	(0.335)	(0.319)	(0.320)
Leather	-0.139	-0.139	-0.138	-0.142
	(0.336)	(0.336)	(0.320)	(0.320)
Wood	-0.184	-0.153	-0.107	-0.112
	(0.337)	(0.337)	(0.322)	(0.322)
PulpPaper	-0.0257	-0.0250	-0.00712	-0.0112
	(0.336)	(0.336)	(0.321)	(0.321)
Print	0.0280	0.0221	0.0712	0.0674
	(0.337)	(0.337)	(0.323)	(0.323)
Petrol	0.0377	0.0126	0.0346	0.0312
	(0.336)	(0.336)	(0.321)	(0.321)
Chemical	-0.0978	-0.101	-0.0657	-0.0692
	(0.336)	(0.336)	(0.320)	(0.320)
Pharmac.	-0.0877	-0.0956	-0.0624	-0.0658
	(0.338)	(0.337)	(0.322)	(0.322)
RubPlastic	-0.119	-0.118	-0.0671	-0.0710
	(0.336)	(0.336)	(0.320)	(0.320)
NonMet	-0.0605	-0.0557	-0.0434	-0.0472
	(0.336)	(0.336)	(0.320)	(0.320)
Metal	-0.0759	-0.0737	-0.0392	-0.0434
	(0.335)	(0.335)	(0.319)	(0.320)
CompElect	-0.0717	-0.0767	-0.0336	-0.0374
	(0.335)	(0.335)	(0.320)	(0.320)
MachEquip.	-0.0326	-0.0341	0.0168	0.0132
	(0.335)	(0.335)	(0.320)	(0.320)
VeichOth	-0.0363	-0.0485	-0.0302	-0.0342
	(0.335)	(0.335)	(0.320)	(0.320)
Furniture	-0.196	-0.187	-0.118	-0.122
	(0.336)	(0.336)	(0.321)	(0.321)
AC	0.390	0.412	0.288	0.289
	(0.400)	(0.400)	(0.463)	(0.463)
AL	-0.274**	-0.265**	-0.220*	-0.221*
	(0.123)	(0.123)	(0.134)	(0.134)
AM	-0.307**	-0.313**	-0.382***	-0.382***
	(0.123)	(0.123)	(0.133)	(0.133)

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

VARIABLES	Δ log Value Added			
	(1)	(2)	(3)	(4)
AP	-0.397	-0.360	-0.563	-0.559
	(0.408)	(0.408)	(0.405)	(0.405)
BA	-0.330***	-0.325***	-0.353***	-0.353***
	(0.122)	(0.122)	(0.132)	(0.132)
CE	-0.288**	-0.295**	-0.344***	-0.343***
	(0.119)	(0.119)	(0.130)	(0.130)
ES	-0.286**	-0.274**	-0.375***	-0.375***
	(0.127)	(0.127)	(0.137)	(0.137)
GO	-0.329***	-0.325***	-0.468***	-0.468***
	(0.124)	(0.124)	(0.135)	(0.135)
MA	-0.184	-0.168	-0.121	-0.122
	(0.160)	(0.160)	(0.175)	(0.175)
MG	-0.338***	-0.337***	-0.381***	-0.382***
	(0.115)	(0.115)	(0.126)	(0.126)
MS	-0.463***	-0.445***	-0.379**	-0.379**
	(0.166)	(0.166)	(0.183)	(0.183)
MT	-0.0811	-0.0728	-0.341**	-0.342**
	(0.143)	(0.143)	(0.158)	(0.158)
PA	-0.275**	-0.255*	-0.334**	-0.334**
	(0.130)	(0.130)	(0.141)	(0.141)
PB	-0.404***	-0.391***	-0.213	-0.214
	(0.139)	(0.139)	(0.153)	(0.153)
PE	-0.169	-0.165	-0.201	-0.202
	(0.120)	(0.120)	(0.132)	(0.132)
PI	-0.179	-0.170	-0.351*	-0.350*
	(0.159)	(0.159)	(0.184)	(0.184)
PR	-0.192*	-0.189	-0.220*	-0.220*
	(0.116)	(0.116)	(0.127)	(0.127)
RJ	-0.248**	-0.257**	-0.300**	-0.302**
	(0.116)	(0.116)	(0.127)	(0.127)
RN	-0.140	-0.154	-0.324**	-0.325**
	(0.138)	(0.138)	(0.151)	(0.151)
RO	-0.195	-0.182	-0.347*	-0.347*
	(0.198)	(0.198)	(0.204)	(0.204)
RR	-1.262	-1.148	-1.262	-1.264
	(3.154)	(3.153)	(2.780)	(2.781)
RS	-0.323***	-0.312***	-0.369***	-0.370***
	(0.115)	(0.115)	(0.126)	(0.126)
SC	-0.304***	-0.304***	-0.371***	-0.372***
	(0.115)	(0.116)	(0.127)	(0.127)
SE	-0.303*	-0.303*	-0.217	-0.216
	(0.161)	(0.161)	(0.172)	(0.172)
SP	-0.279**	-0.280**	-0.329***	-0.329***
	(0.114)	(0.114)	(0.125)	(0.125)
TO	-0.150	-0.139	-0.268	-0.270
	(0.288)	(0.288)	(0.283)	(0.283)
Constan	0.326	0.246	0.366	0.371
	(0.353)	(0.354)	(0.343)	(0.343)
Observa	20,875	20,875	14,791	14,791
R-squar	0.053	0.054	0.069	0.069