THE IMPACT OF THE KYOTO PROTOCOL ON ENVIRONMENTAL EFFICIENCY: A SECTORAL ANALYSIS

A Master's Thesis

by
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August 2017

To my family

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The Graduate School of Economics and Social Sciences
of
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by

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August 2017

I certify that I have read this thesis and have found that it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Arts in Economics.

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ABSTRACT

THE IMPACT OF THE KYOTO PROTOCOL ON ENVIRONMENTAL EFFICIENCY: A SECTORAL ANALYSIS

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This thesis studies sectoral level environmental efficiency changes in the Kyoto countries over the period 2000-2011. First, sectoral level environmental efficiency indexes for the Kyoto countries are computed by using a hyperbolic measure of technical efficiency in a non-parametric piece-wise linear technology. Second, the role of the Kyoto Protocol on environmental efficiency is empirically examined. The results showed that, sectoral level environmental efficiency is significantly improved, especially in dirty sectors, during the years following the Kyoto Protocol's entry into force.

Keywords: Environmental Efficiency Index, Kyoto Protocol, Non-Parametric.

ÖZET

KYOTO PROTOKOLÜ'NÜN ÇEVRESEL ETKİNLİKTEKİ ROLÜ:
SEKTÖREL ANALİZ

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Bu tez çalışması, 2000-2011 döneminde Kyoto ülkelerindeki sektörel düzeydeki çevresel etkinlik kazanımlarını incelemektedir. İlk olarak, Kyoto ülkeleri için sektörel düzeydeki çevresel etkinliklik endeksleri, parametrik olmayan parçalı doğrusal bir teknoloji için, veri zarflama tekniğiyle hiperbolik bir ölçü kullanılarak hesaplanmştır. Kyoto Protokolü'nün sektörel düzeydeki çevresel etkinlik değişiklikleri üzerindeki rolü ampirik olarak incelenmiştir. Sonuçlar, Kyoto Protokolü'nün yürürlüğe girmesinden sonraki dönemlerde sektördeki çevresel etkinliğin iyileştiğini, bu iyileşmenin özellikle kirli sektörlerde görüldüğünü göstermektedir.

Anahtar kelimeler: Çevresel Etkinlik, Kyoto Protokolü, Parametrik olmayan.

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CHAPTER I

INTRODUCTION

The threat of climate change and global warming has become a major concern all over the globe. According to Climate statistics, in the last 45 years, global surface temperature rose at an average rate of about 0.17 ° C more than twice as fast as the 0.07 ° C per decade increase observed for the entire period of recorded observations 1880-2015 (Dahlman, 2017). There is a broad consensus about the main driver of these threats: the emission of Greenhouse Gases (GHG), mostly from the carbon dioxide (CO2) emission. It is argued that industrialization process has triggered the increase of the carbon emission (Harris & Roach, 2007). This rapid growth in industrialization resulted in environmental problems, which also have increased the environmental concerns over the globe.

As environmental issues become more significant, many countries needed to act together. United Nations Framework Convention on Climate Change (UNFCCC) passed the Kyoto Protocol (Kyoto) in 1997 as a first legally binding international environmental agreement that set the targets for 38 industrialized nations (Kyoto countries) [1] which are principally responsible for the current high level of pollution emissions (also referred as Annex-I countries), required to reduce their greenhouse

[1] Australia, Austria, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Luxembourg, Monaco, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, United Kingdom, United States

gas emissions from 1990 levels by an average of 5% over the period 2008-2012. Kyoto became effective in 2005 by the ratification of at least 55 nations, including those responsible for at least 55% of industrialized countries' emissions in 1990. Except the U.S., 37 countries that ratified the Kyoto Protocol had legally binding limitations on emissions in their production processes in order to meet their targets.[2]

As a first legally binding international environmental agreement that sets targets for the Annex-I countries, the Kyoto Protocol is criticized by international organizations and in the media in terms of its effectiveness. It is argued that lack of formal enforcement mechanism of the Kyoto Protocol has resulted in failure. Bederman (2001) states that, "as the international law has no effective control mechanisms, it does not suffice to simply state that international law requires a certain outcome." However, by assuming that the enforcement matters, we cannot directly conclude that the Kyoto has failed and there was no benefit in terms of environmental outcomes. In fact, the Kyoto was a first global step in terms of increasing the global awareness and creating an incentive for the development of environmental technologies. Furthermore, the Kyoto has created a basis for the future international agreement on climate change.

Recently, the Kyoto Protocol is replaced by the Paris Agreement which also aims to strengthen the global climate effort. It is entered into force on November 2016 by the ratification of countries which are representing the 55% of total green house gasses and aims to limit the global warming to below 2° C by developing a co-operation between the countries. In order to achieve sustainable development, both agreements have made a clear point in development of environment friendly technologies. According to the Kyoto Protocol (1997, p. 10), all Parties (without introducing any new commitments for Parties not included in Annex-B): "[...] take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies, know-how, practices and processes pertinent to climate change, in particular to developing countries [...]". Paris Agreement (2015, p. 14) also clearly mentions that: "[...] countries

[2] On 15 December 2011 Canada withdrew from the Kyoto Protocol

shall strengthen cooperative action on technology development and transfer." At this point it is essential to point that whether the Kyoto, as a first step in global awareness in climate change, has made any changes not only in terms of changes in emissions but also in terms of transformation in the technology.

There are a number of studies that evaluates Kyoto's effectiveness in terms of comparing carbon emissions in Kyoto and non-Kyoto countries[3]. This study, unlike previous studies, considers environmental efficiency as an environmental outcome than can be affected by the Kyoto obligations and analyzes Kyoto countries' sectoral level environmental efficiency changes. From an environmental point of view, production is not just a process that uses the technology to convert the inputs into outputs but also a process that uses the technology to convert the inputs into both outputs and pollutants. The producer prefers the production that maximizes the outputs while simultaneously minimizing the inputs. If there are concerns for pollutants, producers may want to minimize pollutants while maximizing the output. However, decreasing pollutants requires transformation such that outputs must be given up to decrease pollutants. Considering that the Kyoto brings concern for pollutants, we analyze whether the Kyoto Protocol has any effect on the sectors. From both an economic and policy point of view it is also interesting to see whether the effect of Kyoto obligations on pollution intensive sectors is different than the Kyoto's effect on clean sectors. We argue that pollution intensive sectors (or dirty sectors) may have preferred a production that also minimizes pollutants which is expected to improve dirty sectors' environmental performance. To show this, we first develop the Kyoto countries' environmental performance that is measured by sectoral level environmental efficiency indexes and then examine the effectiveness of the Kyoto on the countries that have signed and ratified the Protocol with an empirical framework.

In order to develop the environmental efficiency, hyperbolic measure of technical efficiency is computed in a non-parametric piece-wise linear technology that satisfies strong and weak disposability assumptions for the pollutant. The computation of the opportunity cost of turning the production process from one where all out-

[3] See Appendix B for the countries with no obligations.

puts are strongly disposable to the one that pollution is weakly disposable gives the environmental efficiency indexes. It is a non-parametric and non-stochastic output oriented frontier analysis that is computed by the Data Envelopement Analaysis (DEA) which does not require any assumption about the technology. The indexes are computed for 15 sectors of 17 Kyoto commitment countries [4] for the period between 2000-2011, following the comparison of technical efficiency scores of strongly and weakly disposable technical efficiency scores of each unit.

In order to analyze the effectiveness of the Kyoto Protocol, the role of the Kyoto Protocol on sectoral level environmental efficiency in the Kyoto countries is empirically examined. The analysis is based on panel data that covers 16 Kyoto countries and their 15 sectors for the period 2000-2011. First, we investigated the driving forces behind environmental efficiency. We estimated our model using with fixed effects model to address the sector-country specific unobserved heterogeneity. In order to investigate the role of Kyoto Protocol on sectoral level environmental efficiency at the Kyoto countries, we analyzed the environmental efficiency changes in before and after the Kyoto periods. We initially intended to evaluate the target period (2008-2012). However, these dates coincided with the 2008 financial crisis that had a wide spread economic impact on the industrialized countries. Hence, we extended our model by three alternative Kyoto dummies. Furthermore, due to the possible endogeneity problems that may arise from selection bias and omitted variable bias in the regression models, we performed two robustness checks; two-stage Heckman method and fixed effects instrumental variables methods, respectively. We find that, sectoral level environmental efficiency is significantly improved after the Kyoto Protocol's entry into force. The improvement of dirty sectors' environmental efficiencies are more than clean sectors' environmental, efficiencies especially for the pre-crisis period.

The remainder of this thesis is organized as follows. Chapter 2 describes the environmental efficiency index. The section covers the literature on the development of the measures, methodology of its computation, the details of the data and the summary results of the computed environmental efficiency indexes. Chapter 3

[4] Even though United States did not ratify the Kyoto, we included it in the computation of the sectoral level environmental efficiency indexes.

gives the motivation and the background of the Kyoto Protocol, explains the estimation method that examines the environmental efficiency scores obtained in Chapter 2 and reports the robustness checks. Chapter 4 presents the conclusions and policy recommendation.

CHAPTER II

ENVIRONMENTAL EFFICIENCY INDEX

2.1 Motivation

In this section we consider sectoral level environmental efficiency as an alternative measure for the environmental performance of the Kyoto countries' sectors and compute environmental efficiency indexes by adopting the work of Fare et al (1994a) who first applied output oriented Data Envelopment Analysis (DEA). So far, several studies have used CO2 emission per output as a measure for environmental performance. Main reason for using the environmental efficiency as an alternative is analyzing whether the Kyoto countries' sectors have started to concern for the pollutant in their production, after the Kyoto Protocol's entry into force. If the sectors' environmental efficiency have been affected by the Kyoto obligations and pollutant is unwanted in the production, then the producers may want to minimize pollutants. However, decreasing pollutants requires transformation such that either outputs must be given up or inputs have to be increased to decrease pollutants. Environmental efficiency indexes give us the opportunity cost that result from the transformation of the production process from one where there is no concern for the pollutants in the production to the one which producers start to take into account the concern for the pollutant. In this study, we examine whether the Kyoto Protocol's enforcement mechanism may have created a concern for the pollutant in Kyoto countries, and investigate whether sectors' environmental efficiency have changed after the Protocol.

The feature that makes the environmental efficiency preferable as a measure of environmental performance is that, it does not require any assumptions for the shape of production function and can be applied to the sectoral level data. Hence, it provides quantitative information for the evaluation of the each sectors' environmental performance. Considering all of these benefits, we compute environmental efficiency indexes for each of the Kyoto countries and their sectors through the years between 2000-2011. We first explain the literature behind the methodology, then give the details of the model and the data requirements for sectoral level environmental efficiency indexes. Finally we compute the country averages for each sector and each year to discuss the environmental efficiency changes.

2.2 Literature Review

Environmental Efficiency Index is computed by using Data Envelopment Analysis (DEA). [5] This is non-parametric and non-stochastic methodology where the best production function is constructed as a linear piece-wise frontier by using the linear programming methodology. Efficiency measures are computed by examining the units' (plant, sector, or country) relative position to the best production frontier as observed through looking the units' (countries, industries) relative environmental efficient productions. Production is a process that transforms inputs into outputs. The production function explains the relationship between inputs and outputs by showing the amount of outputs that are produced by a given amount of inputs. It also represents the technology of the unit. However, it is possible to consider that by the given amount of inputs, both desirable and undesirable outputs can be produced. The efficiency measures are obtained through computing the opportunity cost resulting from the transformation of the production process from one where all outputs are strongly disposable to the one which bad outputs are weakly disposable. In this section we cover the literature behind the efficiency analyzes in detail.

[5] Environmental efficiency measurement with DEA assumes a static environment for the units. This study can be extended by considering the dynamic environment for the units in the future analysis.

Farrell (1957) did the first empirical study for the production function. He introduced technical efficiency measure that allows making comparison based on the frontiers. By means of comparing the performances of several units' frontier is found by the linear programming for the single output.[6] This is also called Farrell efficiency score. An alternative is is output-oriented efficiency that measures the increase in output level while maintaining the same level of input. The term "efficiency" of a unit depends on the ability to produce the maximum possible output from a given set of inputs. In this study, we are using on output-oriented measures of efficiency definition.

In addition to the production of desirable output, there are a number of studies that consider the production as a process that uses the technology to convert the inputs into both wanted(desirable) outputs and unwanted (undesirable) outputs. Shephard (1970) explicitly included the production of undesirable output in the production model. Caves, Chiristensen and Diewert (CCD) (1982a, 1982b) introduced the multilateral productivity index that considers both undesirable output and desirable output. Pittman (1983) extended the environmental efficiency by considering CCD's multilateral productivity index that contains both desirable and undesirable output. He considered the undesirable output as pollution emission and it is valued by its shadow price rather than its market price. This made possible to measure the environmental efficiency without prices. Fare, Grosskopf and Lovell (1985) introduced the graph measure of efficiency to allow for simultaneous variations in outputs and inputs. They extended the Farrell graph measure (1957) and model the technology with the graph rather than with the input correspondence or the output correspondence.

When production function is estimated with stochastic parametric analysis, a priori function assumption is necessary. However, in real life production is a complex process, so functional form of the production function is unknown. In the non-parametric approach, assumptions about the form of the production function are not required. Empirical study that uses non-parametric approach to measure efficiency is done by Fare et al (1989(a), 1989(b)). They consider undesirable output

[6] His study is on the input-oriented efficiency and measures the level of inputs that are reduced while producing the same level of output.

as Pittman and extend Farrell (1957) by treating the desirable and undesirable outputs asymmetrically. In order to measure efficiency, they adopted the hyperbolic measure of technical efficiency in a non-parametric piecewise linear technology which satisfies weak disposability of undesirable outputs as Shephard (1970) and strong disposability of desirable outputs. Shephard (1970) assumed that undesirable output can be reduced with a proportional decrease in desirable output, i.e. it is weakly disposable. In other words, weak disposability states that undesired output can not be freely disposed of. If one wishes to reduce undesirable outputs, desirable outputs must also be reduced for a given level of inputs. Unlike weak disposability, strong disposability states that undesired output can be freely disposed of without any sacrifice. Desirable output loss due to the lack of strong disposability of undesirable outputs is determined by the difference between weak and strong disposable technologies. Environmental efficiency is obtained by comparing two technologies that differ with respect to their disposability assumption of undesirable output. Hence, the hyperbolic measure of technical efficiency shows the largest proportionate expansion in desired output while contracting the inputs and undesired outputs.

There are several studies on the measurement of the environmental efficiency using the theory of Fare et al (1989). Taşkın and Zaim (2000) adopted macro level data to compute the environmental efficiency for OECD countries. Yörük and Zaim (2006) analyzed the relationship between Environmental Kuznets Curve and environmental efficiency by considering the pollution in the production process. Halkos and Tzeremes (2009) analyze whether there exists a Kuznets curve in countries' environmental efficiency. Moreover, some of the studies have explored the relationship between the environmental efficiency and trade. Taşkın and Zaim (2001) analyzed the impact of the international trade on environmental efficiency and most recently, Doganay et al (2014) measured the environmental efficiency for 111 countries and analyzed the relationship between environmental efficiency and trade.

This study also adopted the theory of Fare et al (1989) to measure environmental efficiency, but differs from other studies by the use of the sectoral level panel data for countries over the period 2000-2011. The further details on theoretical background of the environmental efficiency is explained in the following sections.

2.3 Model

In this study we use non-parametric hyperbolic measure of technical efficiency measure that is developed by Fare et al (1994a)[7] as a theoretical background of environmental efficiency.

2.3.1 The Relationship Between Input And Output

Following Shephard's (1970) work, the production technology transforming inputs x=(x_1,x_2,...,x_N) $R^N_+ = \{x : x \in R^N_+, x \geq 0\}$ into outputs u=(u_1,u_2,...,u_M) $\in R^M_+$ can be represented by the output correspondence P, the input correspondence L, or the graph of the technology GR.

The output correspondence P: $R^N_+ \to P(x) \subseteq R^M_+$ takes input vectors x $\in R^N_+$ into subsets $P(x) \subseteq R^M_+$ of output vectors. P(x) is the output set and denotes the collection of all output vectors u $\in R^M_+$ that can be obtained from the input vector x $\in R^N_+$. The output set P(x) is illustrated for the case M=2 in Figure 1.

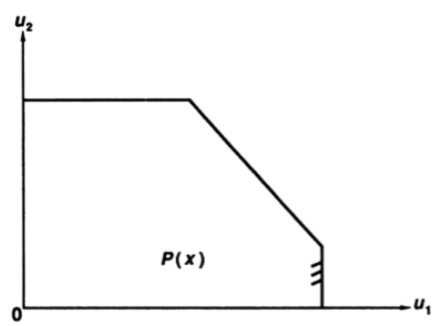

Figure 1: The Output Set

The input correspondence L: $R^M_+ \to L(u) \subseteq R^N_+$ maps output vectors u $\in R^M_+$ into

[7]Fare, R., Grosskopf, S. and Lovell, C. A. K. (1994a). Production Frontiers, Cambridge: Cambridge University Press.

subsets L(u) $\subseteq$ R^N_+ of inputs. L(u) is the input set and denotes the collection of all input vectors x$\in$ R^N_+ that can produce the output vectors u$\in$$R^M_+$. The input set L(u) is illustrated for the case N=2 in Figure 2.

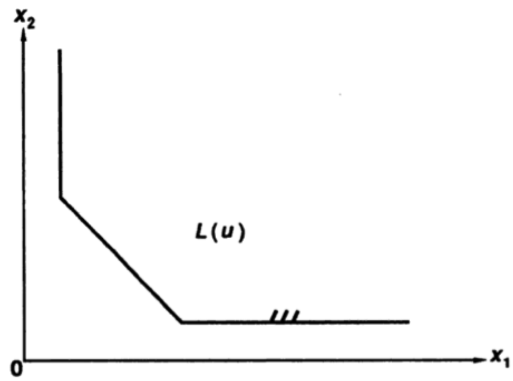

Figure 2: The Input Set

There is an inverse relationship between L and P and it is represented below:

Proposition: x $\in$ L(u) $\iff$ u $\in$ P(x)

The above proposition states that input vector x $\in$ R^N_+ belongs to the input set L(u) iff vector of outputs u $\in$ R^M_+ belong to the output set P(x). It is computed by P(x) = $\{u : x \in L(u)\}$ and L(u) = $\{x : u \in P(x)\}$. Vector of outputs u $\in$ R^M_+ belong to the output set P(x) $\subseteq$ R^M_+ iff input vector x $\in$ R^N_+ belongs to the input set L(u) $\subseteq$ R^N_+. i.e. L(u) = $\{x : u \in P(x)\}$ and P(x) = $\{u : x \in L(u)\}$.

Definition: An input-output vector (x,u) $\in$ R^{N+M}_+ is feasible iff x $\in$ L(u) or equivalently if u $\in$ P(x).

The Graph of the technology is the collection of all feasible input-output vectors, i.e., GR= $\{(x,u) \in R^{N+M}_+ : u \in P(x), x \in RN_+\}$ or GR = $\{(x,u) \in R^{N+M}_+ : x \in L(u), u \in R^M_+\}$. The graph is derived from either the input correspondence, i.e. P(x) = $\{u : (x,u)| \in GR\}$ or the output correspondence, i.e. L(u) = $\{x : (x,u) \in GR\}$.

The link between P, L and GR is represented below:

Proposition: u ∈ P(x) $\iff$ x ∈ L(u) $\iff$ (x, u) ∈ GR

The above proposition states that although the input set, the output set and the graph highlight different aspects of the technology, they model the same production technology where the input set models input substitution, the output set models output substitution and the graph models both input substitution and output substitution.

The relationship between the input set L(u), the output set P(x) and the graph GR is shown for the case M=N=1 in Figure 3.

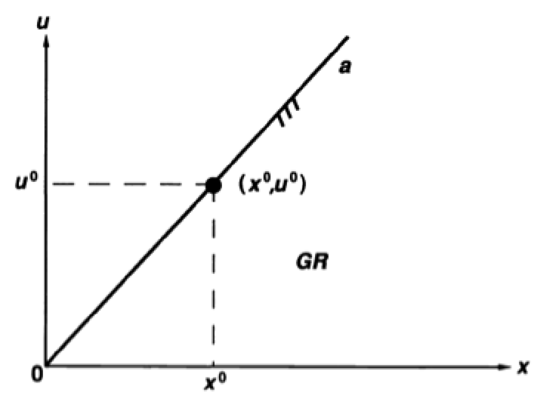

Figure 3: The Relationship Between the Input Set and the Output Set

The graph of the technology is the area bounded by the x-axis and the line (Oa). The output set is $P(x^0) = [0,u^0]$ and the input set is $L(u^0) = [x^0,+)$.

2.3.2 Production Function

Following the Fare et al's (1994a) work[8], the production technology must satisfy certain axioms that are specified below.

[8]Fare, R., Grosskopf, S. and Lovell, C. A. K. (1994a). Production Frontiers, Cambridge: Cambridge University Press.

Axiom.1. $u \notin P(0), u \geq 0$
Axiom.2. $0 \in P(x), \forall x \in R_+^N$
Axiom.3. $\forall x \in R_+^N, \lambda \geq 1, P(x) \subseteq P(\lambda x)$ (Weak disposability of inputs)
Axiom.4. $\forall x, y \in R_+^N, y \geq x, P(x) \subseteq P(y)$ (Strong disposability of inputs)
Axiom.5. $\forall x \in R_+^N$ *and* $u \in P(x)$ $0 \leq \theta \leq 1 \Rightarrow \theta u \in P(x)$ (Weak disposability of outputs)
Axiom.6. $\forall x \in R_+^N$ *and* $u \in P(x)$ $0 \leq \sigma \leq 1 \Rightarrow \sigma \in P(x)$ (Strong disposability of outputs)

First axiom states that input is required for the production and second axiom shows zero output is obtainable from the inputs. Third and fourth axioms show the disposability of inputs. Fifth and sixth axioms show the disposability of outputs. The input disposability axioms also can be stated in terms of the input set L(u).

Axiom.3. is equivalent to:
$\forall u \in R_+^M, x \in L(u)$ *and* $\lambda \geq 1 \Rightarrow \lambda x \subseteq L(u)$
Axiom.4. is equivalent to:
$\forall u \in R_+^M, x \in L(u)$ *and* $y \geq x \Rightarrow y \subseteq L(u)$

The strong disposability and weak disposability of inputs are shown for the case N=2 in the Figure 4.

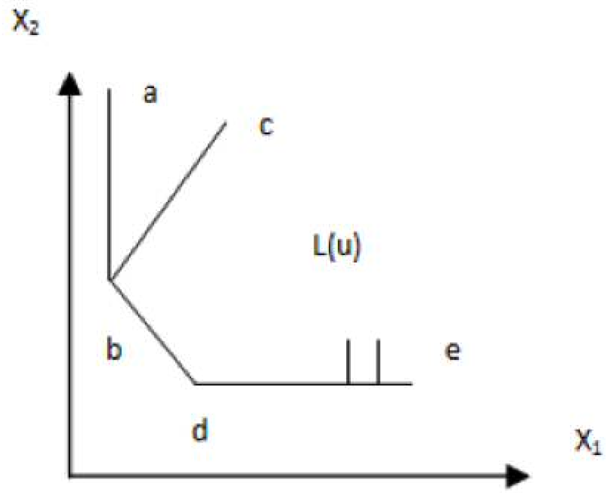

Figure 4: The Strong Disposability and
Weak Disposability of Inputs

Suppose that inputs are weakly disposable (where only Axiom.3. holds) then the input set L(u) $\in R^{2}_{+}$ corresponds to the area bounded by (cbde). Now suppose that inputs satisfy strong disposability (where only Axiom.4. holds), then the input set L(u) $\in R^2_+$ corresponds to the area bounded by (abde).

The strong disposability and weak disposability of outputs are shown for the case N=2 in the Figure 5.

Suppose that outputs are weakly disposable (where only Axiom.5. holds), then the output set P(x) $\in R^2_+$ corresponds to the area bounded by (0bcde0). Now suppose that outputs satisfy strong disposability (where only Axiom.6.holds), then the output set P(x) $\in R^2_+$ corresponds to the area bounded by (0abcde0).

Technology may produce both bads and goods, i.e. u=(y,w), where the sub-vector y denotes good output and w denotes bad output. Hence, we cannot assume that all outputs are strongly disposable which implies the bads as well as goods can be

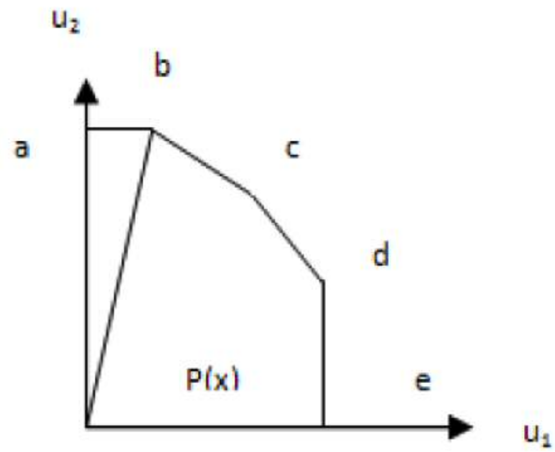

Figure 5: The Strong Disposability and Weak Disposability of Outputs

freely disposed of. Since bads and goods are treated asymmetrically in terms of their disposability characteristics, it is assumed that bads are weakly disposable and goods are strongly disposable, i.e. $(y,w) \in P(x) \Rightarrow (y^{'},w) \in P(x)$ for $y' \leq y$

If one wishes to reduce bads, weak disposability implies that goods must also be reduced for a given level of inputs or more inputs needs to be used to reduce bads but keep the same level of good outputs. On the other hand, strong disposability of goods enables them to be freely disposed.

Since we have non-parametric technology and no priori assumption on the production function, the form of the production function is not required. A non-parametric piece-wise linear technology with one described below having disposability assumptions can be explained as follows:

There exists K production units, i.e. k=1,...,K. N is used to denote a KxN matrix of (observed) inputs whose k,i'th ekement is $x_{i,k}$ (the amount of input i used by unit k). M is used to denote a KxM matrix of (observed) good output levels in which k,i'th element is $y_{i,k}$ (the desirable output i produced by unit k). J is used to denote a KxJ matrix of (observed) bad output levels in which k,i'th element is $w_{i,k}$ (the undesirable output i produced by unit k). N,M,J are non-negative matrices which have strictly positive row sums and column sums.

2.3.3 Disposability of Technology

Following the Fare et al's (1994a) work, constant returns to scale (CRS) technology satisfying the strong disposability of both observed good and observed bad outputs and observed inputs can be represented as an output set as:

$P^S(x)= \{(y,w)\colon zM \geq y,\ zJ \geq w,\ zN \leq x,\ z \in R_+^K \}$
where z is a Kx1 intensity variable.

Constant returns to scale (CRS) technology satisfying the weak disposability of observed bad outputs and strong disposability of observed good outputs and inputs can be represented as an output set as:

$P^W(x)= \{ (y,w)\colon zM \geq y,\ zJ=w,\ zN \geq x,\ z \in R_+^K \}$

The inequality $zJ \geq w$ allows for strong disposability of undesirable outputs and the equality $zJ=w$ allows for weak disposability of undesirable outputs.

The graphical representation of these output sets $P^S(x)$ and $P^W(x)$ can be seen in the Figure 6. below.

The strongly disposable output set $P^S(x)$ is represented by oa, ab, bc and cd bounded lines. The weakly disposable output technology $P^W(x)$ is represented by ob, bc and cd bounded lines. More clearly, if the unit wants to reduce undesirable outputs, strong disposability enables any feasible undesirable output to be freely disposed of. On the other hand, weak disposability implies that good outputs must also be reduced while reducing he undesirable output for a given level of inputs.

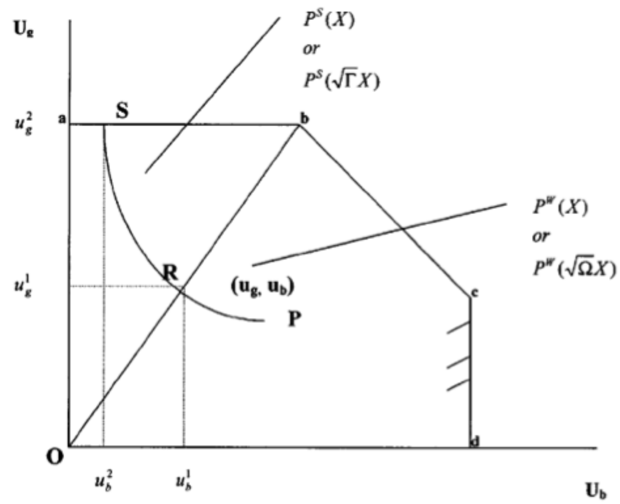

Figure 6: The Difference Between the Output Sets

2.3.4 Construction of the Environmental Efficiency Index

By treating the desirable and undesirable outputs asymmetrically, environmental efficiency index is obtained through choosing the input-output combination that gives maximum desirable output while simultaneously minimizing the input and undesirable output chosen among various input and output combinations.[9] In other words, environmental efficiency is obtained through computing the opportunity cost of turning the production process from one where all outputs are strongly disposable to the one, where undesirable outputs are weakly disposable. This opportunity cost is the ratio of two hyperbolic graph measure of technical efficiency, which seeks the maximization of the desirable outputs and minimization of the inputs and undesirable outputs.

By assuming technology exhibits CRS and satisfies strong disposability of outputs and inputs, hyperbolic graph measure of technical efficiency measure is defined for the production unit k as:

$$H^A(x^k, y^k, w^k) = min \ \{\lambda : (\lambda x^k, \lambda^{-1} y^k, \lambda w^k) P^s(x)\}$$

and for each producing unit k it can be obtained through solving the following programming problem:

[9] This section is adopted from the work of Fare et al (1989a)

$H^A(x^k, y^k, w^k) = min\ \lambda$
s.to (LP1):
$z^T M \geq \lambda^{-1} y^k$
$z^T J \geq \lambda w^k$
$z^T N \leq \lambda x^k$
$z^T \in R_+^K$

LP1 is a non-linear programming problem. Hence LP1 can be transformed into linear programming problem as in LP2 where $\Gamma = \lambda^2$ and Z=λz and the solution is obtained by solving the $\sqrt{\Gamma}$.

$H^A(x^k, y^k, w^k) = min\ \lambda$
s.to (LP2) :
$Z^T M \geq y^k$
$Z^T J \geq \Gamma w^k$
$Z^T N \leq \Gamma x^k$
$Z^T \in R_+^K$

For the technology that assumes weak disposability for the undesirable outputs, and strong disposability for the desirable outputs and inputs, the following linear programming problem can be constructed to get a solution for $\sqrt{\Omega}$ that gives a graph measure of technical efficiency for each unit k.
The following linear programming problem can be constructed to get a solution for $\sqrt{\Omega}$ that gives a graph measure of technical efficiency for each unit k. It is obtained through the assumption of weak disposability for the undesirable outputs, and strong disposability for the desirable outputs and inputs.

$H^B(x^k, y^k, w^k) = min\ \Omega$
s.to(LP3):
$Z^T M \geq y^k$
$Z^T J = \Omega w^k$
$Z^T N \leq \Omega x^k$
$Z^T \in R_+^K$

The ratio of these two efficiency indexes under strongly and weakly disposable technology assumptions give environmental efficiency that is expressed as follows:

$$H = \frac{\sqrt{\Gamma}}{\sqrt{\Omega}} \ .$$

H shows the opportunity cost that is created from turning the production process from one where all outputs are strongly disposable to the one where undesirable outputs are weakly disposable. In other words, H shows how much inputs and pollutants can be reduced while simultaneously increasing its desirable outputs without moving out the feasible production sets. When the production units' technologies are common, their hyperbolic expansions fall on the bc and cd lines and H is equal to 1. If this transformation creates an opportunity cost, then the value of H is less than 1. Hence, the opportunity cost (1-H) shows the percentage of desirable output abandoned due to the reduction of undesirable output.

2.4 Data

In this study, we constructed sectoral level environmental efficiency indexes for the period 2000-2011 in the 17 Kyoto countries that have signed and ratified the Kyoto Protocol. In order to compute these indexes we used sectoral level panel data for output, CO2 emission, labor and capital inputs. Sectors are divided according to their pollution intensity and classified as dirty and clean sectors. To gain further insight into sectoral differences, this classification of dirty and clean sectors in the literature are taken into consideration. The difference in the performance of these sectors are examined as well. The details of the data set are explained in the following sub-sections.

2.4.1 Environmental Efficiency Data

In order to evaluate environmental performance of the countries, we construct the sectoral level environmental efficiency indexes that show how much the production units need to sacrifice good outputs to reduce both CO2 emission and inputs. We use a panel data set of 17 Kyoto countries[10] that have CO2 emission reduc-

[10] Australia, Belgium, Croatia, Czech Republic, Finland, France, Germany, Hungary, Italy, Japan, Lithuania, Netherlands, Poland, Spain, Sweden, United Kingdom, United States

tion obligations and their 15 sectors in the period 2000-2011. In environmental efficiency computations, desirable output is taken as the sectoral output (in USD dollars) and CO2 emissions (in millions of tons) are taken as the undesirable output. The two inputs are considered as capital and labor inputs.[11]

Desirable output is measured by value added (in USD dollars) and the undesirable output is measured by CO2 emissions (in millions of tons). The two inputs are sectoral level labor input measured by number of employees and sectoral level capital input measured by number of capital stock.

The inputs data set have been obtained from the United Nations′ Industrial Statistics database (INDSTAT2 2016 ISIC Revision 3), and data are defined at the two-digit level of the International Standard Industrial Classification (ISIC) code. Even though the data set covers the period between 1963-2014 for 138 countries, some sectoral level data are not present or missing for our sample. Hence, countries are selected according to availability of sectoral level data. [12] In order to make the data set balanced and consistent, data is restricted to 17 countries with 15 sectors and the period is starts from 2000 onwards.

The total sectoral CO2 emissions from fuel combustion[13] data is obtained from the International Energy Agency (IEA) 2015 database. CO2 emission levels for the classified sectors are not readily available in ISIC classification. Hence, the OECD′s correspondence table [14] between CO2 flows and Input-Output (IO) sectoral classification is used in order to get sectoral level carbon emission data for each country and each time period. In order to divide this data into sectoral classification that is in concern, the carbon emissions are allocated according to output

[11] Computation of environmental efficiency can be extended by considering the energy as a third input.

[12] Some of the missing values for employee and investment data are computed by linear projections. To do this, we fitted linear functions for employee and capital stock data lnE=a+bT and lnI=c+dT, respectively, where T is the time trend.

[13] In this study, we only considered the CO2 emissions from fuel combustion and this can be extended by emissions from other sources in the future analysis.

[14] See Appendix.

levels. The sectoral level value added data is obtained from OECD input-output (I-O) tables. Since the sectors value added data in I-O tables observed between the years 1995-2011, our data set is restricted until 2011.

For obtaining capital input at sectoral level, we follow Caselli (2005), and compute capital input for each country and for each sector by using the perpetual inventory method of estimating capital stock. Perpetual inventory equation is specified as follows:

$$K_{i,j,t} = I_{i,j,t} + (1\text{-}d)\ K_{i,j,t-1}.$$

Where $K_{i,j,t}$ and $I_{i,j,t}$ are the capital stock and investment for country i, sector j at time t, respectively. To obtain these estimates, we computed initial capital stock $K_{i,j,0}$ as $[I_{i,j,0} / (g_{i,j} + d)]$[15] , where I_0 is the initial investment that is available and $g_{i,j}$ is the average geometric growth rate in investment in country i, sector j for the ten years starting from the first year of available data.

2.4.2 Defining Pollution Intensive Sectors and Clean Sectors

Considering that the Kyoto Protocol brings concern for pollutants (CO2 emission), we analyze whether dirty and clean sectors have preferred a production that also minimizes CO2 emission and inputs while maximizing the desired output. To show this, we differentiate across the sectors in terms of their pollution intensity and analyze whether Kyoto countries' pollution intensive sectors (dirty sectors) has changed differently than the clean sectors.

We followed Mani and Wheeler (1999) and selected the dirty and clean industries according to their relative pollution intensity. They have used detailed emissions intensities for U.S. manufacturing at the 3-digit Standard Industrial Classification (SIC) level and their computation is based on sectoral rankings for conventional air pollutants, water pollutants, and heavy metals. In order to match the ISIC

[15] Depreciation rate (d) is assumed to be 0.06.

Rev.3 sectoral level data, we took the dirty and clean sector specification from Jug and Mirza (2005) who also follow Mani and Wheeler (1999) and defines dirty and clean sectors' classification in ISIC Rev.3. The classification of the sectors are represented in Table 1.[16]

Table 1: Classification of the Sectors

(Relatively) Dirty Sectors	
ISIC. Rev.3	**Description**
23	Manufacture of coke, refined petroleum, products and nuclear fuel
24	Manufacture of chemicals
25	Manufacture of rubber & plastics products
26	Manufacture of other non-metallic mineral products
27	Manufacture of basic metals
(Relatively) Clean Sectors	
ISIC. Rev.3	**Description**
(15-16)	Manufacture of food products, beverages and tobacco
(17-19)	Manufacture of textiles, textile products, leather and footwear
20	Manufacture of wood and wood products
(21-22)	Manufacture of pulp, paper and paper products, publishing and printing
28	Manufacture of fabricated metal products
29	Manufacture of machinery and equipment
(30-32-33)	Manufacture of computer, electronic and optical equipment
31	Manufacture of electrical machinery and apparatus
34	Manufacture of motor vehicles, trailers and semi-trailers
35	Manufacture of other transport equipment

2.5 Sectoral Level Environmental Efficiency for the Kyoto Countries

Environmental efficiency indexes (H) for each country, each sector, each year is computed by solving two linear programming problems by using General Algebraic Modeling System (GAMS) program. In total, 6120 linear programming problems

[16] Although ISIC 36 is defined as a clean sector in Mani and Wheeler (1999), due to missing data in ISIC 36, we did not include it to be able to have a consistent data in ISIC classification.

are solved. First, 3060 linear programming problems are solved under the assumption of strong disposability of outputs and second, 3060 linear programming problem is solved under the assumption of weak disposability of undesirable output. Environmental efficiency is obtained through the ratio of these two efficiency indexes. The values vary across the countries and sectors for each year. 1-H represents the opportunity cost that arises from reducing CO2 and inputs while simultaneously rising its desirable output in a feasible production set. If restricting the disposability of pollution does not have any impact on the optimization, then the index is 1 and the unit is environmental efficient. If there is an opportunity cost in order to reduce pollution (or undesirable output), H takes the value less than 1.

We computed the country averages of environmental efficiency for all the sectors and for dirty and clean sectors, and they are presented in Figure 7. Our interest is to evaluate how Kyoto Protocol was affected sectoral level environmental efficiency. Even though the Kyoto Protocol's target period is 2008-2012, the 2008 global financial crisis may altered the normal cause of changes in environmental performance. Hence, we choose to examine how environmental efficiency has changed after the Kyoto Protocol's entry into force in 2005. Figure 7 shows that, on average all sectors' environmental efficiency is improved in the period 2006-2007. This improvement is different in clean and dirty sectors where clean sectors' environmental efficiency is higher than the dirty sectors' environmental efficiency. However, overall environmental efficiency is declined during the 2008 global financial crisis.[17]

[17] The effect of the 2008 financial crisis on sectoral level environmental efficiency has to be examined further in the future analysis.

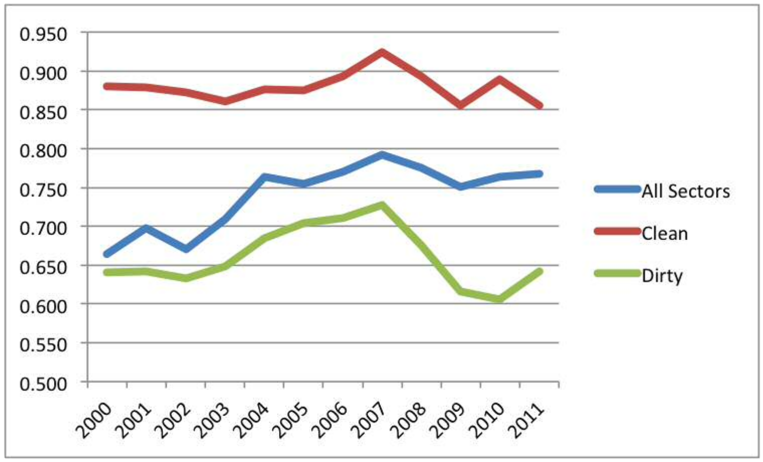

Figure 7: Sectoral Level Environmental Efficiency

We excluded 2005 in our analysis and took the years before and after the Kyoto Protocol's entry into force (2005). Environmental efficiency averages before and after the 2005 are presented in Table 2. Considering the 2008 global financial crisis, we analyzed the changes of environmental efficiency in three different periods: 2006-2007 is considered as the period before the crisis, 2008-2011 is considered as the crisis period that can be influential and 2006-2011 is the period that is after the Kyoto Protocol's entry into force and contains the crisis period too. Table 2 shows that, changes in environmental efficiency in dirty and clean sectors are different and we observe the greatest improvement in environmental efficiency in the clean sectors in the period 2006-2007. Moreover, the effect of the 2008 global can be seen in the averages that include the global financial crisis: 2008-2011 and 2006-2001 as a decline.

Table 2: Sectoral Level Environmental Efficiency

	2000-2004	**2006-2007**	**2008-2011**	**2006-2011**
All sectors	0.694	0.785	0.768	0.774
Clean Sectors	0.701	0.909	0.873	0.891
Dirty Sectors	0.650	0.719	0.635	0.667

In the following section, we examine the changes in environmental efficiency further. Our aim is to identify the impact of the Kyoto Protocol and other economic factors at sectoral and country levels and construct an econometric model that explains sectoral level environmental efficiency for the countries that have signed and ratified the Kyoto Protocol.

CHAPTER III

ESTIMATION: ANALYZING THE IMPACT OF THE KYOTO PROTOCOL

3.1 Motivation and Background

The Kyoto Protocol is signed in 1997 by UNFCC meeting in Kyoto to achieve reduction in GHGs in period between 2008-2012 by 5.3 % of 1990 levels. 38 industrialized countries (Annex-B) are directly addressed and obliged to reduce their GHG emission levels. Hence, member countries are divided as Annex-B countries that have emission reduction targets (Kyoto countries) and non Annex-B countries that have no emission reduction targets (non Kyoto countries). Except the United States, 37 countries have ratified the Kyoto Protocol and it entered into force in 2005.

The Kyoto Protocol is analyzed in several aspects in the literature. Both variation in decision and impact of the Kyoto Protocol are examined by comparisons between Kyoto and non-Kyoto countries. Zahran (2007) and York (2005) empirically discussed the determinants and variation of the Kyoto ratification decision. Their findings suggest that, countries with political rights, highly educated society with high environmental conscious, high energy efficiency and low emissions growth are more likely to ratify the Kyoto. Aichele and Felbermayr (2010) investigate whether Kyoto countries ratification have an effect on the carbon content of bilateral trade by using gravity equation. They calculate the CO2 emissions embodied in bilateral trade flows for a large sample of countries over the period 1995 to 2005 and suggest that ratification of the Kyoto increased the carbon content of imports. Iwata and Okada (2010) considers several GHG emissions such as methane (CH4), nitrous oxide (N2O) , hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF6)) emissions and use the Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) model using the data of 119 countries in 1990, 1995, 2000 and 2005. Their finding suggests that Kyoto has been effective on reduction in CO2 and CH4 emissions. However, they did not address the problem of endogeneity of the Kyoto variable.

The highest contribution to GHG emissions is from the CO2 emissions. Hence, a number of studies have investigated the impact of the Kyoto in terms of carbon emissions. Aichele and Felbermayr (2011) find that on average Kyoto countries CO2 emissions are 10 percent less than non-Kyoto countries. In order to address the endogeneity problem, they use instrumental variable and find that International Criminal Court (ICC) predicts Kyoto ratification. On the other hand, Grunewald and Martinez-Zarzoso (2009) use a static and dynamic panel data model in a panel of 123 countries over the period 1974-2004 to show that Kyoto is not only effective in developed countries CO2 emission reduction but also it is effective in developing countries CO2 emission reduction, too.

There are two most related studies to ours. Both of them investigate the impact of the Kyoto Protocol on environmental efficiency but using different methods to compute aggregate level environmental efficiency. One of the studies is Halkos and Tzeremes (2011) who use Data Envelopment Analysis (DEA) models to compute environmental efficiency of 110 countries. They find that the Kyoto improved environmental efficiency first six years after signing it but after the first six years, Kyoto reduced environmental efficiency. The other study that analyze the effect of the Kyoto Protocol on environmental efficiency is Lin et al. (2013) who study 63 countries over the period 1981-2005. They use a directional distance function model to compute environmental efficiency and divide countries to four groups according to their income levels; high, upper middle, low middle. They apply OLS estimation and find that environmental efficiency is improved in high-income countries more than the countries with other income groups.

Overall, there are several studies that investigate the effectiveness of the Kyoto Protocol. They mainly differ in terms of evaluating the effectiveness in environmental outcomes. The fear of global warming and GHG emissions reduction efforts lead them to adopt some changes in their environmental performance. Therefore, this study investigates whether the Kyoto had an impact on Kyoto countries' environmental performance. The contribution of this study is twofold. First is measuring sectoral level environmental performance which is measured by environmental efficiency for each dirty and clean sectors in Chapter 2. Second, is investigating whether environmental efficiency in Kyoto countries have changed after the Kyoto Protocol's entry into force. Previous studies have compared Kyoto and non-Kyoto countries' environmental performance while analyzing the effectiveness of the Kyoto Protocol. Since the industrialized countries are principally responsible for the current high levels of GHG emissions, the Kyoto Protocol obliged only the industrialized countries that have signed and ratified the Protocol (Kyoto countries). Even though these countries are required to reduce their GHG emissions from 1990 levels by an average of 5% over the period 2008-2012, we consider that the 2008 global financial crisis may have been influential and choose to examine how sectoral level environmental efficiency has changed after the Kyoto Protocol's entry into force (2005). In the following sub-sections we cover the details of the data, explain our model and methodology, discuss the empirical results and perform robustness checks for possible endogeneity problems.

3.2 Data

The dependent variable is sectoral level environmental efficiency, for which detailed explanation for the computation are provided in the previous section. These sectoral level environmental efficiency values are comparable across time, sectors and countries. We aim to investigate the driving forces behind environmental efficiency. Sectoral level output data is obtained from OECD input-output tables (ISIC Rev.3) and sectoral level import data is obtained from OECD Bilateral Trade in Goods by Industry (ISIC Rev.3) (US Thousands Dollars). Country level development of environment related technologies (% all technologies) is obtained from OECD Green Growth Indicators, which represents the number of environment related innovations expressed as a percentage of all domestic innovations (in all technologies).

3.3 Model

We assume that the level of environmental efficiency (log$H_{i,j,t}$) for country i, sector j and year t can be explained as the level of sectoral total output (logVA), the level of sectoral imports (logImp) and the level of development of environment related technologies (logTech). Sectoral level environmental efficiency of 16 Kyoto countries for period 2000-2011 are examined by the equation below where β_0 is the intercept and the $u_{i,j,t}$ is log normally distributed disturbance term:

$$logH_{i,j,t} = \beta_0 + \beta_1 logVA_{i,j,t} + \beta_2 logImp_{i,j,t} + \beta_3 logTech_{i,j,t} + u_{i,j,t} \tag{1}$$

Sectoral level environmental efficiency is expected to be positively related with sectoral level total output. Considering that the Kyoto countries are the industrialized countries, according to Environmental Kuznets Curve, there may be a relationship between the sectoral level environmental degradation and income per capita and this may lead an improvement in environmental efficiency as the sectors expand and produce more. On the other hand, environmental efficiency is expected to be negatively related with the sectoral level imports. This can be explained by the Pollution Haven Hypothesis which suggest that, when the industrialized countries concern about the pollution, the dirty sectors of industrialized countries are migrating to the developing countries. As a result, these countries are becoming net importers of these sectors and environmental efficiency, mostly in dirty sectors, may be higher in sectors where the industrialized countries imports more. Finally, we consider that environmental efficiency and the development of environment related technologies are positively related. Hence, increase in innovation in environment related technologies may lead an improvement in environmental efficiency.

3.4 Empirical Results

Before analyzing the impact of the Kyoto Protocol on sectoral level environmental efficiency, we investigated the driving forces behind environmental efficiency. In the first stage, we estimated equation (1) by pooled OLS. However, the OLS results are biased and not reliable since there exists some sector and country specific differences that cause unobserved heterogeneity. To show this, we applied White Heteroscedasticity Test and got the evidence for heteroskedasticity in the error term. We also checked for autocorrelation of first order by the Wooldridge Test and concluded that there is no autocorrelation in the error term.

Estimating the equation (1) with random effects (RE) or with fixed effects (FE) are two alternatives to address for unobserved heteroskedasticity. First, we test for the pooled OLS relative to random effects and fixed effects. The test results are presented in Table 3. We get p-value less than 0.05 in both two tests. This gives the evidence for rejection of pooled OLS relative to random effects by the Breusch Pagan Lagrange Multiplier (LM) Test and rejection of pooled OLS relative to fixed effects by F-Test. Baier and Bergstrand (2007) states that fixed effects can be applied to overcome the endogeneity bias with panel data. In order to see whether we should use panel fixed effects or random effects, we apply Hausman Test. The result indicates that, random effects estimator is inconsistent, so we should apply fixed effects in our analysis.

Table 3: The Test Results

Breusch-Pagan LM Test	F-Test	Hausman
H_0: OLS H_1: RE	H_0: OLS H_1: FE	H_0: RE H_1: FE
p-value: 0.0000	p-value: 0.0000	p-value: 0.0289

We used sector-country specific panel fixed effects in our model to control for unobserved heterogeneity across sectors and countries that can also affect the environmental efficiency. We also corrected the heteroskedasticity by robust clustered standard errors with sector-country fixed effects. The fixed effects estimation is reported in Table 4 column 1. With the robust estimators the results indicate that, sectoral level total output, imports and development of environment related technologies have statistically significant relationship between environmental efficiency and have the expected signs. Environmental efficiency improves with increase in sectoral total output and the development of environment related technologies. This finding supports the Environmental Kuznets Curve Hypothesis in industrialized countries' sectors. As these sectors expand and produce more, they aim to improve environmental performance with the development of environmental technologies and this leads to an improvement in environmental efficiency and decrease in environmental degradation. Moreover, the Pollution Haven Hypothesis is supported by observing a decrease in environmental efficiency with increase in imports. This finding suggest that, Kyoto countries' concern for their dirty sectors lead them to relocate their dirty sectors to developed countries and this resulted in increase in imports of these dirty sectors.

Our interest is to evaluate the impact of the Kyoto Protocol on sectoral level environmental efficiency. Rather than taking the Kyoto Protocol's target period (2008-2012) as a benchmark in our analysis, we consider the 2008 global financial crisis may have been influential, and take the Kyoto Protocol's entry into force (2005) as a benchmark. We extend our reference model with the three alternative Kyoto dummies, Kyoto1, Kyoto2 and Kyoto3, that differentiate between the before and after the 2005. Kyoto1 is for the periods before and after the 2005 and includes the crisis period. On the other hand, Kyoto2 and Kyoto3 do not include the crisis period by considering the periods before the 2008 and after the 2005. In order to see whether the Kyoto Protocol's effect on environmental efficiency changes are stronger in the periods closer to 2005, we also compare the two years period before and after the Kyoto Protocol's entry into force in Kyoto3. These periods where we examine the structural change is described in below:

$$Kyoto1 = \begin{cases} 0, & \text{if t= } 2000-2004 \\ 1, & \text{if t= } 2006-2011 \end{cases}$$

$$Kyoto2 = \begin{cases} 0, & \text{if t= } 2000-2004 \\ 1, & \text{if t= } 2006-2007 \end{cases}$$

$$Kyoto3 = \begin{cases} 0, & \text{if t= } 2002-2004 \\ 1, & \text{if t= } 2006-2007 \end{cases}$$

Fixed effect models with corrected standard errors are re-estimated with the three Kyoto dummies. Moreover, we consider that environmental efficiency improvements may have been different in dirty and clean sectors and add three interaction dummies (DirtyKyoto1, DirtyKyoto2, DirtyKyoto3), where dirty sectors' dummies are multiplied by the each of the three Kyoto dummies. The fixed effects estimations with the dummy variables are reported in the Table 4.

Table 4: Panel Fixed Effects Estimation with Kyoto Dummies

VARIABLES	(1) FE	(2) Kyoto1	(3) DirtyKyoto1	(4) Kyoto2	(5) DirtyKyoto2	(6) Kyoto3	(7) DirtyKyoto3
logVA	**0.270*** **	**0.281*** **	**0.293*** **	**0.290*** **	**0.345*** **	**0.291** **	**0.351*** **
	(0.0616)	(0.0639)	(0.0651)	(0.107)	(0.105)	(0.134)	(0.129)
logImp	**-0.127** **	**-0.213*** **	**-0.240*** **	**-0.478*** **	**-0.587*** **	**-0.480*** **	**-0.611*** **
	(0.0517)	(0.0651)	(0.0707)	(0.121)	(0.123)	(0.138)	(0.139)
logTech	**0.122*** **	0.0583	0.0573	-0.0799	**-0.0843* **	-0.106	-0.110
	(0.0387)	(0.0427)	(0.0428)	(0.0515)	(0.0504)	(0.0794)	(0.0790)
Kyoto1		**0.105** **	**0.089* **				
		(0.0431)	(0.0458)				
DirtyKyoto1			**0.089* **				
			(0.0516)				
Kyoto2				**0.213*** **	**0.132** **		
				(0.0540)	(0.0574)		
DirtyKyoto2					**0.383*** **		
					(0.0611)		
Kyoto3						**0.247*** **	**0.188*** **
						(0.0574)	(0.0589)
DirtyKyoto3							**0.324*** **
							(0.0574)
Constant	-1.219**	0.123	0.434	4.342***	5.556***	4.386***	5.919***
	(0.535)	(0.840)	(0.896)	(1.294)	(1.332)	(1.479)	(1.514)
Observations	2,835	2,595	2,595	1,635	1,635	1,155	1,155
R-squared	0.016	0.019	0.021	0.020	0.041	0.022	0.041
Number of group1	240	240	240	240	240	240	240
Sector-Country FE	YES	YES	YES	YES	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4 shows six different models with three alternative Kyoto dummies. The results are consistent with the fixed effects model in column 1, except the environment related technologies that loose significance with the three Kyoto dummies. For each alternative Kyoto periods, as sectoral output increases, we observe an improvement in environmental efficiency. However, as imports increase, we observe a decrease in environmental efficiency. These two findings again support the Environmental Kuznets Curve Hypothesis and the Pollution Haven Hypothesis for each alternative Kyoto periods. Furthermore, when we add both Kyoto2 and DirtyKyoto2 dummies in our model (column 5), we observe that the environment related technology is significant at 1% level, but negatively related with environmental efficiency which contradicts with our fixed effects estimation in column 1. We conclude that this effect is not robust in our estimations.

Each of the Kyoto dummies are significant and positively related with the sectoral level environmental efficiency. This suggest that, we observe an improvement in all sectors' environmental efficiency in Kyoto countries[18] after the Kyoto Protocol's entry into force. This improvement is stronger with the Kyoto2 and Kyoto3 dummies that do not include the crisis period. Moreover, when we define the pre and post 2005 periods narrowly that is specified in Kyoto3 in column 6, we observe the strongest improvement in all sectors' environmental efficiency among the three alternative estimations.

We also observe that these environmental efficiency improvements are different in dirty and clean sectors where dirty sectors have improved environmental efficiency more than clean sectors after the Kyoto Protocol's entry into force. This difference is stronger with the Kyoto2 and Kyoto3 dummies that do not include the crisis period. Moreover, we observe the strongest improvement in dirty sectors' environmental efficiency with DirtyKyoto2 specification in column 5.

Overall results indicate that, there is an improvement in all sectors' environmental efficiency after the Kyoto Protocols entry into force and this improvement is more significant before the 2008 global financial crisis. Moreover, dirty sectors environmental efficiencies have improved more than clean sectors environmental efficiency in the Kyoto countries. These results may point out that, the consciousness regarding the environmental damage has increased following the Kyoto Protocol's entry into force. Dirty sectors in the Kyoto countries have preferred a production that also minimizes CO2 emissions after the Kyoto Protocol and that lead an improvement in dirty sectors' environmental efficiency.

3.5 Robustness Check

While analyzing the effectiveness of the Kyoto Protocol on environmental efficiency, we take the Kyoto Protocol's entry into force as a benchmark in our anal-

[18]The Kyoto countries differentiate in terms of their emission reduction targets. Some of them were strictly required to reduce their GHG emissions and others were allowed to increase their GHG emissions by a certain amount. Considering that, further differentiation can be made for differences in policies of each Kyoto countries in a future analysis.

ysis and evaluate whether Kyoto's entry into force has affected the sectoral level environmental efficiency. In this section we analyze whether the estimation results are robust with respect to possible endogeneity problems of the Kyoto variable as a regressor in our model. One concern is that, there may be a reverse causality from environmental efficiency to Kyoto Protocol's entry into force such that Kyoto countries that have been already environmental efficient, so they self-select into Kyoto to make it enter into force. This unknown direction of the causality makes the fixed effect estimation coefficients biased. Another problem may arise with unobserved variables such as countries' environmental consciousness that may lead to omitted variable bias. Two estimation methods that we use are the Heckman two stage estimation (Heckman, 1979) and fixed effects instrumental variable methods.

Both two methods require the determination of variables that can be used as instruments for the Kyoto. Hence, we need an instrument that is not related with the error term, but closely related with the Kyoto dummy variable. In this section, we argue that there are two instruments that can be used for the Kyoto. First instrument is considered as countries' immediate response for participation in the General Agreement on Tariffs and Trade's (GATT) [19] enforcement. We take GATT's entry into force (1948) as a benchmark and create a variable by grouping the countries according to their speed of participation into the GATT's enforcement. [20] The link between the Kyoto Protocol and the GATT comes from countries' willingness to cooperate in international multilateral agreements. If a country sees a benefit from entering into one international cooperation, it is expected to have a similar behavior regarding its participation to another international cooperation. Moreover, it is necessary to these agreements differentiate in terms of policy outcomes, one stands for the environment and the other stands for the trade, which makes the GATT an appropriate instrument for the Kyoto.

Second instrument considered as the implementation of the Universal Health Care (or Coverage) (UHC) program. By implementing UHC, governments aim to im-

[19]GATT is a multilateral agreement that regulates international trade. In 1995, GATT is replaced by the World Trade Organization (WTO).

[20]For example, we indexed countries by 1 if the country has entered into force in 1948 and indexed by 2 if the country has entered into force in 1950, and so on.

prove health standards for every citizens, mostly for the poor people that needs health care. Considering that implementing the UHC shows countries' intend for having progress towards the health standards, we use the government expenditure on health as a share of GDP (defined as Health) as a proxy for UHC. [21] We also consider that the Kyoto Protocol and UHC have similarity in terms of industrialized countries' consciousness for the society's well being. Moreover, among the most industrialized countries, the United States is the only industrialized country that does not implement the UHC, just like in Kyoto Protocol, where it is the only industrialized country that did not ratify the Kyoto Protocol. Moreover, these two policies differentiate in terms of their outcomes. The Kyoto Protocol has environmental outcomes, whereas UHC has health related outcomes. All these considered, we take UHC as a valid instrument that can be used for the Kyoto variable.

3.5.1 Heckman Two-Stage Estimation

In order to address the potential self-selection bias and endogeneity, we apply the two-stage Heckman method (Heckman, 1979). In the first step, we estimate a probit model. By doing this, we generate a latent variable for the probability of Kyoto and regress it to our exogenous variables. The selection equation (3) is:

$$Prob(Kyoto^*_{n,t}) = Z_{i,j,t}\gamma + \varepsilon_{i,j,t} \tag{2}$$

where three Kyoto dummies (Kyoto1, Kyoto2, Kyoto3) are indexed by n=1,2,3. $Z_{i,j,t}$ contains sector and country specific exogenous variables and the two instruments for Kyoto. In the second stage, the latent variable is defined as $Kyoto_{n,t}$ =1 if $Kyoto^*_{n,t}$ >0, and $Kyoto_{n,t}$ =0 otherwise.

$$Prob(Kyoto_{n,t} = 1|Z_{i,j,t}) = \theta(Z_{i,j,t}\gamma)$$

[21] Data for the Government expenditure on health is taken from the World Bank.

and

$$Prob(Kyoto_{n,t} = 0|Z_{i,j,t}) = 1 - \theta(Z_{i,j,t}\gamma)$$

By estimating the probit model, we obtain the inverse Mills ratio (λ)[22] that stand for the identification of the self-selection. In the second stage, we do a regression by including the inverse Mill's ratio (λ) as a regressor in our model and the environmental efficiency equation becomes :

When $\text{Kyoto}^*_{n,t} > 0$, $\text{Kyoto}_{n,t} = 1$:

$$logH_{i,j,t} = \beta X_{i,j,t} + \rho\lambda + \varepsilon_{i,j,t}$$

When $\text{Kyoto}^*_{n,t} \leq 0$, $\text{Kyoto}_{n,t} = 0$:

$$logH_{i,j,t} = \beta X_{i,j,t} + \varepsilon_{i,j,t}$$

where $\text{X}_{i,j,t}$ contains all the explanatory variables and ρ is the coefficient of the inverse Mill's ratio.

The selection bias can be detected by the inverse Mill's ratio's coefficient, ρ. The null hypothesis is: ρ=0. Rejecting the null result in presence of sample selection bias where $\rho \neq$0 and not rejecting the null results in not existence of selection bias where ρ =0. Table 5 and Table 6 show the results from the Two-Stage Heckman Selection Estimation.

Table 5 reports the results of two stage Heckman Selection estimations that con-

[22]The inverse Mills ratio is the ratio of the probability density function and the cumulative density function.

Table 5: Results from the Two-Stage Heckman Selection Estimation-1

	Kyoto1			**Kyoto2**			**Kyoto3**		
VARIABLES	Selection	Regression	λ	Selection	Regression	λ	Selection	Regression	λ
logVA	-0.175***	0.113***		-0.151***	0.0627		-0.230***	0.0829	
	(0.0389)	(0.0332)		(0.0465)	(0.0898)		(0.0541)	(0.112)	
logImp	0.139***	-0.178***		0.214***	-0.157		0.120**	-0.120	
	(0.0428)	(0.0391)		(0.0517)	(0.130)		(0.0604)	(0.0997)	
logTech	3.267***	-0.343		3.167***	-0.521		4.369***	-0.777	
	(0.149)	(0.308)		(0.236)	(1.144)		(0.331)	(1.480)	
Health	0.405***			0.197***			0.178***		
	(0.0415)			(0.0497)			(0.0595)		
GATT	-0.0771**			-0.0579			-0.0673		
	(0.0321)			(0.0382)			(0.0433)		
lambda			**-0.383****			**-0.484**			**-0.492**
			(0.161)			(0.555)			(0.592)
Kyoto1		2.283**							
		(0.996)							
Kyoto2					2.916				
					(4.098)				
Kyoto3								2.612	
								(3.926)	
Constant	-10.23***			-10.39***			-10.30***		
	(0.544)			(0.736)			(0.859)		
Observations	1,965	1,965	1,965	1,245	1,245	1,245	885	885	885

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

siders the all sectors with each of the three alternative Kyoto periods. These results are grouped as Kyoto1, Kyoto2 and Kyoto3. First regression result is for the case of Kyoto1 that includes the 2008 global financial crisis period. The significance of the inverse Mill's ratio (λ) suggest that there is a selection bias in the Kyoto1 variable. On the other hand, second and third regression results are for the case of Kyoto2 and Kyoto3 variables that do not include the crisis period. For both cases, the inverse Mill's ratio (λ) is not significant, so we do not reject the null hypothesis and conclude that, there is no selection bias for the Kyoto2 and Kyoto3 variables. Moreover, except the GATT, the explanatory variables are relevant in the selection equation but they are not relevant for the second stage regression. However, Kyoto2 and Kyoto3 variables are not significant. Hence, the results are not robust in terms of evaluating the all sectors' environmental efficiency improvements after the Kyoto Protocol's entry into force.

Table 6 reports the results of two stage Heckman Selection estimations that differentiate across the sectors by the interaction dummy [23] for each of the alternative Kyoto periods. These results are grouped as Kyoto1 & DirtyKyoto1, Kyoto2 &

[23] Dirty sectors' dummies are multiplied by the each of the three Kyoto dummies.

Table 6: Results from the Two-Stage Heckman Selection Estimation-2

	Kyoto1			**Kyoto2**			**Kyoto3**		
VARIABLES	Selection	Regression	λ	Selection	Regression	λ	Selection	Regression	λ
logVA	-0.175***	0.117***		-0.151***	0.0800		-0.230***	0.100	
	(0.0389)	(0.0335)		(0.0465)	(0.0900)		(0.0541)	(0.112)	
logImp	0.139***	-0.182***		0.214***	-0.179		0.120**	-0.138	
	(0.0428)	(0.0394)		(0.0517)	(0.130)		(0.0604)	(0.0998)	
logTech	3.267***	-0.351		3.167***	-0.602		4.369***	-0.859	
	(0.149)	(0.308)		(0.236)	(1.143)		(0.331)	(1.477)	
Health	0.405***			0.197***			0.178***		
	(0.0415)			(0.0497)			(0.0595)		
GATT	-0.0771**			-0.0579			-0.0673		
	(0.0321)			(0.0382)			(0.0433)		
lambda			**-0.387****			**-0.526**			**-0.526**
			(0.161)			(0.554)			(0.590)
Kyoto1		2.321**							
		(0.996)							
DirtyKyoto1		0.0572							
		(0.0640)							
Kyoto2					3.251				
					(4.095)				
DirtyKyoto2					**0.249****				
					(0.120)				
Kyoto3								2.861	
								(3.919)	
DirtyKyoto3								**0.248****	
								(0.120)	
Constant	-10.23***			-10.39***			-10.30***		
	(0.544)			(0.736)			(0.859)		
Observations	1,965	1,965	1,965	1,245	1,245	1,245	885	885	885

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

DirtyKyoto2 and Kyoto3 & DirtyKyoto3. First regression result is for the case of Kyoto1 & DirtyKyoto1 that represent the dirty sectors' impact on environmental efficiency after the Kyoto Protocol's entry into force. Moreover, it includes the 2008 global financial crisis period. We observe a significant inverse Mill's ratio (λ) that suggests there is a selection bias in the Kyoto1 variable. Again, this can be related with the 2008 global financial crisis period, where Kyoto1 is the only variable that includes the 2008 period. On the other hand, the inverse Mill's ratio (λ) is not significant for the 2 and 3 group regressions constructed for Kyoto2 and Kyoto3. Hence, we do not reject the null hypothesis and conclude that, there is no selection bias for the Kyoto2 and Kyoto3 variables. Again, except the GATT, the explanatory variables are relevant in the selection equation but they are not relevant for the second stage regression. Unlike the previous estimation results that are reported in Table 5, we observe a positive significant and very similar coefficients for DirtyKyoto2 and DirtyKyoto3. This suggests that dirty sectors environmental efficiency is improved more than clean sectors environmental efficiency after the Kyoto Protocols entry into force and this improvement is significant in before the financial crisis period and cannot be extended to the period where financial crisis is included.

3.5.1 Instrumental Variables Method

Since we have two instruments (which is more than our endogenous variable), we do two stage least square (2SLS) estimation. In the first stage, we regress the Kyoto on specified instruments and get the predicted value of Kyoto. Then, in the second stage we regress environmental efficiency on predicted value of Kyoto. The 2SLS estimator results are showed in Table 7.

Table 7: Results from the Instrumental Variables Estimator

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
logVA	**0.243*****	**0.251*****	0.154	**0.278***	0.185	0.345
	(0.0919)	(0.0967)	(0.162)	(0.143)	(0.325)	(0.274)
logImp	-0.313	-0.342	0.588	0.190	0.0845	-0.309
	(0.281)	(0.245)	(0.687)	(0.560)	(0.966)	(0.813)
logTech	0.0122	0.00573	0.369	0.285	0.169	0.109
	(0.200)	(0.192)	(0.278)	(0.250)	(0.296)	(0.274)
Kyoto1	0.197	0.199				
	(0.358)	(0.357)				
DirtyKyoto1		0.0566				
		(0.0969)				
Kyoto2			-0.780	-0.693		
			(0.641)	(0.608)		
DirtyKyoto2				**0.529*****		
				(0.173)		
Kyoto3					-0.216	-0.127
					(0.648)	(0.615)
DirtyKyoto3						**0.332****
						(0.151)
Constant	2.144	2.537	-11.69	-6.408	-3.844	1.040
	(4.944)	(4.436)	(10.57)	(8.878)	(13.06)	(11.10)
Observations	1,965	1,965	1,245	1,245	885	885
Number of group1	180	180	180	180	180	180

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7 reports the results of the instrumental variables estimation. These results are presented for three cases Kyoto1, Kyoto2 and Kyoto3 and their interaction with the dirty sectors' dummies. The results are similar with the Heckman model. First, we include the Kyoto1 dummy into our regression. The results show that Kyoto1 is not significant. Again, this can be explained by its involvement of the 2008 financial crisis that may have affected our model by the potential omitted variables. According to estimations with Kyoto2 and Kyoto3 dummies, we observe that dirty sectors have experienced an improvement in environmental efficiency after the Kyoto Protocol's entry into force. The highest improvement in dirty sectors' environmental efficiency is observed in the model with Kyoto2 case, which is reported in the column 4. In the same estimation, we also observe that the sectoral level total output is significant and positively related with environmental efficiency. This suggests that, the effect of the Kyoto Protocol's entry into force on dirty sectors' environmental efficiency is stronger in the closer periods to 2005.

Based on these results we conclude that we are able to identify the impact of the Kyoto Protocol especially in dirty sectors' environmental efficiency. In two estimation technique we get the same result; this improvement is significant in before the financial crisis period and cannot be extended in the later periods. However, we were not able to find the economic factors that has consistent and robust effect on sectoral level environmental efficiency. The estimator results are not robust to different estimation technique. As a future work, we need to further investigate the economic factors that are influential in determining of environmental efficiency at sectoral level. We also consider that environment related technology variable we have is collected at country level. Hence, as a future work, we hope to find a sectoral level environment related technology data and other more in-depth sectoral information, which may improve our estimation results.

CHAPTER IV

CONCLUSION

In this study, we investigate the impact of the Kyoto Protocol on sectors' environmental performance across the Kyoto countries that have signed and the ratified the Kyoto Protocol. First, by following Fare et al.(1989) work, we measure sectors' environmental performance by computing environmental efficiency for each sectors. It is computed by the Data Envelopment Analysis (DEA) which is a non-parametric and non-stochastic methodology where the best production function is constructed as a linear piece-wise frontier. The difference between the unit's (each countries' each sector's) weakly and the strongly disposable technologies determines the unit's hyperbolic distance that gives relative position to the best frontier. Environmental efficiency indexes are calculated for the period 2000-2011 and for 17 countries that have emission reduction obligations. The results suggest that, on average the environmental efficiency in all sectors have improved in the period 2006-2007, following the Kyoto Protocol's entry into force in 2005. This improvement is different in clean and dirty sectors where clean sectors' environmental efficiency is higher than the dirty sectors' environmental efficiency. However, overall environmental efficiency has declined during the 2008 global financial crisis.

Second, an empirical approach is adopted to examine the role of the Kyoto Protocol in the changes of sectoral level environmental efficiency. Before analyzing the impact of the Kyoto Protocol on environmental efficiency, we argue that three factors; sectoral output, imports and environment related technologies, determine the environmental efficiency changes. We estimated our model with fixed effects to account for sector and country specific differences that cause unobserved heterogeneity. In order to investigate whether environmental efficiency in Kyoto countries have changed after the Kyoto Protocol's entry into force we extended our model by three alternative Kyoto dummies that differentiate between the periods following 2005 by either including or excluding 2008 financial crisis.

We also consider the endogeneity problem that may arise from the each of the Kyoto dummies. Hence, we apply two-stage Heckman and fixed effects instrumental variable methods as robustness checks to address sample selection bias and the omitted variable bias. The results suggest that there are two possible instruments for the Kyoto dummies. First instrument is considered as countries' immediate response for participation in the General Agreement on Tariffs and Trade's (GATT) enforcement and the second instrument is considered as implementing the Universal Health Care (or Coverage) (UHC) program in industrialized countries.

Overall results suggest that, sectors' environmental performance, measured by sectoral level environmental efficiency, have improved in the countries that have signed and ratified the Kyoto Protocol (Kyoto countries) after the Kyoto Protocols entry into force (2005). This improvement is different in clean and dirty sectors, where dirty sectors environmental efficiency is improved more than clean sectors environmental efficiency after the 2005. Our results are robust in terms of observing an improvement in dirty sectors' environmental efficiency before the financial crisis period. However, this cannot be extended to the periods where financial crisis is included.

The Kyoto Protocol has been a first step towards reducing global GHG emissions. Even though the effectiveness of the Protocol in terms of its formal enforcement mechanism is criticized by international organizations and in the media, our results indicates that the Kyoto Protocol resulted in improvement in dirty sectors' environmental efficiency. Hence, the Kyoto Protocol was an important first step for the future multinational environmental agreements, and possible enforcement mechanism are still open to discussion.

This study can be extended by further investigating sectoral level data in order to explain sectors' environmental efficiency changes. Since some of our data set, environment related technology and two instrumental variables (government expenditure on health and GATT) are in country level, finding alternative data in sectoral level may improve our results. Another extension can be done by investigating the impact of the Kyoto Protocol on each individual sectors' environmental efficiency changes after the Kyoto Protocol. Rather than differentiating between clean and dirty sectors, this may enable us to identify the specific sectors that have improved environmental efficiency after the Kyoto Protocol's entry into force.

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APPENDICES

APPENDIX A

Table A1: CO2 Emissions by ISIC Classification

IO Classification		MAINELEC	MAINCHP	MAINHEAT	EPOWERPLT	AUTOPROD	OTHEN	IRONSTL	CHEMICAL	NONFERR	NONMET	TRANSEQ	MACHINE	MINING	FOODPRO	PAPERPRO	WOODPRO	CONSTRUC	TEXTILES	INONSPEC	NEINTREN	ROAD	DOMESAIR	RAIL	PIPELINE	DOMESNAV	TRNONSPE	NETRANS	RESIDENT	COMMPUB	AGRICULT	FISHING	ONONSPEC	NEOTHER	AVBUNK	MARBUNK
Agriculture, hunting, forestry and fishing	C01T05						1															1									1	1				
Mining and quarrying	C10T14						1							1							1	1														
Food products, beverages and tobacco	C15T16						1								1						1	1														
Textiles, textile products, leather and footwear	C17T19					1													1		1	1														
Wood and products of wood and cork	C20						1										1				1	1														
Pulp, paper, paper products, printing and publishing	C21T22					1										1					1	1														
Coke, refined petroleum products and nuclear fuel	C23					1			1												1	1														
Chemicals	C24					1			1												1	1														
Rubber & plastics products	C25						1		1												1	1														
Other non-metallic mineral products	C26					1					1										1	1														
Basic metals	C27					1		1		1											1	1														
Fabricated metal products, except machinery & equipment	C28					1		1		1			1								1	1														
Machinery & equipment, nec	C29						1						1								1	1														
Computer, electronic and optical equipment	C30,32,33						1						1								1	1														
Electrical machinery & apparatus, nec	C31						1						1								1	1														
Motor vehicles, trailers & semi-trailers	C34						1					1									1	1														
Other transport equipment	C35						1					1									1	1														
Manufacturing nec; recycling (include Furniture)	C36T37						1													1	1	1														
Electricity, gas and water supply	C40T41	1	1	1	1		1														1	1														
Construction	C45						1											1			1	1														
Wholesale & retail trade; repairs	C50T52																					1								1			1	1		
Hotels & restaurants	C55																					1								1			1	1		
Transport and storage	C60T63																					1	1	1	1	1	1	1							1	1
Post & telecommunications	C64																					1								1			1	1		
Financial intermediation	C65T67																					1								1			1	1		
Real estate activities	C70																					1								1			1	1		
Renting of machinery & equipment	C71																					1								1			1	1		
Computer & related activities	C72																					1								1			1	1		
Other Business Activities	C73T74																					1								1			1	1		
Public admin. & defence; compulsory social security	C75																					1								1			1	1		
Education	C80																					1								1			1	1		
Health & social work	C85																					1								1			1	1		
Other community, social & personal services	C90T93																					1								1			1	1		
Private households with employed persons	C95																																			
Household final consumption	PrivHH																					1							1							

CO2 emission data in ISIC classification is obtained through dividing each sector's output by total industry output that is also specified in IEA's carbon emission data and it is multiplied by the total sectoral carbon emissions.

APPENDIX B

Countries That Have No Binding Commitments (1)		
AFGHANISTAN	CHAD	PARAGUAY
ALBANIA	CHILE	PERU
ALGERIA	CHINA	GRENADA
ANGOLA	COLOMBIA	GUATEMALA
ANTIGUA AND BARBUDA	COMOROS	GUINEA
ARGENTINA	CONGO	GUINEA-BISSAU
ARMENIA	COOK ISLANDS	GUYANA
AZERBAIJAN	COSTA RICA	HAITI
BAHAMAS	COTE D'IVOIRE	HONDURAS
BAHRAIN	CUBA	INDIA
BANGLADESH	CYPRUS	INDONESIA
BARBADOS	DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA	IRAN (ISLAMIC REPUBLIC OF)
BELARUS	DEMOCRATIC REPUBLIC OF CONGO	IRAQ
BELIZE	DJIBOUTI	ISRAEL
BENIN	DOMINICA	JAMAICA
BHUTAN	DOMINICAN REPUBLIC	JORDAN
BOLIVIA	ECUADOR	KENYA
BOSNIA AND HERZEGOVINA	EGYPT	KIRIBATI
BOTSWANA	EL SALVADOR	KUWAIT
BRAZIL	EQUATORIAL GUINEA	KYRGYZSTAN
BRUNEI DARUSSALAM	ERITREA	LEBANON
BURKINA FASO	ETHIOPIA	LESOTHO
BURUNDI	FIJI	LIBERIA
CABO VERDE	GABON	LIBYA
CAMBODIA	GAMBIA	MADAGASCAR
CAMEROON	GEORGIA	MALAWI
CENTRAL AFRICAN REPUBLIC	GHANA	

Countries That Have No Binding Commitments (2)		
MALAYSIA	PHILIPPINES	TAJIKISTAN
MALDIVES	QATAR	THAILAND
MALI	REPUBLIC OF KOREA	REPUBLIC OF MACEDONIA
MARSHALL ISLANDS	REPUBLIC OF MOLDOVA	TIMOR-LESTE
MAURITANIA	RWANDA	TOGO
MAURITIUS	SAINT KITTS AND NEVIS	TONGA
MEXICO	SAINT LUCIA	TRINIDAD AND TOBAGO
MICRONESIA	SAINT VINCENT AND THE GRENADINES	TUNISIA
MONGOLIA	SAMOA	TURKEY
MONTENEGRO	SAN MARINO	TURKMENISTAN
MOROCCO	SAO TOME AND PRINCIPE	TUVALU
MOZAMBIQUE	SAUDI ARABIA	UGANDA
MYANMAR	SENEGAL	UNITED ARAB EMIRATES
NAMIBIA	SERBIA	UNITED REPUBLIC OF TANZANIA
NAURU	SEYCHELLES	UNITED STATES OF AMERICA*
NEPAL	SIERRA LEONE	URUGUAY
NICARAGUA	SINGAPORE	UZBEKISTAN
NIGER	SOLOMON ISLANDS	VANUATU
NIGERIA	SOMALIA	VENEZUELA
NIUE	SOUTH AFRICA	VIET NAM
OMAN	SRI LANKA	YEMEN
PAKISTAN	SUDAN	ZAMBIA
PALAU	SURINAME	ZIMBABWE
PANAMA	SWAZILAND	
PAPUA NEW GUINEA	SYRIAN ARAB REPUBLIC	

APPENDIX C

Table B1: Environmental Efficiency Index (H) in 2000

	ISIC 20	ISIC 23	ISIC 24	ISIC 25	ISIC 26	ISIC 27	ISIC 28	ISIC 29	ISIC 31	ISIC 34	ISIC 35	ISIC 15-16	ISIC 17-19	ISIC 21-22	ISIC 30-32-33
Australia	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.984	1.000
Belgium	0.892	0.441	1.000	1.000	0.825	0.731	1.000	1.000	1.000	1.000	1.000	0.731	0.420	0.949	0.466
Croatia	0.880	0.068	0.443	0.942	0.579	0.555	1.000	0.498	1.000	1.000	1.000	0.559	0.452	0.926	0.346
Czech Republic	0.618	0.781	1.000	1.000	1.000	1.000	0.789	0.563	0.855	1.000	0.966	0.019	0.815	1.000	0.316
Finland	1.000	1.000	0.924	1.000	0.862	0.574	1.000	0.996	0.991	1.000	1.000	0.035	1.000	1.000	1.000
France	0.892	0.120	0.747	0.666	1.000	1.000	0.902	0.881	0.943	1.000	0.827	0.036	0.677	1.000	0.443
Germany	0.763	0.316	0.862	1.000	0.887	0.514	0.823	0.917	0.967	1.000	0.730	0.022	0.685	0.829	0.465
Hungary	0.192	0.065	0.667	1.000	1.000	0.985	0.643	0.616	0.757	1.000	1.000	0.428	0.301	0.914	0.426
Italy	0.880	0.096	0.542	0.917	0.565	0.298	0.737	0.990	0.912	1.000	1.000	1.000	0.516	0.808	0.396
Japan	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.039	1.000	1.000	0.418
Lithuania	0.536	0.048	0.392	1.000	1.000	1.000	0.830	0.540	1.000	1.000	1.000	0.372	0.859	1.000	0.539
Netherlands	0.996	0.299	0.808	0.850	0.916	0.682	1.000	1.000	1.000	1.000	0.960	0.052	1.000	1.000	0.705
Poland	0.515	0.598	0.813	1.000	1.000	1.000	1.000	0.472	0.936	1.000	1.000	0.197	0.463	1.000	0.586
Spain	0.756	0.321	0.811	0.992	0.743	0.617	0.788	1.000	0.991	1.000	1.000	0.769	0.639	0.988	0.600
Sweden	0.854	0.315	0.563	0.830	0.823	0.603	0.825	0.954	0.782	1.000	0.585	0.043	0.461	0.470	0.357
United Kingdom	0.874	0.095	0.497	0.613	1.000	0.504	0.991	1.000	1.000	1.000	0.872	0.047	1.000	0.967	0.658

Table B2: Environmental Efficiency Index (H) in 2001

	ISIC 20	ISIC 23	ISIC 24	ISIC 25	ISIC 26	ISIC 27	ISIC 28	ISIC 29	ISIC 31	ISIC 34	ISIC 35	ISIC 15-16	ISIC 17-19	ISIC 21-22	ISIC 30-32-33
Australia	1.000	0.709	1.000	1.000	1.000	1.000	1.000	1.000	0.986	1.000	1.000	0.167	1.000	1.000	1.000
Belgium	1.000	0.448	1.000	1.000	0.813	0.651	1.000	1.000	1.000	1.000	1.000	0.157	1.000	1.000	0.791
Croatia	0.814	0.071	0.526	0.766	0.645	0.597	1.000	0.640	1.000	1.000	1.000	0.487	0.471	0.990	1.000
Czech Republic	0.672	0.561	1.000	1.000	1.000	0.991	0.769	0.542	0.808	1.000	0.864	0.094	0.612	1.000	0.392
Finland	1.000	0.838	0.951	1.000	0.843	0.599	1.000	0.998	0.982	1.000	1.000	1.000	0.938	0.914	1.000
France	0.910	0.088	0.744	0.774	0.973	1.000	0.907	0.854	0.864	1.000	0.809	0.146	0.674	0.911	0.332
Germany	0.874	0.383	0.840	1.000	0.878	0.593	0.867	0.911	0.879	1.000	0.631	0.105	0.570	1.000	0.449
Hungary	0.213	0.062	0.639	0.933	1.000	0.948	0.545	0.530	0.608	1.000	1.000	0.186	0.297	0.962	0.255
Italy	1.000	0.094	0.615	1.000	0.619	0.307	0.756	0.959	0.852	1.000	1.000	1.000	0.451	0.850	0.417
Japan	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.083	1.000	1.000	0.997
Lithuania	0.709	0.054	0.366	1.000	1.000	1.000	0.851	0.722	1.000	1.000	1.000	1.000	0.661	1.000	0.749
Netherlands	0.976	0.413	0.861	0.914	0.894	0.561	1.000	1.000	1.000	1.000	0.887	0.098	0.679	1.000	0.705
Poland	0.565	0.459	0.852	1.000	1.000	0.986	1.000	0.458	0.861	1.000	0.966	0.334	0.682	1.000	0.638
Spain	0.616	0.343	0.801	0.989	0.721	0.722	0.882	1.000	0.963	1.000	1.000	0.166	0.477	1.000	0.676
Sweden	0.932	0.272	0.588	0.894	0.779	0.627	0.790	0.939	0.735	1.000	0.551	0.089	0.616	1.000	0.229
United Kingdom	0.960	0.095	0.564	0.763	1.000	0.615	1.000	1.000	0.972	1.000	0.846	1.000	0.955	1.000	0.704

Table B3: Environmental Efficiency Index (H) in 2002

	ISIC 20	ISIC 23	ISIC 24	ISIC 25	ISIC 26	ISIC 27	ISIC 28	ISIC 29	ISIC 31	ISIC 34	ISIC 35	ISIC 15-16	ISIC 17-19	ISIC 21-22	ISIC 30-32-33
Australia	1.000	0.450	1.000	1.000	1.000	1.000	1.000	1.000	0.976	0.993	1.000	1.000	1.000	0.991	1.000
Belgium	0.994	0.323	1.000	1.000	0.838	0.571	0.993	1.000	1.000	1.000	1.000	0.033	0.705	0.596	0.683
Croatia	0.951	0.057	0.464	0.655	0.651	0.761	1.000	0.740	1.000	1.000	0.912	0.131	0.521	1.000	1.000
Czech Republic	0.740	0.277	1.000	1.000	0.862	0.998	0.824	0.578	0.884	0.791	0.633	0.019	0.903	1.000	0.902
Finland	0.999	0.949	1.000	1.000	0.803	0.545	0.996	0.991	0.989	1.000	1.000	0.812	1.000	1.000	1.000
France	0.931	0.083	0.801	0.834	0.884	1.000	0.925	0.863	0.864	0.669	0.802	0.021	0.962	0.959	0.621
Germany	0.920	0.280	0.933	1.000	0.872	0.723	0.907	0.989	0.974	0.725	0.630	0.399	0.981	0.618	0.546
Hungary	0.221	0.089	0.692	0.827	0.863	0.988	0.539	0.533	0.635	0.951	0.865	0.028	0.816	0.986	0.752
Italy	0.994	0.096	0.684	0.961	0.725	0.344	0.859	0.989	0.962	1.000	1.000	1.000	0.798	0.788	0.811
Japan	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.031	1.000	1.000	0.968
Lithuania	0.686	0.046	0.427	1.000	0.867	1.000	1.000	0.830	0.985	1.000	1.000	1.000	0.339	1.000	1.000
Netherlands	0.977	0.329	0.975	0.955	0.918	0.598	1.000	0.995	1.000	1.000	0.752	0.046	0.984	1.000	0.975
Poland	0.589	0.390	1.000	1.000	0.871	1.000	1.000	0.446	0.893	1.000	0.869	0.082	0.581	1.000	0.959
Spain	0.737	0.313	0.896	0.916	0.817	0.777	0.915	0.990	0.994	1.000	1.000	0.030	1.000	0.879	0.830
Sweden	0.962	0.148	0.900	1.000	0.752	0.746	0.847	0.942	0.985	0.594	0.567	0.035	0.686	0.645	0.635
United Kingdom	0.918	0.096	0.676	0.790	0.989	0.620	0.963	1.000	0.972	0.597	0.841	0.041	0.927	0.727	0.674

Table B4: Environmental Efficiency Index (H) in 2003

	ISIC 20	ISIC 23	ISIC 24	ISIC 25	ISIC 26	ISIC 27	ISIC 28	ISIC 29	ISIC 31	ISIC 34	ISIC 35	ISIC 15-16	ISIC 17-19	ISIC 21-22	ISIC 30-32-33
Australia	1.000	0.537	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.197	1.000	0.990	1.000
Belgium	1.000	0.455	0.972	1.000	0.857	0.607	0.995	1.000	1.000	1.000	1.000	0.373	1.000	0.929	0.691
Croatia	0.862	0.076	0.373	0.647	0.679	0.745	1.000	0.558	1.000	1.000	0.851	0.374	0.591	0.939	0.945
Czech Republic	0.674	0.400	0.938	1.000	0.941	1.000	0.836	0.486	0.899	0.790	0.578	0.136	0.831	1.000	0.870
Finland	1.000	0.630	0.889	1.000	0.870	0.561	0.997	0.938	0.944	0.971	1.000	0.301	0.944	0.813	1.000
France	0.917	0.106	0.689	0.824	0.930	0.985	0.966	0.815	0.693	0.745	0.807	1.000	0.644	1.000	0.375
Germany	0.883	0.289	0.831	1.000	0.843	0.754	0.956	0.889	0.900	0.758	0.749	0.295	0.682	0.886	0.554
Hungary	0.247	0.096	0.583	0.755	0.952	1.000	0.486	0.449	0.643	0.939	0.789	0.249	0.522	0.911	0.453
Italy	0.947	0.132	0.770	0.946	0.750	0.423	0.941	0.946	0.881	1.000	1.000	0.594	0.630	1.000	0.428
Japan	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.342
Lithuania	0.646	0.039	0.381	1.000	1.000	1.000	1.000	0.632	0.991	1.000	1.000	0.567	0.354	1.000	0.785
Netherlands	1.000	0.409	0.922	0.947	0.905	0.645	1.000	0.973	1.000	1.000	0.701	0.169	1.000	1.000	0.689
Poland	0.571	0.504	0.836	1.000	0.958	1.000	1.000	0.383	0.909	1.000	0.734	0.395	0.514	1.000	0.720
Spain	0.870	0.386	0.768	0.907	0.762	0.809	0.962	0.946	0.978	1.000	1.000	0.263	0.680	0.822	0.677
Sweden	0.967	0.214	0.916	0.995	0.792	0.718	0.949	0.918	0.935	0.704	0.740	0.124	0.427	1.000	0.374
United Kingdom	0.910	0.102	0.651	0.799	0.969	0.649	0.994	1.000	0.876	0.720	0.886	0.098	0.704	0.955	0.624

Table B5: Environmental Efficiency Index (H) in 2004

	ISIC 20	ISIC 23	ISIC 24	ISIC 25	ISIC 26	ISIC 27	ISIC 28	ISIC 29	ISIC 31	ISIC 34	ISIC 35	ISIC 15-16	ISIC 17-19	ISIC 21-22	ISIC 30-32-33
Australia	1.000	0.708	1.000	1.000	1.000	0.997	1.000	1.000	1.000	1.000	1.000	0.881	1.000	0.983	1.000
Belgium	1.000	0.546	1.000	1.000	0.841	0.592	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.903	0.677
Croatia	0.921	0.108	0.443	0.636	0.657	0.686	1.000	0.571	1.000	1.000	0.962	1.000	0.724	0.955	0.980
Czech Republic	0.765	0.600	1.000	1.000	1.000	0.968	0.847	0.493	0.864	0.800	0.688	0.407	0.590	1.000	0.787
Finland	1.000	0.635	1.000	0.984	0.837	0.544	0.991	0.955	0.936	1.000	1.000	0.612	0.990	0.795	1.000
France	0.891	0.158	0.703	0.805	0.985	0.962	0.992	0.815	0.679	0.821	0.751	0.462	0.748	0.853	0.419
Germany	0.864	0.319	0.891	1.000	0.816	0.780	0.990	0.895	0.942	0.754	0.680	0.518	0.505	0.897	0.629
Hungary	0.274	0.149	0.625	0.745	0.995	0.938	0.554	0.457	0.671	0.914	0.890	0.334	0.383	0.944	0.507
Italy	0.889	0.184	0.857	0.936	0.762	0.403	0.982	0.958	0.893	1.000	1.000	0.612	0.489	1.000	0.474
Japan	1.000	1.000	1.000	1.000	1.000	1.000	0.991	1.000	1.000	1.000	1.000	0.240	1.000	1.000	0.361
Lithuania	0.771	0.058	0.482	1.000	1.000	0.900	1.000	0.705	1.000	1.000	1.000	1.000	0.926	1.000	0.762
Netherlands	1.000	0.443	1.000	0.890	0.901	0.739	1.000	0.997	1.000	1.000	0.902	0.422	1.000	1.000	0.769
Poland	0.727	0.881	0.872	1.000	1.000	1.000	1.000	0.395	0.875	1.000	0.849	0.676	0.761	1.000	0.571
Spain	0.817	0.393	0.857	0.966	0.723	0.813	0.992	0.950	0.979	1.000	1.000	0.585	0.555	0.796	0.659
Sweden	0.948	0.195	0.937	0.961	0.795	0.759	0.982	0.909	0.907	0.710	0.693	0.288	0.544	1.000	0.630
United Kingdom	0.888	0.117	0.644	0.765	0.903	0.665	0.992	1.000	0.866	0.747	0.862	1.000	0.975	0.956	0.702

Table B6: Environmental Efficiency Index (H) in 2005

	ISIC 20	ISIC 23	ISIC 24	ISIC 25	ISIC 26	ISIC 27	ISIC 28	ISIC 29	ISIC 31	ISIC 34	ISIC 35	ISIC 15-16	ISIC 17-19	ISIC 21-22	ISIC 30-32-33
Australia	1.000	0.633	1.000	1.000	1.000	0.949	1.000	1.000	1.000	1.000	0.981	0.812	1.000	0.987	1.000
Belgium	0.976	0.632	1.000	1.000	0.843	0.570	0.979	1.000	1.000	1.000	0.967	0.637	1.000	0.779	0.611
Croatia	0.979	0.105	0.544	0.603	0.663	0.847	1.000	0.616	0.966	1.000	0.974	0.783	0.836	0.972	1.000
Czech Republic	0.794	0.588	1.000	1.000	1.000	1.000	0.873	0.507	0.873	0.758	0.645	0.481	0.530	1.000	0.622
Finland	1.000	0.489	1.000	0.966	0.929	0.584	0.960	0.953	1.000	1.000	1.000	0.541	0.852	1.000	1.000
France	0.809	0.200	0.816	0.839	1.000	0.895	0.942	0.797	0.612	0.717	0.729	0.493	0.597	0.720	0.370
Germany	0.945	0.337	0.918	1.000	0.875	0.808	0.935	0.896	0.889	0.723	0.765	0.541	0.507	0.584	0.538
Hungary	0.306	0.186	0.666	0.676	0.884	0.955	0.652	0.485	0.736	0.937	0.855	0.458	0.507	0.853	0.601
Italy	0.819	0.286	0.851	0.932	0.785	0.461	0.944	0.970	0.872	1.000	1.000	0.591	0.454	0.576	0.494
Japan	1.000	1.000	1.000	0.993	1.000	1.000	0.975	1.000	0.953	1.000	0.876	0.255	0.745	0.666	0.764
Lithuania	0.861	0.075	0.427	1.000	1.000	1.000	1.000	0.801	1.000	1.000	1.000	1.000	0.602	1.000	0.589
Netherlands	1.000	0.602	1.000	0.871	0.909	0.765	1.000	0.996	1.000	1.000	0.858	0.361	0.613	0.786	0.752
Poland	0.689	0.633	0.980	1.000	1.000	1.000	1.000	0.455	0.897	1.000	0.842	0.591	0.666	1.000	0.660
Spain	0.830	0.428	0.856	0.920	0.732	0.813	0.947	0.936	0.962	1.000	1.000	0.732	0.513	0.634	0.578
Sweden	1.000	0.193	1.000	0.907	0.855	0.758	0.958	0.935	0.850	0.640	0.659	0.280	0.830	0.704	0.561
United Kingdom	0.961	0.117	0.816	0.807	0.957	0.693	0.979	1.000	0.840	0.826	0.772	0.997	0.554	0.644	0.689

Table B7: Environmental Efficiency Index (H) in 2006

	ISIC 20	ISIC 23	ISIC 24	ISIC 25	ISIC 26	ISIC 27	ISIC 28	ISIC 29	ISIC 31	ISIC 34	ISIC 35	ISIC 15-16	ISIC 17-19	ISIC 21-22	ISIC 30-32-33
Australia	1.000	0.480	1.000	1.000	1.000	0.817	1.000	1.000	1.000	0.926	0.957	0.652	1.000	0.988	1.000
Belgium	1.000	0.565	0.979	1.000	0.918	0.639	0.988	1.000	1.000	1.000	0.931	0.494	0.728	0.612	0.680
Croatia	0.971	0.089	0.568	0.631	0.742	0.928	1.000	0.787	1.000	1.000	1.000	0.610	0.915	1.000	1.000
Czech Republic	0.842	0.579	1.000	1.000	1.000	1.000	0.896	0.729	0.895	0.779	0.707	0.369	0.772	1.000	0.811
Finland	1.000	0.419	1.000	1.000	0.991	0.711	1.000	0.976	1.000	1.000	1.000	0.470	1.000	0.595	1.000
France	0.887	0.173	0.866	0.846	0.994	0.912	1.000	0.857	0.589	0.807	0.741	0.354	0.923	0.746	0.364
Germany	0.965	0.401	0.941	1.000	0.916	0.880	1.000	0.933	0.876	0.870	0.677	0.439	0.953	0.600	0.619
Hungary	0.441	0.209	0.718	0.681	0.947	0.961	0.611	0.669	0.684	0.914	0.879	0.374	0.727	0.879	0.672
Italy	0.839	0.281	0.891	0.902	0.830	0.557	0.980	0.976	0.820	1.000	0.986	0.437	0.761	0.578	0.494
Japan	1.000	1.000	1.000	0.997	1.000	1.000	1.000	1.000	0.841	1.000	0.788	1.000	1.000	0.644	0.309
Lithuania	0.769	0.074	0.548	1.000	1.000	1.000	1.000	0.708	1.000	1.000	1.000	0.713	0.712	1.000	0.731
Netherlands	1.000	0.416	1.000	0.870	0.934	0.771	1.000	1.000	0.998	1.000	0.897	0.517	0.985	0.803	0.682
Poland	0.716	0.528	1.000	1.000	1.000	1.000	1.000	0.688	0.935	0.991	0.946	0.623	0.785	1.000	0.682
Spain	0.749	0.350	0.853	0.846	0.822	0.843	0.946	0.968	0.987	1.000	0.989	0.675	0.871	0.568	0.664
Sweden	1.000	0.190	0.951	0.878	0.939	0.841	0.965	0.935	0.811	0.714	0.650	0.300	0.632	0.469	0.641
United Kingdom	0.899	0.129	0.847	0.783	0.959	0.818	1.000	1.000	0.802	0.911	0.722	0.740	1.000	0.636	0.687

Table B8: Environmental Efficiency Index (H) in 2007

	ISIC 20	ISIC 23	ISIC 24	ISIC 25	ISIC 26	ISIC 27	ISIC 28	ISIC 29	ISIC 31	ISIC 34	ISIC 35	ISIC 15-16	ISIC 17-19	ISIC 21-22	ISIC 30-32-33
Australia	1.000	0.352	1.000	1.000	1.000	0.854	1.000	1.000	1.000	0.913	0.975	0.846	1.000	1.000	1.000
Belgium	1.000	0.546	0.950	1.000	0.917	0.779	1.000	1.000	1.000	1.000	0.963	0.648	0.702	0.816	0.667
Croatia	0.983	0.101	0.583	0.820	0.777	1.000	1.000	1.000	1.000	1.000	1.000	0.734	1.000	0.998	1.000
Czech Republic	0.867	0.307	1.000	1.000	1.000	1.000	0.839	0.933	0.955	0.808	0.816	0.488	0.986	1.000	0.842
Finland	1.000	0.361	1.000	0.958	1.000	0.841	1.000	1.000	1.000	0.984	1.000	0.649	1.000	0.621	1.000
France	0.833	0.251	0.872	0.881	1.000	1.000	0.949	0.839	0.743	0.890	0.787	0.421	0.989	0.752	0.318
Germany	1.000	0.260	0.934	1.000	0.990	1.000	0.927	0.916	0.904	0.952	0.735	0.643	0.894	0.631	0.619
Hungary	0.494	0.192	0.747	0.766	0.937	1.000	0.651	0.737	0.761	0.930	0.961	0.438	0.773	0.804	0.501
Italy	0.808	0.303	0.859	0.917	0.881	0.692	0.986	0.963	0.916	1.000	0.987	0.589	0.772	0.558	0.479
Japan	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.959	0.859	1.000	0.781	0.356	1.000	0.617	0.294
Lithuania	0.768	0.046	0.778	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.756	0.982	1.000	0.808
Netherlands	1.000	0.384	1.000	0.886	1.000	0.964	1.000	0.985	0.960	1.000	0.955	0.596	1.000	0.801	0.633
Poland	0.793	0.517	1.000	1.000	1.000	1.000	0.999	0.976	1.000	0.994	1.000	0.766	0.996	1.000	0.867
Spain	0.858	0.276	0.865	0.909	0.918	0.982	0.936	0.984	0.994	1.000	0.988	0.704	0.849	0.561	0.716
Sweden	1.000	0.266	0.998	0.961	1.000	1.000	0.978	0.949	0.862	0.756	0.724	0.413	0.604	0.483	0.548
United Kingdom	0.923	0.172	0.880	0.803	0.990	1.000	1.000	0.984	0.892	0.973	0.756	0.286	1.000	0.634	0.624

Table B9: Environmental Efficiency Index (H) in 2008

	ISIC 20	ISIC 23	ISIC 24	ISIC 25	ISIC 26	ISIC 27	ISIC 28	ISIC 29	ISIC 31	ISIC 34	ISIC 35	ISIC 15-16	ISIC 17-19	ISIC 21-22	ISIC 30-32-33
Australia	1.000	0.103	1.000	1.000	1.000	0.876	1.000	0.985	1.000	0.989	1.000	0.947	1.000	1.000	1.000
Belgium	0.948	0.422	0.972	1.000	0.917	0.820	1.000	1.000	1.000	1.000	1.000	0.605	1.000	0.887	0.679
Croatia	0.925	0.056	0.874	0.866	0.668	0.906	1.000	0.962	1.000	1.000	1.000	0.744	1.000	1.000	1.000
Czech Republic	0.820	0.251	1.000	1.000	1.000	1.000	0.800	0.918	0.771	0.567	0.790	0.570	0.998	1.000	0.788
Finland	1.000	0.204	0.930	0.978	1.000	0.803	0.988	1.000	1.000	0.999	1.000	0.689	1.000	0.561	1.000
France	0.843	0.142	0.870	0.865	1.000	1.000	0.944	0.849	0.572	0.726	0.921	0.457	0.996	0.740	0.293
Germany	1.000	0.144	0.909	1.000	1.000	0.957	0.908	0.965	0.850	0.794	0.817	0.682	0.863	0.725	0.637
Hungary	0.389	0.171	0.787	0.813	0.823	0.905	0.665	0.842	0.659	0.803	1.000	0.520	0.867	0.729	0.556
Italy	0.735	0.194	0.842	0.892	0.769	0.643	0.942	0.967	0.831	1.000	0.989	0.596	0.760	0.837	0.485
Japan	1.000	1.000	1.000	0.998	1.000	1.000	0.988	1.000	0.729	0.871	1.000	0.523	1.000	0.902	0.280
Lithuania	0.678	0.068	0.861	1.000	0.990	1.000	0.925	1.000	1.000	1.000	1.000	0.778	0.890	1.000	0.972
Netherlands	1.000	0.341	1.000	0.914	1.000	0.963	1.000	0.990	0.844	1.000	1.000	0.686	1.000	0.854	0.698
Poland	0.707	0.297	0.942	1.000	1.000	0.938	0.926	0.950	0.968	0.945	0.999	0.757	1.000	1.000	0.947
Spain	0.796	0.147	0.872	0.938	0.874	0.871	0.924	0.990	0.946	1.000	1.000	0.866	0.872	0.630	0.758
Sweden	0.818	0.245	0.948	0.952	1.000	0.819	0.922	0.934	0.761	0.490	0.763	0.661	0.629	0.448	0.561
United Kingdom	0.758	0.248	0.977	0.730	0.912	0.901	0.985	0.969	0.841	0.885	1.000	0.379	0.958	0.839	0.624

Table B10: Environmental Efficiency Index (H) in 2009

	ISIC 20	ISIC 23	ISIC 24	ISIC 25	ISIC 26	ISIC 27	ISIC 28	ISIC 29	ISIC 31	ISIC 34	ISIC 35	ISIC 15-16	ISIC 17-19	ISIC 21-22	ISIC 30-32-33
Australia	1.000	0.139	1.000	1.000	1.000	0.727	1.000	0.694	1.000	1.000	1.000	0.898	1.000	1.000	1.000
Belgium	1.000	0.182	0.881	1.000	0.830	0.702	1.000	0.971	1.000	1.000	1.000	0.472	1.000	0.995	0.908
Croatia	0.894	0.091	0.699	0.976	0.682	0.885	0.910	0.377	1.000	1.000	1.000	0.667	1.000	0.977	1.000
Czech Republic	0.617	0.150	0.985	1.000	1.000	1.000	0.815	0.749	0.858	0.863	0.767	0.450	0.935	1.000	0.651
Finland	1.000	0.119	0.979	1.000	1.000	0.539	1.000	0.974	1.000	1.000	0.938	0.500	1.000	0.667	0.982
France	0.752	0.128	0.840	0.827	1.000	1.000	1.000	0.645	0.531	0.619	1.000	0.326	0.864	1.000	0.635
Germany	1.000	0.195	0.858	1.000	0.997	0.998	0.939	0.822	0.874	0.935	0.953	0.603	0.994	0.718	0.889
Hungary	0.310	0.202	0.739	0.847	0.716	0.650	0.686	0.762	0.377	0.872	0.815	0.568	0.773	0.707	0.701
Italy	0.822	0.098	0.839	0.853	0.787	0.353	0.905	0.913	0.787	1.000	1.000	0.431	0.719	0.673	1.000
Japan	1.000	1.000	1.000	1.000	0.997	1.000	1.000	1.000	0.624	1.000	1.000	1.000	1.000	0.695	0.876
Lithuania	0.566	0.042	0.656	0.912	0.791	1.000	0.854	1.000	1.000	1.000	1.000	0.670	0.930	1.000	1.000
Netherlands	1.000	0.310	0.952	1.000	1.000	0.856	1.000	0.860	0.841	0.989	1.000	0.666	1.000	0.994	1.000
Poland	0.603	0.113	0.881	1.000	1.000	0.950	0.866	0.637	0.970	1.000	1.000	0.618	0.913	1.000	1.000
Spain	0.873	0.108	0.836	0.912	0.854	0.839	0.980	0.972	0.922	1.000	1.000	0.826	0.840	0.937	1.000
Sweden	0.869	0.251	1.000	0.799	0.937	0.427	0.716	0.825	0.714	0.393	1.000	0.421	0.477	1.000	1.000
United Kingdom	0.823	0.178	0.962	0.816	0.867	0.983	0.991	0.996	0.751	0.972	0.761	0.305	0.877	0.987	1.000

Table B11: Environmental Efficiency Index (H) in 2010

	ISIC 20	ISIC 23	ISIC 24	ISIC 25	ISIC 26	ISIC 27	ISIC 28	ISIC 29	ISIC 31	ISIC 34	ISIC 35	ISIC 15-16	ISIC 17-19	ISIC 21-22	ISIC 30-32-33
Australia	1.000	0.138	1.000	1.000	1.000	0.586	1.000	0.965	1.000	1.000	0.951	0.973	0.864	1.000	1.000
Belgium	1.000	0.220	0.890	0.968	0.709	0.664	1.000	1.000	1.000	1.000	0.989	0.916	0.668	0.668	0.963
Croatia	0.849	0.116	0.813	0.816	0.462	0.674	0.850	0.989	1.000	1.000	1.000	1.000	0.913	0.961	1.000
Czech Republic	0.556	0.112	1.000	1.000	0.984	0.744	0.686	0.912	0.824	0.776	0.863	0.639	0.835	1.000	0.799
Finland	1.000	0.195	0.987	1.000	0.984	0.589	0.995	1.000	0.969	1.000	0.996	0.627	1.000	1.000	0.898
France	0.719	0.142	0.818	0.805	0.762	0.771	0.928	0.714	0.757	0.717	0.975	1.000	0.725	0.847	0.411
Germany	1.000	0.206	0.887	0.999	0.977	0.753	0.833	0.891	1.000	0.979	0.818	0.956	0.768	0.655	0.853
Hungary	0.299	0.166	0.791	0.809	0.690	0.696	0.558	1.000	0.577	0.782	0.877	0.580	0.750	0.640	0.589
Italy	0.734	0.103	0.851	0.926	0.729	0.351	1.000	0.953	1.000	1.000	0.968	0.737	0.680	0.686	0.888
Japan	1.000	1.000	0.986	1.000	1.000	1.000	1.000	1.000	0.936	1.000	0.984	0.721	1.000	0.728	0.742
Lithuania	0.567	0.058	0.792	0.913	0.705	1.000	0.852	1.000	1.000	1.000	1.000	0.720	0.850	1.000	0.956
Netherlands	1.000	0.217	0.935	0.915	0.961	0.911	1.000	0.977	0.715	1.000	0.982	1.000	1.000	0.943	0.850
Poland	0.607	0.201	0.915	0.950	0.978	0.727	0.837	0.939	0.852	1.000	0.999	0.672	0.841	1.000	1.000
Spain	0.900	0.132	0.858	0.929	0.853	0.828	0.931	0.991	1.000	1.000	0.954	1.000	0.674	0.691	0.902
Sweden	0.778	0.213	1.000	0.939	0.943	0.573	0.897	0.956	0.591	0.624	0.883	0.774	1.000	0.379	0.955
United Kingdom	0.839	0.164	0.880	0.747	0.835	0.734	0.972	0.996	1.000	1.000	0.887	0.671	0.809	0.701	0.952

Table B12: Environmental Efficiency Index (H) in 2011

	ISIC 20	ISIC 23	ISIC 24	ISIC 25	ISIC 26	ISIC 27	ISIC 28	ISIC 29	ISIC 31	ISIC 34	ISIC 35	ISIC 15-16	ISIC 17-19	ISIC 21-22	ISIC 30-32-33
Australia	1.000	0.174	1.000	1.000	1.000	0.647	1.000	0.930	1.000	1.000	0.985	1.000	1.000	1.000	1.000
Belgium	1.000	0.226	0.708	1.000	0.871	0.723	0.962	1.000	0.989	1.000	0.937	0.700	0.684	0.989	1.000
Croatia	0.804	0.187	0.939	0.818	0.524	0.636	0.798	0.968	0.919	1.000	1.000	0.789	1.000	0.904	1.000
Czech Republic	0.494	0.172	0.994	1.000	0.983	0.754	0.627	0.913	0.763	0.705	0.855	0.629	0.951	0.885	0.951
Finland	1.000	0.226	1.000	1.000	0.983	0.614	0.905	1.000	0.820	0.961	1.000	0.712	1.000	0.639	0.804
France	0.685	0.164	0.823	0.747	0.841	0.851	0.853	0.654	0.654	0.738	0.921	0.296	0.846	0.932	0.293
Germany	1.000	0.208	0.933	0.842	0.983	0.781	0.745	0.912	0.796	1.000	0.920	0.593	0.798	0.889	0.958
Hungary	0.289	0.225	0.842	0.742	0.727	0.659	0.512	1.000	0.437	0.722	0.836	0.698	0.702	0.556	0.862
Italy	0.646	0.153	0.840	0.929	0.838	0.396	0.903	0.993	0.813	1.000	0.989	1.000	0.781	0.873	0.895
Japan	1.000	1.000	0.856	1.000	1.000	1.000	0.929	1.000	0.737	1.000	0.927	0.695	0.988	0.757	0.501
Lithuania	0.568	0.092	0.935	0.878	0.817	1.000	0.823	1.000	1.000	1.000	1.000	0.769	1.000	1.000	1.000
Netherlands	1.000	0.333	0.855	0.865	0.954	0.933	1.000	1.000	0.577	1.000	1.000	0.729	1.000	1.000	1.000
Poland	0.612	0.300	0.965	0.903	0.983	0.763	0.792	0.926	0.758	0.964	1.000	0.729	0.911	1.000	0.960
Spain	0.928	0.169	0.917	0.885	0.890	0.913	0.871	0.994	0.854	1.000	0.970	0.857	0.843	0.871	1.000
Sweden	0.687	0.285	0.771	0.952	0.982	0.599	0.826	1.000	0.646	0.581	0.976	0.678	0.501	1.000	1.000
United Kingdom	0.855	0.210	0.761	0.615	0.865	0.649	0.875	1.000	0.830	1.000	0.973	0.435	1.000	0.904	1.000