FONDAZIONE ENI ENRICO MATTEI

NOTA DI LAVORO

74.2014

Going Forward by Looking Backwards on the Environmental Kuznets Curve: an Analysis of CFCs, CO2 and the Montreal and Kyoto Protocols

By Thomas Longden, Fondazione Eni Enrico Mattei and University of New South Wales

Climate Change and Sustainable Development
Series Editor: Carlo Carraro

Going Forward by Looking Backwards on the Environmental Kuznets Curve: an Analysis of CFCs, CO2 and the Montreal and Kyoto Protocols

By Thomas Longden, Fondazione Eni Enrico Mattei and University of New South Wales

Summary
The success of the Montreal Protocol in comparison to the stagnation seen in negotiations surrounding the Kyoto Protocol highlights the importance of a supportive industry group, pre-existing legislation and commitment by a lead nation, affordable and available substitutes, as well as acceptance of the underlying scientific explanation of the link between emissions and a key detrimental impact. The focus on these contrasting intergovernmental agreements within this paper is driven, in part, by the intention to establish that successful emission reductions tend to be associated with a concerted policy effort rather than the level of per capita income. This is in contrast to the concept of the Environmental Kuznets Curve (EKC) which contends that a significant negative relationship exists between high levels of national income and per capita emissions. While a nation's level of development and national income are likely to be linked to an ability to make structural changes and/or the implementation of environmental policy, this paper finds no evidence of an EKC consistent quadratic relationship between income and CFC emissions once key considerations, such as biased estimations and policy effort, have been accounted for.

Keywords: Environmental Kuznets Curve, Montreal Protocol, Kyoto Protocol
JEL Classification: Q5, Q50, Q58

Address for correspondence:
Thomas Longden
Fondazione Eni Enrico Mattei
Corso Magenta 63
20123 Milano
Italy
E-mail: thomas.longden@feem.it

Going forward by looking backwards on the Environmental Kuznets Curve: an analysis of CFCs, CO2 and the Montreal and Kyoto Protocols

Thomas Longden

Fondazione Eni Enrico Mattei
School of Economics, University of New South Wales

September 2014

Abstract

The success of the Montreal Protocol in comparison to the stagnation seen in negotiations surrounding the Kyoto Protocol highlights the importance of a supportive industry group, pre-existing legislation and commitment by a lead nation, affordable and available substitutes, as well as acceptance of the underlying scientific explanation of the link between emissions and a key detrimental impact. The focus on these contrasting intergovernmental agreements within this paper is driven, in part, by the intention to establish that successful emission reductions tend to be associated with a concerted policy effort rather than the level of per capita income. This is in contrast to the concept of the Environmental Kuznets Curve (EKC) which contends that a significant negative relationship exists between high levels of national income and per capita emissions. While a nation's level of development and national income are likely to be linked to an ability to make structural changes and/or the implementation of environmental policy, this paper finds no evidence of an EKC consistent quadratic relationship between income and CFC emissions once key considerations, such as biased estimations and policy effort, have been accounted for.

Correspondence: Corso Magenta, 63, 20123 Milano – Italy. Email: thomas.longden@feem.it.

1 Introduction

The Montreal Protocol is an intergovernmental agreement that has been deemed to be a success and has been associated with the phase out of a range of ozone-depleting substances. In contrast, the concept of the Environmental Kuznets Curve (EKC) infers that emission reductions may be associated with the level of per capita income rather than a concerted policy effort. This disparity has motivated the author to perform a review of whether the success of the Montreal Protocol is evidence that an induced policy response is behind observations of an EKC consistent relationship for CFCs. The concept of the Environmental Kuznets Curve contends that a significant quadratic relationship exists between high levels of national income and per capita emissions. Stern (2004) defines the EKC as “a hypothesized relationship between various indicators of environmental degradation and income per capita.” (Stern, 2004: 1419) And while the level of development and national income are likely to be linked to an ability to make structural changes and/or implement environmental policy, as a prelude to the results of the paper it should be noted that this paper finds no evidence of an EKC consistent negative quadratic relationship between income and CFC emissions once key considerations, such as biased estimations and policy effort, have been accounted for.

1.1 Background on the EKC

The body of literature on the existence of an EKC relationship is an interesting one, especially in light of its original observation being sourced from a paper with no direct intention of examining whether levels of GDP have a direct relationship with environmental quality. In Grossman and Krueger (1991) the focus was on the question of whether reductions in trade barriers would improve or harm environmental quality. Accordingly the paper was titled ‘Environmental Impacts of a North American Free Trade Agreement’. The subsequent discussion within their paper revolves around concerns that a pollution-haven[1] may occur with the (then) impending introduction of the North American Free Trade Agreement (NAFTA). It was expected that "industry groups in the United States will demand less stringent pollution controls in order to preserve their international competitiveness, so that environmental standards will tend toward the lowest common denominator" (Grossman and Krueger, 1991: 2).

With these foundations, it may be concluded that the EKC relationship has been stumbled upon and then subsequently interpreted and estimated before a theoretical basis could be established. Indeed, the original paper by Grossman and Krueger noted that their "findings must remain tentative until better data became available" (Grossman and Krueger, 1991: 36). Within their follow up paper, 'Economic Growth and the Environment', Grossman and Krueger (1995) emphasise that any subsequent process leading to improved environmental conditions was not automatic. And while their paper does note that technological substitution and structural transformation are in principal important, "a review of the available evidence on instances of pollution abatement suggests that the strongest link between income and pollution in fact is via an induced policy response" (Grossman and Krueger, 1995: 372). It is on this basis that skeptism concerning the validity of the EKC relationship should occur; as while there may be a correlation between a country's level of development and their level of environmental quality, the factors driving such a trend are by no means assured. In addition, substitution effects and changes to an economy's structure or preference changes towards

[1] The pollution haven hypothesis has been described as being the situation where increased demand for environmental quality, "assumed to rise with increased income levels, does not lead to a shift to a cleaner production process in the country where the demand is generated, but rather to a movement of the production process to a location outside of the country" (Rothman, D. (1998):186).

environmental quality that may trigger this correlation are sure to be diverse and highlight the need for analysis that caters for the conditions surrounding these changes.

1.2 CFC reductions as an induced policy response

If indeed the underlying EKC relationship is due to an 'induced policy response', as noted by Grossman and Krueger (1995), then an examination of the existence of an EKC relationship between income and emissions related to the consumption of Chlorofluorocarbons (CFCs) is of interest. The Montreal Protocol is a notable intergovernmental agreement and has been deemed successful in reducing harm to the environment from an externality with transboundary implications. The success of the Montreal Protocol is an important factor that underlies the justification of the analysis and it should be noted that as early as 2001 the treaty process for addressing ozone depletion was found to have "fundamentally changed the way certain industries conduct their business, already creating in some countries a complete phase-out of certain classes of chemicals." (DeSombre, 2001: 49) In addition, a report by the US Environmental Protection Agency notes that "the ozone layer has not grown thinner since 1998 over most of the world, and it appears to be recovering because of reduced emissions of ozone-depleting substances." (US EPA, 2007: 5) It also notes that "the Antarctic ozone is projected to return to pre-1980 levels by 2060 to 2075." (US EPA, 2007: 5) In comparison to the Kyoto Protocol, the Montreal Protocol has been ratified by all UN recognised nations.

The reasons for the success of the Montreal Protocol are of interest to both environmental economists and policy makers. And while the success of the Montreal Protocol presents a case where emissions have been reduced by a concerted policy effort, auxiliary explanations for the success of the policy intervention are important. A comparison to the case of the

Kyoto Protocol highlights the importance of: a supportive industry group, pre-existing legislation and commitment by a lead nation, affordable and available substitutes for polluting devices, as well as acceptance of the underlying scientific explanation of the link between emissions and a key detrimental impact.

1.3 CFCs and the EKC

Focusing on CFCs and the Montreal Protocol allows for a simultaneous investigation on whether an EKC consistent relationship exists and whether this relationship may alternatively be explained as an induced policy response related to an intergovernmental agreement that utilises targets that differ based on income (or the level of development). However, while the EKC relationship has been extensively researched, the relationship between GDP and CFCs has been scarcely analysed. For example, Mason and Swanson (2003) noted that to their knowledge only three papers had studied the issue of CFCs and an EKC relationship. In 1997, Cole et al. intended to extend the previous empirical analyses of the EKC relationship by reviewing a wider range of environmental indicators, including CFCs. Using cross-sectional analysis of data from 1986 and 1990 it was found that the adoption of the Montreal Protocol changed the growth profile of CFCs between these two years. This observation was accompanied by the statement that this result illustrated “the importance of multilateral action for a global air pollutant and tends to confirm that, without such a policy initiative, global air pollutants will increase monotonically with income” (Cole, et al. 1997: 412). Having established this result for CFCs, Cole et al. (1997) proceeded to reinforce the view of Grossman and Krueger (1995) that while some developed countries have ‘grown out of’ some pollution problems, “there is nothing inevitable about the relationship between per capita income and environmental quality, as encapsulated in the EKC fitted to historical data" (Cole, et al. 1997: 412).

The conclusion that CFC emissions in the absence of the Montreal Protocol would continue to grow over the foreseeable future due to an excessively high EKC turning point was reinforced by Mason and Swanson (2003). Using an unbalanced panel of CFC production data from 1976 to 1988, Mason and Swanson (2003) find no evidence of an EKC consistent relationship using the traditional functional form specification and an excessively high turning point once a one period lag of CFC production is introduced into the model to allow for serial correlation. While the analysis of Mason and Swanson (2003) does overcome some of the issues from previous analyses (such as utilising cross-sectional data), the period involved limits the analysis to an examination of the impacts of ratification at that point in time. Subsequently the paper also forecasts the eventual impact of the Montreal Protocol using the targets set before the introduction of the Beijing Amendments.

The time span of data is not the only data issue that can be identified within appraisals of the Montreal Protocol. Upon appraising the widely cited article by Murdoch and Sandler (1997), which reviews reductions in emissions and whether they are associated with non-cooperative Nash behaviour or cooperative behavior, Wagner (2009) notes that the use of imputed data by Murdoch & Sandler (1997) leads to a spurious result. Specifically Wagner (2009) states that "the qualitative and quantitative evidence that MS present to support their view relies on largely imputed data from the World Resources Institute … which overstate emission reductions and appear to induce a spurious positive correlation between income and CFC cutbacks" (Wagner, 2009: 192).

With these past papers in mind, the usefulness of the dataset released by The Secretariat for the Vienna Convention and the Montreal Protocol for the period 1992 to 2008 is evident, [2] as it coincides with the first stage of the Montreal targets and covers the period of the Beijing amendments, including the period within which the maximum amount of reductions for all signatories was determined. It is on this basis that this paper will review the existence of an EKC consistent relationship and the impacts of the Montreal Protocol targets using a balanced CFC consumption dataset for the 67 countries within section 3.

Before commencing, it should be noted that recent research utilising the dataset released by the Secretariat for the Vienna Convention and the Montreal Protocol has been conducted. Kleemann and Abdulai (2013) do not find an EKC consistent relationship using this data and relate this finding to the actions surrounding the Montreal Protocol. Consistent with this, the paper notes that "CFC consumption is a good example of effective international pressure." (Kleemann and Abdulai, 2013: 199) However, the analysis within this paper is still important as heteroscedasticity and serial correlation, as well as the issue of policy specific factors, is simultaneously accounted for.

The structure of the paper is as follows. After a brief discussion of some of the concerns over the EKC relationship's 'econometric foundations' in the introduction to section 2, the estimation outline is specified in sub-section 2.1. Section 3 contains the empirical results of the paper. The results of the estimations reviewing an EKC consistent relationship will be

[2] These data have been sourced from the UNEP's GEO Data Portal which provides data compiled by a large range of original data providers. These data can be accessed via the Data Portal (http://geodata.grid.unep.ch) and is cited with respect to the source (UNEP, The GEO Data Portal).

reviewed in sub-section 3.1. With the aim of focusing on the issue of policy success and quantifiable emissions reductions related to policy targets, sub-section 3.2 will focus on whether the emission reduction targets of the Montreal Protocol are attributable to the rate of CFC reductions that occurred. A discussion of the importance of these is conducted in section 4. After a review of the importance of a viable substitute for CFCs in the form of hydrofluorocarbons (HCFCs) in sub-section 4.1, sub-section 4.2 will discuss additional factors that have led to the success of the Montreal Protocol. Section 5 concludes the paper.

2 Econometric Foundations of the EKC and the Estimation Outline

From humble beginnings the EKC relationship has sparked a large debate that has captured the imagination, praise and scorn of many. It proved so topical that within about a year of appearing within the literature, the relationship was included within the World Development Report published by the World Bank in 1992. Differing results across different pollutants and datasets meant that as early as 1994 the discussion of the EKC relationship had extended to focus on reasons why these discrepancies may exist. It is with this that the literature started to review wider considerations related to the existence of the EKC relationship. In 2005, Nahman and Antrobus (2005) described the literature as one being divided between optimists, who strongly support the EKC and interpret it as validating a strategy of growth before all else (or much else), and critics, who suggest that methodological flaws are the reason for the relationship being found and that much more caution is needed when interpreting results showing an EKC consistent relationship (Nahman and Antrobus, 2005: 105). As the EKC relationship has attracted increasing criticism based on the lack of rigidity in much of the econometric underpinning, this review will focus upon the existence of an EKC with respect to policy implementation, while aiming to conduct a sound methodological/econometric analysis.

There has been a substantial literature focusing on the econometric basis of the EKC relationship and while this paper will aim to review this relationship using a solid econometric/methodological foundation, it is by no means a complete econometric review of the EKC. The intention of this paper is to establish whether an EKC consistent relationship exists for a pollutant where persistent decreases have been noted or whether other factors prevail (such as policy initiatives, intergovernmental agreements/targets, or unobserved country specific factors). An increase in studies using econometric methodologies to test the EKC relationship was noted by Stern (2004) and he notes that while “the EKC is an essentially empirical phenomenon ... most of the EKC literature is econometrically weak” (Stern, 2004: 1420). Stern (2004) is critical of the nature of many past studies which look for significant coefficient estimates without paying attention to the statistical properties of the data used. The importance of reviewing the existence of the EKC using a robust empirical methodology is highlighted within the statement that “one of the main purposes of doing econometrics is to test which apparent relationships, or “stylised facts”, are valid and which are spurious correlations” (Stern, 2004: 1420).

Concerns over the methodology applied within reviews of the EKC are not new, as the limitation of a reduced functional form specification led Grossman and Krueger (1995) to acknowledge that the functional form does not “even investigate the means by which income changes influence environmental outcomes” (Grossman and Krueger, 1995: 371). In 1997, Panayotou discussed the implications of using a simple reduced-form approach (which is not coupled to a lengthy theoretical justification) by comparing it to a ‘black box’. This term is especially relevant to the present discussion of the EKC relationship in that this comparison reflects the view that such an approach “hides more than it reveals since income level is used as a catch-all surrogate variable for all the changes that take place with economic development” (Panayotou, 1997: 466). Taking wider considerations into account is important, as an explanation of an appropriate EKC relationship is likely to be complex with a large multitude of underlying factors depending upon the pollutant, the countries included within the sample and the period reviewed.

An additional concern with the interpretation of the EKC relationship is that any level of economic activity implies the use/extraction of resources. This resource use/extraction is not consistent with a functional form allowing the dependant variable to decrease to zero without some transfer between pollutants. Indeed, the first law of thermodynamics means that some waste is inevitable and as a result it should be enquired where this waste could be going. Ultimately, this brings us back to the original Grossman and Krueger (1991) paper, as the transfer of pollution or polluting industries to less developed countries (i.e. the pollution haven hypothesis) has become an explanation for the EKC relationship being found (refer to Cole (2004)).

Indeed Stern was not the first to notice that the lack of explanatory power within substantial EKC studies meant that "explanations for the coefficient estimates are given ex-post, i.e., they are forced upon the regression results but remain untested" (de Bruyn, 1997: 487). In other words, the formulation of theory after estimation has not been rare and this is typically a treacherous foundation for any given relationship. Empirical estimations need a theoretical base otherwise the risk of running a spurious regression is quite high, except in cases where the econometric analysis is particularly strong. As a result, there is an increasingly common consensus that EKC analysis within the literature is not robust, is based purely on prior assumptions and has actually missed some of the basic steps that should occur before estimation can begin. In support of this sentiment it has been suggested that within many of the analyses "choice of the quadratic estimates and their interpretation of these as inverted-U's would therefore seem to derive more from their prior judgement as to plausibility than from the econometric results, which are indeterminate" (Ekins, 2000: 190).

Amongst the work focusing on the econometric validity of the EKC is the review of Perman and Stern (2003) who in focusing on panel cointegration[3] found that the evidence for the EKC relationship is questionable. Amongst the work applying unit root testing and adjustment for cointegration is Day & Grafton (2003) that also finds little evidence of an EKC relationship. Decomposition analysis has also been applied within the literature in applications such as Stern (2002) where the issue of income is said not to matter and that there is an overbearing "importance of globally shared, emissions-specific technical change and total factor productivity growth in individual countries in reducing emissions" (Stern, 2002: 217). Also using decomposition analysis and regression based on SO2 emission reductions, de Bruyen (1997) found that "the downward sloping part of the EKC can be better explained by reference to environmental policy than to structural change" (de Bruyen, 1997: 499). More recently, Bernard et al. (2014) focused on the estimation of tipping-points using parametric inference and their results cast further doubt on the existence of an EKC relationship related to Sulphur and CO2.

2.1 Estimation Outline

Following the standard functional form discussed within the EKC literature[4], this analysis will begin with a review of whether such an EKC consistent relationship is present using the datasets complied. Moving from the standard EKC specification applied to CFCs (equation 1), the review will then examine whether any EKC consistent relationship found is robust enough to persist upon introducing key variables expected to explain the level and trend of CFC consumption during the sample period. Starting with the level of HCFC consumption

[3] Panel cointegration considers the degree of heterogeneity across the 'n' dimension of a sample.

[4] The standard EKC regression model is commonly specified as: $\ln(\frac{E}{P})_{it} = \alpha_i + \gamma_t + \beta_1 \ln(\frac{GDP}{P})_{it} + \beta_2 \ln(\frac{GDP}{P})^2_{it} + \varepsilon_{it}$, with the turning point income specified as: $\tau = \exp(-\frac{\beta_1}{2\beta_2})$ and statistical significance of β_2 implying that a EKC exists.

(eq. 2), as HCFC gases are a commonly identified substitute for CFC gases, this paper will then focus on the impacts of the Montreal Protocol's targets for CFC consumption/production reduction (eq. 3), and allow for the few countries within the sample which have hesitated in ratifying the Protocol (eq. 4). Equation 3 and 4 also contain a Non Article5 time trend variable which allows for the distinction of differences based on both the level of emissions and the change in emissions for these countries overtime.

$$lnCFCpc_{it} = \alpha_i + \beta_1 lnGDPpc_{it} + \beta_2 lnGDPpc_{it}^2 + \beta_3 TimeTrend_t + \mu_{it} \quad (1)$$

$$lnCFCpc_{it} = \alpha_i + \beta_1 lnGDPpc_{it} + \beta_2 lnGDPpc_{it}^2 + \beta_3 TimeTrend_t + \beta_4 lnHCFCpc_{it} + \mu_{it} \quad (2)$$

$$lnCFCpc_{it} = \alpha_i + \beta_1 lnGDPpc_{it} + \beta_2 lnGDPpc_{it}^2 + \beta_3 TimeTrend_t + \beta_4 lnHCFCpc_{it} + \beta_5 NonArticle5_i + \beta_6 NonA5TimeT_{it} + \mu_{it} \quad (3)$$

$$lnCFCpc_{it} = \alpha_i + \beta_1 lnGDPpc_{it} + \beta_2 lnGDPpc_{it}^2 + \beta_3 TimeTrend_t + \beta_4 lnHCFCpc_{it} + \beta_5 NonArticle5_i + \beta_6 NonA5TimeT_{it} + \beta_7 NoOzoneTre_{it} + \mu_{it} \quad (4)$$

All of the equation specifications in this chapter (which are based on the same basic function specified in equation 1) will be estimated using data from the Secretariat for the Vienna Convention and the Montreal Protocol. Table A1 within the appendix lists the countries included within the sample and also denote those belonging to the Non-Article 5 grouping. Dealing with growth paths of countries with differing levels of development implies that the inclusion of a diverse mix of countries within the analysis is important. Indeed, some past research has investigated the EKC using panels of data with only a few countries and some have even been limited to OECD countries. This is concerning as the results are often interpreted as having direct applicability to non-OECD countries. In the case of CFCs, only 12 of the 67 countries are labelled as Non-Article 5 countries and there is a notable representation of non-OECD countries. The mix of countries is important as apart from levels of development, these distinctions also reflect differing levels of policy prescriptions and targets.

3 Empirical Analysis

The aim of this paper is to review the robustness of any EKC consistent result found for the standard functional form (eq. 1) by introducing variables expected to remove any missing variable bias, while adjusting for heteroscedasticity and serial correlation. It is with this that diagnostic tests to confirm whether heteroscedasticity and serial correlation are present have been run on the fixed effect and random effect estimations. As expected, due to the nature of panel data, as well as the nature of the variables, both heteroscedasticity and serial correlation are found for CFCs. Fixed and random effects regression analysis will be applied as it is consistent with the reduced form specification of the EKC and the requirement to allow for unobserved country specific effects. Within the analysis, the fixed effects and random effects estimates will be adjusted for heteroscedasticity and serial correlation on separate incidences (refer to Tables 1 and 2, respectively), with feasible GLS being applied to examine the impact of allowing for both issues simultaneously (refer to Table 3).

3.1 Estimation Results – CFCs and EKC

Within the heteroscedasticity robust (het robust) fixed effect and random effect estimation (fe/re) results shown in table 1 there is some evidence of an EKC consistent relationship for the fixed effect results that were computed for the specification presented in equation 1 and 2. However, upon including the Montreal Protocol target variables specified in equation 3 (Non-Article 5 and Non-A5 Time Trend) this EKC relationship is replaced with significant evidence of a policy induced decline in CFCs by Non-Article 5 countries above the decreases occurring over time by all of the countries in the sample. These results show that an overall decrease in the consumption of CFC gases during the time period is also based on exogenous factors within individual countries[5]. Non-Article 5 countries had significantly higher levels of per capita CFC emissions, which decreased by approximately 0.8% per year during the relevant phase out period.

It should be noted that the targets implemented by the Montreal Protocol mandate both the production and consumption of CFCs. Upon interpreting the results, it needs to be remembered that they apply to the consumption of CFC gases and hence will include the consumption of CFCs from imported goods by the respective Non-Article 5 and Article 5 countries. This is beneficial as any review of the production of CFC gases would need to consider concerns of ‘pollution havens’ and the export of emissions which has been noted as a potential factor behind results showing an EKC consistent relationship (refer to Cole (2004)). In light of these considerations, the results shown within this paper allow for factors that impact upon end user emissions as the consumption of CFCs has been calculated by taking national production of CFCs, adding imports, and subtracting exports, destroyed quantities and feedstock uses of individual CFCs. Upon allowing for autoregressive order one AR(1) disturbances, the results in table 1 are largely replicated within table 2 with similar policy results shown. The estimates show an EKC consistent relationship being replaced by a statistically significant decrease in CFC consumption within Non-Article 5 countries of approximately 0.4% or 0.7% per year depending upon whether fixed effects or random effects are applied.

[5] Indeed a negative trend is expected as action on reducing CFC consumption has existed since the banning of nonessential aerosols in the USA, Canada, Norway and Sweden in 1978 (Auffhamer et al (2005): 379).

While allowances have been made for heteroscedasticity (het) and serial correlation (AR) separately, both of these factors can be simultaneously accounted for by using feasible generalised least squares (FGLS). Allowing for heteroscedasticity and an AR(1) process, the results from these FGLS estimations are shown in table 3. It should be noted that these results do not have the fixed/random effect model specification applied, so specification bias with respect to the usual EKC specification is potentially present. Of interest within these FGLS results is a comparison of the het adjusted estimates (table 1) with the het/AR adjusted estimates (table 3) as they mainly tend to differ in relation to the statistical significance of the coefficient estimates. The discrepancy reflected is consistent with an observation made by Wooldridge (2008) while discussing the simultaneous occurrence of both heteroscedasticity and serial correlation. Wooldridge (2008) notes that "much of the time serial correlation is viewed as the most important problem, because it usually has a larger impact on standard errors and the efficiency of estimators than does heteroscedasticity" (Wooldridge, 2008: 440). Focusing on the results, the policy variables show a significant decrease in CFC consumption within Non-Article 5 countries of approximately 0.7% or 0.8% per year depending on whether het and AR have been controlled for simultaneously. However, within these results there is no significant difference between the level of consumption of Non-Article 5 and Article 5 countries. An EKC consistent result is also not found for the FGLS het and AR adjusted results, casting doubt on the relationship's validity with respect to CFCs with and without the impact of the Montreal Protocol.

Table 1 – CFC per capita – Fixed/Random Effects (1992-2008)

	lgCFCpc – FE	lgCFCpc – RE	lgCFCpc – FE	lgCFCpc – RE	lgCFCpc - FE	lgCFCpc – RE	lgCFCpc - FE	lgCFCpc – RE
Constant	-48.785	-22.893**	-36.260	-15.175	22.748	-7.350	31.186	-7.729
	(34.30)	(9.88)	(31.23)	(9.95)	(28.35)	(6.62)	(26.85)	(6.71)
lgGDPpc	5.983	1.433	4.800	1.089	-4.069	-1.153	-5.903	-1.143
	(5.73)	(1.93)	(5.41)	(1.95)	(4.74)	(1.21)	(4.42)	(1.23)
lgGDPpcsq	-0.260	-0.069	-0.213	-0.061	0.071	0.063	0.157	0.063
	(0.26)	(0.09)	(0.25)	(0.09)	(0.21)	(0.06)	(0.19)	(0.06)
Time Trend	-0.528***	-0.516***	-0.566***	-0.551***	-0.308***	-0.416***	-0.330***	-0.423***
	(0.09)	(0.06)	(0.09)	(0.06)	(0.08)	(0.05)	(0.08)	(0.05)
lgHCFCpc			0.229***	0.211***	0.146**	0.147**	0.142**	0.147**
			(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.08)
Non-Article5					-	-0.764	-	-0.475
					-	(1.12)	-	(1.18)
Non-A5 TimeT					-0.818***	-0.791***	-0.805***	-0.784***
					(0.11)	(0.10)	(0.11)	(0.10)
Ozone Tre.							1.877**	0.596
							(0.84)	(0.57)
n	1139	1139	1139	1139	1139	1139	1139	1139
i	67	67	67	67	67	67	67	67
R^2	0.13	0.19	0.14	0.18	0.16	0.49	0.17	0.49
χ_1^2 [6]		1654.20***		1707.57***		553.93***		541.88***
Equation	(3.1)		(3.2)		(3.3)		(3.4)	

P Value: *** - 1% ** - 5% * - 10%

Note: The variables included within this regression are as follows: Dependent variable – CFC per capita – Amount of CFC emissions per capita, Independent variables – Constant – Intercept, lGDPpc – log of GDP per capita, lGDPpcsq – log of GDP per capita squared, Time Trend – time trend for 1992-2008, lgHCFCpc – log of HCFC emissions per capita, Non-Article5 – Dummy variable for Non-Article 5 countries, Non-A5 TimeT – Time trend for Non-Article 5 countries only, Ozone Tre. – Ratified an Ozone Treaty (zero until year of ratification).

[6] Breusch and Pagan Lagrangian multiplier test for random effects – null hypothesis: Var(ai) = 0 (random effects inappropriate).

Table 2 – CFC per capita – Fixed/Random Effects with AR(1) disturbances (1992/1993-2008)

	lgCFCpc – FE	lgCFCpc – RE	lgCFCpc – FE	lgCFCpc – RE	lgCFCpc - FE	lgCFCpc – RE	lgCFCpc - FE	lgCFCpc – RE
Constant	-21.769**	-17.229**	-20.734**	-15.342*	-6.285	-10.694*	-3.775	-11.037**
	(9.61)	(7.99)	(9.72)	(8.08)	(10.92)	(5.69)	(11.07)	(5.72)
lgGDPpc	4.174	0.371	4.084	0.350	1.175	-0.923	0.694	-0.883
	(5.45)	(1.473)	(5.40)	(1.48)	(5.02)	(1.04)	(5.06)	(1.04)
lgGDPpcsq	-0.303	-0.020	-0.298	-0.021	-0.162	0.055	-0.142	0.05
	(0.26)	(0.07)	(0.26)	(0.07)	(0.23)	(0.05)	(0.23)	(0.05)
Time Trend	-0.656***	-0.573***	-0.657***	-0.584***	-0.548***	-0.463***	-0.546***	-0.467***
	(0.11)	(0.04)	(0.11)	(0.04)	(0.10)	(0.04)	(0.10)	(0.04)
lgHCFCpc			0.034	0.063**	0.035	0.067**	0.037	0.067**
			(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Non-Article5					-	-0.462	-	-0.322
					-	(1.17)	-	(1.19)
Non-A5 TimeT					-0.386***	-0.726***	-0.390***	-0.721***
					(0.14)	(0.10)	(0.14)	(0.10)
Ozone Tre.							0.547	0.314
							(0.97)	(0.51)
n	1072	1139	1072	1139	1072	1139	1072	1139
i	67	67	67	67	67	67	67	67
R^2	0.07	0.19	0.07	0.19	0.13	0.49	0.13	0.49
χ^2_3 [7]		18.31***		21.09***		31.00***		31.02***
Equation	(3.1)		(3.2)		(3.3)		(3.4)	

P Value: *** - 1% ** - 5% * - 10%

Note: The variables included within this regression are as follows: Dependent variable – CFC per capita – Amount of CFC emissions per capita, Independent variables – Constant – Intercept, lGDPpc – log of GDP per capita, lGDPpcsq – log of GDP per capita squared, Time Trend – time trend for 1992-2008, lgHCFCpc – log of HCFC emissions per capita, Non-Article5 – Dummy variable for Non-Article 5 countries, Non-A5 TimeT – Time trend for Non-Article 5 countries only, Ozone Tre. – Ratified an Ozone Treaty (zero until year of ratification).

[7] Hausman specification test – null hypothesis: the individual effects are uncorrelated with the other regressors in the model.

Table 3 – CFC per capita – FGLS with het and AR(1) adjustments (1992-2008)

	het adjusted results				het and AR(1) adjusted results			
	lgCFCpc	lgCFCpc	lgCFCpc	lgCFCpc	lgCFCpc	lgCFCpc	lgCFCpc	lgCFCpc
Constant	-14.967***	-13.951***	-8.413***	-8.475***	-14.233***	-19.630***	-11.599*	-11.793*
	(0.65)	(1.24)	(1.72)	(1.85)	(3.26)	(7.89)	(6.74)	(6.75)
lgGDPpc	-0.056	-0.055	-1.278***	-1.293***	-0.414	0.812	-1.380	-1.564
	(0.13)	(0.24)	(0.36)	(0.36)	(0.60)	(1.57)	(1.36)	(1.37)
lgGDPpcsq	-0.002	-0.004	0.073***	0.075***	0.009	-0.041	0.083	0.099
	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)	(0.08)	(0.07)	(0.07)
Time Trend	-0.516***	-0.510***	-0.388***	-0.386***	-0.536***	-0.564***	-0.467***	-0.492***
	(0.01)	(0.01)	(0.03)	(0.03)	(0.07)	(0.04)	(0.07)	(0.07)
lgHCFCpc		0.040***	0.109***	0.106***		0.016	-0.005	-0.002
		(0.01)	(0.02)	(0.02)		(0.01)	(0.02)	(0.02)
Non-Article5			-0.250	-0.392			0.793	0.972
			(0.47)	(0.48)			(1.10)	(1.06)
Non-A5 TimeT			-0.824***	-0.831***			-0.661***	-0.659***
			(0.04)	(0.04)			(0.09)	(0.09)
Ozone Tre.				-0.119				1.284**
				(0.28)				(0.63)
N	1139	1139	1139	1139	1139	1139	1139	1139
I	67	67	67	67	67	67	67	67
χ^2_3	2494.82***	3544.56***	10036.80***	9765.14***	66.59***	241.37***	633.51***	674.50***
Equation	(3.1)		(3.2)		(3.3)		(3.4)	

P Value: *** - 1% ** - 5% * - 10%

Note: The variables included within this regression are as follows: Dependent variable – CFC per capita – Amount of CFC emissions per capita, Independent variables – Constant – Intercept, lGDPpc – log of GDP per capita, lGDPpcsq – log of GDP per capita squared, Time Trend – time trend for 1992-2008, lgHCFCpc – log of HCFC emissions per capita, Non-Article5 – Dummy variable for Non-Article 5 countries, Non-A5 TimeT – Time trend for Non-Article 5 countries only, Ozone Tre. – Ratified an Ozone Treaty (zero until year of ratification)

3.2 Estimation Results – Emission Reductions and Policy

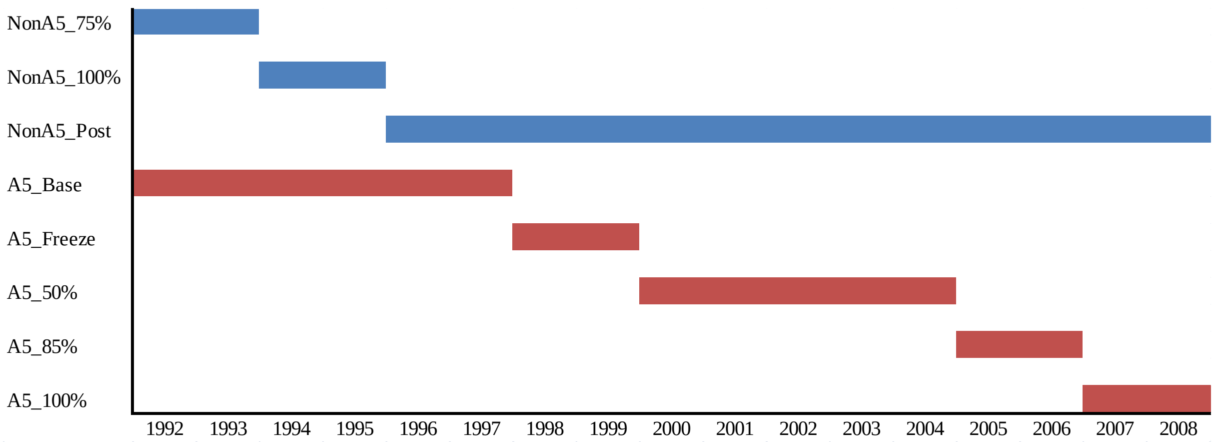
Having established that there is little to no evidence of an EKC consistent relationship within the CFC dataset employed in sub-section 3.1, the analysis will now further develop the discussion on whether emission reductions can be directly linked to the targets of the Montreal Protocol. Within sub-section 3.1 policy impacts were incorporated into the analysis at an aggregate level. In this section there is a concerted effort to disentangle the specific policy target periods and define the stages within which emission reductions were to be met. Table 4 shows the results from a modified analysis which applies the three regression methods applied within section 3.1 to the equation specification shown in equation 5. The major modification is the removal of the Article 5 related variables specified in equation 3 and their replacement with dummy variables representing the timing of the different levels of legislated emission targets. The timing of the targets can be seen in Figure 1.

$$lnCFCpc_{it} = \alpha_i + \beta_1 lnGDPpc_{it} + \beta_2 lnGDPpc_{it}^2 + \beta_3 TimeTrend_t + \beta_4 lnHCFCpc_{it} + \beta_8 NonA5\_75\%RT_{it} + \beta_9 NonA5\_100\%RT_{it} + \beta_{10} NonA5\_PostRT_{it} + \beta_{11} A5\_Base_{it} + \beta_{12} A5\_Freeze_{it} + \beta_{13} A5\_50\%RT_{it} + \beta_{14} A5\_85\%RT_{it} + \beta_{15} A5\_100\%RT_{it} + \mu_{it} \quad (5)$$

Table 4 shows that for the Non-Article 5 countries the stages of having a 75% and 100% reduction target in CFC emissions (denoted in equation 5 as $NonA5\_75\%RT_{it},\ and\ \ NonA5\_100\%RT_{it}$) are significant and that there is a notable trend of emissions reductions above that associated with the time trend. However, while the amounts of reductions for the Non-Article 5 target phases are statistically significant, the overall time trend is still related to a significant decrease in emissions. The largest amount of emission reductions that are related to the timing of the targets occurs when the Montreal

Protocol stipulated that there should be no allowable CFC emissions (as represented by a significant reduction in the *Non-A5 – Post* variable).

Figure 1 – Timing of Montreal Protocol Target Phases



A significant time trend irrespective of statistically significant target phase variables for Non-Article 5 countries is consistent with claims that notable emission reductions were already occurring independent of the Montreal protocol. A pre-existing tendency for reductions is reflected in a consistently significant and negative relationship with the time trend associated with decreases in per capita emissions of between 0.5% and 0.6% per annum from 1992 to 2008. The different stages of the Non-Article 5 targets are associated with greater emission reductions per year, with reductions of approximately 3% per annum during the 75% and 100% phase out periods followed by an 8.5% reduction per annum when CFCs were completely prohibited. These results can be interpreted as the following: notable reductions in CFCs within Non-Article 5 countries can directly be associated with the period that the Montreal protocol was in force, but emission decreases were not solely related to the timing of the reduction targets. In addition, the lack of emission reductions that occurred in Article 5 countries show that decreases in less developed countries were not associated with the stipulated reductions set by the Montreal targets.

This result implies that the success of the Montreal protocol is partly associated with pre-existing industrial factors; as reflected in a significant and decreasing trend in CFCs when the target phases have been accounted for. With respect to Article 5 countries, the results show that a positive relation between the target phases and CFC use persisted throughout the initial phases of the Montreal targets, these being above the overall CFC decline estimated to have occurred across all countries and associated with the time trend. The rationale for separating targets based on Article 5 was intended to allow less developed nations more time to adjust to the policy and these results show that this was utilized by these nations. With respect to the non-Article 5 specific variables, the results show that decreases in CFCs were associated with both the overall time trend and the specific targets set. Note that the current data only reaches the penultimate target period for Article 5 countries and the success of reductions towards zero usage of CFCs cannot be determined using this data.

Table 4 – CFC per capita – Policy Focus (1992-2008)

	FE	RE	FE – AR(1)	RE – AR(1)	FGLS het	FGLS het AR(1)
Constant	8.065	-9.335*	-19.167*	-11.867**	-7.330***	-9.348**
	(17.32)	(5.42)	(11.12)	(5.73)	(1.69)	(4.31)
lgGDPpc	-2.059	-0.578	2.489	-0.549	-1.194***	-1.590*
	(2.70)	(0.98)	(4.75)	(1.04)	(0.34)	(0.92)
lgGDPpcsq	0.019	0.037	-0.167	0.038	0.070***	0.104**
	(0.11)	(0.04)	(0.22)	(0.05)	(0.02)	(0.05)
Time Trend	-0.436***	-0.494***	-0.675***	-0.539***	-0.491***	-0.585***
	(0.06)	(0.04)	(0.10)	(0.05)	(0.02)	(0.04)
lgHCFCpc	0.184***	0.185***	0.051	0.088***	0.137***	0.052***
	(0.04)	(0.03)	(0.03)	(0.03)	(0.01)	(0.01)
Non-A5 – 75%	-	-0.484	-	-1.538	-1.036**	-3.014***
	-	(1.10)	-	(1.16)	(0.49)	(0.97)
Non-A5 – 100%	-0.668	-0.995	0.448	-2.401**	-1.086**	-2.814***
	(1.00)	(1.08)	(1.16)	(1.08)	(0.50)	(0.87)
Non-A5 – Post	-9.086***	-9.379***	-4.342***	-8.532***	-9.849***	-8.486***
	(0.85)	(0.86)	(1.57)	(0.90)	(0.32)	(0.72)
A5 – Base	0.956	-0.053	-0.307	0.109	-0.825**	0.375
	(0.70)	(0.53)	(0.99)	(0.59)	(0.36)	(0.66)
A5 – Freeze	2.402***	1.347**	0.595	0.810	0.354	1.057
	(0.79)	(0.62)	(1.04)	(0.64)	(0.44)	(0.71)
A5 – 50%	3.188***	2.237***	1.844*	1.794***	1.167***	1.900***
	(0.72)	(0.53)	(1.02)	(0.61)	(0.37)	(0.74)
A5 – 85%	2.931***	1.914***	2.163**	1.663**	1.387***	2.86***
	(0.82)	(0.65)	(1.12)	(0.72)	(0.46)	(0.83)
A5 – 100%	-0.147	-1.256**	0.533	-0.408	-2.042***	0.829
	(0.85)	(0.68)	(1.19)	(0.79)	(0.47)	(0.89)
n	1139	1139	1072	1139	1139	1139
i	67	67	67	67	67	67
R^2	0.27	0.52	0.26	0.51		
χ^2_3		646.43***				
Hausman		9.87		34.51***		
Wald Chi²					4238.49***	788.02***

P Value: *** - 1% ** - 5% * - 10%   Note: The variables included within this regression are as follows: Dependent variable – CFC per capita – Amount of CFC emissions per capita, Independent variables – Constant – Intercept, lGDPpc – log of GDP per capita, lGDPpcsq – log of GDP per capita squared, Time Trend – time trend for 1992-2008, lgHCFCpc – log of HCFC emissions per capita, Non-A5 – 75% - Dummy variable for Non-Article 5 countries during the period within which there was a 75% reduction target, Non-A5 – 100% - Dummy variable for Non-Article 5 countries during the period within which there was a 100% reduction target, Non-A5 – Post - Dummy variable for Non-Article 5 countries during the period within which there were no CFC emissions allowed, A5 – Base - Dummy variable for Article 5 countries during the period with no emission targets, A5 – Freeze - Dummy variable for Non-Article 5 countries during the period within which emissions were to show no growth, A5 – 50%/85%/100% - Dummy variable for Non-Article 5 countries during the period within which there was a 50%/85%/100% reduction target.

4 Discussion

Having reviewed whether an EKC relationship exists for CFCs and the relevance of the timing of the Montreal policy targets, some crucial issues need to be highlighted. The first is the importance of a viable substitute as section 3 confirmed that HCFC consumption is related to CFC use and that HCFCs have been widely employed (refer to sub-section 4.2). The second are the auxiliary explanations for the success of the Montreal Protocol and to highlight these details the discussion focuses on a comparison to the Kyoto Protocol (refer to sub-section 4.2).

4.1 The importance of substitutes

In addition to the pollution haven hypothesis that was discussed in the introduction, the new toxins explanation is also of interest to a review of the existence of an EKC relationship and the relationship between CFCs and HCFCs. The new toxins scenario notes that as some pollutants are dealt with, other pollutants emerge and that this may result in overall environmental quality stability, rather than reduction. In others words, "while some traditional pollutants might have an inverted U-shape curve, the new pollutants that are replacing them do not" (Stern, 2004: 1428). Indeed whilst the Montreal Protocol is often described as a success, the reduction in CFC emissions can also be seen as a rare, but fortunate case where a direct substitute for the pollutant was available.

DeSombre (2001) described the substitutability between inputs and the existence of gases such as HCFCs as a 'happy coincidence'. DeSombre also notes that within the United States there was substantial support from industry for the Montreal Protocol and there was evidence of petitioning by major CFC manufacturers (such as DuPont) for the ratification of the Montreal Protocol. Indeed the manufacturers that "were creating substitute chemicals would benefit from international regulation and the increased overseas demand for their new products it would bring" (DeSombre, 2001: 57). In addition, CFCs were produced by a relatively small number of manufacturers who could be effectively monitored and were often the producer of both the substitute (HCFCs) and the 'targeted' problematic gas (CFCs). The US EPA (2007) also notes that by the time the Montreal Protocol had been signed, SC Johnson and DuPont had committed to abandoning CFCs in their products within the US market. Unfortunately, similar examples are not typical in relation to the case of CO2 emissions from fossil fuels as there is a high dependency on such resources and significant barriers to direct substitution.

A factor that reinforces the new toxins explanation is that for many pollutants, measurement and the creation of datasets tends to follow health concerns or the actual implementation of environmental policy. This is true of many datasets, including the one used to source data for the current analysis based on CFCs. It has also been noted that a commonly used database, GEMS - which was used in the original Grossman and Krueger (1991) paper, has focused "on a few 'criteria' pollutants, so-designated because legal statutes have required regulators to specify their damaging characteristics" (Dasgupta, et al. 2002: 150-151). Within the EKC literature itself, there are many and broad classes of emissions that have not been focused upon, especially in the case of toxic pollutants which often cause death, disease or birth defects. Further to this it has been contended by Dasgupta, Laplante, Wang and Wheeler (2002) that "industrial countries surely must consider the daunting possibility that they are not actually making progress against pollution as their incomes rise, but instead are reducing only a few measured and well-known pollutants while facing new and potentially greater environmental concerns" (Dasgupta, et al. 2002: 149).

4.2 Montreal in comparison to Kyoto

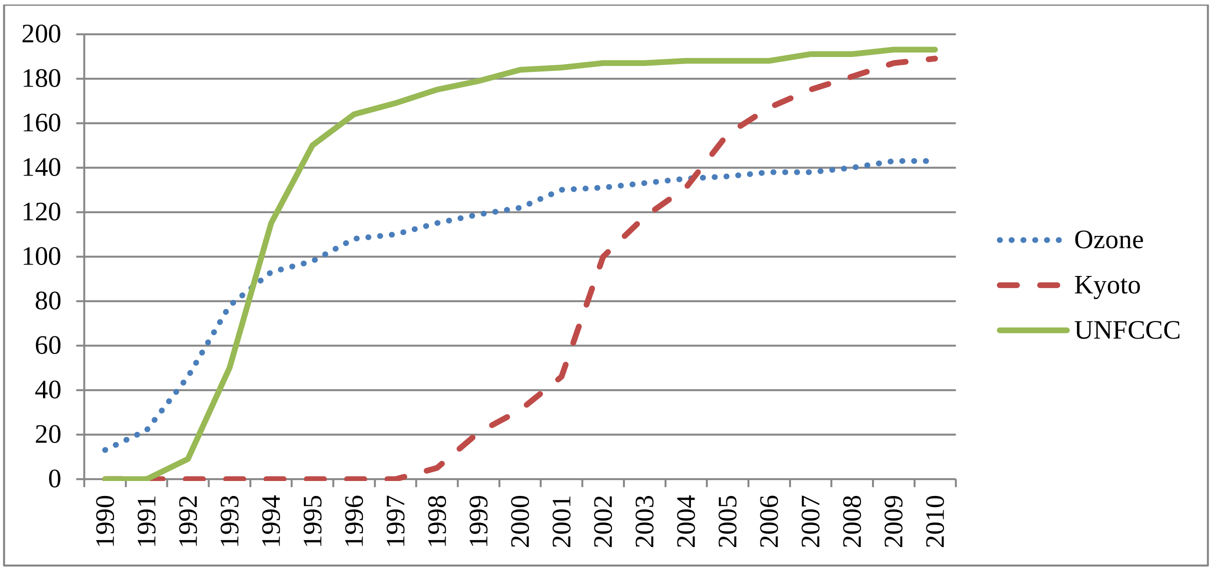
The scant attention given to ozone depleting substances within the EKC literature may be related to the existence and relative success of the Montreal Protocol. With CFC levels having been seen to decrease across developed nations, “by most accounts, the treaty process for addressing ozone depletion is an unqualified success” (DeSombre, 2001: 49). And while the level of ratification and policy action related to the Montreal Protocol has been supposed to have had an impact on the reduction of CFCs, DeSombre (2001) notes that the members of the industry producing ozone-depleting substances (ODS) and market forces have played a valuable role. The qualification here is that some of the market forces underlying a reduction in CFCs are seen to have occurred “as a direct result of the way the Protocol process is structured, and others because of serendipity in the way the industry has made or used ozone depleting substances” (DeSombre, 2001: 57). Further explaining this contention, DeSombre notes that “due to what is in part a happy coincidence, and in part well-developed regulatory incentives, some of the main ODS-producing industries were the main innovators of the substitutes used to replace them” (DeSombre, 2001: 57). This differs substantially to the policy process and the debate surrounding the Kyoto Protocol and the control of CO2 emissions.

Indeed, reduced emissions and policy success are not the only differences between the Montreal and Kyoto protocols, as ratification levels and industry support have substantially differed with climate science being scrutinized and debated. While the identification of climate change and its cause has been a subject of debate, by the time that the Montreal Protocol was introduced, the scientists whom advanced the theory behind the CFC explanation for ozone depletion had already been awarded the Nobel Prize in Chemistry for their work (refer to Molina & Rowland (1974) for the paper). As a result, the risks associated with ozone depletion and their relation to CFC gases was deemed credible and of direct concern to industrialised nations. This broader context is one of the contributing factors of the success of the Montreal Protocol and the support it received from industrialised nations. In contrast, the discussion of the collapse of the climate change negotiations in The Hague in December 2000 within Grubb and Yamin (2001) provides some of the issues that have surrounded the level of ratification of the Kyoto Protocol. In describing “the Protocol’s critics from all shades of the political spectrum” (Grubb and Yamin, 2001: 262), Grubb and Yamin (2001) list the respective critics as follows.

> *These critics include the dwindling band of scientific sceptics who claim that the scientific evidence base is still too weak to justify international action; the predominantly Northern-based economic and industrial critics who claim that industrialized countries’ Kyoto targets are too strong, and that international efforts should focus on a fundamental rewriting of the Protocol to weaken these targets and/or extend them to developing countries; and idealists who believe that (the) targets are too weak to be worthwhile* (Grubb and Yamin, 2001: 262).

Indeed, based on the rate of ratification and reductions of CFCs many have concluded that the Montreal Protocol and its predecessor (the Vienna Convention) are the most effective international agreements in existence. While Figure 2 shows the level of Montreal ratification to be high, upon comparing it to the Kyoto Protocol (using the data compiled by The Secretariat for the Vienna Convention and the Montreal Protocol as well as the United Nations Framework on Climate Change) it can be confirmed that both Protocols had a similar overall level of ratification in 2004. And while the overall level of ratification is important, the profile of the member countries must also be considered. In contrast to the Montreal Protocol, the United States did not ratify the Kyoto Protocol and this directly led to a nervous wait for the agreement to become legally binding due to the requirement for 55 countries accounting for at least 55% of 1990 carbon dioxide emissions to ratify before the Protocol could enter into force. With the receipt of the Russian Federation's instrument of ratification on November 18 2004, the Executive Secretary of the Climate Change Secretariat stated that "a period of uncertainty has closed. Climate change is ready to take its place again at the top of the global agenda" (UNFCCC, 2004).

Figure 2 - Level of Adoption of Intergovernmental Agreements (n = 237)



Focusing on the difficulties of intergovernment agreements and concerns over ratification there is academic debate about whether any international environmental agreement can have a 'real' impact in light of free riding and a lack of penalties/enforcement. Barrett (1990) notes that with no world authority able to intervene and enforce the targets/standards set, "there are strong incentives for government not to co-operate, or to defect from an agreement should one be reached" (Barrett, 1990: 69). This focus on individual parties following their own self-interest leads to the reason why "the core problem in the first period allocations (apart from the US withdrawal) concerned allocations to the EITs (Economies in Transition) that have proved excessive" (Grubb, 2003: 186). The unexpected/unaccounted for fall of the USSR led to a situation where there was an excess of permits and hence a hypothetical Kyoto carbon price was expected to fall close to zero. Indeed, Grubb (2003) notes that projections of the carbon price since 2001 have plummeted upon the introduction of three factors, these being: "the withdrawal of the US, by far the largest source of potential 'demand' in the system; revision of Russian energy projections which greatly increased their projected allowance surplus; and the subsequent Bonn/Marrakech deal on carbon sinks" (Grubb, 2003: 160).

5 Conclusion

From the humble beginnings of a review of the 'Environmental Impacts of a North American Free Trade Agreement', the Environmental Kuznets Curve (EKC) relationship has been the source of a plethora of papers. In recent times this literature has increasingly become critical of the EKC, especially with respect to the fragility and limitations of being based on a reduced functional form. Indeed, the literature has noted many alternate explanations for a reduced form relationship between GDP per capita and per capita emissions. For CFCs within the current sample (1992-2008) there is a significant policy induced negative A significantly different level of CFC consumption between Article 5 and Non-Article 5 countries persists with no indication of an EKC consistent relationship between GDP per capita and CFCs once this policy impact and estimation bias has been allowed for. The confirmation of this result is important as CFCs have had little attention within the EKC literature even though notable progress has been made on reducing the pollutant. For the majority of previous cases where such a relationship has been focused upon the data underpinning the analysis has found to be insufficient. Using the dataset of the Secretariat for the Vienna Convention and the Montreal Protocol has also allowed for a review on whether reductions in CFCs can be attributed to the timing and the levels set within the Montreal Protocol.

Results within section 3 show that significant decreases in CFC consumption occurred within the Non-Article 5 targets. Hence a significant negative decline in CFC consumption between 1992 and 2008 is consistent with the specific timing of the targets of the Montreal Protocol for Non-Article 5 countries. Irrespective of this, the time trend is still significant and has a negative relationship with CFCs that points to the importance of the auxiliary explanations for the success of the Montreal Protocol. Emission reductions occurred during the reduction phases but were not solely linked to the phases specified within the Montreal Protocol. The auxiliary explanations for the success of the policy intervention have been found to be the existence of a supportive industry group, pre-existing legislation and commitment in the United States, affordable and available substitutes, as well as acceptance of the underlying scientific (and Nobel Prize winning) explanation of the link between CFCs and ozone depletion.

Having reviewed the literature on the EKC and conducted my own analysis I believe that significant doubt has been cast on the existence of an EKC consistent relationship for CFCs and the concept of the EKC as a whole. From this I conclude that future work should focus on the effectiveness of induced policy responses, rather than focusing upon the limited cases where a EKC consistent relationship may be found to exist. The auxiliary explanations for the success of the Montreal Protocol also imply that emission reductions from policies enacted by countries with high levels of income are not inevitable. Indeed, policy design and the context surrounding a given environmental issue will be important factors related to policy success.

References

Barrett, S. (1990) 'The problem of global environmental protection', Oxford Review of Economic Policy, Vol. 6 No 1: 68-79.

Bernard, J. T., Gavin, M., Khalaf, L., & Voia, M. (2011). 'Environmental Kuznets Curve: Tipping Points, Uncertainty and Weak Identification'. Environmental and Resource Economics, 1-31.

Cole, M. (2003) 'Trade, the pollution haven hypothesis and the environmental Kuznets curve: examining the linkages', Ecological Economics, Vol. 48, Iss. 1: 71-81.

Cole, M., Rayner, A., and Bates, J. (1997) 'The environmental Kuznets curve: an empirical analysis', Environment and Development Economics, 2, 401-416.

Dasgupta, S., Laplante, B., Wang, H., and Wheeler, D. (2002) 'Confronting the environmental Kuznets Curve', Journal of Economic Perspectives, 16, 147–168.

Day, K. M., & Grafton, R. Q. (2003). 'Growth and the environment in Canada: An empirical analysis', Canadian Journal of Agricultural Economics, 51: 197–216

de Bruyn, S. (1997). 'Explaining the Environmental Kuznets Curve: Structural Change and International Agreements in Reducing Sulphur Emissions', Environment and Development Economics, 2, 485-503.

DeCanio, S. (2003) 'Economic Analysis, Environmental Policy, and Intergenerational Justice in the Reagan Administration The Case of the Montreal Protocol' International Environmental Agreements: Politics, Law and Economics, vol. 3(4), pages 299-321, December.

DeSombre, E. R. (2001) 'The Experience of the Montreal Protocol: Particularly Remarkable and Remarkably Particular'. UCLA Journal of Environmental Law and Policy, 19 (1): 49–81.

Ekins, P. (2000). Economic growth and environmental sustainability: the prospects of green growth. Routledge, New York.

Fan, C., & Zheng, X. (2013). An empirical study of the environmental kuznets curve in sichuan province, china. Environment and Pollution, 2(3): 107-115.

Grossman, G. M., and Krueger, A. B. (1991) 'Environmental impacts of a North American Free Trade Agreement', National Bureau of Economic Research Working Paper 3914, NBER, Cambridge MA.

Grossman, G. M., and Krueger, A. B. (1995) 'Economic growth and the environment', Quarterly Journal of Economics, 110, 353–377.

Grubb, M. (2003) 'The Economics of the Kyoto Protocol' World Economics, vol. 4(3): 143-189.

Grubb, M. and Yamin, F. (2001) 'Climatic Collapse at The Hague: What Happened, Why, and Where Do We Go From Here?', International Affairs, 77, 261-276.

Kleemann, L. and Abdulai, A. (2013) 'The Impact of Trade and Economic Growth on the Environment: revisiting the cross-country evidence', Journal of International Development, 25(2): 180-205.

Lin, C. and Liscow Z. D. (2013) Endogeneity in the Environmental Kuznets Curve: An Instrumental Variables Approach, Am. J. Agr. Econ., 95 (2): 268-274.

Mason, R. and Swanson, T. (2003) 'A Kuznets curve analysis of ozone-depleting substances and the impact of the Montreal Protocol', Oxford Economic Papers, 55, 1-24.

Molina, M. & Rowland, F. (1974) 'Stratospheric sink for chlorofluoromethanes: chlorine atom-catalysed destruction of ozone', Nature, 249: 810-812.

Murdoch, J. C. & Sandler, T. (1997) 'The voluntary provision of a pure public good: The case of reduced CFC emissions and the Montreal Protocol' Journal of Public Economics, vol. 63(3), pages 331-349.

Nahman, A. and Antrobus, G. (2005) 'The environmental Kuznets curve: a literature survey', South African Journal of Economics, 73, 105-120.

Panayotou, T. (1997) 'Demystifying the environmental Kuznets curve: Turning a black box into a policy tool', Environment and Development Economics, 2, 465–484.

Perman, R. and Stern, D. (2003) 'Evidence from panel unit root and cointegration tests that the Environmental Kuznets Curve does not exist', Australian Journal of Agricultural and Resource Economics, 47, 325-347.

Sephton, P. and Mann, J. (2013) 'Further evidence of an Environmental Kuznets Curve in Spain', Energy Economics, Volume 36, March 2013: 177-181.

Shahbaz, M., Mutascu, M. and Azim, P. (2013) 'Environmental Kuznets curve in Romania and the role of energy consumption', Renewable and Sustainable Energy Reviews, Volume 18: 165–173.

Stern, D. (2004) 'The rise and fall of the environmental Kuznets curve', World Development, 32, 1419-1439.

Stern, D. I. (2002). 'Explaining changes in global sulphur emissions: An econometric decomposition approach', Ecological Economics, 42: 201–220.

Tiwari, A. K., Shahbaz, M. and Hye, Q. (2013) 'The environmental Kuznets curve and the role of coal consumption in India: Cointegration and causality analysis in an open economy', Renewable and Sustainable Energy Reviews, Volume 18: 519-527.

United Nations Framework on Climate Change (1997) 'Press Release: Industrialised countries to cut greenhouse gas emissions by 5.2%', http://unfccc.int/cop3/fccc/info/indust.htm, accessed on 23 January 2009.

US EPA (2007) 'Achievements in Stratospheric Ozone Protection – Progress Report'.

Wagner, U. (2009) 'The voluntary provision of a pure public good? Another look at CFC emissions and the Montreal Protocol'. Oxf. Econ. Pap. (2009) 61 (1): 183-196.

Wooldridge, J. (2008) Introductory Econometrics: a modern approach, Third Edition, Thomson South-Western, Mason.

Appendix

Table A1 – CFC per capita – Countries within Sample (1992-2008) n = 67

Antigua and Barbuda	El Salvador	Mali	Saudi Arabia
Argentina	Gambia	Mexico	Seychelles
Australia*	Ghana	Nepal	Sierra Leone
Bangladesh	Guatemala	New Zealand*	Solomon Islands
Belarus*	Guinea	Nicaragua	South Africa
Botswana	Guinea-Bissau	Niger	Sri Lanka
Brazil	Iceland*	Nigeria	Switzerland*
Burkina Faso	India	Norway*	Thailand
Cameroon	Indonesia	Pakistan	Trinidad and Tobago
Canada*	Iran	Panama	Tunisia
Cape Verde	Israel*	Papua New Guinea	Turkey
Chile	Jamaica	Paraguay	Uganda
China	Japan*	Peru	Ukraine*
Croatia	Jordan	Philippines	United States of America*
Dominican Republic	Kenya	Republic of Korea	Uruguay
Ecuador	Kyrgyzstan	Russian Federation*	Venezuela
	Malawi	Rwanda	
	Malaysia		

* denotes Non-Article 5 countries (n = 12)

NOTE DI LAVORO DELLA FONDAZIONE ENI ENRICO MATTEI

Fondazione Eni Enrico Mattei Working Paper Series

Our Note di Lavoro are available on the Internet at the following addresses:
http://www.feem.it/getpage.aspx?id=73&sez=Publications&padre=20&tab=1
http://papers.ssrn.com/sol3/JELJOUR_Results.cfm?form_name=journalbrowse&journal_id=266659
http://ideas.repec.org/s/fem/femwpa.html
http://www.econis.eu/LNG=EN/FAM?PPN=505954494
http://ageconsearch.umn.edu/handle/35978
http://www.bepress.com/feem/

NOTE DI LAVORO PUBLISHED IN 2014

CCSD	1.2014	Erin Baker, Valentina Bosetti, Karen E. Jenni and Elena Claire Ricci: Facing the Experts: Survey Mode and Expert Elicitation
ERM	2.2014	Simone Tagliapietra: Turkey as a Regional Natural Gas Hub: Myth or Reality? An Analysis of the Regional Gas Market Outlook, beyond the Mainstream Rhetoric
ERM	3.2014	Eva Schmid and Brigitte Knopf: Quantifying the Long-Term Economic Benefits of European Electricity System Integration
CCSD	4.2014	Gabriele Standardi, Francesco Bosello and Fabio Eboli: A Sub-national CGE Model for Italy
CCSD	5.2014	Kai Lessmann, Ulrike Kornek, Valentina Bosetti, Rob Dellink, Johannes Emmerling, Johan Eyckmans, Miyuki Nagashima, Hans-Peter Weikard and Zili Yang: The Stability and Effectiveness of Climate Coalitions: A Comparative Analysis of Multiple Integrated Assessment Models
CCSD	6.2014	Sergio Currarini, Carmen Marchiori and Alessandro Tavoni: Network Economics and the Environment: Insights and Perspectives
CCSD	7.2014	Matthew Ranson and Robert N. Stavins: Linkage of Greenhouse Gas Emissions Trading Systems: Learning from Experience
CCSD	8.2013	Efthymia Kyriakopoulou and Anastasios Xepapadeas: Spatial Policies and Land Use Patterns: Optimal and Market Allocations
CCSD	9.2013	Can Wang, Jie Lin, Wenjia Cai and ZhongXiang Zhang: Policies and Practices of Low Carbon City Development in China
ES	10.2014	Nicola Genovese and Maria Grazia La Spada: Trust as a Key Variable of Sustainable Development and Public Happiness: A Historical and Theoretical Example Regarding the Creation of Money
ERM	11.2014	Ujjayant Chakravorty, Martino Pelli and Beyza Ural Marchand: Does the Quality of Electricity Matter? Evidence from Rural India
ES	12.2014	Roberto Antonietti: From Outsourcing to Productivity, Passing Through Training: Microeconometric Evidence from Italy
CCSD	13.2014	Jussi Lintunen and Jussi Uusivuori: On The Economics of Forest Carbon: Renewable and Carbon Neutral But Not Emission Free
CCSD	14.2014	Brigitte Knopf, Bjørn Bakken, Samuel Carrara, Amit Kanudia, Ilkka Keppo, Tiina Koljonen, Silvana Mima, Eva Schmid and Detlef van Vuuren: Transforming the European Energy System: Member States' Prospects Within the EU Framework
CCSD	15.2014	Brigitte Knopf, Yen-Heng Henry Chen, Enrica De Cian, Hannah Förster, Amit Kanudia, Ioanna Karkatsouli, Ilkka Keppo, Tiina Koljonen, Katja Schumacher and Detlef van Vuuren: Beyond 2020 - Strategies and Costs for Transforming the European Energy System
CCSD	16.2014	Anna Alberini, Markus Bareit and Massimo Filippini: Does the Swiss Car Market Reward Fuel Efficient Cars? Evidence from Hedonic Pricing Regressions, a Regression Discontinuity Design, and Matching
ES	17.2014	Cristina Bernini and Maria Francesca Cracolici: Is Participation in Tourism Market an Opportunity for Everyone? Some Evidence from Italy
ERM	18.2014	Wei Jin and ZhongXiang Zhang: Explaining the Slow Pace of Energy Technological Innovation: Why Market Conditions Matter?
CCSD	19.2014	Salvador Barrios and J. Nicolás Ibañez: Time is of the Essence: Adaptation of Tourism Demand to Climate Change in Europe
CCSD	20.2014	Salvador Barrios and J. Nicolás Ibañez Rivas: Climate Amenities and Adaptation to Climate Change: A Hedonic-Travel Cost Approach for Europe
ERM	21.2014	Andrea Bastianin, Marzio Galeotti and Matteo Manera: Forecasting the Oil-gasoline Price Relationship: Should We Care about the Rockets and the Feathers?
ES	22.2014	Marco Di Cintio and Emanuele Grassi: Wage Incentive Profiles in Dual Labor Markets
CCSD	23.2014	Luca Di Corato and Sebastian Hess: Farmland Investments in Africa: What's the Deal?
CCSD	24.2014	Olivier Beaumais, Anne Briand, Katrin Millock and Céline Nauges: What are Households Willing to Pay for Better Tap Water Quality? A Cross-Country Valuation Study
CCSD	25.2014	Gabriele Standardi, Federico Perali and Luca Pieroni: World Tariff Liberalization in Agriculture: An Assessment Following a Global CGE Trade Model for EU15 Regions
ERM	26.2014	Marie-Laure Nauleau: Free-Riding on Tax Credits for Home Insulation in France: an Econometric Assessment Using Panel Data

CCSD	27.2014	Hannah Förster, Katja Schumacher, Enrica De Cian, Michael Hübler, Ilkka Keppo, Silvana Mima and Ronald D. Sands: European Energy Efficiency and Decarbonization Strategies Beyond 2030 – A Sectoral Multi-model Decomposition
CCSD	28.2014	Katherine Calvin, Shonali Pachauri, Enrica De Cian and Ioanna Mouratiadou: The Effect of African Growth on Future Global Energy, Emissions, and Regional Development
CCSD	29.2014	Aleh Cherp, Jessica Jewell, Vadim Vinichenko, Nico Bauer and Enrica De Cian: Global Energy Security under Different Climate Policies, GDP Growth Rates and Fossil Resource Availabilities
CCSD	30.2014	Enrica De Cian, Ilkka Keppo, Johannes Bollen, Samuel Carrara, Hannah Förster, Michael Hübler, Amit Kanudia, Sergey Paltsev, Ronald Sands and Katja Schumacher: European-Led Climate Policy Versus Global Mitigation Action. Implications on Trade, Technology, and Energy
ERM	31.2014	Simone Tagliapietra: Iran after the (Potential) Nuclear Deal: What's Next for the Country's Natural Gas Market?
CCSD	32.2014	Mads Greaker, Michael Hoel and Knut Einar Rosendahl: Does a Renewable Fuel Standard for Biofuels Reduce Climate Costs?
CCSD	33.2014	Edilio Valentini and Paolo Vitale: Optimal Climate Policy for a Pessimistic Social Planner
ES	34.2014	Cristina Cattaneo: Which Factors Explain the Rising Ethnic Heterogeneity in Italy? An Empirical Analysis at Province Level
CCSD	35.2014	Yasunori Ouchida and Daisaku Goto: Environmental Research Joint Ventures and Time-Consistent Emission Tax
CCSD	36.2014	Jaime de Melo and Mariana Vijil: Barriers to Trade in Environmental Goods and Environmental Services: How Important Are They? How Much Progress at Reducing Them?
CCSD	37.2014	Ryo Horii and Masako Ikefuji: Environment and Growth
CCSD	38.2014	Francesco Bosello, Lorenza Campagnolo, Fabio Eboli and Ramiro Parrado: Energy from Waste: Generation Potential and Mitigation Opportunity
ERM	39.2014	Lion Hirth, Falko Ueckerdt and Ottmar Edenhofer: Why Wind Is Not Coal: On the Economics of Electricity
CCSD	40.2014	Wei Jin and ZhongXiang Zhang: On the Mechanism of International Technology Diffusion for Energy Productivity Growth
CCSD	41.2014	Abeer El-Sayed and Santiago J. Rubio: Sharing R&D Investments in Cleaner Technologies to Mitigate Climate Change
CCSD	42.2014	Davide Antonioli, Simone Borghesi and Massimiliano Mazzanti: Are Regional Systems Greening the Economy? the Role of Environmental Innovations and Agglomeration Forces
ERM	43.2014	Donatella Baiardi, Matteo Manera and Mario Menegatti: The Effects of Environmental Risk on Consumption: an Empirical Analysis on the Mediterranean Countries
CCSD	44.2014	Elena Claire Ricci, Valentina Bosetti, Erin Baker and Karen E. Jenni: From Expert Elicitations to Integrated Assessment: Future Prospects of Carbon Capture Technologies
CCSD	45.2014	Kenan Huremovic: Rent Seeking and Power Hierarchies: A Noncooperative Model of Network Formation with Antagonistic Links
CCSD	46.2014	Matthew O. Jackson and Stephen Nei: Networks of Military Alliances, Wars, and International Trade
CCSD	47.2014	Péter Csóka and P. Jean-Jacques Herings: Risk Allocation under Liquidity Constraints
CCSD	48.2014	Ahmet Alkan and Alparslan Tuncay: Pairing Games and Markets
CCSD	49.2014	Sanjeev Goyal, Stephanie Rosenkranz, Utz Weitzel and Vincent Buskens: Individual Search and Social Networks
CCSD	50.2014	Manuel Förster, Ana Mauleon and Vincent J. Vannetelbosch: Trust and Manipulation in Social Networks
CCSD	51.2014	Berno Buechel, Tim Hellmann and Stefan Kölßner: Opinion Dynamics and Wisdom under Conformity
CCSD	52.2014	Sofia Priazhkina and Frank Page: Formation of Bargaining Networks Via Link Sharing
ES	53.2014	Thomas Longden and Greg Kannard: Rugby League in Australia between 2001 and 2012: an Analysis of Home Advantage and Salary Cap Violations
ES	54.2014	Cristina Cattaneo, Carlo V. Fiorio and Giovanni Peri: What Happens to the Careers of European Workers when Immigrants "Take their Jobs"?
CCSD	55.2014	Francesca Sanna-Randaccio, Roberta Sestini and Ornella Tarola: Unilateral Climate Policy and Foreign Direct Investment with Firm and Country Heterogeneity
ES	56.2014	Cristina Cattaneo, Carlo V. Fiorio and Giovanni Peri: Immigration and Careers of European Workers: Effects and the Role of Policies
CCSD	57.2014	Carlos Dionisio Pérez Blanco and Carlos Mario Gómez Gómez: Drought Management Plans and Water Availability in Agriculture. A Risk Assessment Model for a Southern European Basin
CCSD	58.2014	Baptiste Perrissin Fabert, Etienne Espagne, Antonin Pottier and Patrice Dumas: The Comparative Impact of Integrated Assessment Models' Structures on Optimal Mitigation Policies
CCSD	59.2014	Stuart McDonald and Joanna Poyago-Theotoky: Green Technology and Optimal Emissions Taxation
CCSD	60.2014	ZhongXiang Zhang: Programs, Prices and Policies Towards Energy Conservation and Environmental Quality in China
CCSD	61.2014	Carlo Drago, Livia Amidani Aliberti and Davide Carbonai: Measuring Gender Differences in Information Sharing Using Network Analysis: the Case of the Austrian Interlocking Directorship Network in 2009
CCSD	62.2014	Carlos Dionisio Pérez Blanco and Carlos Mario Gómez Gómez: An Integrated Risk Assessment Model for the Implementation of Drought Insurance Markets in Spain
CCSD	63.2014	Y. Hossein Farzin and Ronald Wendner: The Time Path of the Saving Rate: Hyperbolic Discounting and Short-Term Planning
CCSD	64.2014	Francesco Bosello and Ramiro Parrado: Climate Change Impacts and Market Driven Adaptation: the Costs of Inaction Including Market Rigidities
CCSD	65.2014	Luca Di Corato, Cesare Dosi and Michele Moretto: Bidding for Conservation Contracts

CCSD	66.2014	Achim Voß and Jörg Lingens: What's the Damage? Environmental Regulation with Policy-Motivated Bureaucrats
CCSD	67.2014	Carolyn Fischer, Richard G. Newell and Louis Preonas: Environmental and Technology Policy Options in the Electricity Sector: Interactions and Outcomes
CCSD	68.2014	Carlos M. Gómez, C. Dionisio Pérez-Blanco and Ramon J. Batalla: The Flushing Flow Cost: A Prohibitive River Restoration Alternative? The Case of the Lower Ebro River
ES	69.2014	Roberta Distante, Ivan Petrella and Emiliano Santoro: Size, Age and the Growth of Firms: New Evidence from Quantile Regressions
CCSD	70.2014	Jaime de Melo and Mariana Vijil: The Critical Mass Approach to Achieve a Deal on Green Goods and Services: What is on the Table? How Much to Expect?
ERM	71.2014	Gauthier de Maere d'Aertrycke, Olivier Durand-Lasserve and Marco Schudel: Integration of Power Generation Capacity Expansion in an Applied General Equilibrium Model
ERM	72.2014	ZhongXiang Zhang: Energy Prices, Subsidies and Resource Tax Reform in China
CCSD	73.2014	James A. Lennox and Jan Witajewski: Directed Technical Change With Capital-Embodied Technologies: Implications For Climate Policy
CCSD	74.2014	Thomas Longden: Going Forward by Looking Backwards on the Environmental Kuznets Curve: an Analysis of CFCs, CO2 and the Montreal and Kyoto Protocols
ERM	75.2014	Simone Tagliapietra: The EU-Turkey Energy Relations After the 2014 Ukraine Crisis. Enhancing The Partnership in a Rapidly Changing Environment
CCSD	76.2014	J. Farlin, L. Drouet, T. Gallé, D. Pittois, M. Bayerle, C. Braun, P. Maloszewski, J. Vanderborght, M. Elsner and A. Kies: Delineating Spring Recharge Areas in a Fractured Sandstone Aquifer (Luxembourg) Based on Pesticide Mass Balance
CCSD	77.2014	F. Branger and P. Quirion: Reaping the Carbon Rent: Abatement and Overallocation Profits in the European Cement Industry, Insights from an LMDI Decomposition Analysis
CCSD	78.2014	Johannes Emmerling : Sharing of Climate Risks across World Regions
CCSD	79.2014	Brigitte Knopf, Nicolas Koch, Godefroy Grosjean, Sabine Fuss, Christian Flachsland, Michael Pahle, Michael Jakob and Ottmar Edenhofer: The European Emissions Trading System (EU ETS): Ex-Post Analysis, the Market Stability Reserve and Options for a Comprehensive Reform
CCSD	80.2014	Yana Rubashkina, Marzio Galeotti and Elena Verdolini: Environmental Regulation and Competitiveness: Empirical Evidence on the Porter Hypothesis from European Manufacturing Sectors