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

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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 is driven, in part, by the intention to establish that successful emission reductions tend to be associated with a concerted policy effort. 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 implement environmental policy, 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.

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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. It was noted in 2001 that the treaty process for addressing ozone depletion "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 and the reasons for success 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.

The review of the success of the Montreal Protocol in comparison to the stagnation of the negotiations surrounding the Kyoto Protocol is driven, in part, by the intention to establish that successful emission reductions tend to be associated with a concerted policy effort. 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. 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, 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.

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. Grossman and Krueger (1991) actually set out to review whether reductions in trade barriers would improve or harm environmental quality with a focus upon the ‘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).

[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).

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 is 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 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.

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 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. 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 that has targets that differ based on income (or the level of development). The EKC relationship and CFCs has been studied previously, refer to Mason and Swanson (2003) and Kleemann and Abdulai (2013) for a validation and a refutation of the link between the EKC and CFCs. Since the Montreal Protocol is not the only intergovernmental agreement to separate the level of policy response based on income levels, and hence the level of development, the investigation in this paper will be extended to analyse the existence of the EKC relationship within CO2 data and whether any such relationship found is impacted by the ratification of the Kyoto Protocol and the intention to fulfil the targets implied by this action.

The structure of the paper is as follows. A literature review and background discussion is conducted in section 2. After an initial review of the 'humble beginnings' of the EKC relationship and subsequent concerns over its validity/robustness in the sub-section 2.1, the paper then highlights the 'scarce attention given to CFCs' in sub-section 2.2. Upon discussing CFCs and CO2, it is important that the impact of the Montreal and Kyoto Protocols on the differing pollutant trends is addressed and this occurs in sub-section 2.3. After a brief discussion of some of the concerns over the EKC relationship's 'econometric foundations' in sub-section 2.4, empirical analysis then follows in section 3. Diagnostic tests and functional forms to be estimated are specified in sub-section 3.1. Before concluding the paper in section 4, the results of the estimations reviewing an EKC consistent relationship will be reviewed for CFCs in sub-section 3.2, followed by the results for reviewing an EKC consistent relationship and CO2 emissions from fossil fuels in sub-section 3.3. With the aim of focusing on the issue of policy success and quantifiable emissions reductions, sub-section 3.4 will focus on whether the emission reduction targets of the Montreal Protocol are attributable to the rate of CFC reductions that occurred. In addition, sub-section 3.4 will assess whether any

CO_2 emission reductions in ratifying countries increased at a faster rate in the period after the Kyoto protocol became a binding agreement.

2 Literature Review and Background Discussion

2.1 Humble Beginnings

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 subsequent 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 extended to focus on reasons why these discrepancies may exist. It is with this that the literature started to review wider considerations of 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 maintaining a sound methodological/econometric basis.

Concerns over the methodology applied within reviews of the EKC are not new, as the limitation of a reduced function 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)).

In addition to the pollution haven hypothesis, the new toxins explanation is also of interest to a review of the existence of an EKC relationship and the relationship between CFCs and hydrofluorocarbons (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 this 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 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). 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 for 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).

2.2 Scarce Attention Given to CFCs

Even though the EKC relationship has been extensively researched, the relationship between GDP and CFCs has been scarcely analysed and the data used within the existing studies are often insufficient. Mason and Swanson (2003) note that to their knowledge only three papers have 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. While the analysis of Mason and Swanson (2003) does overcome some of the issues from previous analyses (such as cross-sectional data), the period involved limits the analysis to an examination of the impacts of ratification at that point in time and 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).

On this basis, 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 chapter 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 sub-section 3.3. In addition to this, an analysis of an EKC consistent relationship and the impacts of the ratification of the Kyoto Protocol will also be presented within sub-section 3.4 using a balanced CO2 dataset spanning

[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).

from 1990 to 2007 for 124 countries compiled by the Carbon Dioxide Information Analysis Center (CDIAC)[3].

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 to come is still important as heteroscedasticity and serial correlation, as well as the issue of policy specific factors, are all simultaneously accounted for.

[3] 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).

2.3 Montreal in comparison to Kyoto

The scant attention given to ozone depleting substances within the EKC literature may be associated with 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 thought to have had an impact on the reduction of CFCs, DeSombre (2001) notes that the members of 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.

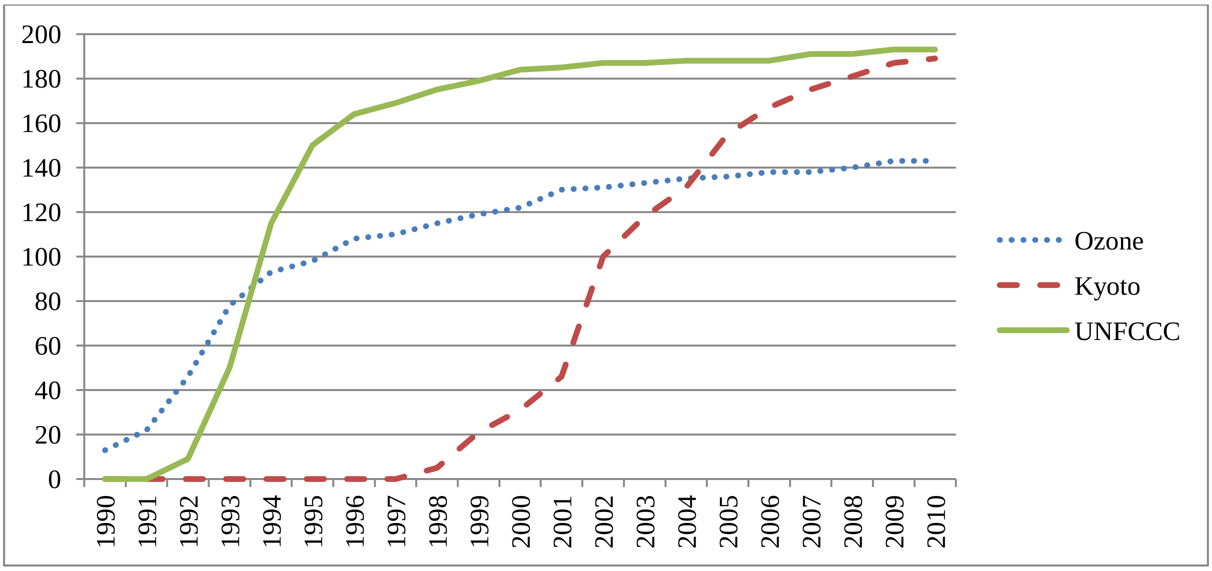
Reduced emissions and policy success are not the only differences between the Montreal and Kyoto protocols, as ratification levels and industry support have substantially differed with climate science being scrutinized and debated. While the identification of climate change and its cause has been a subject 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 in 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 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 3.1 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 had a similar overall level of ratification as at 2004. 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 for the Protocol to 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 3.1 - 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 of individual parties following their own selfinterest and private property rights 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 has lead to a situation where there was an excess of permits and hence the 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).

2.4 Econometric Foundations of the EKC

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 the 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). The increase in studies using econometric methodologies to test the EKC relationship has been noted by Stern (2004) and can be seen as quite important as 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).

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 is not as rare as it is treacherous. 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 the EKC analysis 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 with 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[4] 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 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). A recent study focused on CO2 emissions for Canada has utilised a range of estimation methods and finds no EKC relationship, indeed per-capita GDP and per-capita emissions increase monotonically (He & Richard, 2010). Indeed, much of the research completed since 2010 has focused on within country analysis with Shahbaz et al. (2013) for Romania, Fan and Zheng (2013) for China, Tiwari et al. (2013) for India, and Sephton and Mann (2013) for Spain cited as examples. An exception to this is Lin and Liscow (2013) that focuses upon instrumental variables and water pollution.

[4] Panel cointegration considers the degree of heterogeneity across the ‘n’ dimension of a sample.

3 Empirical Analysis

Having established that policy has been found to be more important than structural changes, a similar result will be established for CO2 and CFCs within this paper. Indeed, the aim of this paper is to review the robustness of any EKC consistent result found using the standard functional form 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 both pollutants in each of the model specifications described in the following sub-section. Fixed and random effects regression analysis will be applied as it is expected that the reduced form specification of the model requires the allowance for unobserved country specific effects. The fixed effects and random effects estimates will be adjusted for heteroscedasticity and serial correlation on separate incidences, with feasible GLS being applied to examine the impact of allowing for both issues simultaneously.

This section reviews the empirical analysis that focuses upon whether an EKC consistent relationship can be found for CFCs (sub-section 3.2) and CO2 (sub-section 3.3), as well as reviewing whether the timing of the targets of the Montreal Protocol are consistent with the emission reductions that occurred (sub-section 3.4). Sub-section 3.1 presents an outline of the estimations that will occur in sub-section 3.2 and sub-section 3.3. Sub-section 3.4 is self-contained as it focuses on Emission Reductions and Policy, rather than the existence of an EKC consistent relationship.

3.1 Estimation Outline

Following the standard functional form discussed within the EKC literature[5], 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 for CFCs (equation 3.1), 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 (eq. 3.2), as HCFC gases are a commonly identified substitute for CFC gases, this chapter will then focus on the impacts of the Montreal Protocol's targets for CFC consumption/production reduction (eq. 3.3), and allow for the few countries within the sample which have hesitated in ratifying the Protocol (eq. 3.4). Equation 3.3 and 3.4 also contain the Non Article5 time trend variable which allows for the separation of level of emissions with the change in emissions for these countries overtime.

$$lnCFCpc_{it} = \alpha_i + \gamma_t + \beta_1 lnGDPpc_{it} + \beta_2 lnGDPpc_{it}^2 + \beta_3 TimeTrend_t + \mu_{it} \tag{3.1}$$

$$lnCFCpc_{it} = \alpha_i + \gamma_t + \beta_1 lnGDPpc_{it} + \beta_2 lnGDPpc_{it}^2 + \beta_3 TimeTrend_t + \beta_4 lnHCFCpc_{it} + \mu_{it} \tag{3.2}$$

$$lnCFCpc_{it} = \alpha_i + \gamma_t + \beta_1 lnGDPpc_{it} + \beta_2 lnGDPpc_{it}^2 + \beta_3 TimeTrend_t + \beta_4 lnHCFCpc_{it} + \beta_5 NonArticle5_i + \beta_6 NonA5TimeT_{it} + \mu_{it} \tag{3.3}$$

$$lnCFCpc_{it} = \alpha_i + \gamma_t + \beta_1 lnGDPpc_{it} + \beta_2 lnGDPpc_{it}^2 + \beta_3 TimeTrend_t + \beta_4 lnHCFCpc_{it} + \beta_5 NonArticle5_i + \beta_6 NonA5TimeT_{it} + \beta_7 NoOzoneTre_{it} + \mu_{it} \tag{3.4}$$

A similar analysis will then be conducted for CO2 emissions, starting with the same specification for testing an EKC consistent relationship (eq. 3.5). Having established this

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

basis, the robustness of any EKC consistent relationship will be tested with the inclusion of variables indicating CO2 levels, Kyoto Ratification and UNFCCC participation. With the addition of the level and trend of CO2 emissions for Annex A countries, the estimates are expected to reflect the underlying justification for setting targets for these countries alone (eq. 3.6). Having established the basis and justification for targets being set for Annex A countries, the analysis will then evaluate the impacts of the respective views of the validity of the Kyoto Protocol and the expectation of the eventual/actual introduction of binding targets as reflected in the relationship between emissions and the number of years of Kyoto ratification and/or UNFCCC participation (eq. 3.7). Separate time trends for Annex 1 countries and the number of years a country has been a UNFCCC signatory have been included in equations 3.6 and 3.7. The accumulative number of years the Kyoto protocol has been ratified by each country specified is denoted as $KyotoRat_{it}$ for country i, period t.

$$lnCO2pc_{it} = \alpha_i + \gamma_t + \beta_1 lnGDPpc_{it} + \beta_2 lnGDPpc_{it}^2 + \beta_3 TimeTrend_t + \varepsilon_{it} \tag{3.5}$$

$$lnCO2pc_{it} = \alpha_i + \gamma_t + \beta_1 lnGDPpc_{it} + \beta_2 lnGDPpc_{it}^2 + \beta_3 TimeTrend_t + \beta_4 KyotoRat_{it} + \beta_5 UNFCCC_{it} + \beta_6 Annex1_i + \beta_7 Annex1TimeT_{it} + \varepsilon_{it} \tag{3.6}$$

$$lnCO2pc_{it} = \alpha_i + \gamma_t + \beta_1 lnGDPpc_{it} + \beta_2 lnGDPpc_{it}^2 + \beta_3 TimeTrend_t + \beta_4 KyotoRat_{it} + \beta_5 UNFCCC_{it} + \beta_6 Annex1_i + \beta_7 Annex1TimeT_{it} + \beta_8 YrsKyotoRat_{it} + \beta_9 YrsUNFCCC_{it} + \varepsilon_{it} \tag{3.7}$$

The introduction of this model specification has been based on the concerns during the sample period reviewed (1990-2009), over whether the Kyoto Protocol would reach the prescribed requirements for binding legality. Under this uncertainty, it can be expected that the countries ratifying relatively early are likely to be the countries determined to take action in line with the intentions of the Kyoto Protocol and the UNFCCC (rather than taking a ‘wait and see approach’). Additionally upon ratifying the Protocol, these countries also have a direct incentive to take earlier action to meet their prescribed target for the first phase (2008-2012) as they have been based on their respective 1990 baseline emission level. As discussed within the earlier comparison between the Montreal Protocol and the Kyoto Protocol, these policy and motivational aspects are important contrasting factors which need to be taken into account upon discussing emission reductions, especially upon focusing on CFCs and CO_2. Subsequently sub-section 3.5 directly focuses on these issues with the estimation of an additional specification.

All of the equation specifications in this chapter (which are based on the same basic origins of equation 3.1) will be estimated using data from the Secretariat for the Vienna Convention and the Montreal Protocol (CFCs) and the Carbon Dioxide Information Analysis Center (CO_2). Apart from including a more extensive time dimension (14 to 16 years), the balanced datasets compiled have a range of countries (with differing levels of CFCs/CO_2 and GDP per capita) within the respective samples of 67 and 124 countries, respectively. Table A1 and A2 within the appendix list the countries included within these samples and also denote those belonging to the Non-Article 5 and Annex A groupings.[6] Dealing with growth paths of countries with differing levels of development implies that 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 – with the results often being 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. In the case of CO_2, only 28 of the 124 countries are labelled as Annex A countries. This mix is

[6] Non-Article 5 countries are those which have been allocated targets under the first phase of the Kyoto Protocol and tend to be classified as developed countries by the World Bank. In other words, these are those countries who that not granted a reprieve from country specific targets in the first phase of Kyoto.

important as apart from levels of development, these distinctions also reflect differing levels of policy prescriptions and targets.

3.2 Estimation Results – CFCs and EKC

Within the heteroscedasticity robust (het robust) fixed effect and random effect estimation (fe/re) results shown in table 3.1 there is some evidence of an EKC consistent relationship under both the fixed effect estimation techniques using the functional form specified in equation 3.1 and 3.2. However, upon including the Montreal Protocol target variables specified in equation 3.3 (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 in addition to an overall decrease in the consumption of CFC gases during the time period and based on exogenous factors within individual countries[7], Non-Article 5 countries had significantly higher levels of per capita CFC emissions, decreasing 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. In 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 table 3.1 reflect the influence of the factors impacting upon end user emissions as the consumption of CFCs has been calculated by taking national production of CFCs, adding imports, and subtracting exports, destroyed

[7] 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).

quantities and feedstock uses of individual CFCs. Upon allowing for autoregressive order one AR(1) disturbances, the results in table 3.1 are largely replicated within table 3.2 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.

While allowances have been made for heteroscedasticity (het) and serial correlation (AR) separately, both of these factors can be simultaneously controlled using feasible generalised least squares (FGLS). Allowing for heteroscedasticity and an AR(1) process, the results from these FGLS estimations are shown in table 3.3. These results do not have the fixed/random effect model specification applied, so specification bias and differences with the previous results are potentially present. Of interest within these FGLS results is a comparison of the het adjusted estimates with the het/AR adjusted estimates which mainly differ upon reviewing the statistical significance of the respective 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 joint-adjusted results, casting doubt on the relationship's validity with respect to CFCs with and without the impact of the Montreal Protocol.

Table 3.1 – 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
	(18.88)	(7.88)	(18.71)	(7.99)	(17.77)	(5.55)	(18.00)	(5.58)
lgGDPpc	5.983**	1.433	4.800*	1.089	-4.069	-1.153	-5.903**	-1.143
	(2.94)	(1.45)	(2.90)	(1.44)	(2.75)	(1.00)	(2.83)	(1.01)
lgGDPpcsq	-0.260**	-0.069	-0.213*	-0.061	0.071	0.063	0.157	0.063
	(0.12)	(0.07)	(0.12)	(0.06)	(0.11)	(0.05)	(0.12)	(0.05)
Time Trend	-0.528***	-0.516***	-0.566***	-0.551***	-0.308***	-0.416***	-0.330***	-0.423***
	(0.05)	(0.03)	(0.05)	(0.03)	(0.05)	(0.03)	(0.05)	(0.03)
lgHCFCpc			0.229***	0.211***	0.146***	0.147***	0.142***	0.147***
			(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
Non-Article5					-	-0.764	-	-0.475
					-	(0.96)	-	(0.99)
Non-A5 TimeT					-0.818***	-0.791***	-0.805***	-0.784***
					(0.06)	(5.55)	(0.06)	(0.06)
Ozone Tre.							1.877***	0.596
							(0.70)	(0.48)
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 [8]		1654.20***		1707.57***		553.93***		541.88***
χ^2		3.44		7.96*		6.69		13.19**
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).

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

Table 3.2 – 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)	(19.45)	(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***	-0.725***	-0.390***	-0.721***
					(0.14)	(0.10)	(0.14)	(0.10)
Ozone Tre.							0.547	0.314
							(0.96)	(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 [9]		18.31		21.09***		31.00***		28.80***
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).

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

Table 3.3 – 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)

3.3 Estimation Results – CO_2 and EKC

The analysis now turns to an examination of an EKC consistent relationship and the impacts of the ratification of the Kyoto Protocol. This is conducted using CO_2 data spanning from 1990 to 2007 and compiled by the Carbon Dioxide Information Analysis Center (CDIAC). Within table 3.4 (het robust results) it can be noted that there is evidence of a significant EKC relationship upon applying the random effects estimation procedure to equation 3.5. Upon introducing the Annex A variables (with the estimation of equation 3.6) it can be noted that during the full sample period these countries had a significantly higher rate of per capita emissions (approximately higher than non-Annex A countries by 1.32%). Having controlled for country specific effects, per capita CO_2 emissions in Annex A countries decreased by approximately 0.02% per year. These results reflect the justification for separating the policy making and target setting into two groups as the Annex A countries were noted to have higher emissions due to their level of development. Indeed, Grubb (2003) notes that higher per capita emissions in the industrialized countries are "one of the reasons why industrialized countries accepted the responsibility for leading climate change efforts in the UNFCCC and subsequent Kyoto negotiations: unless they can control their own high emissions there is little prospect of controlling emissions from developing countries that start from a very much lower base" (Grubb, 2003: 144).

The decrease of only 0.02% per year reflects a lack of action in reducing emissions during this period and reinforces a statement made in a 1997 United Nations Framework Convention on Climate Change (UNFCCC) press release outlining the negotiated targets accompanying the Protocol. Using projected emission statistics for the year 2000, the UNFCCC noted that even though industrialised nations have been postulated to reduce their collective GHG emissions by 5.2%, "the total reductions required by the Protocol will actually be about 10%; this is because many industrialised countries have not succeeded in meeting their earlier non-binding aim of returning their emissions to 1990 levels by the year 2000" (UNFCCC, 1997). Upon estimating equation 3.7 and hence adding the amount of years of Kyoto ratification and UNFCCC participation into the model there is no significant decrease of per capita CO2 emissions based on the number of years of ratification and participation. A lack of significance is unsurprising due to the differing views on the validity of the Kyoto Protocol and the low expectation of the eventual/actual introduction of binding targets.

Within table 3.5 the results allow for AR(1) disturbances and again find no evidence of an EKC relationship. With the introduction of the Annex A variables it can be noted that during the full period reviewed these countries had a significantly higher rate of per capita emissions[10] which decreased by approximately 0.03% per year, having controlled for country specific effects. Table 3.6, which presents results for FGLS (adjusted for heteroscedasticity and serial correlation simultaneously), shows little similarity with the fixed and random effects results leading to concerns of misspecification bias. Hence priority will be given to the previous fe/re results within table 3.5 as these results allow for country specific effects and have been adjusted for serial correlation.

[10] This is noted to be at least 1.36% above the country specific differences and the emissions of non-Annex countries – reflected in an intercept of -0.87.

Table 3.4 – CO2 per capita – Fixed/Random Effects (1990-2007)

	lgCO2pc – FE	lgCO2pc – RE	lgCO2pc – FE	lgCO2pc – RE	lgCO2pc - FE	lgCO2pc – RE
Constant	-23.242***	-20.787***	-21.059***	-18.367***	-21.222***	-18.404***
	(0.94)	(0.84)	(1.01)	(0.88)	(1.02)	(0.88)
lgGDPpc	0.561***	0.419***	0.364***	0.201***	0.374***	0.203***
	(0.08)	(0.08)	(0.09)	(0.08)	(0.09)	(0.08)
lgGDPpcsq	-0.004**	-0.003*	-0.000	0.001	-0.000	0.001
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Time Trend	-0.009***	-0.002**	-0.004	0.006*	0.005	0.012*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)
Kyoto Rat.			-0.021	-0.019	-0.002	-0.004
			(0.02)	(0.02)	(0.03)	(0.03)
UNFCCC Part.			0.020	0.017	0.004	0.005
			(0.02)	(0.02)	(0.02)	(0.02)
Annex A			-	1.315***	-	1.320***
			-	(0.31)	-	(0.31)
Annex A TimeT			-0.016***	-0.018***	-0.016***	-0.018***
			(0.00)	(0.00)	(0.00)	(0.00)
Yrs Kyoto Rat.					-0.005	-0.004
					(0.01)	(0.01)
Yrs UNFCCC					-0.009	-0.007
					(0.01)	(0.01)
n	2232	2232	2232	2232	2232	2232
i	124	124	124	124	124	124
R^2	0.22	0.22	0.21	0.34	0.21	0.34
χ^2_1 [11]		17628.07***		17217.10***		17072.76***
Hausman		33.02***		42.40***		44.12***
Equation	(3.5)		(3.6)		(3.7)	

P Value: *** - 1% ** - 5% * - 10% Note: The variables included within this regression are as follows: Dependent variable – CO2 per capita – Amount of CO2 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 1990-2007, Kyoto Rat. – Ratified the Kyoto Protocol (zero until year of ratification), UNFCCC Part. – Participate in the UNFCCC, (zero until year of commencement), Annez A – Dummy variable for Annex A countries, Annex A TimeT – Time trend for Annex A countries only, Yrs Kyoto Rat. – Years since Kyoto Protocol was ratified (used to distinguish between long-term and recent ratification), Yrs UNFCCC – Years of UNFCCC participation (used to distinguish between long-term and recent participation).

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

Table 3.5 – CO2 per capita – Fixed/Random Effects with AR(1) disturbances (1990/1991-2007)

	lgCO2pc – FE	lgCO2pc – RE	lgCO2pc – FE	lgCO2pc – RE	lgCO2pc - FE	lgCO2pc – RE
Constant	-15.488***	-17.308***	-14.737***	-16.052***	-15.040***	-16.067***
	(0.23)	(1.11)	(0.24)	(1.11)	(0.25)	(1.11)
lgGDPpc	-0.022	0.137	-0.104	0.031	-0.098	0.030
	(0.15)	(0.11)	(0.15)	(0.11)	(0.16)	(0.11)
lgGDPpcsq	0.005	0.002	0.008*	0.003	0.007*	0.03
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.03)
Time Trend	-0.003	0.002	0.003	0.011***	0.034	0.016**
	(0.01)	(0.00)	(0.01)	(0.00)	(0.02)	(0.01)
Kyoto Rat.			-0.010	-0.012	-0.005	-0.008
			(0.02)	(0.02)	(0.02)	(0.02)
UNFCCC Part.			0.007	0.011	0.015	0.010
			(0.01)	(0.02)	(0.02)	(0.02)
Annex A			-	1.680***	-	1.671***
			-	(0.31)	-	(0.31)
Annex A TimeT			-0.022***	-0.021***	-0.022**	-0.021***
			(0.24)	(0.01)	(0.01)	(0.01)
Yrs Kyoto Rat.					-0.010	-0.003
					(0.01)	(0.01)
Yrs UNFCCC					-0.021	-0.006
					(0.02)	(0.01)
n	2108	2232	2108	2232	2108	2232
i	124	124	124	124	124	124
R^2	0.24	0.23	0.22	0.38	0.21	0.38
χ^2_3 [12]		5.41		-		-
Equation	(3.5)		(3.6)		(3.7)	

P Value: *** - 1% ** - 5% * - 10% Note: The variables included within this regression are as follows: Dependent variable – CO2 per capita – Amount of CO2 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 1990-2007, Kyoto Rat. – Ratified the Kyoto Protocol (zero until year of ratification), UNFCCC Part. – Participate in the UNFCCC, (zero until year of commencement), Annez A – Dummy variable for Annex A countries, Annex A TimeT – Time trend for Annex A countries only, Yrs Kyoto Rat. – Years since Kyoto Protocol was ratified (used to distinguish between long-term and recent ratification), Yrs UNFCCC – Years of UNFCCC participation (used to distinguish between long-term and recent participation).

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

Table 3.6 – CO2 per capita – FGLS with het and AR(1) adjustments (1990-2007)

	het adjusted results			het and AR(1) adjusted results		
	lgCO2pc	lgCO2pc	lgCO2pc	lgCO2pc	lgCO2pc	lgCO2pc
Constant	-12.685***	-13.470***	-13.4307***	-15.187***	-11.788***	-11.083
	(0.18)	(0.15)	(0.19)	(2.01)	(2.16)	(2.64)
lgGDPpc	-0.286***	-0.154***	-0.155***	-0.040	-0.366	-0.459*
	(0.02)	(0.02)	(0.02)	(0.20)	(0.23)	(0.28)
lgGDPpcsq	0.011***	0.006***	0.006***	0.005	0.012**	0.015**
	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)	(0.01)
Time Trend	0.005***	-0.013***	-0.034***	-0.002	0.010*	0.014
	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)	(0.01)
Kyoto Rat.		0.211***	-0.004		-0.015	-0.001
		(0.02)	(0.02)		(0.03)	(0.03)
UNFCCC Part.		0.161***	0.217***		0.008	-0.004
		(0.02)	(0.02)		(0.02)	(0.02)
Annex A		-	-		-	-
		-	-		-	-
Annex A TimeT		-	-		-	-
		-	-		-	-
Yrs Kyoto Rat.			0.081***			-0.028**
			(0.01)			(0.01)
Yrs UNFCCC			0.020***			-0.008
			(0.01)			(0.02)
n	2232	2232	2232	2232	2232	2232
i	124	124	124	124	124	124
χ^2_3	3767.57***	2439.70***	2228.58***	37.69***	42.68***	37.98***
Equation	(3.5)		(3.6)		(3.7)	

P Value: *** - 1% ** - 5% * - 10% Note: The variables included within this regression are as follows: Dependent variable – CO2 per capita – Amount of CO2 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 1990-2007, Kyoto Rat. – Ratified the Kyoto Protocol (zero until year of ratification), UNFCCC Part. – Participate in the UNFCCC, (zero until year of commencement), Annez A – Dummy variable for Annex A countries, Annex A TimeT – Time trend for Annex A countries only, Yrs Kyoto Rat. – Years since Kyoto Protocol was ratified (used to distinguish between long-term and recent ratification), Yrs UNFCCC – Years of UNFCCC participation (used to distinguish between long-term and recent participation).

3.4 Estimation Results – Emission Reductions and Policy

Having established that there is little to no evidence of an EKC consistent relationship within the CFC and CO2 datasets employed in sub-sections 3.3 and 3.4, the analysis will now further develop the discussion on whether emission reductions can be directly linked to intergovernmental agreements. Within sub-section 3.3 and 3.4 policy impacts were incorporated 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 3.7 shows the results from a modified analysis which applies the three regression methods to the equation specification shown in equation 3.8. The major change to this equation is the removal of the Article 5 related variables specified in equation 3.3 and their replacement with dummy variables representing the timing of the different levels of legislated emission targets – refer to equation 3.8.

$$lnCFCpc_{it} = \alpha_i + \gamma_t + \beta_1 lnGDPpc_{it} + \beta_2 lnGDPpc_{it}^2 + \beta_3 TimeTrend_t + \beta_4 lnHCFCpc_{it} + \beta_8 NonA5\_75\%RT_{it} + \beta_9 NonA5\_100\%RT_{it} + \beta_{10} NonA5\_PostRT_{it} + \beta_{11} A5\_Base_{it} + \beta_{12} A5\_Freeze_{it} + \beta_{13} A5\_50\%RT_{it} + \beta_{14} A5\_85\%RT_{it} + \beta_{15} A5\_100\%RT_{it} + \mu_{it} \tag{3.8}$$

Table 3.7 shows that for the Non-Article 5 countries the stages of having a 75% and 100% reduction target in CFC emissions (denoted in equation 3.8 as $NonA5\_75\%RT_{it}$, $and\ \ NonA5\_100\%RT_{it}$) are insignificant and that there was no notable trend of emissions reductions above that associated with the time trend. This lack of defined action occurs until after the policy stipulates no allowable CFC emissions (as represented by a significant reduction in the *Non-A5 – Post* variable) and can be reconciled with claims that emission reductions were already occurring independent of the Montreal protocol. This pre-existing tendency is reflected in a consistently significant and negative relationship with the time trend implying decreases in per capita emissions of between 0.4% and 0.6% per annum from

1992 to 2008. These results can be interpreted as the following: notable reductions in CFCs can directly be associated with the period that the Montreal protocol was in force, but not the timing of the reduction targets. In addition, the low rate of emission reductions that did occur in Non-Article 5 countries cannot be associated with the stipulated reductions set by the Montreal targets. This result coincides with the earlier discussion of the success of the Montreal protocol being associated with pre-existing industrial factors reflected in a decreasing relationship over time and captured in the constant (which is partially associated with the non-Article 5 75% reduction target period of the Montreal targets). With respect to Article 5 countries, the results show that higher rates of CFC use persisted throughout the initial phases of the Montreal targets, these being above the overall CFC decline seen in all countries and associated with the time trend and the constant - which in part represents the decreases associated with the initial period of Non-Article 5 targets. The rationale for separating targets was intended to allow less developed nations more time to adjust to the policy and this indeed was utilized by these nations. With respect to the Article 5 specific variables, the results show that decreases in CFCs were associated with the overall time trend, rather than 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 use cannot be determined using this data.

Turning our focus to the Kyoto protocol, equation 3.7 has been adapted to include the period since the Kyoto protocol became binding and includes a variable which represents whether the protocol has been ratified (as reflected in *TargetandRat* equation 3.9). Table 3.8 slao allows for a focus on the Post Binding period variable (*PostBinding*) which shows that there is a no significant difference in the emission rate of CO2 by countries who are subject to the binding targets. There was also no evidence of a difference in per capita emissions based on the target set for the respective countries and this adds uncertainty to whether emission rates have reduced specifically due to the Kyoto protocol or due to other underlying factors. One consideration is that the European Union (which makes up a large proportion of the countries within the Annex 1 category) had enacted strong policies before the post binding period and that associated emission reductions are likely to be part of the significant and negative time trend representing the period from 1990 to 2007. In addition to this are factors such as continued inaction by a range of countries, the doubt over continued climate change policy, and that the data set does not cover the initial emissions reduction target period which is 2008 to 2012. Review of this period has been left for future research.

$$lnCO2pc_{it} = \alpha_i + \gamma_t + \beta_1 lnGDPpc_{it} + \beta_2 lnGDPpc_{it}^2 + \beta_3 TimeTrend_t + \beta_4 KyotoRat_{it} + \beta_5 UNFCCC_{it} + \beta_6 Annex1_i + \beta_7 Annex1TimeT_{it} + \beta_8 YrsKyotoRat_{it} + \beta_9 YrsUNFCCC_{it} + \beta_{10} PostBinding_{it} + \beta_{11} TargetandRat_{it} + \varepsilon_{it} \qquad (3.9)$$

Table 3.7 – CFC per capita – Policy Focus (1992-2008)

	FE	RE	FE – AR(1)	RE – AR(1)	FGLS het	FGLS het AR(1)
Constant	8.065	-9.462*	-19.167*	-12.455**	-7.627***	-11.553***
	(17.32)	(5.41)	(11.12)	(5.75)	(1.65)	(4.05)
lgGDPpc	-2.059	-0.565	2.489	-0.467	-1.184***	-1.262
	(2.70)	(0.98)	(4.75)	(1.05)	(0.34)	(0.89)
lgGDPpcsq	0.019	0.035	-0.167	0.032	0.069***	0.086*
	(0.11)	(0.04)	(0.22)	(0.05)	(0.02)	(0.05)
Time Trend	-0.436***	-0.494***	-0.675***	-0.527***	-0.476***	-0.552***
	(0.06)	(0.03)	(0.10)	(0.05)	(0.02)	(0.04)
lgHCFCpc	0.184***	0.184***	0.051	0.084***	0.132***	0.048***
	(0.04)	(0.03)	(0.03)	(0.03)	(0.01)	(0.01)
Non-A5 – 75%	-	-	-	-	-	-
	-	-	-	-	-	-
Non-A5 – 100%	-0.668	-0.718	0.448	-1.395*	-0.845*	-0.931
	(1.00)	(0.88)	(1.16)	(0.78)	(0.49)	(0.73)
Non-A5 – Post	-9.086***	-9.124***	-4.342***	-7.877***	-9.796***	-7.642***
	(0.85)	(0.64)	(1.57)	(0.77)	(0.29)	(0.72)
A5 – Base	0.956	0.014	-0.307	0.116	-0.695*	0.857
	(0.70)	(0.50)	(0.99)	(0.57)	(0.37)	(0.64)
A5 – Freeze	2.402***	1.406**	0.595	1.011	0.420	1.477**
	(0.79)	(0.61)	(1.04)	(0.63)	(0.44)	(0.69)
A5 – 50%	3.188***	2.282***	1.844*	1.960***	1.181***	2.238***
	(0.72)	(0.52)	(1.02)	(0.60)	(0.37)	(0.73)
A5 – 85%	2.931***	1.949***	2.163**	1.809***	1.367***	3.067***
	(0.82)	(0.64)	(1.12)	(0.71)	(0.47)	(0.82)
A5 – 100%	-0.147	-1.224*	0.533	-0.276	-2.087***	0.997
	(0.85)	(0.68)	(1.19)	(0.79)	(0.48)	(0.88)
n	1139	1139	1139	1139	1139	1139
i	67	67	67	67	67	67
R^2	0.27	0.52	0.26	0.51		
χ^2_3		647.04***				
Hausman		9.91		36.09***		
Wald Chi^2					3728.65***	718.98***

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.

Table 3.8 – CO2 per capita – Policy Focus (1990-2007)

	FE	RE	FE – AR(1)	RE – AR(1)
Constant	-21.187***	-18.338***	-15.035***	-16.069***
	(1.03)	(0.89)	(0.25)	(1.11)
lgGDPpc	0.370***	0.196**	-0.099	0.030
	(0.09)	(0.08)	(0.16)	(0.11)
lgGDPpcsq	-0.000	0.001	0.007*	0.003
	(0.00)	(0.00)	(0.00)	(0.00)
Time Trend	0.006	0.013*	0.034	0.016**
	(0.01)	(0.01)	(0.02)	(0.01)
Kyoto Rat.	-0.012	-0.014	-0.010	-0.011
	(0.03)	(0.03)	(0.02)	(0.02)
UNFCCC Part.	0.004	0.005	0.016	0.010
	(0.02)	(0.02)	(0.02)	(0.02)
Annex A	-	1.332***	-	1.671***
	-	(0.31)	-	(0.31)
Annex A TimeT	-0.019***	-0.021***	-0.023**	-0.021***
	(0.01)	(0.01)	(0.01)	(0.01)
Yrs Kyoto Rat.	-0.005	-0.004	-0.010	-0.002
	(0.01)	(0.01)	(0.01)	(0.01)
Yrs UNFCCC	-0.010	-0.007	-0.021	-0.006
	(0.01)	(0.01)	(0.02)	(0.01)
Post Binding	0.001	0.001	-0.007	-0.011
	(0.05)	(0.05)	(0.03)	(0.03)
Target and Rat	-0.001	-0.001	-0.003	-0.002
	(0.01)	(0.01)	(0.00)	(0.01)
n	2232	2232	2108	2232
i	124	124	124	124
R^2	0.21	0.36	0.21	0.38
χ^2_3		499.25***		220.78***
Hausman		44.03***		1.40

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

Note: The variables included within this regression are as follows: Dependent variable – CO2 per capita – Amount of CO2 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 1990-2007, Kyoto Rat. – Ratified the Kyoto Protocol (zero until year of ratification), UNFCCC Part. – Participate in the UNFCCC, (zero until year of commencement), Annez A – Dummy variable for Annex A countries, Annex A TimeT – Time trend for Annex A countries only, Yrs Kyoto Rat. – Years since Kyoto Protocol was ratified (used to distinguish between long-term and recent ratification), Yrs UNFCCC – Years of UNFCCC participation (used to distinguish between long-term and recent participation), Post Binding – Period within which the Kyoto Protocol became binding, Target and Rat – Percentage target of emission cuts if the country ratified the Kyoto Protocol.

4 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 a reduced functional form. Indeed, the literature has noted many possible 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 relationship for Non-Article 5 countries subject to targets under the Montreal Protocol. This negative relationship is noted to be up to 0.8% per year above the existing decline for all countries within the same sample. 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. In previous cases where such a relationship has been focused upon the data underpinning the analysis was 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 sub-section 3.5 show that while significant decreases in CFC consumption occurred during the 100% reduction phase of the Non-Article 5 targets; a significant negative decline in CFC consumption between 1992 and 2008 is not consistent with the specific timing of the targets of the Montreal Protocol. This decline is likely to be driven by the auxiliary explanations for the success of the Montreal Protocol as emission reductions occurred during the reduction phases but were not directly linked to the targets specified. 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.

In the case of CO2 and the Kyoto Protocol, when an EKC consistent relationship did occur in this analysis it was replaced by evidence that Annex A countries have decreased their per capita CO2 fossil fuel emissions by 0.02% per year, once country specific effects were allowed for. It should be pointed out that the emission reductions were not found to be linked to GDP per capita. As the sample period is between 1990 and 2007, the CO2 analysis is limited to a review of the impacts of a country's ratification of the Protocol and an incentive for early action to fulfil the targets implied by this action. The lack of a relationship between emissions reductions and ratification of the Kyoto Protocol or the level of targets set for the first phase are likely to be due to the range of issues that have been discussed in sub-section 2.3. In addition to doubts over the establishment of binding commitments, the data applied is from before the first phase of binding targets and the analysis is limited to establishing whether early action has been conducted. Such initiatives (as represented in the pre-first phase establishment of the EU trading scheme) are likely to be captured within the statistically significant decrease in CO2 emissions of 0.02% per capita for each year between 1990 and 2007.

Irrespective of the contrasts between the Montreal Protocol and the Kyoto Protocol, and the underlying substitution possibilities for CFCs and CO2, the success of policy should be evaluated after the full period of enforcement has passed. Applicable to the case of Kyoto and Non-Annex 5 members of the Montreal Protocol, many contingencies can occur and the success of both Protocols is sure to be the subject of future research. Further work will be needed to determine the success of the Kyoto Protocol, but this analysis confirms that the initial signs were not encouraging. As significant doubt has also been cast on the existence of an EKC consistent relationship for CO2 and CFCs, 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.

References

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

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.

He, J. and Richard, P. (2010) ‘Environmental Kuznets Curve for CO2 in Canada’, Ecological Economics, 69: 1083-1093.

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)

Table A2 – CO2 per capita – Countries within Sample (1990-2004) n = 124

Albania	Cape Verde	France*	Jamaica	Netherlands*	Samoa	Turkey*
Algeria	Chad	Gabon	Japan*	New Zealand*	Saudi Arabia	Uganda
Angola	Chile	Gambia	Jordan	Nicaragua	Senegal	United Kingdom*
Antigua/Barbuda	China	Germany*	Kenya	Niger	Seychelles	U R of Tanzania
Argentina	Comoros	Ghana	Lao	Nigeria	Sierra Leone	United States*
Australia*	Congo	Greece*	Lebanon	Norway*	Singapore	Uruguay
Austria*	Cote d'Ivoire	Grenada	Luxembourg*	Pakistan	Solomon Islands	Vanuatu
Bangladesh	Cyprus	Guatemala	Madagascar	Panama	South Africa	Venezuela
Belgium*	D R of the Congo	Guinea	Malawi	Papua New Guinea	Spain*	Viet Nam
Belize	Denmark*	Guinea-Bissau	Malaysia	Paraguay	Sri Lanka	Yemen
Benin	Dominica	Guyana	Mali	Peru	Sudan	Zambia
Bolivia	Dominican Republic	Honduras	Malta	Philippines	Swaziland	
Botswana	Ecuador	Hungary*	Mauritania	Poland*	Sweden*	
Brazil	Egypt	Iceland*	Mauritius	Portugal*	Switzerland*	
Bulgaria*	El Salvador	India	Mexico	Romania*	SAR	
Burkina Faso	Ethiopia	Indonesia	Mongolia	Rwanda	Thailand	
Burundi	Finland*	Iran	Morocco	Saint Lucia	Togo	
Canada*		Ireland*	Mozambique	Saint Vincent	Tonga	
		Israel	Namibia		Trinidad/Tobago	
		Italy*	Nepal		Tunisia	

* denotes Annex A countries (n = 28)

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