UNIVERSITY OF
CAMBRIDGE
Department of Land Economy

Environmental Economy and Policy Research

Discussion Paper Series

The Clean Development Mechanism and Sustainable Development: A Panel Data Analysis

by

Yongfu Huang and Terry Barker

2008

Number: 39.2008

The Clean Development Mechanism and Sustainable Development: A Panel Data Analysis

Yongfu Huang and Terry Barker

4CMR, Department of Land Economy, University of Cambridge, UK

Abstract

The Clean Development Mechanism (CDM) of the Kyoto Protocol is designed to allow the industrialised countries to earn credits by investing in greenhouse gas (GHG) emission reduction projects in developing countries, which contribute to sustainable development in the host countries. This research empirically investigates the long-run impacts of CDM projects on CO2 emissions for 18 CDM host countries over 1990-2007. By allowing for considerable heterogeneity across countries, this research provides strong evidence in support of a significant effect of CDM projects on CO2 emission reductions in the host countries. It offers ample recommendation for improving CDM development and serves to encourage the developing countries to strengthen their national capacity to effectively access the CDM for their sustainable development objectives.

Keywords: Clean Development Mechanism; CO2 Emissions; Heterogeneous Dymanic Panels

Address for correspondence

Yongfu Huang
University of Cambridge
Department of Land Economy
19 Silver Street, Cambridge CB3 9EP; United Kingdom
Tel: 0044-1223 764873
Fax: 0044-1223 337130
Email: yh279@cam.ac.uk

1 Introduction

Over the past 20 years, how to tackle climate change and achieve sustainable development has become one of the most important challenges facing the international community. As part of the Kyoto response towards mitigation of global warming, the Clean Development Mechanism (CDM) was designed to create opportunities for synergies between cost-effective climate change mitigation and sustainable development. However, the question on whether the CDM is doing what it promises to do has given rise to much controversy. The research reported below empirically examines whether CDM projects contribute to sustainable development in developing countries, based on dynamic heterogeneous panels for 18 CDM host countries over 1990-2007.

As a global effort to respond to climate change and protect the environment, the Kyoto Procotol was introduced in 1997, coming into force on 16 February 2005. The Protocol calls for legally-binding limits on greenhouse gas (GHG) emissions by the developed countries (or the Annex I countries) of 5.2% below their 1990 levels over the first commitment period (i.e. 2008-2012). The CDM is an innovative cooperative mechanism under the Kyoto Protocol. As part of the emerging global carbon market, the CDM aims to achieve the dual aims of assisting developing countries in achieving sustainable development and assisting developed countries in achieving compliance with their GHGs emission reduction commitments.[1] The number of projects proposed as candidate CDM projects has been steadily rising. By the end

[1] At the global level, the CDM projects do not explicitly lead to a net decline in carbon emissions; instead, the emission reductions the CDM projects promise to bring about are essentially a "zero-sum" game in the sense that these reductions merely take place in a different place, not in the Annex I countries but in the non-Annex I countries. Therefore, whether or not the CDM contributes to the mitigation of global warming relies on the extent to which it results in reduced emissions in developing countries.

of September 2008, there were 3967 CDM projects in the pipeline.[2]

The CDM is the only Kyoto mechanism that involves developing countries in the climate change negotiations. The CDM is expected to stimulate foreign direct investment and speed up the transfer and deployment of low and zero carbon technologies from developed countries to developing countries. It is also anticipated to arouse business interest and engagement from the private sector into the issue of climate change mitigation via environmentally friendly investment, and ultimately help direct the host countries onto a lower carbon trajectory.

However, there has been much controversy as to the impacts of the CDM on sustainable development in developing countries. Examples are Banuri and Gupta (2000), Kolshus *et al.* (2001), Brown *et al.* (2004), Kim (2004), Cosbey *et al.* (2005), Sutter and Parreño (2007) and Boyd *et al.* (2007) to mention a few.[3] The existing research in this field is made up of one group of research supporting positive impacts, another group of research indicating negative impacts, and some having mixed views. Some forward-looking research (for example Banuri and Gupta, 2000) suggests that CDM projects could cause the widespread adoption of less GHGs-intensive technologies in non-Annex I countries, which would have positive implications for emission reductions in the non-Annex I countries. However, recent studies, at either the aggregated levels or the project level, suggest that, left to market forces, the CDM does not significantly contribute to sustainable development because the trade-off between the two benefits of the CDM falls in favor of cost-effective reduction benefits, and neglects the sustainable development benefits, which are not monetised in the carbon market (Sutter and Parreño,

[2] Data from the UNEP Risoe Centre (2008).

[3] See Olsen (2007) for a recent review of literature on the sustainable development contributions of the CDM.

2007; Kolshus *et al.* 2001). Since it is crucial to examine whether the CDM is fulfilling its sustainable development objective, this research carries out a panel data analysis into this issue.

One difficulty facing this research is that the actual definitions of sustainable development vary across countries. As decided by the Kyoto Protocol that it is the prerogative of host country to determine whether a CDM project contributes to its sustainable development objective, different CDM host countries define different sustainable development criteria according to their development priorities. Olsen (2007) shows that the sustainable development contributions of CDM projects can be evaluated at least in economic, social and environmental dimensions, and "there is no single, authoritative and universally accepted approach or methodology applicable to any CDM project regardless of project type or location".[4] Given that the primary objective of the CDM is to combat global warming, this research focuses on the environmental dimension of sustainable development in terms of CO_2 emission reductions.

More specifically, we empirically evaluate whether CDM projects lead to a decline in CO_2 emissions, at aggregated level, for 18 CDM host countries over 1990-2007. Within an Environmental Kuznets Curve framework, this research investigates the long-run and short-run dynamics of CDM project development, while controlling for country specific effects. This research employs the pooled mean group procedure to identify a common long-run effect for CDM projects, while allowing for short-run dynamics to differ across countries. This research provides strong evidence in support of a decline in CO_2 emissions associated with CDM projects. The finding of this

[4] Some approaches have been proposed for sustainability assessment of CDM projects, but they are qualitative in nature (Olsen and Fenhann, 2008; Cosbey *et al.*, 2005; Anagnostopoulos *et al.*, 2004).

research adds to the growing debate on this topic, and serves to encourage the developing countries to strenghen their national capacity to effectively access the CDM.

The remainder of the paper proceeds as follows. Section 2 describes the data and shows some preliminary evidence. Section 3 presents the econometric methods. The empirical results are reported in Section 4. Section 5 concludes.

2 Data and preliminary evidence

This section outlines the measures and data for CO_2 emissions, CDM, and GDP.

The dependent variable is the logarithm of CO_2 emissions, denoted by $\mathbf{CO_2}$. This analysis mainly makes use of the CO_2 emissions from fuel combustion (by reference approach), in total as well as the emissions from coal, gas and oil combustion, respectively. Data on CO_2 emissions from 1990 up to 2007 are from the Global Energy Market Data (2008) of Enerdata. To check for robustness, it also considers the total CO_2 emissions from fuel combustion (by sectoral approach) for the period 1990-2006, which are taken from Enerdata as well.

The independent variable is an indicator (dummy) variable for the Clean Development Mechanism, simply denoted by **CDM**. It takes the value of one in the year when a country has a CDM project in the pipeline and in all years afterwards. The CDM projects in the pipeline include not only those called "confirmed projects" that have been at the registration stage, either registered or requested registration, but also those called "probable projects" that are at the validation stage, waiting to be registered and implemented over the next 3 years. Data on CDM projects in the pipeline are from the

UNEP Risoe Centre (2008).

To reflect the so-called Environmental Kuznets Curve, which suggests an inverse U-shaped pattern between carbon emissions and economic development, this analysis includes the logarithms of GDP and GDP squared in the regression, denoted by **GDP** and $\mathbf{GDP}^2$, respectively. Data on GDP in US dollars at constant purchasing power parity in 2005 over 1990-2007 are taken from the Global Energy Market Data (2008) of Enerdata.

The whole sample includes 18 CDM host countries as listed in the Appendix Table 1. We exclude the CDM host countries which have their first CDM projects in the pipeline after year 2006 and those which have no CO_2 emissions data for 2006 and 2007.

Figure 1 presents some simple evidence for 11 CDM host countries.[5] The upper chart of Figure 1 displays the cross-country median CO_2 emissions 4 years before and after having their first CDM projects in the pipeline. The lower chart of Figure 1 plots the coefficients on the fixed effect estimates of 8 time dummies before and after the year when they started to have their first CDM projects in the pipeline to reflect the dynamic effect of the CDM development. The regression is estimated by OLS in which the unobserved country specific effects, time effects and control variables such as the logarithms of GDP and GDP squared are included. The two figures show that CO_2 emissions in the sample countries in general move upwards prior to having CDM projects in the pipeline. After having CDM projects in the pipeline, CO_2 emissions immediately experience a drop. The charts vividly portray the main features of CO_2 emissions before and after CDM projects are made available. The effect of CDM projects on CO_2 emission

[5] To facilitate a before-and-after event study, 11 CDM host countries are selected which had their first CDM projects in the pipeline before 2005 and have CO_2 emissions data in 2007.

reductions, at least in the short run, has been observed. However, this, alone, is not very convincing evidence. A more detailed econometric analysis of the relationship between **CDM** and CO_2 emissions will be conducted in what follows, based on panel data of 18 CDM host countries over 1990-2007.

3 Econometric methods

This analysis studies the impacts of CDM projects on CO_2 emissions in 18 host countries over the period from 1990 to 2007. Since we are dealing with a very dynamic process in which the geographic distribution of CDM projects has been observed as uneven, and the CO_2 emissions differ across countries, we need a unique method by which these features can be better captured. This section sets out a methodology that accounts for heterogeneous dynamic panels.

We assume the interactions between CDM projects and CO_2 emissions are represented by the unrestricted autoregressive distributed lag ARDL(p, q, q, q) systems:

$$\begin{aligned} \mathbf{CO_2}_{it} &= \sum_{j=1}^{p} \alpha_{ij} \mathbf{CO_2}_{i,t-j} + \sum_{j=0}^{q} \beta_{ij} \mathbf{CDM}_{i,t-j} + \\ & \sum_{j=0}^{q} \gamma_{ij} \mathbf{GDP}_{i,t-j} + \sum_{j=0}^{q} \delta_{ij} \mathbf{GDP}^2_{i,t-j} + \theta_i t + \mu_i + v_{it} \\ i &= 1, 2, ..., 18 \text{ and } t = 1, ..., 18 \end{aligned} \tag{1}$$

where $\mathbf{CO_2}_{it}$ is the dependent variable and $\mathbf{CDM}_{it}$, $\mathbf{GDP}_{it}$ and $\mathbf{GDP}^2_{it}$ are the explanatory variables, as described in section 2. t is a time trend. μ_i are the unobservable country specific effects. v_{it} are errors assumed to be serially uncorrelated and independently distributed across countries. We allow for richer dynamics in the representations to control for business cycle influences.

Following Perman and Stern (2003), Müller-Fürstenberger and Wagner (2007) and Wagner and Müller-Fürstenberger (2008), we assume that the series of $\mathbf{CO_2}_{it}$, $\mathbf{CDM}_{it}$, $\mathbf{GDP}_{it}$ and $\mathbf{GDP}^2_{it}$ are integrated, and cointegrated for any individual countries, therefore v_{it} is a stationary process for all i. As shown by Engle and Granger (1987), there must be a vector error correction representation governing the co-movements of these series over time. The corresponding error correction equation to Equation (1) is as follows:

$$
\begin{aligned}
\triangle \mathbf{CO_2}_{it} &= \alpha_{ij}^{'} \left(\mathbf{CO_2}_{i,t-1} + \frac{\beta_{ij}^{'}}{\alpha_{ij}^{'}} \mathbf{CDM}_{it} + \frac{\gamma_{ij}^{'}}{\alpha_{ij}^{'}} \mathbf{GDP}_{it} + \frac{\delta_{ij}^{'}}{\alpha_{ij}^{'}} \mathbf{GDP}^2_{it} \right) \\
&\quad - \sum_{j=1}^{p-1} \left[\left(\sum_{m=2}^{1} \alpha_{im} \right) \triangle \mathbf{CO_2}_{i,t-1} \right] \\
&\quad - \sum_{j=0}^{q-1} \left[\left(\sum_{m=j+1}^{1} \beta_{im} \right) \triangle \mathbf{CDM}_{i,t-1} \right] \\
&\quad - \sum_{j=0}^{q-1} \left[\left(\sum_{m=j+1}^{1} \gamma_{im} \right) \triangle \mathbf{GDP}_{i,t-1} \right] \\
&\quad - \sum_{j=0}^{q-1} \left[\left(\sum_{m=j+1}^{1} \delta_{im} \right) \triangle \mathbf{GDP}^2_{i,t-1} \right] \\
&\quad + \mu_i + v_{it} \\
i &= 1, 2, ..., 18 \text{ and } t = 1, ..., 18 \qquad (2)
\end{aligned}
$$

where

$$\begin{aligned}
\alpha'_{ij} &= -\left(1 - \sum_{j=1}^{p} \alpha_{ij}\right) \\
\beta'_{ij} &= \sum_{j=0}^{q} \beta_{ij} \\
\gamma'_{ij} &= \sum_{j=0}^{q} \gamma_{ij} \\
\delta'_{ij} &= \sum_{j=0}^{q} \delta_{ij}
\end{aligned}$$

where α'_{ij} is the coefficient for the speed of adjustment. $\frac{\beta'_{ij}}{\alpha'_{ij}}$, $\frac{\gamma'_{ij}}{\alpha'_{ij}}$, and $\frac{\delta'_{ij}}{\alpha'_{ij}}$ are the long-run coefficients for $\mathbf{CDM}_{it}$, $\mathbf{GDP}_{it}$ and $\mathbf{GDP}^2_{it}$, respectively, while $\sum_{m=j+1}^{q} \beta_{im}$, $\sum_{m=j+1}^{q} \gamma_{im}$, and $\sum_{m=j+1}^{q} \delta_{im}$ are the short-run coefficients for $\mathbf{CDM}_{it}$, $\mathbf{GDP}_{it}$ and $\mathbf{GDP}^2_{it}$, respectively.

To analyze a set of panel data with large time and large cross-sectional dimensions, a number of methods have been proposed in the literature, for example the within groups (WG) estimator, mean group (MG) estimator due to Pesaran and Smith (1995) and pooled mean group (PMG) estimator due to Pesaran *et al.* (1999).

The WG estimator is consistent for the dynamic homogeneous model when time series dimemsion $\mathbf{T}$ is large, as cross-sectional dimention $\mathbf{N} \rightarrow \infty$ (Nickell, 1981). However, the WG estimator is based on rather restrictive assumptions in terms of the homogeneity of all slope coefficients and error variances, which are often not consistent with the reality for this context. Here the divergent patterns of CO_2 emissions, the development of CDM projects, and the level of income are observed across countries.

The MG approach instead allows all slope coefficients and error variances to differ across countries, having considerable heterogeneity across countries.

The MG approach applies an OLS method to estimate a separate regression for each country to obtain individual slope coefficients, and then averages the country-specific coefficients to derive a long-run parameter for the panel[6]. For large T and N, the MG estimator is consistent. With sufficiently high lag order, the MG estimates of long-run parameters are super-consistent even if the regressors are nonstationary (Pesaran *et al.*, 1999). However, for small samples or short time series dimensions, the MG estimator is likely to be inefficient (Hsiao *et al.*, 1999). For small T, the MG estimates of the coefficients for the speeds of adjustment are subject to a lagged dependent variable bias (Pesaran and Zhao, 1999).

Unlike the MG approach, which imposes no restriction on slope coefficients, the PMG approach imposes cross-sectional homogeneity restrictions only on the long-run coefficients, but allows short-run coefficients, the speeds of adjustment and the error variances to vary across countries. The restriction of long-run homogeneity can be tested via a likelihood ratio test.[7] Under the null hypothesis of long-run homogeneity, the PMG estimators are consistent and more efficient than the MG estimators. Since the PMG estimator as well as the WG estimator are restricted versions of the set of individual group equations, the likelihood ratio test tends to reject the null at the conventional significance levels. Moreover, Pesaran *et al.* (1999) show that the PMG estimators are consistent and asymptotically normal irrespective of whether the underlying regressors are I(1) or I(0).

The PMG approach requires that the long-run coefficients for $\mathbf{CDM}_{it}$,

---

[6] More specifically, the MG estimator and its standard errors are calculated as $\widehat{\theta}_{MG} = \bar{\theta} = \frac{\sum_{i=1}^{N}\widehat{\theta}_i}{N}$ and $se(\widehat{\theta}_{MG}) = \frac{\sigma(\widehat{\theta}_i)}{\sqrt{N}} = \frac{\sqrt{\sum_{i-1}^{N}\frac{(\widehat{\theta}_i - \bar{\theta})^2}{N-1}}}{\sqrt{N}}$, respectively.

[7] The restriction of long-run homogeneity can also be tested via a Hausman test, which is asymptotically distributed as a $\chi^2(p)$, where p is the number of parameters.

$\mathbf{GDP}_{it}$ and $\mathbf{GDP}^2_{it}$ are common across countries, that is,

$$\begin{aligned} \alpha'_{ij} &= -\left(1-\sum_{j=1}^{p}\alpha_j\right) \\ \beta'_{ij} &= \sum_{j=0}^{q}\beta_j \\ \gamma'_{ij} &= \sum_{j=0}^{q}\gamma_j \\ \delta'_{ij} &= \sum_{j=0}^{q}\delta_j \end{aligned}$$

4 Empirical evidence

In this section, the WG approach, MG approach and PMG approach are applied and compared to determine whether CDM project development leads to a decline in CO_2 emissions for the host countries.

The number of lags is constrained by the number of observations. As shown by Pesaran *et al.* (1999), the PMG estimator seems quite robust to outliers and the choice of ARDL order, especially when T is large. We adopt an autoregressive distributed lag ARDL(1, 1, 1, 1) system for this analysis with the corresponding error correction equation as follows.[8]

[8] The parameters reported in Tables 1, 2 and 3 for speeds of adjustment, long-run coefficients and short-run coefficients correspond to model parameters α'_{i1}, $\frac{\beta'_{i1}}{\alpha'_{i1}}$, $\frac{\gamma'_{i1}}{\alpha'_{i1}}$, $\frac{\delta'_{i1}}{\alpha'_{i1}}$, $-\beta_{i1}$, $-\gamma_{i1}$, $-\delta_{i1}$ of equation (3), respectively.

$$
\begin{aligned}
\triangle \mathbf{CO_2}_{it} &= \alpha_{i1}^{'}\left(\mathbf{CO_2}_{i,t-1}+\frac{\beta_{i1}^{'}}{\alpha_{i1}^{'}}\mathbf{CDM}_{it}+\frac{\gamma_{i1}^{'}}{\alpha_{i1}^{'}}\mathbf{GDP}_{it}+\frac{\delta_{i1}^{'}}{\alpha_{i1}^{'}}\mathbf{GDP}_{it}^{2}\right) \\
&\quad -\beta_{i1}\triangle \mathbf{CDM}_{i,t-1}-\gamma_{i1}\triangle \mathbf{GDP}_{i,t-1}-\delta_{i1}\triangle \mathbf{GDP}_{i,t-1}^{2}+\mu_i+v_{it} \\
i &= 1,2,...,18 \text{ and } t=1,...,18 \qquad (3)
\end{aligned}
$$

where

$$
\begin{aligned}
\alpha_{i1}^{'} &= -(1-\alpha_{i1}) \\
\beta_{i1}^{'} &= \beta_{i0}+\beta_{i1} \\
\gamma_{i1}^{'} &= \gamma_{i0}+\gamma_{i1} \\
\delta_{i1}^{'} &= \delta_{i0}+\delta_{i1}
\end{aligned}
$$

Table 1 examines whether CDM projects result in reduced CO_2 emissions in the host countries, with the dependent variable being the total CO_2 emissions (by reference approach) in log. It reports three alternative pooled estimates of WG, PMG and MG with and without a time trend. We expect the long-run effects of CDM projects, level of GDP and squared GDP on CO_2 emissions to be homogenous across countries, although the short-run adjustments are more likely to differ across countries. This analysis centers on the PMG estimates.

The coefficients corresponding to the speeds of adjustment in Table 1 are significantly different from zero for two specifications, suggesting that Granger causality going from CDM projects to CO_2 emissions exists in the cointegrated system.

Moving from the WG to PMG estimates, we find the PMG estimates suggest much faster adjustment in two specifications than their WG counterparts. Imposing homogeneity on all slope coefficients except for the intercept, the WG estimates in two specifications suggest that there are negative long-run effects of CDM projects on CO_2 emissions (at about 12-28% significance level). The WG estimates also show that an Environmental Kuznets Curve can be observed in these countries in the sense that pollution goes up when the level of income increases; however, when the income reaches a certain level, a decline in CO_2 emissions can be expected. When heterogeneity is sought, the PMG estimates, which impose homogeneity only on the long-run coefficients, provide strong evidence in support of a negative effect of CDM projects on CO_2 emissions. This tends to underscore the importance of allowing for heterogeneity across countries in this context. However, the PMG estimates find no evidence for an Environmental Kuznets Curve in these countries.

Moving from the MG to PMG in Table 1 changes the results significantly as well. In particular, imposing long-run homogeneity reduces the standard errors and the speeds of adjustment. As it is clear, the MG estimator imposes no restriction on all slope coefficients, and is potentially inefficient for small sample size. The MG estimates suggest a positive effect of CDM projects on CO_2 emissions when a time trend is absent while a negative effect when a time trend is allowed. The MG approach also finds no evidence in support of significant long-run effects of income on CO_2 emissions. When the MG and PMG estimates are compared, the likelihood ratio tests strongly reject the null of equality of all of long-run coefficients at conventional levels; therefore it doesn't appear that we are imposing too strong a constraint on data.

Table 2 uses the CO_2 emission (by reference approach) from fuel combustions of coal, gas and oil, respectively. The PMG estimates suggest CDM projects reduce CO_2 emissions from either coal (at about 20% significance level), gas or oil combustions. The significant impact of income on CO_2 emissions from coal and oil combustions is also observed.

As a robustness test, Table 3 makes use of the total CO_2 emissons data (by sectoral approach) over 1990-2006.[9] The MG estimates provide strong evidence on the impact of CDM projects on CO_2 emission reductions. The PMG estimates also show CDM projects are associated with CO_2 emission reductions (at 25% significance level) when a time trend is not allowed.

In sum, after allowing for heterogeneity across countries, this analysis on annual data clearly shows a significant effect of CDM projects on CO_2 emission reductions. The findings in general suggest that the development of CDM projects could cause a decline in CO_2 emissions and has the potential to help developing countries achieve their sustainable development objective. On the impacts of income on CO_2 emissions, the WG estimates support an EKC hypothesis while the MG and PMG estimates do not support it. This finding is in line with Halkos (2003) among others who suggest that the EKC hypothesis is hard to be tested due to enomous heterogeneity acorss countries.

5 Concluding remarks

Under the Kyoto Procotol, the CDM is designed to allow the Annex I countries to invest in GHGs emission reduction projects in non-Annex I countries, while providing the non-Annex I countries with access to the flows of technology and capital that could contribute to their sustainable development objectives. The CDM projects in a country should act as a substantial stimulus to the development of low-carbon technologies, which, in turn, pro-

[9] Data on CO_2 emissions (sectoral approach) in 2007 are not available when this research is being carried out.

mote reduced CO_2 emissions, and should also be conducive to increased energy efficiency and conservation, increased investment flows and technology transfers, private and public capacity development as well as health, rural development and poverty reduction. Substantial research has been carried out to examine whether CDM projects contribute to sustainable development, suggesting contradictory findings. Due to a lack of data, panel data analysis or time series analysis on this issue at aggregated level has been hitherto lacking.

To investigate the impacts of CDM projects on CO_2 emissions, we conducted a dymanic panel data study allowing for considerable heterogeneity across countries for 18 CDM host countries over 1990-2007. It mainly focuses on the pooled mean group procedure which allows for heterogeneous dynamic adjustments towards a common long-run equilibrium. This research in general provides strong evidence in support of a significant impact of CDM projects on CO_2 emission reductions, indicating a decline in CO_2 emissions can be expected in the CDM host countries in the long run.

The finding shows that the CDM can play an important role in reducing CO_2 emissions and achieving sustainable development in developing countries. It provides ample recommendation for improving CDM development and serves to encourage the developing countries to strengthen their national capacity to effectively access the CDM for national sustainable development objectives. Governments of developing countries should improve its institutional quality and formulate favorable policies to stimulate productivity of CDM projects, especially at their early stage of development. Governments can strengthen their capacity through international exchanges of experience or international networking to acquire beneficial information on other countries' CDM programs.

References

[1] Anagnostopoulos, Kostantinos, Alexandros Flamos, Argyris G. Kagiannas and John Psarras, 2004.“The impact of clean development mechanism in achieving sustainable development.” *International Journal of Environment and Pollution*, 21(1): 1-23.

[2] Banuri, Tariq and Sujata Gupta, 2000. “The Clean Development Mechanism and sustainable development: An economic analysis.” In Ghosh P (ed) *In Implementation of the Kyoto Protocol,* Asian Development Bank.

[3] Boyd, Emily, Nathan E. Hultman, Timmons Roberts, Esteve Corbera, Johannes Ebeling, Diana M. Liverman, Kate Brown, Robert Tippman, John Cole, Phil Mann, Marius Kaiser, and Mike Robbins, 2007. “The Clean Development Mechanism: An assessment of current practice and future approaches for policy”. Tyndall Centre Working Paper No. 114.

[4] Brown, Katrina, W. Neil Adger, Emily Boyd, Esteve Corbera-Elizalde and Simon Shackley, 2004. “How do CDM projects contribute to sustainable development?” Tyndall Centre Technical Report No. 16.

[5] Cosbey, Aaron, Jo-Ellen Parry,Jodi Browne, Yuvaraj Dinesh Babu, Preety Bhandari, John Drexhage, Deborah Murphy, 2005. “Realizing the development dividend: making the CDM work for developing countries.” Phase 1 Report—Pre-publication Version, International Institute for Sustainable Development.

[6] Engle, Robert F and Clive W J Granger, 1987. “Co-integration and error correction: Representation, estimation, and testing.” *Econometrica,* 55: 251-76.

[7] Global Energy Market Data (2008), the Enerdata. www.enerdata.fr.

[8] Halkos, George E., 2003. “Environmental Kuznets Curve for Sulfur: Evidence using GMM estimation and random coefficient panel data models.” *Environment and Dvelopment Economics*, 8: 581-601.

[9] Hsiao, Cheng, M Hashem Pesaran and A. Kamil Tahmiscioglu, 1999. “Bayes estimation of short-run coefficients in dynamic panel data models”. in C. Hsiao, K. Lahiri, L-F Lee and M.H. Pesaran (eds), *Analysis of Panels and Limited Dependent Variables: A Volume in Honour of G S Maddala,* Cambridge University Press, chapter 11, pp.268-296.

[10] Kim, Joy A., 2004. “Sustainable development and the Clean Development Mechanism: A South African case study.” *The Journal of Environment & Development,* 13(3): 201-219.

[11] Kolshus, Hans H., Jonas Vevatne, Asbjørn Torvanger and Kristin Aunan, 2001. “Can the Clean Development Mechanism attain both cost-effectiveness and sustainable development objectives?” CICERO Working Paper 2001: 8. Oslo, Norway.

[12] Müller-Fürstenberger, Georg and Martin Wagner, 2007. “Exploring the Environmental Kuznets hypothesis: Theoretical and econometric problems.” *Ecological Economics*, 62: 648-660.

[13] Nickel , Stephen J, 1981. “Biases in dynamic models with fixed effects”. *Econometrica,* 49: 1418-1426.

[14] Olsen, Karen Holm, 2007. “The Clean Development Mechanism’s contribution to sustainable development: A review of the literature.” *Climatic Change,* 84 (1): 59-73.

[15] Olsen, Karen Holm and Jørgen Fenhann, 2008. "Sustainable development benefits of clean development mechanism projects: A new methodology for sustainability assessment based on text analysis of the project design documents submitted for validation." *Energy Policy,* 36(8): 2819-2830.

[16] Perman, Roger and David I. Stern, 2003. "Evidence from panel unit root and cointegration tests that the Environmental Kuznets Curve does not exist". *The Australian Journal of Agricultural and Resource Economics*, 47 (3): 325-347.

[17] Pesaran, M Hashem and Zhongyun Zhao, 1999. "Bias reduction in estimating long-run relationships from dynamic heterogeneous panels". in C. Hsiao, K. Lahiri, L-F Lee and M.H. Pesaran (eds), *Analysis of Panels and Limited Dependent Variables: A Volume in Honour of G S Maddala,* Cambridge University Press, chapter 12, pp.297-321.

[18] Pesaran, M Hashem and Ron Smith. 1995. "Estimating long-run relationships from dynamic heterogeneous panels." *Journal of Econometrics,* 68: 79-113.

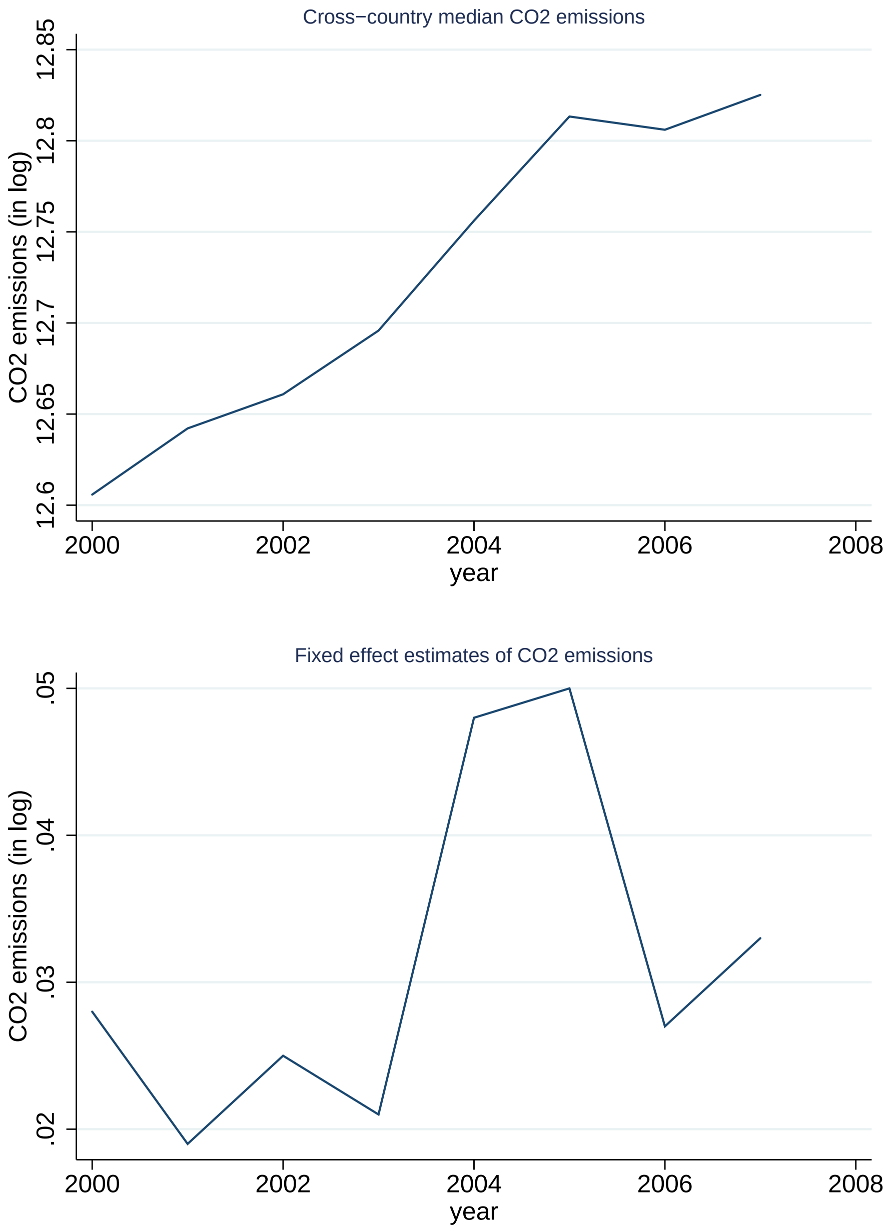
[19] Pesaran, M Hashem, Yongcheol Shin and Ron Smith. 1999. "Pooled mean group estimation of dynamic heterogeneous panels." *Journal of American Statistical Association* 94: 621-34.

[20] Sutter, Christoph and Juan Carlos Parreño, 2007. "Does the current Clean Development Mechanism (CDM) deliver its sustainable development claim? An analysis of officially registered CDM projects." *Climatic Change,* 84 (1): 74-90.

[21] UNEP Risoe Centre, CDM/JI Pipeline Analysis and Database (2008)

[22] Wagner, Martin and Georg Müller-Fürstenberger, 2008. "The carbon Kuznets Curve: A cloudy picture emitted by bad econometrics?" Forthcoming in *Resource and Energy Economics*.

Figure 1: CO2 emissions before and after having CDM projects in the pipeline



Note: 11 CDM host countries which had their first CDM projects in the pipeline by the end of 2004 and for which data for CO2 emissions (reference approach) in 2006 and 2007 are available. Variables and data sources are described in the text. Upper figure shows the cross−country median CO2 emissions for these countries while the lower figure plots the coefficients of fixed effect estimates of 8 time dummies around the year when their first CDM projects were in the pipeline. The regression is estimated by OLS in which the country effects, time effects, logarithms of GDP and GDP squared are included.

Table 1. Does CDM contribute to CO_2 emission reductions (reference approach)? 1990-2007

Dependent Variable: CO_{2it}	Without Time Trend			With Time Trend		
	Within Groups	Pooled Mean Group	Mean Group	Within Groups	Pooled Mean Group	Mean Group
Speed of adjustment	-0.358	-0.428	-0.576	-0.375	-0.520	-0.763
	[0.004]***	[0.000]***	[0.000]***	[0.010]***	[0.000]***	[0.000]***
Long-run coefficients						
CDM_{it}	-0.048	-0.037	0.116	-0.057	-0.034	-0.217
	[0.281]	[0.011]**	[0.111]	[0.119]	[0.027]**	[0.475]
GDP_{it}	1.822	0.142	0.000	1.598	0.025	0.000
	[0.008]***	[0.845]	[1.000]	[0.041]**	[0.986]	[1.000]
GDP^2_{it}	-0.037	0.026	0.012	-0.033	0.035	-0.001
	[0.107]	[0.306]	[0.891]	[0.125]	[0.528]	[0.986]
Short-run coefficients						
$\Delta CDM_{i,t-1}$	0.023	2.228	0.000	0.062	1.835	0.000
	[0.034]**	[0.003]***	[0.997]	[0.468]	[0.000]***	[0.000]***
$\Delta GDP_{i,t-1}$	-1.105	0.025	0.032	0.023	0.031	0.046
	[0.478]	[0.693]	[0.001]***	[0.027]**	[0.883]	[0.993]
$\Delta GDP^2_{i,t-1}$	0.055	-0.052	-0.001	-1.259	-0.069	-0.103
	[0.355]	[0.813]	[0.999]	[0.353]	[0.891]	[0.651]
Trend				0.003	-0.003	0.023
				[0.579]	[0.421]	[0.000]***
Observations	304	304	304	304	304	304
Number of Countries	18	18	18	18	18	18
Log Likelihood	436.31	633.74	698.84	437.38	658.56	761.13

Note: The dependent variable is CO2 emissions in total (reference approach). Variables and data sources are described in the text. This table presents the within group estimates, the Pesaran, Shin and Smith (1999)'s Pooled Mean Group estimates (PMG) and the Pesaran and Smith (1995)'s Mean Group estimates (MG), without and with a time trend, respectively. The PMG approach uses the MG estimates of long-run coefficients as initial values, and the Newton-Raphson algoithm. For the case of within group estimates, the standard errors are corrected for possible heteroscedasticity in the cross-sectional error variances. All equations included a constant country-speific term. Log Likelihood is to examine the null hypothesis of equality of all of the long-run coefficients. P-values are reported in the brackets. *, **, *** significant at 10%, 5%, 1%, respectively.

Table 2. Does CDM contribute to CO_2 emission reductions (reference approach)? 1990-2007

Dependent Variable: CO_{2it}	Coal			Gas			Oil		
	Within Groups	Pooled Mean Group	Mean Group	Within Groups	Pooled Mean Group	Mean Group	Within Groups	Pooled Mean Group	Mean Group
Speed of adjustment	-0.553	-0.640	-0.801	-0.150	-0.484	-0.649	-0.391	-0.365	-0.795
	[0.000]***	[0.000]***	[0.000]***	[0.000]***	[0.000]***	[0.000]***	[0.000]***	[0.000]***	[0.000]***
Long-run coefficients									
CDM_{it}	0.093	-0.031	-0.418	-0.531	-0.043	0.033	-0.117	-0.062	-0.010
	[0.443]	[0.233]	[0.000]***	[0.333]	[0.075]*	[0.467]	[0.021]**	[0.027]**	[0.758]
GDP_{it}	3.885	-5.344	0.000	-0.860	2.536	0.000	2.937	-6.715	0.000
	[0.218]	[0.017]**	[0.999]	[0.825]	[0.490]	[1.000]	[0.004]***	[0.048]**	[0.995]
GDP^2_{it}	-0.094	0.219	0.107	0.011	-0.073	-0.080	-0.069	0.364	-0.658
	[0.360]	[0.009]***	[0.579]	[0.944]	[0.606]	[0.652]	[0.045]**	[0.009]***	[0.048]**
Short-run coefficients									
$\Delta CDM_{i,t-1}$	-0.724	-53.891	0.109	0.180	0.161	0.089	-5.489	0.020	-0.406
	[0.873]	[0.309]	[1.000]	[0.247]	[0.815]	[0.501]	[0.207]	[0.064]*	[0.235]
$\Delta GDP_{i,t-1}$	-0.005	2.958	0.000	5.195	16.684	0.176	0.229	-1.653	0.000
	[0.105]	[0.377]	[0.003]***	[0.198]	[0.111]	[0.000]***	[0.042]**	[0.047]**	[0.994]
$\Delta GDP^2_{i,t-1}$	18.688	0.031	0.103	-0.184	-0.807	0.000	0.027	39.200	0.051
	[0.102]	[0.164]	[0.663]	[0.129]	[0.846]	[0.999]	[0.173]	[0.072]*	[0.000]***
Trend	-0.001	-0.015	0.329	0.025	0.030	0.042	-0.010	-0.012	0.010
	[0.940]	[0.596]	[0.000]***	[0.150]	[0.223]	[0.006]***	[0.009]***	[0.323]	[0.212]
Observations	297	297	297	304	304	304	304	304	304
Number of Countries	18	18	18	18	18	18	18	18	18
Log Likelihood	-126.17	328.97	414.62	-92.14	393.92	478.29	349.47	557.94	647.65

Note: The dependent variable is CO2 emissions (reference approach) from fuel combustion of Coal, Gas and Oil, respectively. Variables and data sources are described in the text.
See Table 1 for more notes.

Table 3. Does CDM contribute to CO_2 emission reductions (sectoral approach)? 1990-2006

Dependent Variable: CO_{2it}	Without Time Trend			With Time Trend		
	Within Groups	Pooled Mean Group	Mean Group	Within Groups	Pooled Mean Group	Mean Group
Speed of adjustment	-0.358	-0.340	-0.492	-0.379	-0.530	-0.855
	[0.004]***	[0.000]***	[0.000]***	[0.009]***	[0.000]***	[0.000]***
Long-run coefficients						
CDM_{it}	-0.020	-0.023	-0.475	-0.034	-0.002	-0.032
	[0.662]	[0.250]	[0.000]***	[0.388]	[0.864]	[0.079]*
GDP_{it}	2.364	1.122	0.000	1.981	-0.195	0.000
	[0.002]***	[0.202]	[0.995]	[0.041]**	[0.850]	[1.000]
GDP^2_{it}	-0.056	-0.008	0.307	-0.048	0.030	0.171
	[0.026]**	[0.794]	[0.267]	[0.081]*	[0.451]	[0.592]
Short-run coefficients						
$\Delta CDM_{i,t-1}$	0.009	0.005	-0.173	0.008	-1.927	0.001
	[0.462]	[0.774]	[0.996]	[0.423]	[0.910]	[0.223]
$\Delta GDP_{i,t-1}$	-1.294	-0.069	0.011	0.070	0.001	0.018
	[0.445]	[0.371]	[0.532]	[0.458]	[0.902]	[0.987]
$\Delta GDP^2_{i,t-1}$	0.061	1.696	0.000	-1.498	0.051	-0.327
	[0.345]	[0.774]	[0.000]***	[0.330]	[0.942]	[0.000]***
Trend				0.003	0.006	0.003
				[0.520]	[0.253]	[0.764]
Observations	284	284	284	284	284	284
Number of Countries	18	18	18	18	18	18
Log Likelihood	422.17	620.18	687.55	423.72	656.45	747.43

Note: The dependent variable is CO2 emissions from fuel combustion in total (by sectoral approach) over 1990-2006. Variables and data sources are described in the text.
See Table 1 for more notes.

Appendix Table 1: The List of Countries in the Full Sample

No.	Country Name	Country Code	First CDM Year
1	Argentina	ARG	2004
2	Armenia	ARM	2005
3	Bangladesh	BGD	2005
4	Brazil	BRA	2003
5	Chile	CHL	2003
6	China	CHN	2004
7	Colombia	COL	2005
8	Indonesia	IDN	2004
9	India	IND	2003
10	Iran	IRN	2005
11	Israel	ISR	2005
12	Korea, Rep. (South)	KOR	2003
13	Morocco	MAR	2004
14	Mexico	MEX	2004
15	Malaysia	MYS	2004
16	Nigeria	NGA	2005
17	Thailand	THA	2005
18	South Africa	ZAF	2004

Note: This table lists the country codes and country names for 18 CDM host countries considered in this analysis. The First CDM Year is the year when a country had its first CDM project in the pipeline. Data are from the UNEP Risoe Centre CDM/JI Pipeline Analysis and Database (2008).