The Clean Development Mechanism and Low Carbon Development: A Panel Data Analysis*

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Abstract

The Clean Development Mechanism (CDM) of Kyoto Protocol, designed for the industrialised countries to earn emission credits by investing in greenhouse gas (GHG) emission reduction projects in developing countries, shall contribute to emission reductions and sustainable development in the host countries. However, whether the CDM is achieving its dual goals has been questionable. This research empirically investigates the long-run impacts of CDM projects on CO_2 emission reductions for 80 eligible CDM host countries over 1993-2009. By allowing for considerable heterogeneity across countries, this research provides evidence in support of a decline in CO_2 emissions associated with CDM projects. It serves to encourage developing countries to effectively develop CDM projects towards low carbon development.

Keywords: Clean Development Mechanism; CO_2 Emissions; Heterogeneous Dynamic Panels; Developing Countries; China

JEL Classification: O19; Q54; Q56

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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 international community. As part of 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. This research empirically examines whether CDM projects contribute to emission reductions in the host countries, based on a dynamic heterogeneous panel of 80 eligible CDM host countries over 1993-2009.

As a global effort to respond to climate change and protect the environment, the Kyoto Protocol was introduced in 1997, coming into force on 16 February 2005.[1] The CDM is an innovative cooperative mechanism under the Kyoto Protocol, aiming to achieve the dual aims of sustainable development and emission reductions. It 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. According to UNFCCC (1997), the emission reductions due to CDM projects in the host countries

[1] 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).

should be “additional to any that would occur in the absence of the certified project activity”.

However, there has been much controversy in terms of whether CDM has achieved its dual objectives. This research focuses on the effectiveness of achieving its objective of emission reductions.[2]

The existing research on whether the CDM projects are effective in achieving emission reductions objective is made up of one group of research supporting positive impacts while another group of research indicating negative impacts. Some forward-looking research, for example Banuri and Gupta (2000), finds 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. With a multi-sector and multi-region intertemporal computing general equilibrium model, Kallbekken (2006) finds that, under realistic assumptions on CDM activity, CDM can significantly reduce carbon leakage by the reduced emissions trading permit prices, which lower the abatement cost in Annex I countries. However, Schneider (2007) shows that CDM has not been very successful in achieving its emission reductions objective based on survey, interview and systematic evaluation of 93 CDM projects. Wara and Victor (2008) review the actual experience of global CDM market and find that “much of the current CDM market does not reflect actual reductions in emissions”. Due to a lack of data, panel data analysis or time series analysis

[2] A number of research has been done to study the sustainable development objective of CDM. Among others, recent studies by Sutter and Parreño (2007) and Kolshus *et al.* (2001) suggest that, left to market forces, the CDM at either the aggregated level or project level does not significantly contribute to sustainable development because the trade-off between the two benefits of CDM falls in favor of cost-effective reduction benefits, and neglects the sustainable development benefits, which are not monetised in the carbon markets. See Olsen (2007) and Paulsson (2009) for a recent review of literature on sustainable development contributions of the CDM.

on this issue at the aggregated level has been hitherto lacking.

This research carries out a panel data analysis into the impact of CDM projects on CO_2 emission reductions. More specifically, we empirically evaluate whether CDM projects registered lead to a decline in CO_2 emissions, at the aggregated level, for 80 eligible CDM host countries over 1993-2009. We suppose that an Environmental Kuznets Curve (EKC) exists.[3] Based on this framework, this research investigates the long-run and short-run dynamics of CDM project development. It 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 evidence in support of a decline in CO_2 emissions associated with CDM projects, adding to the growing debates on this topic.

This research has significant implications for the CDM development in developing countries. The finding of this research serves to encourage the developing countries to strengthen their national capacity to effectively access the CDM. As a comprehensive cross-country study, this research contributes to the literature by complementing the existing project-level studies, which question the additionality of a significant proportion of CDM projects implemented in terms of emission reductions (Schneider, 2007).

The remainder of the paper proceeds as follows. Section 2 describes the

[3] The EKC hypothesis refers to an inverse U-shaped relationship between per capita GDP and per capita CO_2 emissions in the sense that emissions first increase with the growing GDP, pass through a peak at a certain income level and go down afterwards while income continues to rise. This hypothesis has been questioned recently. For example, Müller-Fürstenberger and Wagner (2007) and Wagner (2008) argue that the literature in estimating EKC "has to be regarded questionable" as it ignores the nonlinear transformations of nonstationary regressors and the existence of cross-sectional dependence. Romero-Ávila (2008) adds to this criticism that the existing literature neglects the effects of multiple structural breaks. However, whether the issue of cross-sectional dependence is relevant to this context is still questionable; or put in other way, it is not clear that, unlike GDP or other macroeconomic variables, an increase of CO_2 emissions in one country will induce emission changes in other countries.

econometric methods and data. Section 3 reports some preliminary evidence and econometric evidence. Section 4 concludes.

2 Methodology and Data

2.1 Econometric Methods

This analysis studies the link between CDM projects and CO_2 emissions per capita for 80 countries over 1993-2009. Apparently, CO_2 emissions differ across countries while differences in geographic characteristics across countries have been found relevant to CDM development (Huang, 2011, Chapter 6). Since we are dealing with a very dynamic process, we need a unique method to better capture these features. A number of methods have been proposed in the literature to analyze a set of panel data with large time and large cross-sectional dimensions, for example, 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). This section sets out the methodology that deals with the heterogeneous dynamic panels.

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

$$\begin{aligned}
\mathbf{CO_2}_{it} &= \sum_{j=1}^{p} \alpha_{ij} \mathbf{CO_2}_{i,t-j} + \sum_{j=0}^{q} \beta_{ij} \mathbf{CDM}_{i,t-j} + \\
&\quad \sum_{j=0}^{q} \gamma_{ij} \mathbf{GDP}_{i,t-j} + \sum_{j=0}^{q} \delta_{ij} \mathbf{GDP}^2_{i,t-j} + \theta_i t + \mu_i + v_{it} \\
i &= 1, 2, ..., 80 \text{ and } t = 1, ..., 17 \qquad (1)
\end{aligned}$$

where $\mathbf{CO_2}_{it}$ is the dependent variable and $\mathbf{CDM}_{it}$, $\mathbf{GDP}_{it}$ and $\mathbf{GDP}^2_{it}$

are explanatory variables. t, μ_i and v_{it} are the time trend, unobservable country specific effects and 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.

Perman and Stern (2003), Müller-Fürstenberger and Wagner (2007) and Wagner (2008) show that the series of $\mathbf{CO_2}_{it}$, $\mathbf{GDP}_{it}$ and $\mathbf{GDP}^2_{it}$ are integrated, and cointegrated for any individual countries. Following Romero-Ávila (2008) who studies the environment-income nexus, we assume that a long-run relationship exists in this context.

As shown by Engle and Granger (1987), there must be an error correction representation governing the co-movements of these series over time. Since the PMG estimator seems quite robust to outliers and the choice of ARDL order, especially when T is large (Pesaran *et al.*, 1999), we adopt an autoregressive distributed lag ARDL(1, 1, 1, 1) system for this analysis with its corresponding error correction equation as follows.

$$\begin{aligned} \triangle \mathbf{CO_2}_{it} &= \alpha'_{i1}\left(\mathbf{CO_2}_{i,t-1} + \frac{\mu'_i}{\alpha'_{i1}} + \frac{\beta'_{i1}}{\alpha'_{i1}}\mathbf{CDM}_{it} + \frac{\gamma'_{i1}}{\alpha'_{i1}}\mathbf{GDP}_{it} + \frac{\delta'_{i1}}{\alpha'_{i1}}\mathbf{GDP}^2_{it}\right) \\ &\quad -\beta_{i1} \triangle \mathbf{CDM}_{i,t-1} - \gamma_{i1} \triangle \mathbf{GDP}_{i,t-1} - \delta_{i1} \triangle \mathbf{GDP}^2_{i,t-1} + \theta_i t + v_{it} \\ i &= 1, 2, ..., 80 \text{ and } t = 1, ..., 17 \qquad (2) \end{aligned}$$

where

$$\alpha_{i1}^{'} = -(1-\alpha_{i1})$$
$$\mu_i^{'} = \mu_i$$
$$\beta_{i1}^{'} = \beta_{i0}+\beta_{i1}$$
$$\gamma_{i1}^{'} = \gamma_{i0}+\gamma_{i1}$$
$$\delta_{i1}^{'} = \delta_{i0}+\delta_{i1}$$

where $\alpha_{i1}^{'}$ is the coefficient for the speed of adjustment. $\frac{\beta_{i1}^{'}}{\alpha_{i1}^{'}}$, $\frac{\gamma_{i1}^{'}}{\alpha_{i1}^{'}}$, and $\frac{\delta_{i1}^{'}}{\alpha_{i1}^{'}}$ are the long-run coefficients for $\mathbf{CDM}_{it}$, $\mathbf{GDP}_{it}$ and $\mathbf{GDP}_{it}^2$, respectively, while β_{i1}, γ_{i1}, and δ_{i1} are the short-run coefficients for $\mathbf{CDM}_{it}$, $\mathbf{GDP}_{it}$ and $\mathbf{GDP}_{it}^2$, respectively.

The WG estimator is consistent for the dynamic homogeneous model when time series dimension $\mathbf{T}$ is large, as cross-sectional dimension $\mathbf{N}\to\infty$ (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 patterns of CO_2 emissions, the CDM development, and the level of income are observed divergent across countries.

The MG approach instead allows all slope coefficients and error variances to differ across countries, having considerable heterogeneity. 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[4]. For large T and N, the MG estimator is consistent. With sufficiently high

[4] 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.

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 downward lagged dependent variable biase (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 the short-run coefficients, speeds of adjustment and error variances to vary across countries. The restriction of long-run homogeneity can be tested via a Hausman test, which is asymptotically distributed as a $\chi^2(p)$, where p is the number of parameters.[5] Under the null hypothesis of long-run homogeneity, the PMG estimators are consistent and more efficient than the MG estimators. 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 $\mathbf{CDM}_{it}$, $\mathbf{GDP}_{it}$ and $\mathbf{GDP}^2_{it}$ are common across countries, that is,

$$\begin{aligned} \alpha'_{i1} &= -(1-\alpha_1) \\ \beta'_{i1} &= \beta_0+\beta_1 \\ \gamma'_{i1} &= \gamma_0+\gamma_1 \\ \delta'_{i1} &= \delta_0+\delta_1 \end{aligned}$$

[5]The restriction of long-run homogeneity can be tested via a likelihood ratio test; however, this test tends to reject the null at the conventional significance levels for cross country studies (Pesaran *et al.*, 1998).

2.2 Data and Sample

The dependent variable is CO_2 emissions per capita, denoted by $\mathbf{CO_2}$. This analysis mainly makes use of CO_2 emissions from fuel combustion (by sectoral approach), in total as well as the emissions from energy sector and manufacturing industries, respectively. To check for the robustness of the results, it also considers CO_2 emissions per capita from fuel combustion (by reference approach). The analysis uses the logarithm of 1000 times CO_2 emissions per capita. Data on CO_2 emissions (by either sectoral or reference approach) are taken from the Enerdata's Global Energy Market Data (2010).[6] Data for population are from the World Bank World Development Indicators Database (2010).

The main independent variable is the Clean Development Mechanism, simply denoted by **CDM**. It is an indicator (dummy) variable taking value one in the year when a country has a CDM project registered before 2007 and in all years afterwards for the period from 1993 to 2009, and 0 otherwise.[7] The CDM projects considered only include those that have been at the registration stage, either registered or requested registration. Data on CDM projects at the registration stage are from the UNEP Risoe Centre (2011).

To reflect the so-called Environmental Kuznets Curve, this analysis in-

[6] Sectoral Approach and Reference Approach contain total CO2 emissions from fuel combustion as calculated using the IPCC Tier 1 Sectoral Approach and IPCC Reference Approach, respectively. Sectoral Approach estimates include emissions only when the fuel is actually combusted while Reference Approach estimates, based on energy supply in a country, are likely to overestimate national CO2 emissions.

[7] In this analysis only the effects of CDM implemented before 2007 are considered because it might take some time for the CDM projects implemented to take effects. Since this research is to capture the dynamic evolution of CO_2 emissions per capita during the implementation of CDM projects, it treats the implementation of CDM projects as an event using dichotomous (or binary) indicators. The dummy variable equal to 1 reflects the presence of such a climate mitigation mechanism and thereafter. As time goes, one direction for further research is to use data for the number of CDM projects, volume of CDM credits or investment to revisit this issue.

cludes GDP per capita in log and its squared term in the regression, denoted by **GDP** and **GDP^2**, respectively. Data for real GDP per capita (constant prices: chain series) are taken from the Penn World Table 7.0 due to Heston *et al.* (2011).

To test the robustness of the results, we include the level of democracy, denoted by **DEMO**, and trade share, denoted by **TRADE**, into the model, separately.[8] We use the logarithm of trade share in the analysis. Data for trade openness in constant prices are taken from the Penn World Table 7.0 due to Heston *et al.* (2011). Data for the level of democracy captured by the Polity indicator "polity2" are taken from the PolityIV Database (Marshall and Jaggers, 2010). The Polity indicator has been often used to measure institutional quality based on the freedom of suffrage, operational constraints, balances on executives, and respect for other basic political rights and civil liberties.

The whole sample includes 80 eligible CDM host countries over 1993-2009.[9] We exclude any countries which have less than 17 observations for dependent variable or any independent variables.

3 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.[10]

[8] FDI and the ratio of manufacturing, taken from the World Bank World Development Indicators Database (2010), are also ideal variables to be considered as controlling variables. Due to insufficient observations, we are not able to include them in the model.

[9] The start year is 1993 since many transition economies have missing data for many variables before 1993. The inclusion of some eligible CDM countries which do not have CDM projects registered rules out the possibility that the effect of CDM projects is simply picking up a structural break.

[10] The parameters reported in Tables 1, 2 and 3 (as well as Tables 4 and 5) for speeds of adjustment, long-run coefficients and short-run coefficients correspond to model para-

Table 1 examines whether CDM projects result in reduced CO_2 emissions for 80 eligible CDM host countries over 1993-2009, with the dependent variable being the CO_2 emissions (by sectoral approach) per capita 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 homogeneous across countries, although the short-run adjustments are more likely to differ across countries. This analysis centres on the PMG estimates.

Insert Table 1 here

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 WG to PMG estimates, we find that PMG estimates suggest much faster adjustment in two specifications than their WG counterparts, especially when a time trend is allowed. Imposing homogeneity on all slope coefficients except for the intercept, the WG estimates in two specifications suggest a negative but not significant long-run effect of CDM projects on CO_2 emissions. However, the WG estimates 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 significantly negative effect of CDM projects on CO_2 emissions. This tends to

meters $\alpha_{i1}^{'}$, $\frac{\beta_{i1}^{'}}{\alpha_{i1}^{'}}$, $\frac{\gamma_{i1}^{'}}{\alpha_{i1}^{'}}$, $\frac{\delta_{i1}^{'}}{\alpha_{i1}^{'}}$, $-\beta_{i1}$, $-\gamma_{i1}$, $-\delta_{i1}$ of equation (2), respectively.

underscore the importance of allowing for heterogeneity across countries in this context. When a time trend is allowed, PMG estimates confirm the significant impact of income on CO_2 emissions.

Moving from MG to PMG in Table 1 changes the results significantly as well. In particular, imposing long-run homogeneity reduces 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 approach finds a negative but not significant long-run effect of CDM projects on CO_2 emissions when a time trend is allowed. When the MG and PMG estimates are compared, the restriction of long-run homogeneity can not be rejected at a conventional level via a Hausman test no matter if a time trend is included; therefore it doesn't appear that we are imposing too strong a constraint on the model.

Following Goldstein (1992), the size of effect for CDM has been calculated. The long-run coefficient of CDM by PMG approach can be interpreted as 10.11 and 1.31 percentage reductions in the original CO_2 emissions per capita per change in the dummy variable CDM, without and with a time trend, respectively.

Insert Table 2 here

Table 2 looks at the impact of CDM development on CO_2 emissions per capita from manufacturing industries and energy sector, respectively, when a time trend is included. Hausman test can not reject the null of equality of all long-run coefficients for two main sectors. Both WG and MG estimates suggest a negative impact while PMG estimates suggest a significantly negative impact of CDM projects on CO_2 emissions per capita from either the manufacturing industries or energy sector. The size of effect for CDM from PMG estimates shows that the percentage reductions in the original CO_2 emissions per capita in two main sectors are in the range of 3-8% per change in the dummy variable CDM.

Insert Table 3 here

Table 3 makes use of the CO_2 emissons (by reference approach) per capita over 1993-2009. No matter whether a time trend is allowed, the speeds of adjustment coefficients are significantly different from zero and Hausman test can not reject the null of equality of all long-run coefficients. We naturally focus on PMG estimates, which in both cases confirm that the CDM projects are associated with CO_2 emission reductions. The size of effect for CDM shows that the percentage reductions in the original CO_2 emissions per capita from PMG estimates are in the range of 2-3% per change in the dummy variable CDM.

Insert Table 4 here

In the following we test whether the above findings are robust to various model specifications by considering the inclusion of the level of democracy (**DEMO**) and trade share (**TRADE**) separately, as additional regressor.[11] Table 4 makes use of the CO_2 emissions per capita (by sectoral approach) for the robustness test while Table 5 uses the CO_2 emissions per capita (by reference approach). A time trend is allowed here. In Table 4 the speeds of adjustment coefficients in both cases are significantly different from zero and Hausman test can not reject the null of equality of all long-run coefficients. PMG estimates further confirm that the CDM projects contribute to CO_2 emission reductions in those countries for the inclusion of either the level

[11] Democratic regimes, compared to the autocratic regimes, have been found to place a lower relative cost on pollution abatement, and therefore tend to choose stricter environmental standards (for example, Congleton, 1992). In terms of trade share, research has suggested that the imports of developed countries from developing countries increase the emissions of carbon dioxide than if the goods were produced in the West, because factories in developing nations tend to use more energy than in the developed countries (Weber and Matthews, 2007).

of democracy or trade share. Together with Table 5 (with similar pattern) the PMG estimates clearly indicate that the inclusion of either variable does not alter the above findings. Moreover, the PMG estimates in both tables show that the level of democracy is negatively while trade share is positively related to CO_2 emissions per capita, implying that better governance or institutional quality is conducive to emission reductions while more trade openness is likely to increase the level of CO_2 emissions per capita. Tables 4 and 5 show that the percentage reductions in the original CO_2 emissions per capita from PMG estimates are in the range of 1-8% per change in the dummy variable CDM.

Insert Table 5 here

In sum, after allowing for heterogeneity across countries, this analysis 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 low carbon development objective. On the impacts of income on CO_2 emissions, the analysis doesn't consistently support the hypothesis of Environmental Kuznets Curve where WG estimates tend to provide evidence for such a hypothesis but not for the PMG and MG estimates. This is in line with Halkos (2003), among others, who finds that the Environmental Kuznets Curve hypothesis is hard to be tested due to enormous heterogeneity across countries.

4 Concluding Remarks

To investigate the impacts of CDM projects on CO_2 emissions per capita, this research conducts a dynamic panel data study allowing for considerable heterogeneity across countries for 80 eligible CDM host countries over

1993-2009. 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 evidence in support of a significant impact of CDM projects on CO_2 emission reductions, indicating that a decline in CO_2 emissions can be expected in the CDM host countries in the long run.

The findings show that CDM projects in a country can act as a significant stimulus to low-carbon development. Since the CDM has been criticized as having weak governance, inefficient operation and limited scope, to stimulate productivity of CDM projects for low-carbon development, especially at their early stage of development, the governments of developing countries should improve their institutional quality, formulate favourable policies, and strengthen their capacity through international exchanges of experience or international networking for beneficial information on other countries' CDM programs.

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Table 1. The impacts of CDM projects on CO_2 emission reductions (sectoral approach): 1993-2009

Dependent Variable: CO_{2it}	Without Time Trend				With Time Trend			
	Within Groups	Pooled Mean Group	Mean Group	Hausman	Within Groups	Pooled Mean Group	Mean Group	Hausman
Speed of adjustment	-0.307***	-0.350***	-0.640***		-0.316***	-0.539***	-0.849***	
	[0.040]	[0.032]	[0.046]		[0.040]	[0.038]	[0.053]	
Long-run coefficients								
CDM_{it}	-0.007	-0.106***	0.011	0.20	-0.023	-0.013**	-1.489	0.62
	[0.051]	[0.014]	[0.040]		[0.049]	[0.005]	[1.531]	
GDP_{it}	1.515***	-0.680**	22.718		1.494***	0.696***	-234.517	
	[0.361]	[0.270]	[33.008]		[0.349]	[0.266]	[288.217]	
GDP^2_{it}	-0.061***	0.086***	-1.506		-0.066***	-0.007	17.374	
	[0.023]	[0.017]	[2.214]		[0.023]	[0.015]	[20.790]	
Short-run coefficients								
$\Delta CDM_{i,t-1}$	0.022	0.017**	0.017		0.023	0.019	-0.030	
	[0.016]	[0.008]	[0.016]		[0.016]	[0.016]	[0.037]	
$\Delta GDP_{i,t-1}$	0.598	-36.696**	-21.306		0.545	-34.561*	-44.781**	
	[0.792]	[18.283]	[13.657]		[0.814]	[20.604]	[17.848]	
$\Delta GDP^2_{i,t-1}$	-0.024	2.161**	1.171		-0.020	1.946	2.731**	
	[0.045]	[1.046]	[0.828]		[0.046]	[1.187]	[1.124]	
Trend					0.002	0.003	0.011	
					[0.001]	[0.002]	[0.007]	
Observations	1280	1280	1280		1280	1280	1280	
Number of Countries	80	80	80		80	80	80	
Size of Effect (CDM)	-0.83%	-10.11%	1.07%		-2.39%	-1.31%	-93.01%	

Note: The dependent variable is CO2 emissions (sectoral approach) per capita in log. Variables and data sources are described in the text. This table presents the within group estimates (WG), Pooled Mean Group estimates (PMG) and 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 WG, standard errors are corrected for possible heteroscedasticity in the cross-sectional error variances. All equations include a constant. Hausman test is to examine the null of long-run homogeneity. Standard errors are reported in the brackets. The Size of Effect (CDM) reports the percentage change in the dependent variable per change in the dummy variable CDM. *, **, *** significant at 10%, 5%, 1%, respectively.

Table 2. The impacts of CDM projects on CO_2 emission reductions (by sector): 1993-2009

Dependent Variable:	Manufacturing Industries				Energy Sector			
CO_{2it}	Within Groups	Pooled Mean Group	Mean Group	Hausman	Within Groups	Pooled Mean Group	Mean Group	Hausman
Speed of adjustment	-0.374***	-0.626***	-0.946***		-0.237***	-0.505***	-0.832***	
	[0.061]	[0.036]	[0.045]		[0.032]	[0.039]	[0.042]	
Long-run coefficients								
CDM_{it}	-0.073	-0.040**	-0.003	0.75	-0.061	-0.075***	-0.085	0.99
	[0.106]	[0.016]	[0.071]		[0.125]	[0.018]	[0.157]	
GDP_{it}	2.371**	1.457***	-13.273		4.733	-3.857***	15.268	
	[1.054]	[0.307]	[92.288]		[2.897]	[0.855]	[59.295]	
GDP^2_{it}	-0.094	-0.063***	0.112		-0.267*	0.283***	-0.889	
	[0.060]	[0.016]	[5.306]		[0.161]	[0.052]	[3.937]	
Short-run coefficients								
$\Delta CDM_{i,t-1}$	0.026	-0.009	0.042		0.014	0.013	0.103	
	[0.028]	[0.018]	[0.071]		[0.028]	[0.022]	[0.135]	
$\Delta GDP_{i,t-1}$	0.903	-102.444**	-89.286		1.479	-12.928	40.440	
	[1.051]	[43.705]	[58.616]		[0.987]	[29.967]	[44.349]	
$\Delta GDP^2_{i,t-1}$	-0.046	5.963**	5.638		-0.079	0.743	-3.026	
	[0.061]	[2.530]	[3.944]		[0.062]	[1.979]	[3.103]	
Trend	-0.003	-0.001	-0.008		0.006	0.007	-0.012	
	[0.004]	[0.004]	[0.017]		[0.004]	[0.006]	[0.022]	
Observations	1280	1280	1280		1280	1280	1280	
Number of Countries	80	80	80		80	80	80	
Size of Effect (CDM)	-7.54%	-3.89%	-0.56%		-6.63%	-7.25%	-9.32%	

Note: The dependent variable is CO2 emissions per capita in log from manufacturing industries and energy sector, respectively. Variables and data sources are described in the text.
See Table 1 for more notes.

Table 3. The impacts of CDM projects on CO_2 emission reductions (reference approach): 1993-2009

Dependent Variable:	Without Time Trend				With Time Trend			
$CO_{2\,it}$	Within Groups	Pooled Mean Group	Mean Group	Hausman	Within Groups	Pooled Mean Group	Mean Group	Hausman
Speed of adjustment	-0.311***	-0.386***	-0.646***		-0.318***	-0.564***	-0.872***	
	[0.039]	[0.029]	[0.045]		[0.039]	[0.039]	[0.050]	
Long-run coefficients								
CDM_{it}	-0.004	-0.030**	-0.006	0.88	-0.017	-0.024***	0.203	0.74
	[0.049]	[0.013]	[0.038]		[0.048]	[0.007]	[0.184]	
GDP_{it}	1.614***	0.138	185.151		1.597***	1.017***	105.268*	
	[0.383]	[0.246]	[179.952]		[0.374]	[0.353]	[58.801]	
GDP^2_{it}	-0.068***	0.032**	-12.996		-0.072***	-0.016	-7.184*	
	[0.025]	[0.015]	[12.705]		[0.024]	[0.019]	[4.066]	
Short-run coefficients								
$\Delta CDM_{i,t-1}$	0.022	0.009	0.020		0.023	0.026	-0.029	
	[0.016]	[0.008]	[0.016]		[0.016]	[0.017]	[0.037]	
$\Delta GDP_{i,t-1}$	0.484	-28.950**	-25.017*		0.440	-30.059**	-44.301***	
	[0.772]	[13.427]	[13.327]		[0.794]	[15.027]	[14.701]	
$\Delta GDP^2_{i,t-1}$	-0.017	1.787**	1.505*		-0.014	1.776**	2.786***	
	[0.044]	[0.791]	[0.821]		[0.045]	[0.892]	[0.924]	
Trend					0.001	-0.000	0.009	
					[0.001]	[0.002]	[0.007]	
Observations	1280	1280	1280		1280	1280	1280	
Number of Countries	80	80	80		80	80	80	
Size of Effect (CDM)	-0.49%	-2.99%	-0.67%		-1.76%	-2.37%	20.51%	

Note: The dependent variable is CO2 emissions per capita from fuel combustion (by reference approach) in log. Variables and data sources are described in the text. See Table 1 for more notes.

Table 4. Robustness test - sectoral approach

Dependent Variable: $CO_{2\,it}$	Democratization				Trade Share			
	Within Groups	Pooled Mean Group	Mean Group	Hausman	Within Groups	Pooled Mean Group	Mean Group	Hausman
Speed of adjustment	-0.315***	-0.541***	-0.910***		-0.314***	-0.487***	-0.946***	
	[0.040]	[0.040]	[0.057]		[0.040]	[0.039]	[0.062]	
Long-run coefficients								
CDM_{it}	-0.021	-0.013***	-0.215	0.89	-0.016	-0.049***	0.144	0.71
	[0.048]	[0.004]	[0.146]		[0.047]	[0.007]	[0.155]	
GDP_{it}	1.476***	2.755***	-10.916		1.438***	-0.864*	57.978	
	[0.356]	[0.301]	[30.427]		[0.345]	[0.464]	[49.299]	
GDP^2_{it}	-0.065***	-0.123***	0.755		-0.062***	0.113***	-4.025	
	[0.023]	[0.016]	[1.855]		[0.023]	[0.027]	[3.352]	
NEW VARIABLE	0.003	-0.004***	0.024		0.026	0.365***	-0.154	
	[0.006]	[0.001]	[0.040]		[0.104]	[0.031]	[0.239]	
Short-run coefficients								
$\Delta CDM_{i,t-1}$	0.023	0.021	0.006		0.020	0.028	-0.048	
	[0.016]	[0.017]	[0.047]		[0.017]	[0.018]	[0.055]	
$\Delta GDP_{i,t-1}$	0.544	-36.116*	-57.109***		0.717	-14.808	-46.670**	
	[0.816]	[20.884]	[19.987]		[0.783]	[15.186]	[23.408]	
$\Delta GDP^2_{i,t-1}$	-0.020	2.004*	3.572***		-0.031	0.800	2.993**	
	[0.046]	[1.213]	[1.251]		[0.044]	[0.913]	[1.517]	
NEW VARIABLE	0.001	-0.006	-0.010*		0.046	0.028	0.032	
	[0.002]	[0.004]	[0.006]		[0.035]	[0.047]	[0.081]	
Trend	0.002	0.000	0.018*		0.002	-0.004**	0.000	
	[0.001]	[0.002]	[0.009]		[0.001]	[0.002]	[0.013]	
Observations	1280	1280	1280		1280	1280	1280	
Number of Countries	80	80	80		80	80	80	
Size of Effect (CDM)	-2.22%	-1.32%	-20.18%		-1.73%	-4.82%	14.13%	

Note: Robustness test with CO2 emissions per capita by sectoral approach (in log). Variables and data sources are described in the text. See Table 1 for more notes.

Table 5. Robustness test - reference approach

Dependent Variable:	Democratization				Trade Share			
$CO_{2\,it}$	Within Groups	Pooled Mean Group	Mean Group	Hausman	Within Groups	Pooled Mean Group	Mean Group	Hausman
Speed of adjustment	-0.317***	-0.573***	-0.952***		-0.317***	-0.506***	-0.966***	
	[0.039]	[0.040]	[0.054]		[0.040]	[0.041]	[0.055]	
Long-run coefficients								
CDM_{it}	-0.016	-0.016**	-0.178*	0.82	-0.012	-0.077***	0.939	0.86
	[0.048]	[0.007]	[0.104]		[0.047]	[0.009]	[0.820]	
GDP_{it}	1.585***	0.889***	-2.308		1.561***	1.544***	93.065*	
	[0.377]	[0.329]	[30.353]		[0.370]	[0.347]	[49.812]	
GDP^2_{it}	-0.071***	-0.012	0.248		-0.070***	-0.012	-6.230*	
	[0.024]	[0.018]	[1.898]		[0.024]	[0.022]	[3.241]	
NEW VARIABLE	0.002	-0.002**	0.024		0.029	0.468***	-1.654	
	[0.006]	[0.001]	[0.039]		[0.106]	[0.030]	[1.826]	
Short-run coefficients								
$\Delta CDM_{i,t-1}$	0.023	0.025	0.012		0.021	0.034*	-0.048	
	[0.016]	[0.017]	[0.047]		[0.016]	[0.018]	[0.055]	
$\Delta GDP_{i,t-1}$	0.440	-34.432**	-56.397***		0.551	-11.472	-43.401**	
	[0.797]	[15.258]	[17.330]		[0.754]	[13.754]	[20.691]	
$\Delta GDP^2_{i,t-1}$	-0.014	2.044**	3.590***		-0.020	0.644	2.818**	
	[0.045]	[0.907]	[1.082]		[0.042]	[0.846]	[1.340]	
NEW VARIABLE	0.001	-0.005	-0.008		0.027	-0.011	0.040	
	[0.002]	[0.004]	[0.006]		[0.034]	[0.045]	[0.080]	
Trend	0.001	0.000	0.015*		0.001	-0.010***	-0.004	
	[0.001]	[0.002]	[0.009]		[0.001]	[0.003]	[0.013]	
Observations	1280	1280	1280		1280	1280	1280	
Number of Countries	80	80	80		80	80	80	
Size of Effect (CDM)	-1.67%	-1.59%	-16.74%		-1.35%	-7.46%	82.81%	

Note: Robustness test with CO2 emissions per capita by reference approach (in log). Variables and data sources are described in the text. See Table 1 for more notes.

Appendix Table 1: Descriptive Statistics

Variable		Mean	Std. Dev.	Min	Max	Observations
CO2	overall	0.04	1.55	-4.13	3.78	N=1360
(sectoral approach)	between		1.54	-3.36	3.68	n=80
	within		0.20	-0.88	1.08	T=17
CO2	overall	-1.69	2.72	-10.45	2.89	N=1360
(energy sector)	between		2.69	-9.30	2.70	n=80
	within		0.50	-4.56	1.76	T=17
CO2	overall	-1.68	1.81	-7.49	3.13	N=1360
(manufacturing industries)	between		1.78	-5.97	3.01	n=80
	within		0.38	-4.65	-0.14	T=17
CO2	overall	0.08	1.55	-4.13	3.81	N=1360
(reference approach)	between		1.55	-3.36	3.71	n=80
	within		0.20	-0.86	1.09	T=17
CDM	overall	0.15	0.36	0.00	1.00	N=1360
	between		0.13	0.00	0.35	n=80
	within		0.33	-0.20	0.97	T=17
GDP	overall	8.15	1.11	4.76	11.98	N=1360
	between		1.10	5.46	11.26	n=80
	within		0.18	7.46	9.12	T=17
GDP^2	overall	67.73	18.50	22.70	143.51	N=1360
	between		18.36	29.94	126.87	n=80
	within		3.01	57.56	84.36	T=17
DEMO	overall	1.92	6.60	-10	10	N=1360
	between		6.26	-10	10	n=80
	within		2.19	-10.08	12.69	T=17
TRADE	overall	4.22	0.53	2.66	6.09	N=1360
	between		0.49	3.07	5.89	n=80
	within		0.20	3.27	5.61	T=17

Note: See text for the description of each variable.

Appendix Table 2: Correlations among variables

	SECTORAL	ENER	MANU	REFERENCE	CDM	GDP	GDP^2	DEMO	TRADE
SECTORAL	1.00								
ENER	0.88	1.00							
MANU	0.93	0.81	1.00						
REFERENCE	1.00	0.88	0.92	1.00					
CDM	0.10	0.11	0.08	0.09	1.00				
GDP	0.90	0.75	0.84	0.90	0.16	1.00			
GDP^2	0.89	0.73	0.83	0.89	0.15	1.00	1.00		
DEMO	-0.02	0.09	-0.02	-0.03	0.17	0.02	0.00	1.00	
TRADE	0.35	0.25	0.28	0.35	0.04	0.30	0.30	0.01	1.00

Note: SECTORAL, ENER, MANU and REFERENCE are CO2 emissions per capita in log in total by sectoral approach, from energy sector, from manufacturing industries, and in total by reference approach, respectively. See text for the description of other variables.

Appendix Table 3: The List of Sample Countries (80)

Country Code	Country Name	1st CDM Year	Country Code	Country Name	1st CDM Year
ALB	Albania	2010	MAR	Morocco	2005
ARE	United Arab Emirates	2009	MDA	Moldova, Rep. of	2006
ARG	Argentina	2005	MDG	Madagascar	2010
ARM	Armenia	2005	MEX	Mexico	2005
AZE	Azerbaijan		MKD	Macedonia, FYR	2009
BGD	Bangladesh	2005	MLI	Mali	2010
BOL	Bolivia	2005	MNG	Mongolia	2006
BRA	Brazil	2004	MOZ	Mozambique	
BTN	Bhutan	2010	MUS	Mauritius	
CHL	Chile	2005	MYS	Malaysia	2006
CHN	China	2005	NGA	Nigeria	2006
CIV	Cote d'Ivoire	2009	NIC	Nicaragua	2006
CMR	Cameroon	2010	NPL	Nepal	2005
COL	Colombia	2006	OMN	Oman	
CRI	Costa Rica	2005	PAK	Pakistan	2006
CUB	Cuba	2007	PAN	Panama	2005
CYP	Cyprus	2006	PER	Peru	2005
DOM	Dominican Rep.	2006	PHL	Philippines	2006
ECU	Ecuador	2006	PNG	Papua New Guinea	2006
EGY	Egypt, Arab Rep.	2006	QAT	Qatar	2007
ETH	Ethiopia	2009	RWA	Rwanda	2010
FJI	Fiji	2005	SAU	Saudi Arabia	
GEO	Georgia	2007	SDN	Sudan	
GHA	Ghana		SEN	Senegal	2010
GTM	Guatemala	2005	SGP	Singapore	2008
GUY	Guyana	2008	SLV	El Salvador	2006
HND	Honduras	2005	SWZ	Swaziland	
IDN	Indonesia	2006	SYR	Syrian Arab Rep.	2009
IND	India	2005	TGO	Togo	
IRN	Iran, Islamic Rep.	2009	THA	Thailand	2007
ISR	Israel	2006	TUN	Tunisia	2006
JAM	Jamaica	2006	TZA	Tanzania	2007
JOR	Jordan	2008	UGA	Uganda	2007
KEN	Kenya	2008	URY	Uruguay	2007
KGZ	Kyrgyz Republic		UZB	Uzbekistan	2009
KHM	Cambodia	2006	VNM	Vietnam	2006
KOR	Korea, Rep. (South)	2005	YEM	Yemen, Rep.	
LAO	Lao PDR	2007	ZAF	South Africa	2006
LBY	Libya		ZAR	Congo, Dem. Rep.	
LKA	Sri Lanka	2005	ZMB	Zambia	2010

Note: This table lists the country codes and country names for 80 eligible CDM host countries considered in this analysis. The 1st CDM Year is the year when a country had its first CDM project registered. Data are from the UNEP Risoe Centre CDM/JI Pipeline Analysis and Database (April 2011).