

the upper chart, and the distance to the country with the smallest CDM credit flows in the lower chart. Data on the great circle distance are from Gleditsch *et al.* (2001). This figure clearly shows that countries closer to the biggest CDM host country, which is China, tend to have more CDM credit flows, whereas countries closer to the smallest CDM host country, which is Paraguay, tend to have less CDM credit flows.¹¹ Countries with more (less) CDM credit flows appear to be geographically clustered with other larger (smaller) CDM host countries.

By using two different spatial weighting matrices, an inverse-distance spatial weighting matrix and a binary spatial weighting matrix, two standard test statistics of spatial autocorrelation have been calculated (Table 1). The inverse-distance spatial weighting matrix gives the inverse of the distance to each sample point within a 4000km neighbourhood, and zero otherwise, while the binary spatial weighting matrix gives a weight of 1 to all sample points within a 4000km neighbourhood, and zero otherwise.¹² Both matrices are row-standardized of one. Following Kelejian and Prucha (1999), the spatial weighting matrices have been “idealized” so that each unit has the same number of neighbours with “one neighbour ahead and one neighbour behind” in a wrap around world.

Table 1 contrasts the Moran’s I and Gearcy’s C statistics for CDM credit flows. Both Moran’s I and Gearcy’s C statistics examine the null hypothesis of no spatial dependence. No matter which matrix is chosen, two Moran’s I statistics are greater than the expected value (-0.021) and two Gearcy’s C statistics are smaller than the expected value (1.000), suggesting posi-

¹¹This evidence is preliminary. One might find that countries like Brazil, closer to Paraguay, have large CDM credit flows. This suggests that, apart from geographic distance, other geographic variables are also important in the process of CDM development, and so are the institutional variables and financial variables.

¹²Data on the great circle distance are from Gleditsch *et al.* (2001) as well.

tive spatial dependence of CDM credit flows across countries.¹³ Moreover, both Moran’s I and Geary’s C statistics reject the null at about 10% significance level with an inverse-distance spatial weighting matrix, and at 5% significance level with a binary spatial weighting matrix. This shows that the positive spatial dependence of the CDM credit flows is significant across countries.

Tables 2 and 3 investigate whether countries with particular geographic endowments are more likely to attract CDM projects, for which 8 geographic endowment variables as explained earlier are selected from various sources.¹⁴

Column 1 of Table 2 reports the OLS estimates for the non-spatial model (1). Firstly, an OLS heteroskedasticity test due to White (1980) and Koenker (1981) is conducted to examine whether there is heteroskedasticity in the estimation regression that is related to any of the geographic variables we examine.¹⁵ The White/Koenker test rejects the null at 10% significance level, indicating that heteroskedasticity exists in the estimations and should be taken into account for this context.

To test for which type(s) of spatial dependence, spatial lag dependence

¹³If Moran’s I is greater (smaller) than its expected value, $E(I)$, and/or Geary’s C is smaller (larger) than its expected value, $E(C)$, the overall distribution of the variable in question can be reflected by positive (negative) spatial autocorrelation.

¹⁴In this analysis, we also explore the impacts on CDM credit flows of other geographic factors such as being landlocked, minimum distance from one of the three capital-goods-supplying centers (New York, Rotterdam and Tokyo), mean distance to nearest coastline or seanevitable river, the proportion of a country’s total land area with 100km of the ocean or ocean-navigable river, and the proportion of a country’s total land area in Koeppen-Geiger temperate zones. In general we find no evidence to support any significant associations between these factors and CDM credit flows. This may suggest that, as more and more modern technologies have been employed in the areas of transportation and telecommunications, and more and more railways, automobiles, airtransport and all forms of telecommunications become available, the geographic advantages in terms of easy access to the sea and/or international trade centers tend to be diminishing in the process of economic development.

¹⁵Under the null of no heteroskedasticity, the test statistic is distributed as Chi-square with degree of freedom being the total number of the regressors.

or spatial error dependence or both, exist(s) in this context, we carry out two simple Lagrange Multiplier tests (LM) separately. The hypothesis of no spatially lagged dependent variable is rejected at about 10% significance level while the hypothesis of no spatially autocorrelated error term can not be rejected. Furthermore, the p-values for the robust LM tests due to Anselin *et al.* (1996) and the log-likelihood statistics are reported to test for whether a spatial lag model is more appropriate than a spatial error model for this context. The evidence that the robust LM test doesn't reject the null hypothesis of no spatially autocorrelated error term, but reject the null of no spatially lagged dependent variable (at about 10% significance level), together with the evidence that the log-likelihood statistic for the spatial lag model (-41.03) is bigger than that for the spatial error model (-41.61), suggest that a spatial lag model is preferred to a spatial error model.

Columns 2 to 4 report the ML estimates for the spatial lag model (2) and spatial error model (3), and the GS2SLS estimates due to Kelejian and Prucha (2007) for the SARAR (1, 1) model (4). An inverse-distance spatial weighting matrix has been used to calculate the ML estimates and GS2SLS estimates.¹⁶

The spatial autocorrelation parameter, “ ρ ” appears to be insignificant in both the spatial error model and the SARAR(1,1) model. For the spatial autoregressive parameter, “ λ ”, it has been found weakly significant in the spatial lag model and significant in the SARAR(1, 1) model, with larger coefficient in the SARAR (1,1) model. The GS2SLS estimate of “ λ ” in the SARAR(1, 1) model shows that the CDM credit flows in a country increase by 0.34 units if those in its neighbouring countries increase by one unit.

The explanatory variables described in Section 2, except for *EXPMANU*,

¹⁶The spatial weighting matrices, W_n and M_n , are treated as the same.

have been found closely related to CDM credit flows with expected signs. In particular, the GS2SLS estimates show that the geographic variables, *LATITUDE* and *ELEV*, are positively associated with CDM development. For the resource and commodity exporter dummies, *EXPSERV* is positively, while *RESPOINT*, *RESDIFF* and *RESCOFF* are negatively related to CDM development. All control variables including *GDP03*, *POP03*, *ETHNIC*, *RELIGION* and legal origin dummies (*CIVLEG*, *COMLEG*) are in general found significantly associated with CDM development and should be included in the model.¹⁷

With a row-standardized binary weighting matrix, Table 3 in general confirms the findings of Table 2 in terms of positive impacts of *LATITUDE*, *ELEV* and *EXPSERV*, and negative impacts of *RESPOINT*, *RESDIFF* and *RESCOFF* on CDM credit flows. Table 3 seems to provide stronger evidence than Table 2, especially for the spatial autoregressive coefficients, “ λ ” and “ ρ ”. According to the SARAR(1, 1) model, the degree of neighbourhood effects for the CDM credit flows increases to 0.48.

The finding on the positive association between absolute latitude and CDM credit flows is consistent with the literature. On the one hand, research by Diamond (1997), Gallup *et al.* (1999) and Sachs (2003) suggests that countries in the tropical location in terms of a smaller absolute latitude are often associated with poor crop yields and production due to adverse ecological conditions such as fragile tropical soils, unstable water supply and prevalence of crop pests. On the other hand, tropical location can be characterised as an inhospitable disease environment, believed to be a primary cause for “extractive” institutions and in conjunction with weaker institutions according to the settler mortality hypothesis of Acemoglu *et al.*

¹⁷The GS2SLS estimates suggest that the impacts of *AREA* and *EXPPRIM* have been less precisely estimated.

(2001). Countries further from the Equator are more likely to have better climate conditions and stronger institutions, which are conducive to CDM project development.

The finding on the positive association between elevation and CDM credit flows is in line with recent research. It is widely known that the Earth's average surface temperature has risen by approximately 0.6°C in the 20th century and will rise a few degree (C) in this century. Global warming is likely to raise the sea level and change the land area and elevation for many countries. Countries with higher elevations are therefore supposed to have more potentials to attract CDM projects.

Some growth literature indicates that natural resource abundance is connected with social and economic instability and weak institutional quality, which hamper CDM project development. Isham *et al.* (2005) find that, in comparison to manufacturing exporters, the exporting countries of "point source" natural resources (e.g. oil, diamonds, plantation crops) and coffee/cocoa natural resources are more likely to have severe social and economic divisions, and less likely to develop socially cohesive mechanisms and effective institutional capacities for managing shocks.

In sum, this research produces the following significant findings. Firstly, this research provides evidence for the presence of positive spatial dependence among observations for this context, especially the spatial lag dependence associated with neighbourhood effects and social interactions. CDM credit flows in a country is significantly affected by those of its neighbouring countries, more specifically, the CDM credit flows in a country increase by about 0.34 to 0.48 units if those in its neighbouring countries increase by one unit. Secondly, by allowing for spatial dependence and accounting for the size of economy (initial population and initial GDP per capita), this

research finds that the absolute latitude and elevation have positive impacts on the CDM credit flows, suggesting that countries further from the equator and having higher elevation tend to initiate more CDM projects and issue more CDM credit flows. Countries with more exports of service seem to have more advantages in attracting CDM projects, and on the contrary, countries with more exports of natural resources have smaller CDM credit flows, indicating that natural resource abundance may not be necessarily conducive to CDM development.

5 Concluding remarks

Under the Kyoto Protocol, the Clean Development Mechanism (CDM) is designed to provide the non-Annex I countries (developing countries and economies in transition) with access to the flows of technology and capital that could contribute to their sustainable development objectives, while allowing Annex 1 countries to earn credits to meet their Kyoto commitments by investing in GHG emission reduction projects in non-Annex I countries.

This paper investigates whether the cross-sectional differences in geographic endowments can explain the cross-sectional differences in CDM credit flows. It conducts a cross-country study allowing for both spatial error dependence and spatial lag dependence for 48 CDM host countries over 12/2003-09/2008.

This research leads to two significant findings. Firstly, it provides evidence for a positive relationship between CDM credit flows in a country and those in its neighbouring countries, more specifically, the CDM credit flows in a country increase by about 0.34 to 0.48 units if those in its neighbouring countries increase by one unit. Countries with larger (smaller) CDM credit flows have been found geographically clustered with other larger (smaller)

CDM host countries. Secondly, by allowing for spatial dependence and accounting for the size of economy (initial population and initial GDP per capita), this research finds that the absolute latitude and elevation have positive impacts on CDM credit flows, suggesting that countries further from the equator and having higher elevations are in better positions to attract CDM projects. Countries with more exports of service are more associated with larger CDM credit flows, on the contrary, countries with more exports of natural resources have fewer CDM credit flows, indicating that natural resource abundance doesn't necessarily play a large role in promoting CDM development. These findings are robust to the choices of different spatial weighting matrices, an inverse-distance spatial weighting matrix and a binary spatial weighting matrix. We also control for an ethnic fractionalisation index, a religious fractionalisation index and legal origin dummies.

This finding sheds light on the geographic determinants of uneven CDM project development across countries, and has rich implications for developing countries in terms of international cooperation and national capacity building to effectively access the CDM for their national sustainable development objective. This research may contribute to our understanding of the cross-country differences in CDM development and contain some merits for the UNFCCC in terms of improving geographic distribution of CDM project activities and capacity building. This research also suggests that the geographic considerations should be introduced into the econometric and theoretical cross-country studies of climate change and mitigation.

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Table 1. Moran's I and Geary's C for CDM

	Moran's I	E(I)	SD(I)	z-statistic	p-value
Inverse-distance Weights	0.086	-0.021	0.084	1.250	[0.102]
Binary Weights	0.094	-0.021	0.067	1.714	[0.043]**
	Geary's C	E(C)	SD(C)	z-statistic	p-value
Inverse-distance Weights	0.902	1.000	0.092	-1.064	[0.144]
Binary Weights	0.870	1.000	0.074	-1.748	[0.040]**

Note: This table reports Moran's I and Geary's C tests for spatial autocorrelation for the averaged CDM credit flows in logs for 48 CDM host countries listed in the Appendix Table 1. The test statistics are calculated using an inverse-distance weighting matrix and a binary weighting matrix, respectively, as described in the text. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 2. Geography and Clean Development Mechanism (by inverse-distance weights)

	Non-spatial Model	Spatial Lag Model	Spatial Error Model	SARAR (1, 1)
λ		0.185 [0.135]		0.339 [0.033]**
ρ			0.315 [0.226]	-0.300 [0.239]
LATITUDE	0.016 [0.090]*	0.017 [0.088]*	0.016 [0.111]	0.018 [0.140]
ELEVATION	0.276 [0.048]**	0.270 [0.008]***	0.255 [0.012]**	0.274 [0.031]**
AREA	0.155 [0.150]	0.135 [0.173]	0.125 [0.219]	0.118 [0.331]
EXPSERV	0.965 [0.004]***	0.888 [0.002]***	0.851 [0.004]***	0.860 [0.020]**
EXPPRIM	-0.287 [0.368]	-0.320 [0.211]	-0.337 [0.184]	-0.307 [0.333]
RESPOINT	-1.587 [0.013]**	-1.642 [0.000]***	-1.565 [0.000]***	-1.678 [0.002]***
RESDIFF	-1.059 [0.013]**	-1.098 [0.002]***	-0.998 [0.005]***	-1.147 [0.010]***
RESCOFF	-1.368 [0.022]**	-1.484 [0.001]***	-1.435 [0.001]***	-1.525 [0.011]**
GDP03	0.258 [0.259]	0.236 [0.090]*	0.279 [0.056]*	0.185 [0.264]
POP03	0.360 [0.004]***	0.366 [0.001]***	0.367 [0.001]***	0.360 [0.007]***
ETHNIC	1.336 [0.050]*	1.467 [0.015]**	1.367 [0.031]**	1.606 [0.027]**
REGLIGION	2.077 [0.013]**	2.067 [0.000]***	2.061 [0.000]***	2.001 [0.004]***
COMLEG	0.557 [0.261]	0.541 [0.117]	0.520 [0.135]	0.552 [0.190]
CIVLEG	1.278 [0.046]**	1.354 [0.004]***	1.393 [0.003]***	1.331 [0.022]**
Constant	-4.312 [0.074]*	-5.175 [0.003]***	-4.064 [0.018]**	-5.571 [0.006]***
Observations	48	48	48	48
R-squared	0.73	0.74	0.72	
Log Likelihood		-41.03	-41.61	
White/Koenker test	[0.105]			
Spatial lag:				
LM	[0.107]			
Robust LM	[0.107]			
Spatial error:				
LM	[0.572]			
Robust LM	[0.570]			

Note: Dependent variable is the averaged CDM credit flows (2012 kCERs) in logs. Robust p values are reported in brackets. Variables and data sources are described in text. λ is the spatial autoregressive parameter in dependent variable in the spatial lag model and SARAR (1,1) model. ρ is the spatial autoregressive parameter in the disturbance in spatial error model and SARAR (1,1) model. The White/Koenker test is to examine the null of no heteroskedasticity. The spatial weighting matrix used here is a row-standardized inverse-distance weighting matrix described in text. Robust p values are reported in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 3. Geography and Clean Development Mechanism (by binary weights)

	Non-spatial Model	Spatial Lag Model	Spatial Error Model	SARAR (1, 1)
λ		0.288 [0.068]*		0.476 [0.023]**
ρ			0.495 [0.041]**	-0.299 [0.205]
LATITUDE	0.016 [0.090]*	0.018 [0.065]*	0.016 [0.094]*	0.020 [0.108]
ELEVATION	0.276 [0.048]**	0.255 [0.011]**	0.232 [0.018]**	0.256 [0.047]**
AREA	0.155 [0.150]	0.115 [0.244]	0.118 [0.232]	0.087 [0.479]
EXPSERV	0.965 [0.004]***	0.831 [0.004]***	0.779 [0.006]***	0.796 [0.034]**
EXPPRIM	-0.287 [0.368]	-0.334 [0.187]	-0.401 [0.118]	-0.319 [0.306]
RESPOINT	-1.587 [0.013]**	-1.671 [0.000]***	-1.574 [0.000]***	-1.717 [0.002]***
RESDIFF	-1.059 [0.013]**	-1.127 [0.001]***	-1.023 [0.003]***	-1.182 [0.008]***
RESCOFF	-1.368 [0.022]**	-1.515 [0.001]***	-1.529 [0.001]***	-1.546 [0.009]***
GDP03	0.258 [0.259]	0.220 [0.111]	0.267 [0.063]*	0.162 [0.325]
POP03	0.360 [0.004]***	0.382 [0.000]***	0.358 [0.001]***	0.392 [0.004]***
ETHNIC	1.336 [0.050]*	1.581 [0.009]***	1.395 [0.027]**	1.765 [0.018]**
REGLIGION	2.077 [0.013]**	1.940 [0.000]***	2.011 [0.000]***	1.834 [0.006]***
COMLEG	0.557 [0.261]	0.559 [0.101]	0.482 [0.150]	0.602 [0.155]
CIVLEG	1.278 [0.046]**	1.407 [0.002]***	1.408 [0.002]***	1.457 [0.014]**
Constant	-4.312 [0.074]*	-5.591 [0.001]***	-3.544 [0.042]**	-6.221 [0.003]***
Observations	48	48	48	48
R-squared	0.73	0.75	0.71	
Log Likelihood		-40.56	-40.99	
White/Koenker test	[0.105]			
Spatial lag:				
LM	[0.055]*			
Robust LM	[0.070]*			
Spatial error:				
LM	[0.385]			
Robust LM	[0.563]			

Note: The spatial weighting matrix used for the spatial lag model, spatial error model and SARAR(1,1) model in this table is a row-standardized binary weighting matrix described in the text. See Table 2 for more notes.

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

Code	Country Name	Code	Country Name
ARE	United Arab Emirates	KHM	Cambodia
ARG	Argentina	KOR	Korea, Rep. (South)
ARM	Armenia	LKA	Sri Lanka
AZE	Azerbaijan	MAR	Morocco
BGD	Bangladesh	MDA	Moldova, Republic of
BOL	Bolivia	MEX	Mexico
BRA	Brazil	MNG	Mongolia
BTN	Bhutan	MYS	Malaysia
CHL	Chile	NGA	Nigeria
CHN	China	NIC	Nicaragua
COL	Colombia	PAK	Pakistan
CRI	Costa Rica	PAN	Panama
CYP	Cyprus	PER	Peru
DOM	Dominican Republic	PHL	Philippines
ECU	Ecuador	PRY	Paraguay
EGY	Egypt, Arab Rep.	SGP	Singapore
GEO	Georgia	SLV	El Salvador
GTM	Guatemala	THA	Thailand
HND	Honduras	TZA	Tanzania
IDN	Indonesia	UGA	Uganda
IND	India	URY	Uruguay
ISR	Israel	UZB	Uzbekistan
JOR	Jordan	VNM	Vietnam
KEN	Kenya	ZAF	South Africa

Note: This table lists the country codes and country names for 48 CDM host countries considered in this analysis. Data are from the UNEP Risoe Centre CDM/JI Pipeline Analysis and Database (2008).

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