Who Uses the Clean Development Mechanism? An Empirical Analysis of Projects in Chinese Provinces*

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Abstract

China is by far the largest host of projects implemented under the Kyoto Protocol's Clean Development Mechanism (CDM). However, earlier studies shed little light on the determinants of the distribution of CDM projects across Chinese provinces. Given China's large size and political-economic diversity, this dearth of research is troubling. We provide an empirical analysis of 2,097 CDM projects in 30 Chinese provinces, 2004-2009. We find that high electricity consumption, low per capita income, and a lack of foreign direct investment are all associated with CDM project implementation. The findings are particularly strong for electricity and foreign direct investment. These findings are consistent with the economic theory of CDM project implementation. Project developers focus on minimizing the cost of carbon abatement. Moreover, they suggest that the CDM can, despite its limitations, contribute to reducing economic inequality and uneven development in China.

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1 Introduction

To reduce the Kyoto Protocol's compliance cost, the Clean Development Mechanism (CDM) allows industrialized countries to substitute carbon credits, which are acquired from climate mitigation projects implemented by investors from developing countries, for domestic emissions reductions (CDM Pipeline, 2011). An important criterion for CDM carbon credits is "additionality," which states that eligible carbon abatement projects must not be economically feasible without the carbon credits. China is by far the most important host of carbon abatement projects implemented under the CDM. On December 1, 2011, China held 3,564 of the 8,836 projects that were available from the CDM/JI Pipeline Database (CDM Pipeline, 2011). This accounts for 40% of all CDM projects since 2003 that were registered, waiting for registration, or at validation stage under the regulations of the CDM. These projects allowed China to reduce its rapidly growing greenhouse gas emissions in various ways, ranging from hydroelectricity to wind power and avoiding methane from agriculture. This concentration of the CDM in China is understandable given that China is the world's largest developing economy and consumes enormous amounts of energy. Moreover, the Chinese government has actively promoted the CDM to increase investment in the energy sector and to induce technology transfer from industrialized countries (World Bank, 2004).

While China's dominance in the CDM is unsurprising, it is important to remember that China itself is a large and diverse economy. In this article, we conduct a statistical analysis of the distribution of CDM projects across Chinese provinces and over time. This analysis is useful because it helps scholars and practitioners understand exactly why China has proven such a lucrative CDM host. Additionally, the analysis allows us to test the applicability of standard economic theories, which emphasize the importance of carbon abatement costs for CDM project implementation, within one national legislative context. Finally, the analysis can offer lessons for other developing countries interested in increasing the use of the CDM. By analyzing the determinants of CDM project implementation in China, we can shed light on those regional characteristics that are conducive to CDM projects. This allows both governments in developing countries and foreign investors to plan their investments in the CDM more carefully.

The empirical analysis provides three key insights into the determinants of CDM project allocation. First, Chinese CDM projects are heavily concentrated in poorer provinces in China's interior, such as Yunnan or Sichuan, rather than in Guangdong and other rich coastal provinces that have become the world's factory. This finding is consistent with the logic of marginal abatement costs: poor provinces have less access to advanced technology than rich provinces, so opportunities for profitable carbon abatement are more abundant in poor than wealthy provinces. An industrial or energy development project in Yunnan absent CDM might use heavily polluting technology a generation or more behind the times, whereas the industrial economies of China's Yangtze and Pearl river delta regions are among the world's most sophisticated.

While consistent with previous research (Han and Han, 2011), the negative association between economic development and CDM implementation contrasts with findings from the empirical literature on the global distribution of CDM projects. In general, CDM projects are heavily concentrated in large and rapidly industrializing countries with institutional capacity for project implementation, including China (Jung, 2006; Michaelowa, 2007; Castro and Michaelowa, 2011). In our view, the internal logic in China is different because there is institutional capacity for project implementation even among the poorer Chinese provinces. This capacity explains why economic development reduces CDM implementation in China, even as it increases CDM implementation in the global setting. While many least developed countries in Sub-Saharan Africa have ample potential for carbon abatement, their institutional weaknesses inhibit CDM project implementation. This constraint is not present for poor Chinese provinces.

Second, Chinese CDM projects are more common in provinces that consume a lot of electricity. Again, this is consistent with standard economic theories, as electricity use creates opportunities for climate mitigation. Of the two effects, the effect of electricity consumption appears larger than that of GDP per capita, suggesting that the increased use of electricity is more important for the creation of CDM opportunities than the inefficiencies associates with low income levels.

Finally, we find that inflows of foreign direct investment (FDI) deter CDM project implementation. This finding may appear surprising because large FDI inflows mean that foreign investors have experience with, and information about a province. Despite much folklore about the paramount importance of connections (*guanxi*) in Chinese economic and political life, we find that other factors can trump such relationships. Project developers invest in CDM projects, not where FDI is directed, but in other locations. Large FDI inflows mean that the province already has access to foreign technology; moreover, production may already be relatively clean because foreign investors from industrialized countries have incentives to "green" their image by reducing their carbon dioxide emissions.

Our findings suggest that the distribution of CDM projects in China is economically efficient. The CDM has allowed China to reduce greenhouse gas emissions in provinces where the cost of doing so is low. For the future, the findings also suggest that unless the CDM system collapses due to the deadlock in multilateral climate negotiations, China will continue to benefit from the CDM. Large parts of China remain poor, consume rapidly growing amounts of electricity, and draw little FDI. Given this, China's bet on the benefits of the CDM seems warranted. Moreover, the Chinese government should pay particular attention to improving the quality of CDM projects, ensuring that they promote economic growth in a sustainable manner.

We begin with a brief discussion of our three hypotheses. Next, we provide an overview of the CDM in Chinese provinces. The remainder of the article consists of the presentation of our research design and our main results as well as a concluding section. A supplementary appendix contains additional data description and robustness tests.

2 Using the Clean Development Mechanism: Hypotheses

The CDM is a Kyoto Protocol "flexibility mechanism" (Article 12) that allows industrialized countries to reduce the cost of complying with their emissions obligations by funding climate mitigation projects in the developing world (UNFCCC, 2012). While developing countries are not obliged to reduce their emissions under the Kyoto Protocol, many developing countries could reduce their emissions at a low cost due to inefficient energy technology. The CDM allows industrialized countries to substitute carbon credits from developing country projects for domestic emissions reductions. In practice, the projects are usually implemented by project developers from the host country; therefore, the CDM is itself not a form of FDI (Lütken and Michaelowa, 2008).

According to economic theory, the use of the CDM should depend on the marginal cost of reducing greenhouse gas emissions. The global demand for carbon credits depends on carbon abatement costs in industrialized countries. Given the expected demand, project developers can be expected to implement potential CDM projects whenever the total project cost falls below the benefit. Building on this insight, we examine some determinants of CDM project allocation in the largest CDM host, China. In our empirical analysis, the unit of analysis is a province-year, so we examine province characteristics.

To begin with, we consider the role of electricity consumption. A large number of CDM projects are intended to reduce the otherwise large carbon footprint of the electricity sector. All else constant, then, we expect increased electricity consumption to increase the number of opportunities for profitable CDM projects. Provinces that consume a lot of electricity should host more CDM projects than provinces that consume little electricity, and if electricity consumption within a province grows over time, then the number of CDM projects hosted should increase.

Hypothesis 1 (electricity consumption and project implementation). *The higher a province's electricity consumption at a given time, the higher is the number of CDM projects implemented in that province at that time.*

Alternatively, one could focus on total energy consumption or greenhouse gas emissions. Total energy consumption is somewhat problematic for a CDM analysis because there is considerable variation in the suitability of different energy types for carbon abatement. For greenhouse gas emissions, accurate measurements at the province-year level are unfortunately not available. Another determinant of CDM project allocation is wealth. Within a given country, some areas are wealthier than other areas. According to economic theory, productivity is an important determinant of wealth (Grossman and Helpman, 1991; Keller, 1996). Since sustained economic growth requires productivity improvements, technological advances are important for economic growth. In a country like China, energy technologies play a particularly important role, as much of the economy's growth occurs in energy-intensive sectors such as manufactured exports.

Moreover, high levels of economic wealth are associated with a large service sector, with financial centers such as Shanghai playing an increasingly important role in China. Since the service sector often has a low energy intensity, it is not ideal for CDM projects. To illustrate, the data we use below shows that GDP per capita is, for province-years in the 2003-2011 period, positively correlated with the size of the service sector ($r = 0.601$, statistically significant at $p < 0.001$).

Consequently, it is reasonable to assume that, on average, wealthier provinces rely on more advanced energy technologies than poorer provinces. This means that the marginal cost of carbon abatement should be higher in wealthier than in poorer provinces. Consequently, poor provinces should host more CDM projects than wealthy provinces. This tendency would be further amplified by the Chinese government's incentive to support CDM project implementation in poor provinces that do not otherwise draw much foreign or domestic investment.

Hypothesis 2 (per capita income and project implementation). *The higher a province's per capita income at a given time, the lower is the number of CDM projects implemented in that province at that time.*

The third factor we consider is FDI. Here, formulating *a priori* expectations proves challenging. On the one hand, large previous or current FDI flows may mean that foreign investors have experience with the province, and this could reduce the transaction costs of project implementation. However, this argument ignores that increased FDI flows also mean that the province already has access to foreign technologies that enhance productivity (Saggi, 2002). Moreover, foreign investors may invest in emissions reductions to "green" their image; that is, for reputational reasons (Vogel, 2008). Consequently, FDI can be expected to reduce opportunities for profitable CDM projects. By enhancing productivity and improving energy efficiency, FDI increases the marginal cost of carbon abatement. In turn, this increased marginal cost reduces the profitability of CDM projects. Based on this logic, we can formulate the following hypothesis:

Hypothesis 3 (foreign direct investment and project implementation). *The higher a province's foreign direct investment flows at a given time, the lower is the number of CDM projects implemented in that province at that time.*

While foreign investors could also register with the CDM projects intended to green their image, this is only possible if these projects meet the additionality requirements of the CDM. To the extent that previous FDI reduces the energy intensity of production, it also prevents foreign investors from using the CDM for reputational purposes.

Notably, our argument for a negative association between FDI and the CDM is *not* political. We do not expect provincial governments in China to consider FDI and the CDM as substitutes. Since total FDI is a much larger factor than the CDM, we do not expect changes in FDI to shape political incentives in the provinces to implement CDM projects. Instead, our argument is based on the expectation that FDI shapes the profitability of CDM projects for economic reasons.

3 China and the Clean Development Mechanism

Before presenting our quantitative research design, we discuss the most important features of the CDM in the Chinese context. China's relationship to the CDM is a strong one. China is by far the biggest user of the program, intending to use the program to bring in investment and acquire new technologies as it continues its economic development and in particular building out its energy infrastructure.

While the CDM is a global initiative, China dominates the program in almost all categories. A single province in China's interior, Yunnan, alone boasts 276 CDM projects through the end of 2010. When compared to other countries, this total is staggering. Brazil and Malaysia, the third and fourth most popular host countries respectively, combined only have 270 projects (CDM Pipeline, 2011). As shown in Figure 1, China's dominance is a relatively recent phenomenon. In 2004 and 2005 combined, only 27 projects were submitted for registration, while in the year 2007 the number was 693.

[Figure 1 about here.]

As the world's most populous country and home to one of the top performing economies in the world, opportunities for CDM projects abound. China's economic growth has come with costs, and the environment – air and water quality in particular – have borne the brunt of these costs. Given that one of the CDM's key goals is to promote sustainable development, it is indeed important to note that environmental concerns are increasingly a critical part of the political landscape of China. The Government Work Report from Premier Wen Jiabao and the State Council delivered at the March 2012 National People's Congress noted the significance of the challenge and the government's efforts to address it. "We made progress in conserving energy, reducing emissions, and protecting the ecological environment" (Wen, 2012: 4). Middle class Chinese increasingly are demonstrating over environmental issues. In the southern city of Xiamen in 2007, large protests were held decrying the locating of a dangerous PX chemical plant too close to the city (Washington Post, 2007). In addition to these "not in my backyard" protests, calls for improved air quality in China's cities, as well as transparency in their measurement, are more and more common. Discrepancies abound between official Chinese pollution estimates and those from independent sources, such as an air quality monitor at the US Embassy in Beijing (Los Angeles Times, 2011). The CCP regime has set maintaining strong economic performance while avoiding such environmental catastrophes as a main goal. The CDM clearly fits these parameters.

Environmental concerns are not the sole driver of policy. The Chinese regime believes clean energy projects are an important industrial sector that domestic companies should compete in. To this effect, China has made it clear that technology transfer is also a goal of the policy, requiring that CDM projects must be implemented by a Chinese-owned entity or jointly with at least one Chinese-controlled entity (Curnow and Hodes, 2009: 28). This requirement is intended to facilitate the growth of domestic technical expertise. For our purposes, it also points to the possibility that since Chinese CDM projects must have a Chinese counterpart, provincial characteristics may be essential for understanding geographic variation in project implementation. We refrain from discussing the role of the foreign companies and governments who purchase the carbon credits, because their interests are largely aligned with those of the Chinese project developers: minimize the cost of carbon abatement to profit from the CDM.

That China's use of the CDM is in part industrial policy promoting sustainable development can also be observed through the taxes associated with profits from the projects. The Chinese government taxes revenue accruing from the sale of certified emissions reductions (CERs) differently depending on the type of project, with sustainable development projects being the beneficiaries of dramatically lower tax rates. Taxes range from 2% to 65% varying based on this sustainability criterion with renewable energy projects paying the lower rates. The revenues collected from taxes on the CERs are placed into a clean development fund to further enhance and promote China's sustainable industries (Curnow and Hodes, 2009: 65).

The system that the regime has created to manage CDM in China is indicative of the regime's overlapping jurisdictions. Similar to Brazil,the regulatory structure that China uses to approve projects is essentially an "Inter-Ministerial Committee" (Curnow and Hodes, 2009). China's political regime has long been characterized as "fragmented authoritarianism," and the large number of central ministries involved in the CDM process shows this remains the case (Lieberthal and Oksenberg, 1990). China's designated national authority for approving projects is the National Development and Reform Commission (NDRC) working with the Ministries of Foreign Affairs and of Science and Technology (Curnow and Hodes, 2009). Projects are evaluated based on assessments emanating from the National CDM Project Examination Board set up by the National Coordination Committee on Climate Change, which itself is led by the Ministry of Science and Technology and NDRC with other representatives coming from those two agencies along with the Ministries of Agriculture, Environmental Protection, Finance, and Foreign Affairs along with the China Meteorological Bureau (Curnow and Hodes, 2009: 22). In the provinces, China has also established "CDM service centers" that raise awareness of the CDM and support the implementation of projects (Schroeder, 2009*b*: 380). The Chinese National Development and Reform Commission's Department of Climate Change includes listings for twelve provincial service centers in their list of CDM consulting agencies: Hunan, Gansu, Guangdong, Ningxia, Hebei, Shanxi, Jiangsu, Hubei, Sichuan, Guizhou, Yunnan, and Shandong (Department of Climate Change, 2012). According to Wang (2010), domestic consultants and local governments represent critical actors in the successful development and monitoring of CDM projects (e.g., Ningxia CDM Service Center, 2009). Despite the large number of players involved, the political and bureaucratic processes have not been too arduous to keep CDM projects from taking off in China like nowhere else.

The geographic distribution of the projects does not align with conventional views of China's economic development: most CDM projects are not located in the rapidly growing eastern coastal provinces. Figure 2 shows the cumulative number of CDM projects in Chinese provinces through 2009. Whereas much of China's economic rise emanates from coastal factories in the east, the projects are mostly located in the interior and western provinces, where industry's presence in the economy is limited and often resource-related (Niederberger and Saner, 2005). These interior provinces are not where other FDI tends to locate itself and remain areas where the primary sector (farming) remains a prominent part of the economy. While to some extent the map corresponds to renewable energy resources, the correlation is imperfect as Xinjiang, in the far northwest, is known for having tremendous wind resources in addition to its fossil fuel deposits.

[Figure 2 about here.]

Several scholars have analyzed the CDM in China, though mostly from a descriptive or speculative perspective. For example, Wang and Chen (2010) describe CDM projects in China through 2009, arguing that there are three major barriers to using CDM to promote renewable energy: the difficulty of demonstrating the "additionality" of emissions reductions, the high cost of renewable energy, and the lack of technology transfer from abroad to China. According to Schroeder (2009*b*), who analyzes the CDM in China from a political perspective, the central government is actively using the CDM to promote its economic goals by promoting technology transfer and directing CDM projects into priority sectors, such as energy conservation and renewables. However, these studies do not present testable hypotheses that could be falsified. In what follows, we test our hypotheses concerning the CDM's geographic distribution in China.

4 Quantitative Analysis

To test our hypotheses, we collected data on the number of CDM projects in 30 Chinese provinces for the years 2004-2009. The temporal coverage is determined by data availability for the explanatory variables. The "provincial level" includes provinces as well as "autonomous regions" and "municipalities." China is divided into 31 provincial units, but Tibet is omitted due to missing data. The CDM data were provided by the CDM Pipeline (2011) and include registered projects as well as projects waiting for registration and at the validation stage. The unit of analysis is province-year. We examine whether the values of three key explanatory variables (electricity, per capita income, and FDI inflows) predict the number of new CDM projects in a province-year. To do so, we estimate negative binomial regressions with random effects. Overall, we have 179 observations, or an almost perfectly balanced panel.

4.1 Dependent Variable

The dependent variable is the number of new CDM projects implemented in a province-year. In our dataset, the value of this variable ranges from zero (for example, Anhui and Hainan in years 2004 and 2005) to 100 (for example, Yunnan in 2007). In Table 1 we summarize the number of CDM projects by region, province, and year.

Counting the number of new CDM projects is warranted for several reasons. First, count models can account for non-normal distributions. If we instead computed total carbon abatement in a province-year, large individual projects could produce severe outlier problems. Second, using cumulative total abatement instead of project counts may be problematic as this measure depends on the "stock" of CDM projects in a given province. Provinces with many projects in the early years of the CDM will necessarily have higher cumulative abatement levels; this would unduly bias our results towards projects implemented during the early years of the CDM. Third, emissions reductions are expected in the future, so they cannot be directly measured. Finally, in the supplementary appendix we show that the average number of CDM projects in a province during the time period of investigation is highly correlated with expected total abatement by 2020 ($r = 0.598$, statistically significant at $p = 0.01$ level); on the contrary, there is no statistically significant correlation between the average number of CDM projects and average expected abatement from a project in a province. Indeed, the five provinces with the highest number of projects (Yunnan, Sichuan, Inner Mongolia, Hunan, Gansu) produce 26% of expected carbon abatement by 2020.

In addition to analyzing the distribution of all projects, we examine separately the count of new renewable and non-renewable projects for each province-year. Analyzing these categories is important because the determinants of renewable and non-renewable projects could be quite different. For example, good wind conditions should presumably increase the number of renewable projects, without having a corresponding effect on the number of non-renewable projects. By distinguishing between different types of CDM projects, we can also examine whether our hypotheses hold equally well across renewable and non-renewable projects. The insights from this additional analysis will be discussed below.

[Table 1 about here.]

4.2 Main Explanatory Variables

To test our hypotheses, we need data on three main explanatory variables. The first is electricity consumption. This explanatory variable captures the idea that high electricity consumption creates profitable opportunities for carbon abatement. This is particularly appropriate for China because the country is heavily dependent on coal, which has the highest carbon content of all traditional fossil fuels. The data are measured in trillion kilowatt hours and found in the China Energy Statistical Yearbook.

Our second explanatory variable is real GDP per capita in US$ in constant 2005 prices. We normalize this variable to obtain a measure of economic wealth net of inflation. To do so, we use economic data measured in yuan and current prices as provided by the University of Michigan's (China Data Online, 2012). We convert the data into constant 2005 US$ using yuan-dollar exchange rates provided by the Board of Governors of the Federal Reserve System. This variable captures relative economic wealth in a province at a given time. As real GDP per capita increases, we expect the number of CDM projects to decrease.

Our third explanatory variable is inflow of FDI. As FDI increases, we expect the number of CDM projects to decrease. The data are measured in billion US$ and are provided by the China Data Online database as well. Distributions of all three of our main explanatory variables can be found in the supplementary appendix.

4.3 Additional Variables

Our goal is to build a parsimonious statistical model of CDM project distribution across Chinese provinces and over time. Nonetheless, we add several potentially important control variables to our regressions. First, to account for size differences across provinces, we control for total population. The data are measured in millions and come from the China Data Online database. Intuitively, one might expect population to increase the number of CDM projects, if only due to scale effects.

Second, we control for real economic growth. The data are measured in percentage points relative to the previous year, where previous years are indexed by 100. For example, a measure of 125 on our growth variable in 2007 translates into real economic growth of 25% against a 2006 baseline. These data also come from the China Data Online database. Even controlling for total electricity consumption and real GDP per capita, it may be that project developers exploit the opportunities provided by a growing economy. Therefore, we complement our set of additional variables with a control for economic growth.

Third, we control for the value of primary production (farming, forestry, animal husbandry, and fisheries) in a province at a given time. To avoid very high collinearity with our population measure, we normalize this variable relative to total GDP. Our primary sector variable, therefore, captures the share of primary production relative to total production in a given province-year. It seems plausible that provinces with relatively large primary sectors encourage CDM project implementation, because primary production is usually highly energy intensive. Again all data is taken from the China Data Online database. Histograms for all our three control variables can be found in the supplementary appendix.

Since CDM project allocation is likely to be influenced by differences in solar, wind, or hydroelectricity potential across Chinese provinces, we add binary control variables for all three categories to all our models. To code solar potential, we use direct normal radiation data, provided by the (National Renewable Energy Laboratory, N.d.) Hang et al. (2008: 2510) emphasize that solar installations are only economical with more than 5 kWh per square meter per day, which allows us to code all provinces above that threshold as "1" for our solar potential dummy. All other provinces are coded zero. With this coding scheme, the following provinces hold solar potential: Gansu, Inner Mongolia, Qinghai, Tibet, and Xinjiang. For wind potential, we draw on a map detailing the wind-generated electricity potential by McElroy et al. (2009: 1378);

again, we construct a dummy variable for high and low wind potential. Using capacity factors of deployment for 1.5 MW turbines that are above the Chinese average of 23% (McElroy et al., 2009: 1378) as a threshold, we classify Beijing, Hebei, Heilongjiang, Inner Mongolia, Jilin, Liaoning, Shandong, Shanxi, Tianjin, and Tibet as provinces with high wind potential. Finally, provinces named in Huang and Yan (2009: 1654) "to have an abundance of hydro resources" are coded as "1" for our hydroelectricity dummy and zero otherwise. This classifies the following provinces as having high hydroelectricity potential: Chongqing, Fujian, Gansu, Guangdong, Guangxi, Guizhou, Hubei, Hunan, Jiangxi, Jilin, Liaoning, Qinghai, Shanxi, Sichuan, Yunnan, Zhejiang. While these binary categorizations are crude, they align well with the conventional wisdom on renewable energy potential in China. The northern parts in Inner Mongolia, Jilin, and Heilongjiang, for instance, hold considerable potential for wind energy, provinces through which the Yangtze or Yellow River are flowing have abundant access to hydro resources, and the southwestern provinces close to the Tibetan plateau, such as Tibet, Qinghai, or Xinjiang promise enormous solar potential.

Besides these renewable potential controls, all our models include year fixed effects to account for temporal trends. We also include regional fixed effects to account for geographic differences, other than solar, wind, or hydroelectricity potential, that could explain CDM project distribution. Here, we divide Chinese provinces into the following six geographical regions: North China (Beijing, Hebei, Inner Mongolia, Shanxi, Tianjin), Northeast China (Heilongjiang, Jilin, Liaoning), East China (Anhui, Fujian, Jiangsu, Jiangxi, Shandong, Shanghai, Zheijang), South-Central China (Hainan, Henan, Hubei, Hunan, Guangdong, Guangxi), Southwest China (Chongqing, Guizhou, Sichuan, Tibet, Yunnan), Northwest China (Gansu, Qinghai, Ningxia, Shaanxi, Xinjinag). We do not include province fixed effects because we only have six years of data for each province.

The summary statistics for our regressions are provided in Table 2. The table shows that for both the dependent and independent variables, there is considerable variation across observations. Perhaps most importantly, the dependent variable does not appear normally distributed. Our count model was specifically chosen to account for the distribution of count data.

[Table 2 about here.]

A correlation matrix can be found in Table 3. The bivariate correlations show some interesting facts. First, there is no correlation between the number of CDM projects and real GDP per capita or FDI, respectively. Second, electricity consumption is positively correlated both with real GDP per capita and FDI. These observations highlight the importance of a careful multivariate statistical analysis. Since we expect electricity consumption to increase the number of CDM projects, while FDI and per capita income should decrease this number, the fact that electricity is positively correlated with the other two explanatory variables is not a problem. However, we must acknowledge that the high correlation between FDI and real GDP per capita creates some uncertainty surrounding their relative importance in the regressions below. Since both are expected to influence CDM project implementation through similar causal channels, based on the cost of carbon abatement, this uncertainty is not an obstacle to meaningful inference.

[Table 3 about here.]

4.4 Statistical Model

We estimate a negative binomial model with random effects to account for unobserved differences between provinces. This model accounts for the fact that our dependent variable is count. To test for zero inflation, we implemented the Vuong (1989) test and were able to reject the null hypothesis of zero inflation. According to likelihood ratio tests, the random effects are also warranted: we can reject the null hypothesis that the distribution of the error terms is the same across the provinces.

4.5 Findings

The results of the regression analysis are presented in Table 5. Models (1)-(3) examine the distribution of all CDM projects, while models (4)-(6) focus on renewable and models (7)-(9) on non-renewable CDM projects. Other than this distinction, the models are only differentiated by the choice of control variables. All models include renewable potential dummies for solar, wind, and hydroelectricity potential as well as year and region fixed effects.

[Table 4 about here.]

The results provide some support for all three hypotheses. Consider first electricity consumption. In models (1)-(3), electricity consumption has a positive coefficient throughout and is always statistically significant at conventional levels. Equally important, the coefficient is large: as we demonstrate below, changes in electricity consumption have large effects on the expected number of CDM projects that a province implements at a given time. This finding is consistent with the notion that the availability of inexpensive carbon abatement opportunities is a key determinant of CDM project implementation in China.

Real GDP per capita has a consistently negative coefficient, though it lacks statistical significance in one out of the three main models. Given the high correlation between our income and primary sector variables, it is unsurprising that statistical significance of income decreases due to instability in the estimation of regression coefficients. This suggests that higher wealth levels reduce the number of CDM projects, which is consistent with standard economic theory. The sign on FDI is also negative and strongly statistically significant in all three models. As discussed above, this suggests that CDM projects in China are implemented in regions that would not otherwise attract a lot of investment. The results for renewable and non-renewable projects are remarkably similar. Despite minor differences in the degrees of statistical significance, this suggests that the logic of CDM project implementation in China is not dependent on project type.

For our population and economic growth control variables we find virtually no effects, even though all of the signs are positive. The primary sector variable capturing the share of GDP produced in the primary sector shows an interesting pattern. While this coefficient is non-significant in model (3), it has a strongly positive and statistically significant influence on *renewable* CDM project allocation, but shows a negative and statistically significant effect for *non-renewable* CDM projects. Primary sector production is extremely carbon intensive, and our analysis suggests that, controlling for renewable potential, renewable projects are a more cost-effective way to bring down carbon emissions than non-renewable projects.

Assessing the effects of our renewable potential controls is not straightforward, as focusing on single coefficients may be misleading. As shown in the supplementary appendix, wind potential has a negative, but statistically insignificant sign in all nine models, while solar and hydroelectricity potential tentatively increase the number of CDM projects in the first six models. Interestingly, for non-renewable CDM projects all renewable potential dummies, except for hydroelectricity potential in model (8), show negative signs, some of which are statistically significant. This lends further credibility to the classification of our potential dummies. Moreover, likelihood ratio tests for all nine models indicate that including the full set of renewable potential dummies for wind, solar, and hydroelectricity potential considerably increases the model fit in the models with renewable project count as dependent variable, but does not show any improvement in models (7) to (9) for non-renewable projects.

To illustrate the magnitude of the effects of these factors, we simulated the first differences in predicted numbers of CDM projects (King, Tomz, and Wittenberg, 2000). Figure 3 shows differences in the number of CDM projects when we increase our key explanatory variables from the mean to one standard deviation above the mean. The simulated effects are based on model (3) with all continuous variables at their means and all binary variables at their median values. Renewable potential controls, region, and year fixed effects are also held at their medians.

First and foremost, these simulated differences indicate that the number of CDM projects decreases with increasing FDI inflows, but increases for higher levels of electricity consumption. In addition to this, we can also infer that the absolute value of these differences is the highest for electricity consumption. An increase by one standard deviation in electricity consumption increases the number of CDM projects by 5.93 on average, while the same change decreases the number of CDM projects by 2.61 for foreign direct investments. Hence, the impact of a change in electricity consumption is more than twice as high as a corresponding change in FDI inflows.

Figure 3 also shows that the effect of increasing GDP per capita from its mean to one standard deviation above is negative, but small and statistically insignificant. This result is not surprising because our simulations are based on our comprehensive model (3), where the GDP coefficient is statistically insignificant. Given the high negative correlation between our GDP variable and the primary sector control ($r = -0.732$), the standard errors are inflated, and so levels of statistical significance decrease. Indeed, the coefficient for GDP per capita is larger in models (1) and (2).

[Figure 3 about here.]

In the supplementary appendix, we analyze the robustness of the results. First, if we account for the large number of zeroes in our data by using a zero inflated negative binomial model, our original results are actually stronger: all signs remain unchanged, and the statistical significance of the results is improved. Second, we include a series of political variables. Neither the age of the provinces' governor nor the age of the provincial party secretary seems to influence outcomes, so it initially seems as if the new thinking of younger leaders is not driving CDM project implementation. Moreover, leadership turnover appears to have no effect. However, we do find some support for the hypothesis that the retirement of a governor or party secretary is important: these retirements increase CDM project implementation. Overall, new leaders initially seem to increase CDM project implementation, but the effect disappears soon. The increase is particularly strong for renewable CDM projects, while coefficients for non-renewable projects are estimated to be positive, but statistically insignificant. This resonates with the idea that renewable CDM projects seem to be particularly attractive for incoming political leaders.

The supplementary appendix also reports a descriptive analysis of technology transfer based on data from the UNFCCC (2010). The data were coded by a UNFCCC research team. We only have these data for the years 2006-2009, so we cannot use it in a regression analysis. The key variable is a binary indicator for technology transfer, and the coding is based on the project design documents. Any project featuring foreign imports of equipment or knowledge is coded as "1", while any projects that explicitly denounces technology transfer or fails to mention it is coded as "0". Interestingly, we find that the more projects a province implements on average, the lower the share of projects that feature technology transfer (see also Wang, 2010). This observation can be interpreted in three ways. First, poorer provinces may be able to implement profitable projects that do not require advanced foreign technologies. Second, the Chinese government's technology transfer strategy is only partially successful, as technology transfer is most common in provinces that need it the least. Finally, technological learning from projects may reduce the need for additional foreign transfers.

Since urban CDM projects, especially in the transportation and building sectors are more difficult to register under the CDM scheme, we checked if these projects can affect our results.

Since our dataset only comprises 21 transportation and energy efficiency household projects, we find that differences in applicable baselines and methodologies indeed affect the demand for CDM registration, but cannot bias our main results.

5 Conclusion

Our findings illuminate the distribution of CDM projects in China. Examining the implementation of CDM projects in 30 Chinese provinces for the years 2004-2009, we have found three important determinants: electricity consumption (positive effect), real GDP per capita (negative, if small, effect), and FDI (negative effect). In our interpretation, these results are consistent with the economic theory of CDM project implementation. Project developers focus on minimizing the cost of carbon abatement. What is more, the results are consistent with the Chinese government's using CDM as an instrument of development, as poor provinces that obtain little FDI are given priority in China. In contrast, our political variables do not seem to influence CDM project implementation in Chinese provinces.

These results corroborate many central arguments from the extant literature on CDM project implementation. As Lütken and Michaelowa (2008) have argued, the economic logic seems central to project implementation. Castro (2012) finds that most developing countries continue to have considerable potential for implementing projects with low abatement costs, and the Chinese case supports the argument.

For Chinese politics, the findings also offer some useful insights. According to our findings, the CDM allows project developers in poorer provinces to enhance the profitability of project implementation. Given China's uneven pattern of development, with the coastal provinces growing much more rapidly than most inland provinces, the CDM seems to hold potential as a way to promote development in remote and backward parts of the country. Equally important, the CDM could promote sustainable development in areas that have traditionally been heavily dependent on coal mining and burning, such as Inner Mongolia. While we cannot establish that the CDM projects are genuinely additional, so that they would not have been implemented without the carbon credit system, CDM projects frequently feature transfers of clean technology and increase, at least on the margin, the profitability of climate mitigation. Indeed, available evidence suggests that the CDM has supported the deployment of renewable energy in China (Schroeder, 2009*a*; Lewis, 2010), but inconsistencies between international rules and China's policies have prevented the central government from realizing the CDM's full potential.

Our findings also raise new questions for future research. First, does the pattern we identified for China also hold in other major CDM host countries, such as India and Brazil? According to economic logic, the same covariates that predict CDM project implementation in China should also predict CDM project implementation elsewhere. Data on the provinces that implement CDM projects are also available for other host countries, so this analysis is eminently feasible. Second, do political factors affect the CDM in China? Our initial findings do not lend support to political considerations, but we caution against jumping into conclusion based on a preliminary analysis. Many other political factors, such as interest group strength and corruption in implementing agencies, could be more important than the leader characteristics we have analyzed.

As to policy implications, our findings suggest that improving governance capacity in the least developed countries could promote CDM project implementation in them. In China, economic wealth is negatively associated with CDM project implementation, while the opposite is true on a global scale. We suspect that improved governance capacity could significantly promote CDM projects in Africa, where opportunities for carbon abatement are abundant.

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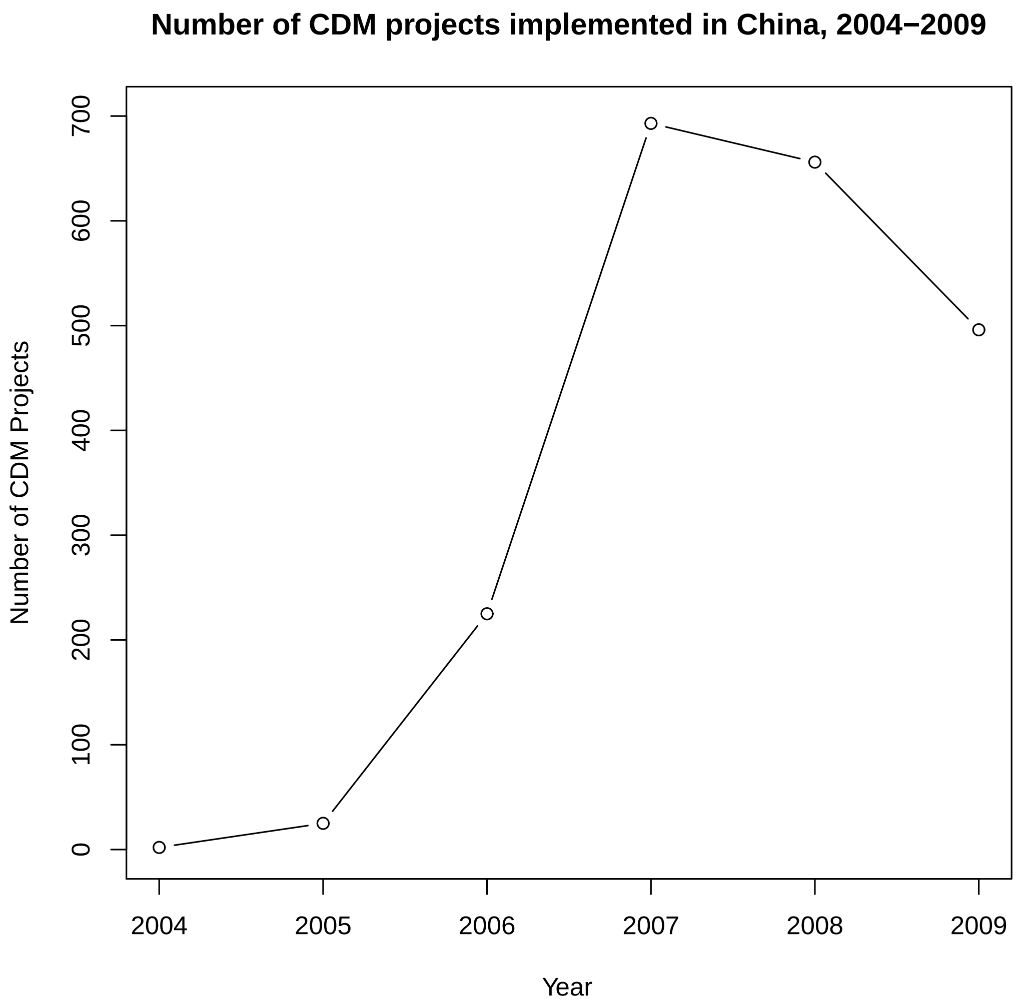

Figure 1: Total number of CDM projects in China through 2009.

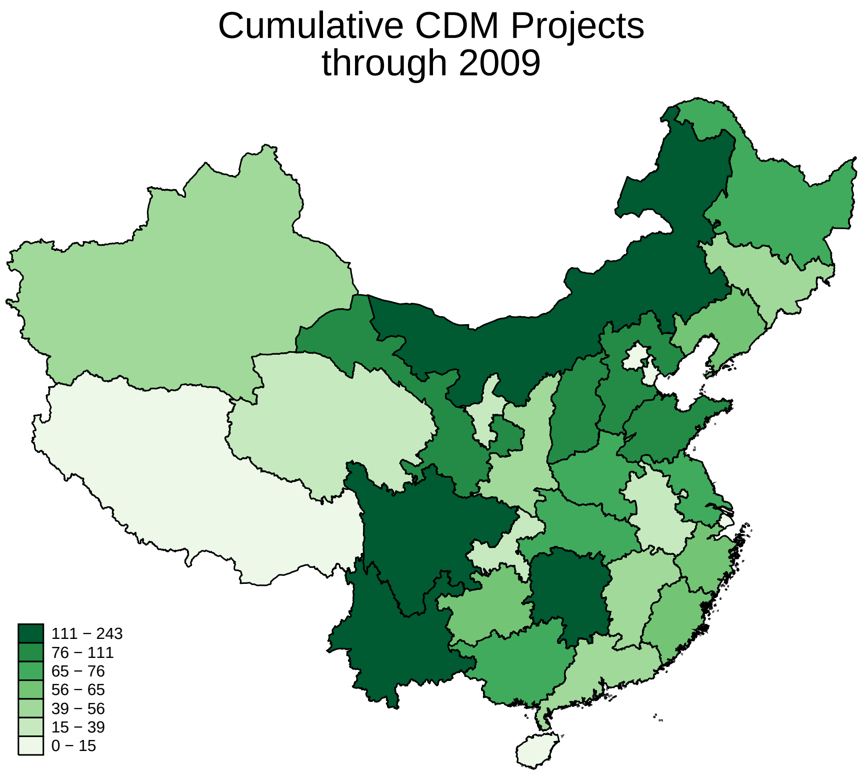

Figure 2: Total number of CDM projects in different Chinese provinces through 2009.

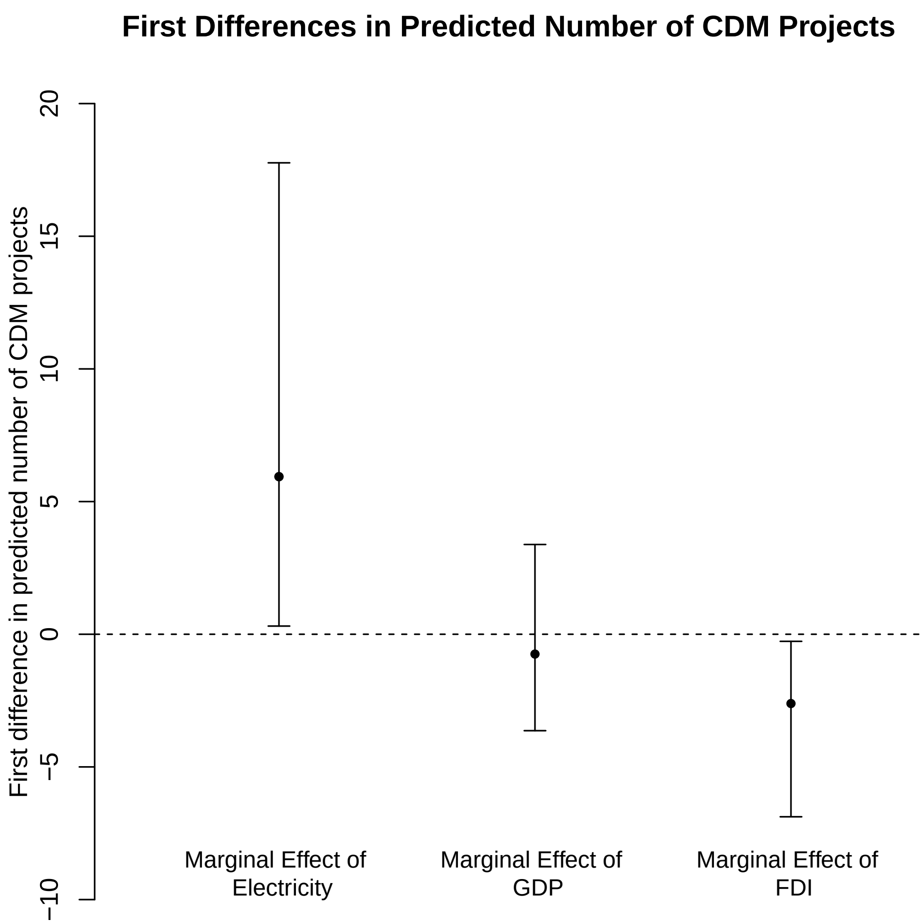

Figure 3: Simulated first differences in predicted numbers of CDM projects for changes in electricity consumption, real GDP, and FDI from the mean to one standard deviation above the mean. The errors bars indicate 95% confidence intervals.

Distribution of CDM projects by region, province, and year

#	Province	2004	2005	2006	2007	2008	2009	Sum
	Northern Provinces							349
1	Beijing	1	0	0	6	3	1	11
2	Hebei	0	1	11	19	28	30	89
3	Inner Mongolia	1	0	16	36	57	47	157
4	Shanxi	0	1	7	44	23	13	88
5	Tianjin	0	0	1	0	3	0	4
	Northeastern Provinces							182
6	Heilongjiang	0	0	8	13	24	23	68
7	Jilin	0	5	6	11	18	16	56
8	Liaoning	0	2	7	16	18	15	58
	Eastern Provinces							385
9	Anhui	0	0	9	14	9	7	39
10	Fujian	0	1	4	15	30	14	64
11	Jiangsu	0	3	13	23	18	10	67
12	Jiangxi	0	0	3	12	17	13	45
13	Shandong	0	2	17	20	38	21	98
14	Shanghai	0	0	1	5	4	4	14
15	Zhejiang	0	1	10	10	23	14	58
	South-Central Provinces							413
16	Hainan	0	0	2	1	10	2	15
17	Henan	0	0	11	20	20	25	76
18	Hubei	0	0	3	28	26	15	72
19	Hunan	0	1	17	51	28	26	123
20	Guangdong	0	3	4	20	14	12	53
21	Guangxi	0	0	5	31	22	16	74
	Southwestern Provinces							533
22	Chongqing	0	0	8	6	15	7	36
23	Guizhou	0	0	9	39	7	10	65
24	Sichuan	0	0	13	76	72	28	189
25	Tibet	na	na	na	na	na	na	na
26	Yunnan	0	1	8	100	69	65	243
	Northwestern Provinces							235
27	Gansu	0	1	26	30	29	25	111
28	Qinghai	0	0	0	14	3	1	18
29	Ningxia	0	2	3	6	5	6	22
30	Shaanxi	0	0	1	17	13	13	44
31	Xinjiang	0	1	2	10	10	17	40
	Total	2	25	225	693	656	496	2,097

Table 1: Number of CDM projects by region, province, and year.

Summary statistics

	count	mean	sd	min	max
CDM Projects (#)	179	11.72	15.92	0.00	100.00
Electricity Consumption	179	0.10	0.08	0.01	0.36
Real GDP p.c.	179	2.54	1.79	0.82	10.17
FDI	179	3.76	4.86	0.02	25.32
Wind Potential	179	0.30	0.46	0.00	1.00
Solar Potential	179	0.13	0.34	0.00	1.00
Hydroelectricity Potential	179	0.54	0.50	0.00	1.00
Population	179	43.41	26.23	5.39	101.30
Economic Growth	179	112.99	2.08	105.40	120.50
Primary Sector (% of GDP)	179	0.13	0.07	0.01	0.35

Table 2: Summary statistics for all CDM projects in China. The summary statistics are based on the sample including the control variables discussed above.

Correlation matrix

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) CDM Projects (#)	1.000									
(2) Electricity Consumption	0.226**	1.000								
(3) Real GDP p.c.	-0.078	0.311***	1.000							
(4) FDI	0.017	0.807***	0.574***	1.000						
(5) Wind Potential	0.006	0.072	0.285***	0.033	1.000					
(6) Solar Potential	0.059	-0.233**	-0.155*	-0.253***	-0.066	1.000				
(7) Hydroelectricity Potential	0.161*	-0.044	-0.330***	-0.105	-0.256***	-0.011	1.000			
(8) Population	0.223**	0.765***	-0.121	0.461***	-0.088	-0.362***	0.070	1.000		
(9) Economic Growth	0.063	0.037	0.008	0.089	0.212**	0.013	-0.085	0.056	1.000	
(10) Primary Sector (% of GDP)	0.074	-0.378***	-0.732***	-0.503***	-0.340***	0.091	0.144	0.054	-0.121	1.000

Table 3: Correlation matrix for all CDM projects in China. The correlations are based on the sample including the control variables discussed above.

Main regression results									
	(1) Model	(2) Model	(3) Model	(4) Model	(5) Model	(6) Model	(7) Model	(8) Model	(9) Model
Electricity Consumption	7.824***	4.945*	5.652**	7.265***	5.336	7.726**	8.237***	5.259*	3.694
	(1.725)	(2.663)	(2.662)	(2.582)	(4.002)	(3.768)	(1.819)	(2.700)	(2.643)
Real GDP p.c.	-0.207***	-0.145*	-0.071	-0.222**	-0.183*	0.043	-0.186***	-0.114	-0.248**
	(0.068)	(0.075)	(0.094)	(0.097)	(0.106)	(0.126)	(0.067)	(0.076)	(0.096)
FDI	-0.061**	-0.059**	-0.059**	-0.057	-0.055	-0.062	-0.052*	-0.052*	-0.046*
	(0.028)	(0.029)	(0.028)	(0.042)	(0.043)	(0.040)	(0.029)	(0.029)	(0.028)
Population		0.012	0.012*		0.008	0.008		0.014*	0.013*
		(0.007)	(0.007)		(0.011)	(0.010)		(0.008)	(0.008)
Economic Growth		0.028	0.037		0.023	0.051		0.043	0.029
		(0.027)	(0.028)		(0.037)	(0.038)		(0.031)	(0.031)
Primary Sector (% of GDP)			3.385			9.957***			-6.022**
			(2.659)			(3.509)			(2.947)
Year Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Renewable Potential Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	179	179	179	179	179	179	179	179	179
Likelihood ratio tests: full model against model without renewable potential controls.									
LR-test statistic, $\chi^2(3)$	5.43	7.17	7.99	7.72	8.32	11.51	3.49	3.33	1.83
p-value	0.142	0.066	0.046	0.052	0.039	0.009	0.322	0.343	0.608

Standard errors in parentheses
Dependent Variable in Models (1) to (3): Number of CDM Projects.
Dependent Variable in Models (4) to (6): Number of Renewable CDM Projects.
Dependent Variable in Models (7) to (9): Number of Non-renewable Projects.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4: Main regression results from random effects model.