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Mark T. Buntaine[a] & William A. Pizer[b]
[a] Bren School of Environmental Science & Management, University of California, 2400 Bren Hall, Santa Barbara, CA 93106, USA
[b] Sanford School of Public Policy, Duke University, Duke Box 90239, Durham, NC 27708, USA
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Encouraging clean energy investment in developing countries: what role for aid?

MARK T. BUNTAINE[1]*, WILLIAM A. PIZER[2]

[1] Bren School of Environmental Science & Management, University of California, 2400 Bren Hall, Santa Barbara, CA 93106, USA
[2] Sanford School of Public Policy, Duke University, Duke Box 90239, Durham, NC 27708, USA

A large portion of foreign assistance for climate change mitigation in developing countries is directed to clean energy facilities. To support international mitigation goals, however, donors must make investments that have effects beyond individual facilities. They must reduce barriers to private-sector investment by generating information for developers, improving relevant infrastructure, or changing policies. We examine whether donor agencies target financing for commercial-scale wind and solar facilities to countries where private investment in clean energy is limited and whether donor investments lead to more private investments. On average, we find no positive evidence for these patterns of targeting and impact. Coupled with model results that show feed-in tariffs increase private investment, we argue that donor agencies should reallocate resources to improve policies that promote private investment in developing countries, rather than finance individual clean energy facilities.

Policy relevance

We suggest that international negotiations could usefully shift the focus of climate change finance towards adaptation in exchange for mitigation-improving policy reforms in developing countries. There is little evidence that mitigation-related financing is having broader effects on energy production, so new financial arrangements should be the focus of future negotiations. Additionally, international donors should focus efforts on reforming policies to attract private investment.

Keywords: clean energy; climate change; finance; foreign aid; investment

1. Introduction

In the next two decades, GHG emissions from energy production in developing countries are expected to increase by more than 50%, which will eclipse even the most ambitious mitigation efforts by developed countries (Clarke et al., 2009; IEA, 2010, pp. 68–69).[1] The International Energy Agency (IEA) predicts that 93% of the increase in energy demand between 2010 and 2035 will originate in developing countries, with a projected US$30 trillion of investment in new energy production (IEA, 2010). International climate negotiations have increasingly focused on financing mitigation in developing countries as a response. In the 2009 Copenhagen Accord, developed countries committed to 'mobilizing jointly 100 billion dollars a year by 2020 to address the needs of developing countries', including both public and private funds for climate change mitigation and adaptation.

To play a role in meeting international mitigation goals, donor financing of clean energy production will need to catalyse private financing at a much larger scale. Private financing already supports the

*Corresponding author. *E-mail*: buntaine@bren.ucsb.edu

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majority of clean energy production worldwide, including in developing countries (UNEP & Frankfurt School, 2012). Donor financing is too limited to reach mitigation goals directly, even under optimistic scenarios, which has made policy makers search for a broader catalytic impact. As US Secretary of State Hillary Clinton predicted about the US contribution to the United Nations Sustainable Energy for All initiative at the Rio + 20 conference in June 2012, 'the United States and African Nations will use $20 million in U.S. Government funding to unlock hundreds of millions of dollars in private financing for clean energy projects in Africa and beyond.'[2] Yet, this crucial assumption – that donor financing can be used to catalyse private investment in clean energy – remains largely untested.[3] To have this catalytic effect, donor financing must improve the investment environment for the private sector beyond individual facilities.

For many donor agencies, the majority of mitigation-related funding is directed to commercial-scale clean energy facilities.[4] While these investments directly result in new facilities, they often aim to have broader indirect effects, including new infrastructure, reformed policies, or operational experience. If accompanied by the necessary technology developments and domestic policy reforms in donor countries, these broader effects might support and catalyse investment by the private sector in developing countries at a scale needed to meet international mitigation goals.

Opportunities for broader catalytic effects are numerous. Clean energy facilities depend on transportation networks and electricity grids for operations. Private-sector clean energy projects require appropriate policies on foreign investment, energy tariffs, power grid regulations, permitting, and possibly clean energy subsidies. New institutions or regulatory processes that are established as part of donor investments in facilities might support private investment along these dimensions. Donor investments in facilities also provide recipient countries with an opportunity to showcase a commitment to the successful planning and operation of clean energy facilities, offering a signal to potential investors about the implementation of future projects. Given the small scale of donor investment compared to the private sector, these indirect effects are likely to be the most important impacts that donors can achieve.

In light of the potential for broader effects, we ask whether investments in clean energy facilities are successful at *indirectly* improving the investment environment and catalysing private-sector investment. If this is not the case, resources should be targeted differently. There are certainly reasons to think that donor agencies will not catalyse the private sector, despite the potential for broader catalytic effects. Donors might direct projects to countries where the private sector is already viable, thus crowding out private investment, or to countries where the risks to the private sector are overwhelming and not likely to be overcome by project finance. Private investors might take donor investments as a signal that there are few profitable opportunities in a particular country or sector. Recipient governments might even delay the policy reforms that are needed to attract private investment when they face lower financial pressure from donors that are unlikely to withdraw from unprofitable projects.

To bring some clarity to this debate, we investigate whether investments in commercial-scale wind and solar facilities by donor agencies, such as the World Bank or the German KfW Development Bank, are targeted to countries with limited private investment and whether they increase private investment over time. We choose to focus on the wind and solar sectors because by 2012 they represented 90% of worldwide investment in new renewable energy production, with developing countries attracting almost half of all new investment (UNEP & Frankfurt School, 2013, pp. 17–21). Wind and solar energy also have the greatest potential to achieve the scale needed to transform energy systems (Delucchi & Jacobson, 2011; Jacobson & Delucchi, 2011).

We argue that to be catalytic, donors should invest in facilities and countries that are not being financed by the private sector. For a particular type of clean energy facility in a given country, as private-sector investments accumulate, the number of donor investments should wane. Additionally, if donor financing catalyses private investment, we should observe a faster accumulation of private investments in countries where donors are early investors compared to countries where they are not. We test these hypotheses using a dataset of financial deals for individual wind and solar power facilities around the world, compiled by Bloomberg New Energy Finance.

Despite optimism about a catalytic effect, we find little evidence that donors are catalysing the private sector by financing clean energy facilities. On average, donor agencies target their investments to countries that already have substantial private investment for the same types of facilities. When donor agencies are early investors, we find no evidence that they make private investment more likely in later years when compared to countries where they are not early investors. Coupled with model results showing that domestic feed-in tariffs increase private investment, we argue that donor agencies should shift away from financing facilities and instead support policy reforms, infrastructure, institutions, and processes. Further work will be needed to identify the best actions to support an improved investment environment for clean energy, including the interaction between donor programmes and important domestic efforts that do not directly hinge on financing. More broadly, this article contributes to a growing literature about the role of aid in promoting private-sector development and describes several constraints on this process.

The present results ultimately have implications for international negotiations. Donors have often emphasized mitigation over adaptation finance in climate change negotiations, because mitigation delivers global environmental benefits, but adaptation does not. If the real global benefits come from policy reforms that support private investment in clean energy, we argue that donors might shift resources into adaptation in exchange for mitigation-improving policy reforms.

2. Theory and hypotheses

2.1. Defining the catalytic effect

The notion of a 'catalytic effect' has become a common refrain from donor agencies (Meles & Stoltenberg, 2010, para. 28; World Bank, 2008, para. 13). Documents and websites of donor agencies are filled with claims about how their investments in clean energy facilities will create the conditions necessary for much larger volumes of private investment. This is a departure from past focus, when donor agencies pursued additionality – financing that allows individual clean energy projects to go forward where they would not under private market forces (Greiner & Michaelowa, 2003). A 'catalytic investment' improves the investment environment for the private sector beyond an individual facility (Edgren, 2002), making it both harder to achieve and more desirable.

We define a catalytic investment in terms of the existing investment environment and the expectation for future private investment. Conceptually, we distinguish between countries and sectors with sustained private-sector investment and countries and sectors without it. A catalytic investment has two characteristics, both of which lead to theoretical and empirical questions:

- Such an investment should be allocated to a country, sector, and time period without sustained private-sector investment.

- It should increase the probability that there will be sustained private-sector investment in the future for that country and sector.

Donor agencies offer assistance through a variety of modalities – investments in physical projects, financing for public infrastructure, budget support for the implementation of policies, technical consultations, and advice. We focus specifically on financial investments in commercial-scale facilities that generate electricity, whether provided as a concessional grant or a non-concessional loan. This type of assistance is both prominent and well-documented in the available data. Although important, this article does not consider efforts from donors to support policy reforms that do not involve financing for new facilities (see Dornan, 2014, for an example of this approach).

2.2. General theoretical perspectives

Empirical research has not uncovered a strong relationship between foreign aid and foreign direct investment at the country level (Carro & Larrú, 2010; Harms & Lutz, 2006; Papanek, 1973).[5] However, as Kimura and Todo (2010) argue, there are likely to be multiple positive and negative ways that funding from donors affects investment. Research that aggregates investment to the country level might pool the positive and negative effects of aid, leading to ambiguous or null results.

Proceeding from this perspective, the challenge is to differentiate whether any positive effects of aid are greater than any negative effects for a particular sector, country, and type of project. Foreign aid might positively affect private investment when it supports complementary infrastructure, produces information about the investment environment that reduces risks for firms, or results in policy changes that support private business transactions and operations. Foreign aid might have a negative effect on investment when it crowds out private investment or signals a negative investment environment. Finally, foreign aid may have no effect on investment beyond an individual project.

When aid supports infrastructure, it can make private capital more productive and increase both foreign and domestic private investment. Private firms need access to transportation networks, suppliers, electricity grids, and skilled labour in order to be profitable. The infrastructure associated with these needs is most often funded with public resources, which are scarce in aid recipients. Research generally finds that infrastructure leads to more private investment and economic activity (Fedderke, Perkins, & Luiz, 2006; Khadaroo & Seetanah, 2010, 2009; Sahoo & Dash, 2012). Selaya and Sunesen (2012) finds that infrastructure built with donor resources is no exception. For a particular sector, the question is whether infrastructure can support the productive activities of many firms and facilities, which is most likely when firms in the sector are geographically clustered (Lakshmanan, 2011).

Aid projects may also create incentives for officials in recipient countries to improve the policy environment for private investment. Donors routinely insist on policy reforms that reduce risks and increase the profitability of private investment when financing projects. Such reforms could include changes in tax policy, permitting, and legal protections for investments and intellectual property. Ratha (2001) finds that aid has a positive effect on private investment in the medium term, which she attributes to policy changes that are induced by donor projects. Agostino (2008) disputes this finding at the aggregate level, but agrees that policy reforms may affect investment within particular sectors. In terms of political reforms, Jensen (2003) shows that democratic institutions decrease expropriation and deter rapid policy changes, thereby increasing private investment.

Finally, aid projects might provide information to private firms about the business environment in a particular sector and country, as well as implementation issues that are likely to arise during operations. Some bilateral aid has a 'vanguard effect' on foreign investment from the donor country, probably because of the business and intergovernmental relationships that are created in the process of disbursing aid. When foreign firms are contracted to implement aid projects, they may gain information on the operational environment and learn about conducting business in a particular setting. This effect has been found for both Japanese and Korean aid projects (Blaise, 2005; Kimura & Todo, 2010; Kang, Lee, & Park, 2011). Moreover, successful implementation of a donor-funded project can provide a signal to private investors about the commitment of local governments to expedient permitting, enforcement of contracts, and timely co-financing or subsidy arrangements, potentially alleviating risks to projects that involve foreign participants (Bayer, Dolan, & Urpelainen, 2013; Bayer, Marcoux, & Urpelainen, 2013).

Aid might also have a null or negative effect on private investment when targeted in certain ways. Aid donors might not target their investments to locations where they are able to provide broad benefits to private firms, leading to null effects. Both multilateral and bilateral aid agencies are known to choose the locations of aid projects based on political considerations, such as security concerns for bilateral donors or shareholder preferences for multilateral donors (Alesina & Dollar, 2000; Fleck & Kilby, 2006). This kind of targeting might detract attention from countries or sectors with opportunities to change the investment environment. Additionally, officials in recipient countries may site projects to maximize political benefits (Briggs, 2012), rather than to most productively use funding.

When aid agencies are under substantial pressure to disburse funds, they are more likely to favour projects that can be designed, approved, and implemented quickly. Appropriations to donor agencies are often based on the ability of agencies to disburse their existing budget (Svensson, 2003). Under this pressure, donor agencies might focus their attention on countries where the policy environment is already favourable and operational constraints are limited, which will probably mean that the private sector is already active. For the Clean Development Mechanism, Pearson (2007) argues that in an attempt to find easily bankable projects, investors do not identify projects that can shape long-term patterns of energy production.

More negatively, some research suggests that donor investments in commercial activities can crowd out private investment (Dutschke & Michaelowa, 2006). Instead of pursuing investment that could result in sustained private ventures, private firms may engage in rent seeking by trying to win low-productivity aid contracts, but at high gain to the firms (Harms & Lutz, 2006). Herzer and Grimm (2012) find that aid increases public investment, which has a negative effect on private investment in a wide range of developing countries.

2.3. Do donors target their investments in clean energy to have a catalytic effect?

These theoretical expectations lead to testable hypotheses about the effects of donor financing on investment by the private sector for clean energy. The first hurdle to having a catalytic effect is targeting aid projects to countries and sectors where the private sector is currently absent or not yet robustly established, but where it could be in the future. A donor interested in having a catalytic effect will only finance projects when private investors have not financed similar projects in previous periods. This expectation about targeting leads to the first hypothesis associated with the catalytic effect.

Hypothesis 1: Donor agencies are less likely to finance clean energy facilities in a given country and year as the cumulative number of privately financed facilities in the same sector and country increases.

As has been outlined more generally here, donor agencies might not target clean energy projects to countries and sectors that have low levels of private investment. Donor agencies have incentives to secure the control of new resources by demonstrating that they can disburse resources quickly and grow their portfolios of clean energy investments. Bilateral aid agencies and multilateral development organizations have responded enthusiastically to the possibility of increased financing for clean energy, as it offers an opportunity for these agencies to control new resources. Multilateral donors have produced numerous reports that showcase how quickly they have increased support for clean energy (ADB, 2010; World Bank, 2009). In many ways, donor agencies are competing to be the favoured vehicles for climate finance in the future.

By demonstrating they can manage a rapidly expanding portfolio of clean energy projects, donor agencies set themselves up to control more resources. Indeed, some observers asserted that the World Bank used its significant experience with climate finance and clean energy projects to gain interim trusteeship of the Green Climate Fund (Redman, Reyes, Reddy, Mwenda, & Maynard, 2012). The previous president of the World Bank, Robert Zoellick, was explicit in his view that the World Bank needed to move in a 'green' direction to remain relevant (Zoellick, 2008). Similarly, the African Development Bank made an overt bid to manage a large portion of the funding pledged as part of the Copenhagen Accord and follow-on agreements in 2011 (AFDB, 2011). Bilateral donors also see climate change as a growth area among otherwise anaemic increases in aid budgets. For example, the United States Agency for International Development (USAID) released a strategy in January 2012 that envisions climate change projects to be a main pillar of US foreign assistance in the years ahead (USAID, 2012).

With incentives to expand their portfolios and control resources, donor agencies are likely to seek out recipient countries that are most interested in attracting clean energy facilities. Donor agencies often work within set financing windows for individual recipient countries, and counterparts in recipient countries play important roles in setting lending priorities (Bayer, Marcoux, & Urpelainen, 2014; Humphrey & Michaelowa, 2013). Recipient countries that request investment in clean energy facilities are likely also to be the countries that establish good policies for attracting private investment in clean energy (Martinot, Chaurey, Lew, Moreira, & Wamukonya, 2002). While this selection process ensures aid is aligned with domestic priorities, it is unlikely to lead to a catalytic effect, because the environment for investment is already good.

2.4. Do early donors catalyse the private sector?

Although donor agencies can potentially have a catalytic effect when they target clean energy projects to countries without much private-sector investment, this is not enough. Early donor investments must make private investments more likely in later periods by improving the environment for investment. Thus, donor investments must identify and decrease barriers that prevent private investors from risking capital on clean energy projects (Martinot et al., 2002; Painuly, 2001). If they are able to do so, they may realize the second hypothesis associated with the catalytic effect:

Hypothesis 2: Sustained private sector investment is more likely in a country and sector where donors are involved as early investors.

Table 1 Possible ways to catalyse investment in clean energy

Scale	Catalytic mechanism
Global	• Technology improvements
National	• Favourable national incentives and standards
	• Energy market reforms, including higher tariffs
	• Profitable ownership structures for energy production facilities
	• Profitable policies on foreign direct investment
	• Reformed legal system and the protection of property rights
	• Availability of skilled labour force
	• Maturity of financial sector and domestic credit markets
	• Access to international credit markets
	• Fossil subsidy reform
Local	• Complementary infrastructure
	• Supply chain development
	• Subnational incentive schemes, such as state-level renewable standards or tax incentives

There has been little written about a catalytic effect for specific technologies and industries associated with energy production. Newell (2009) discusses the idea that first-of-a-kind demonstration projects for climate mitigation, sometimes supported by public resources, can speed the diffusion of technologies when implemented alongside technology agreements. Demonstration projects may lead to design improvements, lower technological risks, and prompt an improved policy environment. However, research on demonstration projects frequently notes failure to improve the commercial viability of similar projects (Brown & Hendry, 2009; Cohen & Noll, 1991; Hendry, Harborne, & Brown, 2010). We consider three geographic scales at which donor projects might catalyse private investment in clean energy, assuming they have been targeted effectively (Table 1).

First, donor investments in developing countries might overcome global barriers to private investment in clean energy. This would mainly involve technological progress that makes clean energy more cost-competitive with traditional fossil fuel technologies. Indeed, once clean energy technologies pass this threshold, there is every reason to believe that they will scale rapidly without any donor support. Donor spending patterns suggest this is not a likely avenue. There is little evidence that donors are supporting research and development, which is the main way to bring down technology costs. Furthermore, donor projects represent less than 2% of clean energy projects in developing countries, according to the Bloomberg New Energy Finance Database. This suggests little scope for donors to make a major contribution to global technology development (de Coninck, Fischer, Newell, & Ueno, 2008; Evans, 1999; Worrell et al., 2001), which does not preclude a role for national or local operational learning. Indeed, donors are unlikely to have a catalytic effect on private investment by supporting risky or unproven technologies when fundamental constraints at the local and national levels remain.

Donor projects might overcome barriers to private investment that are relevant to specific locales. Most importantly, donor investments might create infrastructure that supports private investment

in clean energy. For example, in many countries, electricity grids are not properly designed to make the distribution of clean energy from dispersed sites financially viable (Barnes & Floor, 1996; Kaundinya, Balachandra, & Ravindranath, 2009). Clean energy installations must often be sited away from population centres where wind or sunshine are abundant, making these challenges more significant. Donor projects often include funding for complementary infrastructure and grid improvement activities (World Bank, 2009). These improvements may catalyse a certain amount of additional private investment activity.[6]

Although donor investments have some scope to be catalytic at the local level, there are a large variety of ways that they can make private investment more likely by overcoming barriers at the national level. In many developing countries, systems of energy tariffs are underdeveloped, private-sector participation in energy production is limited by law, property rights and investment contracts are not protected, and operational experience among local contractors is limited (Barton & Osborne, 2007; Tirpak & Adams, 2008). Donors can address all of these national-scale barriers. When donors negotiate investment contracts, they frequently either include funding for policy changes or have certain policy preconditions. These policy reforms may include everything from establishing national incentive schemes for clean energy, to modernizing rules on foreign investment and contractor participation. If donors are able to use project finance as a vehicle to prompt policy reform at the national level, then they have the potential for a wider catalytic effect. For particularly large countries, certain policies including energy price regulation and renewable incentive schemes could also be prompted at a sub-national level.[7]

Donor projects might generate operational experience in the clean energy sector for in-country firms. This operational experience might make private projects more profitable in the future, an effect that has found tentative support in research on other sectors (Ferro & Wilson, 2011). In the clean energy sector, Bayer, Dolan, et al. (2013) find that as a country increases renewable energy production, it is also more likely to generate high-value patents in the clean energy sector. Together, these findings suggest that the endogenous development of a clean energy sector will be more likely when some baseline of projects and firms are active, as a result of positive network effects. However, because clean energy facilities are located in areas with access to specific geophysical assets, the same level of clustering as with some other industries is not anticipated, which leads to the expectation that any network effects will occur at a national scale.

Because it is expected that donor projects have the greatest potential for a catalytic effect at the national scale, we use countries as the unit of analysis, although future work could usefully explore more or less aggregated levels. While donor agencies that stay involved in countries with robust private-sector activity may be targeting projects to underserved areas or earlier-stage technologies, we expect there to be a more limited scope for a catalytic effect at the local and global levels.

3. Methods and results

3.1. Leading or following the private sector?

Our first empirical question is whether donors are targeting projects to countries and sectors underserved by the private sector at the time of investment. This approach circumvents a common difficulty of establishing whether a project would not happen without donor involvement, so-called 'investment

Table 2 Descriptive data for clean energy investments, 2000–2011

	Number of wind investments	Installed wind capacity (MW)	Number of solar investments	Installed solar capacity (MW)
Private-only financing	2,523	108,702	557	5,868
Public-supported financing[a]	82	4,342	49	354
Donor-supported financing[b]	36	2,174	17	543

Notes: [a]May include private investors as co-financiers. [b]May include both private and domestic public investors as co-financiers.

additionality', by looking at the broader market environment (Schneider, 2009). For our purposes, the number of previous private investments captures a necessary condition for a catalytic effect, which is that the private sector is not already independently financing similar projects.

In particular, we examine how the cumulative number of privately financed wind and solar facilities influences the number of investments that are approved by donor agencies for each country and year. Because we seek to understand donor financing, all countries classified by the World Bank as low- or middle-income that received at least one clean energy investment from any source at any time during the study period are included in our analysis (World Bank, 2012). This excludes countries that do not regularly receive financing and grants from donor agencies and those that offer no attraction to investors. The majority of countries in this sample are middle-income countries (see online Table A1).

Data on individual investments made in low- and middle-income countries, both donor supported official development assistance and other official flows (ODA and OOF) and privately financed, are available through the Bloomberg New Energy Finance Database. These data include the closing date, investing organizations, and installed capacity for 3264 clean energy investments in low- and middle-income countries between 2000 and 2011. The investments are all commercial-scale electricity generation projects in the wind or solar sector. We matched every investing organization against a list of international aid donors from the AidData database to identify projects financed with donor support. The binary measure of donor support is whether or not an international aid donor is among the financial sponsors of the project. Consistent information about the relative contribution of each sponsor is not available.

The five largest donor agencies in the sample, by number of projects, are the World Bank (19), the Asian Development Bank (10), the German KfW (9), the Global Environment Facility (5), and the Central American Bank for Economic Integration (4). Several other multilateral and bilateral donor agencies supported up to three projects. We also matched every investing organization against a list of public agencies in the Bloomberg database to distinguish private-only projects from projects with domestic, public-sector investment. Table 2 shows the total number of projects and their associated capacity for both the solar and wind sectors across all countries in the sample. These data show that private investment vastly outstrips donor investment, making it even more critical that donor organizations do not follow the private sector.

One simple way to examine whether donors are targeting projects to countries without a history of private financing is to look at their investments across the first project in each country, investments in

Table 3 Descriptive data for timing of donor-supported clean energy investments, 2000–2011

	Non-donor deals	Donor deals	Total
1st deal	70	12	82
2nd to 10th deal	185	18	203
>10th deal	2,956	23	2,979
Total	3,211	53	3,264

the next few projects, and investments once the market becomes mature. Table 3 presents a simple cross-tabulation. Here and elsewhere, early investments are defined as the first ten projects in a country and sector. In our empirical models, we examine the robustness of our results to measuring early investments as all counts between the first three to the first ten projects, which produces no changes in the basic results.

Table 3 suggests that a slight majority of donor investments occurred at or before the tenth deal. Expressed as a share of total deals at any given stage, donors have a decreasing proportional involvement as private-sector investments accumulate (from 15%, to 9%, to under 1%). However, a large number of investments still occur 'late', when the private sector is well established as a source of financing, which suggests that absolute levels of donor investment do not decrease over time.

While informative, this simple analysis fails to take into consideration other features that might be influencing donor activity, such as national income or annual foreign assistance received. To provide a better test of whether donors are targeting projects to countries where the private sector is not a well-established source of financing, we create a panel and use the 'country-year' as the unit of analysis. The outcome variable for the models is the total number of donor investments in clean energy facilities in each country-year. Because the outcome variable is a count, we use a quasi-Poisson regression for estimation (Ver Hoef & Boveng, 2007), though the results are robust to a negative binomial count model and models that take the dependent variable to be a binary indicator of whether any donor invested (see online Table A4).

The primary independent variable for this analysis is the cumulative number of private-only investments (*Private Wind/Solar Cumulative*) made in a particular country prior to each country-year. We report models both with and without country-level fixed effects. In models without fixed effects we identify the effect of interest partly from variation across countries and whether donors are more active in countries that have low private-sector activity throughout the sample period. However, this model risks confounding effects from omitted variables reflecting time-invariant differences among countries. In models with fixed effects, we identify the effect of interest entirely from within-country changes in private-sector investment and donor activity. In this model, countries that have no donor activity do not provide usable information and are dropped.

Examining both models allows us to investigate whether the relationship between private-sector investment and donor financing is consistent both within and between countries. In addition, we drop all country-years that are prior to the year of the first clean energy investment in either the wind or solar sector in each country, as we have no data that allow us to assess when a recipient

country first becomes eligible – whether through policy, interest, or investment environment – for clean energy investments.

If donors are investing in ways that are consistent with catalytic intentions, then donor investments should become less numerous as the cumulative number of private-sector deals increases. The distribution of cumulative private-only investments is highly skewed, with most countries having few investments and some countries having high numbers of investments. This makes parametric modelling difficult, because of problems with model convergence. To address this problem, we code each country-year into one of three categories representing low, medium, and high numbers of cumulative private-only investments, based on qualitative inflection points in the distribution of the data. For wind projects, 249 country-years have 0–2 deals, 33 country-years have 3–10 deals, and 29 country-years have 11 or more deals. For solar projects, 299 country-years have 0–1 deals, 5 country-years have 2–5 deals, and 7 country-years have 6 or more deals.[8] We model the wind and solar sectors separately to ensure that the results are robust across project types.

We add several control variables to account for other factors that may affect donor investments. First, we include the concurrent number of projects financed with domestic public resources (*No. Public Concurrent*), to account for the possibility that donor resources are requested by countries that also invest domestic resources in the expansion of clean energy. Second, we include *GDP per capita* to account for the possibility that donors become less involved as countries near 'graduation' from official development assistance (although our measure of donor involvement includes both ODA and OOF). Third, we control for the total *Net Aid* in each country-year, which is the total amount of official development assistance received that year by all sources minus the amount repaid. This is a preferred measure for country size relevant for donor activity, versus gross domestic product (GDP) or population, because donors can become less active in middle-income countries. Finally, we include a linear year variable or a year indicator variable to account for country-invariant time effects that might be responsible for increased numbers of clean energy projects in the later years of the panel. We report summary statistics for the model variables in online Table A2. We report regression estimates that use this set of variables in Table 4.

The results in Table 4 show that donors, on average, are not targeting investments according to a catalytic logic. When looking across countries for wind sector investments (wind pooled), donors are more likely to invest in countries that have higher numbers of cumulative private-sector investments. Even more striking, our results show that *within* individual countries with donor activity (wind fixed effects), donors are more likely to invest as private investments accumulate.

Similarly, when we look across countries in the panel (solar pooled) we find that donors are more likely to invest in countries that have more private-sector investments. Unlike the wind sector, there is no evidence that donors are more likely to invest as private-sector deals accumulate within countries (solar fixed effects). Although we find countries that have accumulated higher levels of private-sector investments to be more likely to attract donor investments compared to the reference level of no investments, the two levels of accumulated private investment included in each regression are only distinguishable from one another in the pooled wind model. With the caveats noted previously about national versus local barriers, these results cast doubt on whether the current system of donor financing is consistent with catalytic goals on average.

We completed a number of robustness checks (reported in the Appendix) that warrant mention. If we split the model to examine the targeting choices of bilateral versus multilateral donors, we find

Table 4 Factors influencing donor investments in the wind and solar sectors

Sector	Wind (pooled)	Wind (fixed effects 1)	Wind (fixed effects 2)	Solar (pooled)	Solar (fixed effects)
Private Wind Cumulative (3–10)	0.99 (0.60)	2.93** (1.40)	2.56* (1.51)		
Private Wind Cumulative (11 +)	1.91** (0.48)	3.71** (1.55)	3.23** (1.70)		
Private Solar Cumulative (2–5)				2.70** (0.74)	0.54 (1.41)
Private Solar Cumulative (6 +)				2.69** (0.76)	1.04 (1.47)
No. Public Concurrent	− 0.01 (0.13)	0.02 (0.14)	0.00 (0.17)	0.05 (0.07)	0.00 (0.08)
GDP per capita ($ thousand)	− 0.16 (0.10)	− 2.06** (1.07)	− 2.70** (1.38)	0.05 (0.13)	0.40 (2.23)
Net Aid ($ billion)	0.09 (0.22)	0.37 (0.42)	0.40 (0.53)	0.36 (0.27)	2.45** (1.20)
Year controls	Indicators	Linear	Indicators	Linear	Linear
Fixed effects (Country Indicators)	No	Yes	Yes	No	Yes
Observations (Countries)	294 (53)	128 (17)	128 (17)	294 (53)	76 (9)
Pseudo R^2	0.22	0.27	0.32	0.36	0.50

Notes: Dependent variable is count of donor projects for each country-year observation. The estimated effect of cumulative private projects is relative to a low-investment reference group (0–2 projects for wind, 0–1 projects for solar).
**Statistical significance of two-tailed test, $p < 0.05$.
*Statistical significance of two-tailed test, $p < 0.1$.

that the multilateral donors allocate projects consistent with the reported effects (see online Table A3). With only 13 bilateral clean energy deals in the entire sample, we are not able to reject the null that the cumulative number of private deals does not affect the allocation of bilateral donors, although this is to be expected given the low statistical power. We also examined whether these results are driven by outlier countries in the sample by iteratively dropping each country and re-estimating the models reported in Table 4. The results hold in the vast majority of models (Figures A1–A4). Finally, we considered the possibility that controlling for risks to investment would yield different results, because donors might focus on such concerns for clean energy projects more than other types of investment, which we have controlled for directly. The results are substantively unchanged, although statistical power is decreased because of data availability (see online Table A5).

To aid substantive interpretation of the main results, Figure 1 shows the predicted number of donor projects that an average country would receive per year using the pooled wind model, together with total model uncertainty. All variables except the number of past investments and GDP per capita are held at their mean (continuous variables) or median (discrete variables). For low-income countries, having a large number of private deals raises the predicted number of donor investments eightfold compared to countries that receive none or few projects. Additionally, as countries graduate from donor assistance they received fewer donor projects regardless of the history of private-sector investment. If donors were acting to catalyse, we should see the vertical ordering of these lines reversed.

3.2. Do early donors catalyse the private sector?

While the preceding analysis suggests that, on average, donors are not focused on catalytic investments, this does not rule out the possibility that they will have a catalytic effect when they invest

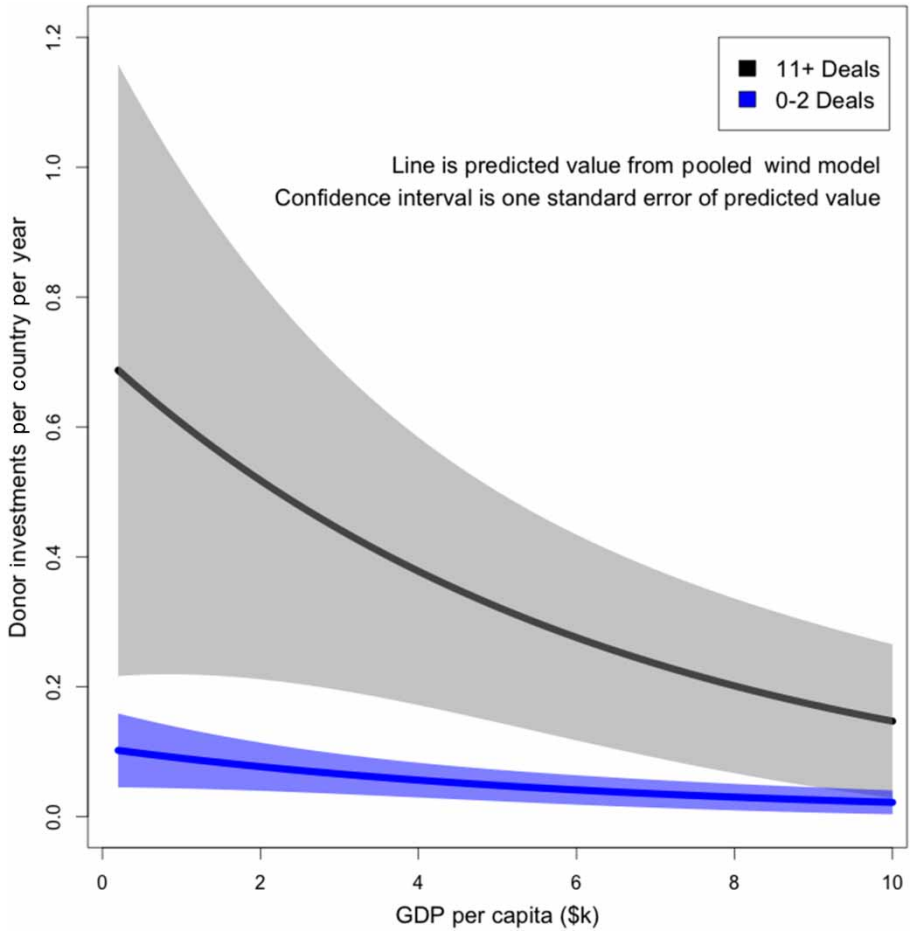

Figure 1 Predicted number of donor-supported wind investments under different historic scenarios of private-sector investment

early. To test this possibility, we evaluate the role of early donor investments on subsequent private-sector investments in both the wind and solar sectors.

An initial examination of the data is suggestive of a relationship between early donor involvement and subsequent private-sector investments. As Table 5 shows, among countries with early participation by donors, 22.7% saw more than 10 deals, while among countries without early participation by donors, that number was 11.7%. Although this simple table is suggestive that an early donor is associated with more private deals, it does not rule out the possibility that country size or the relative length of investment history confounds the results.

To further explore the hypothesis that early donor involvement can create the conditions necessary for private-sector investment, we modelled the aggregated privately installed capacity through 2011 in all countries that have received at least one wind or solar investment of any type. We aggregate at the

Table 5 Cross-tabulation of early donor investments and total deals by 2011

Total clean energy investments by 2011	No early donor (first 10)	Early donor (first 10)
1–10 deals	53	17
>10 deals	7	5
Probability (>10 deals)	11.7%	22.7%

country level through 2011 because (1) we want to explain which countries have achieved a high level of private-sector investment, (2) without attempting to explain the high year-to-year variance in investment amounts within particular countries, while (3) controlling for country size and the duration of investment history. Thus, the outcome variable for all our models is the log of the privately financed capacity in MW up to the end of 2011. Our independent variable is either the count of donor projects among the first ten in each country or an indicator variable for whether this count is greater than zero. Because donors seem to follow the private sector, we are concerned about endogeneity: private activity leads to donor activity and donor activity leads to private activity. To account for this possibility, only donor projects that occur within the first ten projects in a particular country are counted to construct the independent variable. This should eliminate endogenous donor activity as early projects cannot be influenced by prior activity. We also check robustness to narrower definitions of this variable that examine the first three to ten projects. In no case did we find the results to be qualitatively and statistically different from those reported in the following table. Moreover, to the extent that endogeneity occurs, it will tend to overestimate a positive donor effect and make our estimates favour a positive conclusion.

Several control variables are included in the models. The first is a binary variable that is positive whenever any donor has funded at least one energy policy project in a given country since 2000 (*Donor Energy Policy*), where these are projects that do not install physical capacity, but seek to upgrade policies in the energy sector. These projects are identified by filtering on the AidData 'energy policy' purpose code in the AidData database (Tierney et al., 2011). This allows us to test the possibility that donors are having a systematic effect on private-sector investment with a different aid modality. The second control variable is a binary indicator of whether a feed-in tariff was in place at some point in each of the countries (*Feed in Tariff*). We compile these data from the Renewable Energy Information Portal (REEGLE, 2012). A feed-in tariff commits governments or utilities to purchasing wind and/or solar energy at above market rates for a specified duration of time and is a primary tool used to promote clean energy (Cory, Couture, & Kreycik, 2009). Third, we expect the size of a country's economy to impact total energy needs, and thus we include the log of GDP in 2010 (*Log 2010 GDP*). Finally, there are likely to be unobserved factors particular to individual countries that affect the potential for clean energy expansion, such as wind patterns or the average number of sunshine days (Lu, McElroy, & Kiviluoma, 2009). To control for these differences, we include the number of years that the private sector has been active in a particular country (*Years Since First*). We expect this variable to account for unobserved factors that make countries attractive for private-sector investment.

Table 6 The effect of early donor involvement on total privately installed wind capacity

Sector	Wind 1	Wind 2	Solar 1	Solar 2
Early Donor (Binary)	− 0.15 (0.58)		1.24 (0.79)	
Early Donor (Count)		− 0.08 (0.30)		0.36 (0.40)
Donor Energy Policy	0.21 (0.68)	0.21 (0.67)	0.93 (1.28)	0.95 (1.33)
Feed in Tariff	1.20** (0.55)	1.18** (0.55)	0.78 (0.88)	0.74 (0.96)
Log 2010 GDP	0.40** (0.18)	0.39** (0.18)	0.58** (0.25)	0.61** (0.25)
Years Since First	0.27** (0.09)	0.27** (0.09)	0.30** (0.12)	0.30** (0.12)
Countries	55	55	27	27
Adjusted R^2	0.48	0.48	0.65	0.62

Notes: Dependent variable is the log of cumulative installed wind/solar capacity by 2011.
**Statistical significance $p < 0.05$.

None of the models displayed in Table 6 contain positive evidence that early donor investments increased privately installed capacity by 2011, on average, after controlling for other relevant factors. If we specify a simple model that explains total private-sector capacity only in terms of a binary or count variable of early donor involvement without other control variables, we also do not find a positive effect. These results are unaffected by endogeneity concerns, given that such concerns would produce a positive effect. It is found that a longer elapsed time since the first investment and higher GDP increase cumulative privately installed capacity. Admittedly, we used a sample that contains many countries with few clean energy investments, which could limit the ability to detect a donor effect. This possibility is particularly concerning for the model 'Solar 1', which suggests a need to follow up as more data accumulate.

In contrast, we find that domestic feed-in tariffs positively affect privately financed capacity. For the wind sector, countries that established feed-in tariffs had significantly higher total installed capacity by 2011 than countries that did not establish such policies. This finding suggests that systematic incentives are more important for creating a positive investment environment than are donor projects. In line with this result, Burer and Wustenhagen (2009) surveyed a sample of clean energy venture capitalists and private equity firms, and found that feed-in tariffs are perceived to be the policy that can best attract private investment for clean energy.

We considered the possibility that early donor involvement might be responsible for the later adoption of feed-in tariff policies in our sample countries, thereby biasing our results *against* finding an effect for early donor involvement. If we remove the feed-in tariff variable from the regressions reported in Table 6, we do not find early donor involvement to be associated with greater installed capacity in any of the model specifications. Alternatively, if we drop the variables for early donor involvement, the feed-in tariff remains a positive predictor of installed capacity in the wind sector, but not in the solar sector.

To aid substantive interpretation of this result, Figure 2 shows the predicted amount of private-sector wind capacity in terms of a country's economic size and the presence of a feed-in tariff policy, including total model uncertainty. For countries that established feed-in tariff policies, the predicted amount of

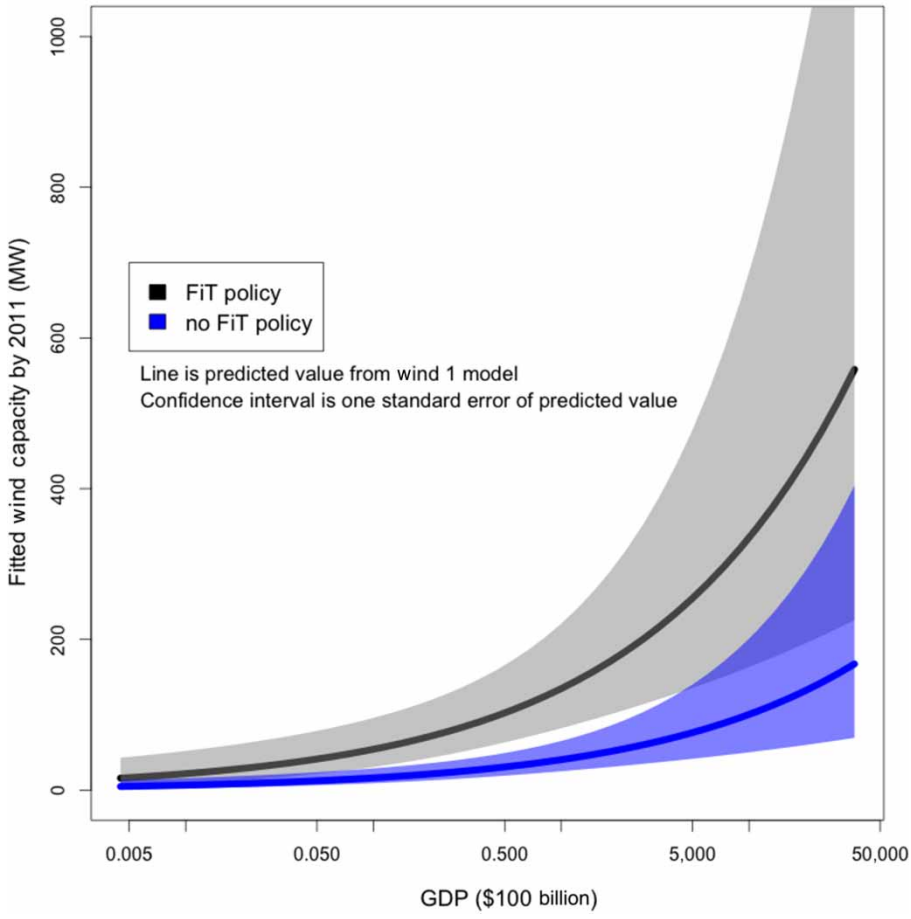

Figure 2 Feed-in tariff policies and privately financed wind capacity

privately financed capacity is approximately three times that of countries that have not established the policy. More investigation is needed to understand how donors can support the design and implementation of these systemic policies. Although existing research has not evaluated the cumulative effect of donor efforts to reform policies related to clean energy, case studies highlight the positive role donors can play (Dornan, 2014; Rickerson, Hanley, Laurent, & Greacen, 2013).

4. Discussion

Donor agencies are tasked with astonishingly large goals, including the mitigation of climate change. The resources available to accomplish these goals are limited. It is critical to understand whether donor agencies are spending resources in ways that are likely to have the largest impact. Given that even optimistic projections of future donor resources pale in comparison to private investment, the only successful

strategy is one that involves catalysing the private sector and complementing domestic policy changes. This is the rhetoric that donor agencies use themselves. A necessary condition for catalytic investment is channelling resources to countries where private investment is not yet profitable, but could be.

The majority of donor investments in clean energy support solar and wind facilities. It is known from previous research that donor organizations have significant incentives to allocate investments quickly to maintain and gain control of resources. This could lead them towards investment opportunities in countries with proven capacity, including projects that would happen without their involvement. Such tendencies are exactly the opposite of catalytic investing. Looking at patterns of donor project investments over time and across countries, we find that donors on average are less likely to invest in countries and sectors that have limited private investment. The average donor investment occurs where the private sector is already active and therefore has little to catalyse.

Our data are limited, because we do not have consistent information on the relative contributions of donors and other investors to new clean energy facilities. A large number of small investments, where the donor role is minor, could explain why we find little difference in patterns of investment between donors and the private sector. However, this does not avoid the question of why donors are investing at all if they are taking such minor stakes and having little influence.

It is possible that, even in countries and sectors where the private sector is active, there are underserved subsectors and subregions. Past research suggests that the largest number of barriers to investment occur at the national scale, making us question whether such catalytic investment could account for the bulk of donor investments. It is also possible that, because we look at donor investments pooled across many traditional donor agencies, the results might be different for climate-specific funds. We do not have the data necessary to investigate this possibility at present. In the future, it would be useful to examine whether the Clean Technology Funds invest primarily in countries that have limited private financing. Given these caveats, we cannot rule out the possibility that some donor investments target underserved areas, even though the average project does not.[9] Nonetheless, it is troubling that so many donor resources are being spent on wind and solar facilities in countries where the private sector is already active.

We also find that even where donors are early investors, there is little evidence that they make future private-sector activity more likely. Although the raw data show that accelerated private investment occurs more frequently among countries with early donor projects, this effect disappears when we control for country size and length of time since the first project. We find that national policies have a positive effect. Feed-in tariffs that provide higher purchase prices for renewable energy are associated with higher privately installed capacity. This should not be surprising, and points to a potentially larger opportunity to refocus donor financing on improving the investment environment. Our data do not allow us to measure the catalytic impact of other types of support provided by donor agencies, such as infrastructure, incentives and standards, an improved legal framework, access to foreign capital, and the removal of subsidies for fossil fuels. We can speculate, however, that such activities might have larger catalytic effects.

It is possible that donors are attempting to have catalytic effects but are simply missing the mark. Renewable energy financing in developing countries is a complex matter. Donors may face obstacles to knowing where catalytic potential exists, and where it is hopeless. Our analysis cannot speak to the full range of efforts under way; we are only measuring the average effect of investments in commercial-scale facilities, which represents the bulk of investment for many donor agencies. Nonetheless,

that we are not able to reject a null effect of donor investments on private investment suggests more attention should be paid to evaluating the sector-level results of donor activities.

Donor agencies face a conundrum. Donors are expected to support the shift to clean energy. There is little evidence that the shift can occur without the private sector. Yet the ability of donor agencies to leverage the private sector is limited, both when donor incentives are aligned to move resources quickly and when donors alone cannot surmount the barriers to private investment. The one promising direction appears to be country policies. Mirroring our results, Smith and Urpelainen (2013) find that feed-in tariffs can have a large and cost-effective role in promoting renewable energy production in industrialized countries. If donor investments can more frequently target policy changes and systematic incentives in developing countries, either directly supporting government efforts or acting as a quid pro quo in exchange for such changes, those policy changes might have a large effect on private investment. This will be necessary to mitigate climate change.

Our results suggest a potential lesson for international negotiators. Developed countries have traditionally emphasized mitigation in discussions of financial support, embracing adaptation only in the context of the compromise text of the Copenhagen Accord. This position follows the logic that mitigation spending delivers global environmental benefits. However, our results indicate a potentially limited role for direct donor spending on mitigation projects. Allowing the negotiations to further shift donor spending towards adaptation – and instead emphasizing mitigation-related policy reforms as a quid pro quo – could be a more promising avenue for reducing GHG emissions.

Supplemental data

Supplemental data for this article can be accessed here. [10.1080/14693062.2014.953903]

Notes

1. In our research 'developing' country refers to those classified as low- or middle-income by the World Bank in 2011. Other cited research may use slightly different definitions.
2. The full text of Secretary of State Clinton's speech was retrieved (March 2014) from http://www.state.gov/secretary/20092013clinton/rm/2012/06/193910.htm. Note that this is part of a larger $7+ billion dollar 'Power Africa' initiative announced later that month – most of which comprises non-concessional lending through Overseas Private Investment Corporation (OPIC) and the Export–Import Bank.
3. The Overseas Development Institute has recently examined the pattern of direct government support for private-sector projects in the US, UK, Germany, and Japan (http://www.odi.org.uk/projects/2643-mobilising-private-climate-finance). However, their study does not try to look at how such activities indirectly influence future (fully) private-sector investments, which is the focus of our study.
4. For example, over the period 2011–2012, the World Bank Group invested $6.6 billion in renewable energy facilities, versus only $4.8 billion for transmission, distribution, and 'other' (which includes energy policy support). Moreover, the $4.8 billion includes investments supporting fossil fuels as well as renewables, suggesting an even larger ratio of mitigation funding going to clean energy facilities. See http://go.worldbank.org/ERF9QNT660.
5. Most previous worked has used ODA as tracked by the Development Assistance Committee of the Organisation for Economic Co-operation and Development. There is considerable controversy over this measure, both because it may count too much or too little (e.g. http://oecdinsights.org/2013/05/04/yes-it-is-time-to-revisit-the-concept-of-official-development-assistance/). For the present purposes, we count 'foreign aid' as any level

of project involvement by an international aid donor in the AidData database, where the donor's contribution could be either ODA or OOF.

6. As a developed country example, recent expansion of transmission lines in Texas – for the sole purpose of bringing renewable energy to market – is credited with creating a 7.5 GW expansion of wind power to market. See http://www.eenews.net/climatewire/stories/1059995041.
7. For example, three-fifths of US states have renewable portfolio standards; two-fifths do not (http://www.eia.gov/todayinenergy/detail.cfm?id=4850).
8. As an alternative, we divided the number of cumulative private projects into terciles within each sector for the subset of countries with donor activity in the sector, with boundary values falling into the terciles with a higher count of that value (Wind: 0, 1–2, 3 + ; Solar: 0, 0, 1 +). This makes no qualitative difference for our model of solar project investment, which now includes just a binary indicator of whether there have been any investments. For our model of wind projects, we find some evidence that donors are less likely to invest in countries with only 1–2 private deals, but most likely to invest in countries with 3 + deals, as compared to zero. This suggests a possible dip in activity as the private sector enters a country, but does not change the result that activity is highest in country-years with the most private investment.
9. Anecdotal evidence from conversations with regional development bank officials suggests this is exactly the case – the banks look for a portfolio of projects, some relatively safe and some more risky.

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