Energy Research & Social Science 86 (2022) 102441

Contents lists available at ScienceDirect

Energy Research & Social Science

journal homepage: www.elsevier.com/locate/erss

Pushing out or pulling in? The determinants of Chinese energy finance in developing countries

Zhongshu Li [a], Kevin Gallagher [b,*], Xu Chen [c], Jiahai Yuan [d], Denise L. Mauzerall [e]

[a] Princeton School of Public and International Affairs, Princeton University, Princeton, NJ 08544. Now at: Boston Consulting Group, China
[b] Pardee School of Global Studies, Global Development Policy Center, Boston University, Boston, MA 02215, USA
[c] Princeton School of Public and International Affairs, Princeton University, Princeton, NJ 08544, USA
[d] School of Economics and Management North China Electric Power University, Beijing, China
[e] Princeton School of Public and International Affairs and Department of Civil and Environmental Engineering, Princeton University, Princeton, NJ 08544, USA

ARTICLE INFO

Keywords:
China
Overseas energy finance
Climate change
Development

ABSTRACT

China is now one of the world's largest financiers and investors in the global electric power sector. While a number of important qualitative analyses have examined the determinants of Chinese energy finance, this paper deploys new data to perform the first econometric analysis to examine the determinants of Chinese overseas financing for electric power plants. Drawing on that earlier work, we examine a number of 'push factors' –incentives in China that facilitate investment abroad—and 'pull factors' –incentives in recipient countries that facilitate Chinese investment into their country. On the push side, we find that domestic overcapacity in China plays a key role in facilitating China's development finance in these plants. On the pull side, we find that the size of local demand for new power projects and the resource potential for electric power in recipient countries are significantly correlated with the size of Chinese financing. We also find existing Chinese involvement in past power projects likely facilitates new Chinese overseas financing.

1. Introduction

Whereas carbon emissions are showing some signs of stabilizing in some advanced economies, emissions from most developing countries continue to rise as those nations strive to raise their standards of living [1]. The energy sector is pivotal from both a climate and development perspective. While energy is a key driver of economic development, the energy sector is also the source of two-thirds of global greenhouse gas emissions. Redirecting financial flows towards renewable energy technologies (RETs) in developing countries is crucial to minimize future emissions and to limit climate change to manageable levels [2–3]. Indeed, Article 2.1(c) of the Paris Agreement aims to "mak[e] finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development." Importantly, finance for the energy sector in developing countries, and power sector development in particular, comes from a combination of domestic and international sources. Multilateral development banks (MDBs), national development banks (NDBs), and international power developers are all important sources of finance for new power projects in developing countries [4–8]. While most development banks have transparent lending practice guidelines and open data portals, relatively little is known about the lending practices and detailed project information of Chinese development banks, or overseas investments of Chinese power companies. While the Belt and Road Initiative (BRI) is expected to further increase the influence of Chinese finance in developing countries' power sector, recent estimates within 15 BRI countries found that the BRI's carbon footprint is significantly carbon intensive–with only 9% of investments in green technologies [9–10]. In order to steer Chinese finance more towards RETs in the power sectors of developing countries, an understanding of the drivers of Chinese energy financing is critical (Table 1).

While the Chinese government does not publish a project-by-project breakdown of its overseas finance activities, extensive data collection efforts have identified two major mechanisms of Chinese finance in the global power sector. The first mechanism is development finance (DF) provided by China's policy banks and Chinese export credit agencies (ECA) to host governments in developing countries in the form of trade credits, concessional loans, and non-concessional lending. Through development finance institutions, China's policy banks provide debt finance to sovereign governments and do not directly own the projects nor are they involved in the development of the power projects; the

* Corresponding author.
E-mail address: kpg@bu.edu (K. Gallagher).

https://doi.org/10.1016/j.erss.2021.102441
Received 5 July 2021; Received in revised form 15 October 2021; Accepted 23 November 2021
Available online 23 December 2021

Table 1
List of variables.

Variable name	Definition	Source
Dependent variables		
Chinese development finance (log, unit:MW)	Chinese development finance in developing countries‘ power sector by capacity	Gallagher et al., 2020
Chinese development finance (log, unit: million US $)	Chinese development finance in developing countries‘ power sector by 2015 US dollar	Gallagher et al., 2020
Chinese_FDI (log, unit:MW)	Chinese FDI in developing countries‘ power sector by capacity	Li et a., 2020
Push factors		
Overcapacity (log, unit:MW)	Excess capacity in Chinese power manufacturing firms and engineering companies	Platts and peak year method
Voting distance	Alignment of voting behavior in the United Nations between China and the recipient countries. Rank order	Bailey at al., 2017 & UN General Assembly
Chinese_trade (log, unit:USD)	Chinese outgoing trade in developing countries’ power sector	UN Comtrade
Resource rent (unit: %)	Natural resource rent as percentage of recipient countries’ GDP	World Bank Database
Pull factors		
New power capacity (log, unit:MW)	Added power capacity in recipient countries’ power sector	Platts
GDP per capita (log, unit:USD)	GDP per capita in recipient countries	World Bank Database
Power resource potential (log, unit:MWh)	Resource potential for power generation, coal/gas reserve for coal and gas plants, hydropower potential for hydropower plants, fixed all year for a given country	BP, Zhou et al., 2018
Control Variables		
Population (log)	Population in recipient countries	World Bank Database
Polity2	Regime authority of 21-point scale ranging from + 10 (consolidated democracy) to −10 (hereditary monarchy)	Polity IV (Marshall et al., 2014)
BRI	1 for BRI signature year and each year thereafter since the country signed a BRI MOU with China and 0 before signing BRI MOU with China	China’s government website
Trade with China in the power sector (log, unit:MW)	Added power capacity in the last 5 years utilizing EPC or equipment from China	Platts
Trade in the power sector with US, Japan and Germany (log, unit:MW)	Added power capacity in the last 5 years involved with EPC or equipment from major players in global power industry (US, Japan and Germany)	Platts

sovereign governments and the local developers which receive Chinese finance build and own the power projects. A second mechanism is foreign direct investment (FDI) made by Chinese power companies into new power projects in developing countries as project developers and owners. In this mechanism, Chinese power companies provide equity finance and directly own part or all of a project. For Chinese DF, the Chinese major state-owned policy banks—the China Development Bank and the Export-Import Bank of China—provide the vast majority of Chinese development finance. For Chinese FDI, Chinese state-owned enterprises are involved in 85% of all overseas power projects receiving Chinese FDI.

While significant work has been conducted to date that establishes the level of Chinese DF and FDI engagement in the power sector abroad, there is relatively less understanding of the determinants of Chinese energy finance. There have been a handful of papers on the broad determinants of Chinese overseas finance across all sectors. Dreher et al., 2018 analyzed Chinese development finance to Africa from 2000 to 2012 and found the drivers of Chinese development finance to be largely driven by the market forces of supply and demand, rather than the geopolitical drivers that many assumed [11]. This finding is supported by a more recent study that compares Chinese development finance in 157 developing countries from 2000 to 2014 with development finance from the World Bank. This study also found that Chinese development finance is driven by market forces to a larger extent than World Bank financing [12]. However, little research specifically examines Chinese overseas financing in the power sector. Kong and Gallagher [14,15] developed a framework to qualitatively analyze various “push” and “pull” drivers of Chinese development finance in overseas coal power projects. Through field research in several case countries, in this journal Gallagher et al. [13] finds that Chinese and other foreign financing can be heavily influenced by host country demand. They found domestic pull factors to be key drivers of such investment. Kong and Gallagher [14,15] come to similar conclusions in specific case study analyses of overseas renewables and coal respectively. Besides these qualitative studies, relatively little quantitative work has been conducted analyzing the drivers of Chinese overseas financing flows in developing countries’ power sector.

To address this gap, we first compiled a comprehensive dataset which synthesizes previously collected data and includes all new power projects in developing countries receiving either Chinese DF or FDI from 2005 to 2018 [7,16–17]. Our newly created dataset covers 66.0 GW of new power projects which have received Chinese DF or FDI and were built from 2005 to 2018 in 35 developing countries. Compared with the total 369 GW of new power projects built in these 35 developing countries during the same period, Chinese overseas finance was involved in the development of 18% of power projects in these countries. Trends, energy mix and the overlap pattern of Chinese energy financing are included in Figs. S1-5. Second, we developed an analytical framework based on Kong and Gallagher [14,15] which includes a list of potential drivers for Chinese overseas financing in the power projects of developing countries. Third, we deploy an econometric model to analyze the extent to which these push and pull factors explain the level and distribution of Chinese electric power financing. After presenting our results, we further discuss the most significant drivers of Chinese finance, and then consider how our results inform a renewable energy transition in developing countries.

2. Materials and method

2.1. Analytical framework and potential drivers

We utilize the “push and pull” analytical framework of Kong and Gallagher [15,16] to examine the determinants of Chinese overseas energy finance in the power sectors of developing countries, including two types of energy finance, Chinese DF and Chinese FDI in the power sector. “Push” factors are described as Chinese domestic drivers that “push” Chinese finance out to overseas markets. We are particularly interested in four potential push factors. First, industrial overcapacity in the Chinese domestic market is often discussed as a push factor that drives Chinese finance overseas and is applicable to the power sector, particularly coal and hydropower generation [18–20]. Power generation in China grew rapidly between 2002 and 2007 with an average of 100 GW new generation brought on-line every year [22–23]. As the number of new power projects increased, the Chinese electric power industry also increased technical capacity in power equipment manufacturing, project design and construction, as well as project financing capabilities [24–25]. After 2007, the growth of new power projects in China gradually slowed, which led to overcapacity in China's technical ability to build new power plants. Such a domestic overcapacity coincided with increasing Chinese overseas finance in the global power sector after the Global Financial Crisis (GFC). Recent qualitative analysis stipulate that Chinese finance was in part driven by a state objective to alleviate and export Chinese domestic overcapacity [13,15,16]. The second potential push factor is the Chinese incentive to use Chinese financing as leverage to gain influence and political alignment with host governments [11,25]. The third potential push factor on Chinese finance that we explore is the abundance of natural resources in the recipient country. Resource-seeking theory on foreign direct investment indicates that overseas finance could be driven by interests to secure strategic overseas assets, such as energy resources and we examine whether that applies to Chinese overseas finance [26–27]. We also examine how Chinese finance has been driven by the magnitude of bilateral trade between China and the host country, as the fourth push factor.

"Pull" factors are host countries' demand factors that "pull" Chinese finance into their market. We examine three pull factors. The first pull factor is a host country's energy policies which usually determine the plan for new power projects for the next five to ten years, including total capacity, energy mix and even siting for large projects. Through a series of case studies of Chinese finance abroad published in this journal, Gallagher et al. [13] found that foreign financing can be heavily influenced by local demand. They found domestic pull factors to be key drivers of such investment. In this paper, we use the new power capacity built in host countries as a proxy for the local demand for new power projects. We also include local coal reserves, gas reserves and hydropower potential as the second pull factor to explain the different technology choices made by Chinese financiers. For the overall economy, we examine the effect of gross domestic product (GDP) per capita as the third pull factor on Chinese finance (indicating total aggregate demand in the host country).

In addition to the push and pull factors, we also control for a number of other factors, including population, institutionalized democracy, the signing of a BRI memorandum of understanding (MOU) with China, existing trade with China in power equipment and power engineering services, and existing trade with major developed countries in power equipment and power engineering services.

2.2. Econometric model

We use a multivariate fixed-effect regression model to understand the effects of different independent variables on each type of Chinese finance (development finance, DF and foreign direct investment, FDI) in each developing countries' power sector. The model is given as:

$$\text{Chinesedevelopmentfinance}_{ijt} = \beta_0 + \beta_1 push_{ijt} + \beta_2 pull_{ijt} + \beta_3 control_{ijt} + \eta_t + \tau_t + \varepsilon_{it}$$

$$\text{Chineseforeigndirectinvestment}_{ijt} = \beta_0 + \beta_1 push_{ijt} + \beta_2 pull_{ijt} + \beta_3 control_{ijt} + \eta_t + \tau_t + \varepsilon_{it}$$

Chinese development finance or foreign direct investment are the two different mechanisms of Chinese overseas financing to country i in technology j in year t; $push_{ijt}$ is a vector of four push factors (overcapacity; voting distance; trade with China; resource rent); $pull_{ijt}$ captures the three pull factors (new power demand; GDP per capita; power resource potential); $control_{ijt}$ stands for the five controlled variables (population; BRI; the level of instutionalized democracy; trade with China in the power sector; trade with other countries in the power sector); η_t and τ_t stands for the year- and country-fixed effect, respectively, and ε_{it} is a stochastic error term. Data sources and description for each variable is shown in the Data collection section below.

We converted the project-level data on Chinese finance and the potential driving factors (independent variables) into a panel dataset covering 35 countries from 2005 to 2018 for three power technologies (coal, gas and hydropower). For Chinese development finance, we measure it by both project capacity (MW) and monetary value (million US dollar). For Chinese foreign direct investment, we measure it by project capacity only due to a lack of monetary value information. We also ran the Hausman test to determine whether the fixed effect or random effect model is more appropriate for our data set and thus chose the fixed effect model.

2.3. Data collection

We use Boston University China's Global Power (CGP) database as our source for Chinese development finance, and FDI in the global electric power sector, which are derived from Li et al. [7] and Chen et al. [17]. These datasets complement those by AidData, which are widely used as a data source for Chinese development finance globally. The CGP has a focus on the power sector, includes FDI, and includes more years of observations that are not included in the AidData suite [17]. We compare the development finance data we use from CGEF with AidData in the power sector and the results are shown in Fig. S6-7. For Chinese development finance, we use information on project capacity (MW) and monetary value (million US $). We run two sets of regressions for both. For Chinese foreign direct investment, we only have complete information on project capacity and we only run regression using Chinese foreign direct investment in the unit of project capacity (MW). The 35 countries examined are listed and all independent variables are described below with a detailed list of their sources in the Supplementary Information at the end of this document.

2.3.1. Push factors

For overcapacity, we use the peak year method to measure excess capacity in the Chinese domestic power industry. We collect the annual added power capacity in China from 2005 to 2018 for coal, gas and hydropower plants through the Platts database [29]. The key assumption is that Chinese industrial capacity to build new power projects stays the same after the peak year of installment for each of the technologies. Therefore, the amount of overcapacity can be quantified as the difference between the peak year installment and the new capacity installed in a given year. For voting distance, we use the dataset developed by Bailey et al. [30] based on the United Nations General Assembly voting database. The voting distance measures how the recipient countries' vote align with the Chinese vote for all votes taken at the United Nations. We use its log form in our model. For total bilateral trade data, we collected both import and export data reported by China from the International Trade Statistics Database developed by UN Comtrade [31]. We use its log form in our model. For resource rent, the value gained from the sales of natural resources after all monetary costs have been accounted for, we use the natural resource rent indicator developed by the World Bank's World Development Indicators (WDI), which measures the total natural resource rent as a share of gross domestic product (GDP) in a given country [32].

2.3.2. Pull factors

For new power capacity, we collect new power capacity additions for coal, hydro and gas power plants in 35 host countries from 2005 to 2018 from Platts. We use its log form in our model. We collect GDP per capita from the World Bank's World Development Indicators [31]. For potential power resource, we collect coal and gas reserves from the BP Statistical Review and use its log form in our model. We collect hydropower potential based on Zhou et al. [33] and assume the potential remains the same from 2015 to 2018. We use the log form for all three technologies. We do not analyze solar or wind resources in this analysis.

2.3.3. Control factors

For existing trade in power equipment and engineering services with

China and other developed countries, we use Platts to trace the source country of key power equipment and engineering services in all power projects globally. For power equipment, we include steam supply systems, turbines and generators and source their manufactures through the abbreviation list provided by Platts. For engineering services, we include primary construction contractors and primary architecture/engineering firms and source their country of origin through the abbreviation list. For developed countries, we include Japan, Germany, US. We use the log form by capacity of the power projects examined in our model. We collect population from the World Bank database and use its log form in our model. For the level of institutionalized democracy, we use the Polity2 variable developed by the Polity IV project which scales from + 10 (consolidated democracy) to −10 (hereditary monarchy) [33]. For BRI, we collected records of MOU signatures from the Belt and Road Portal website supported by the Chinese government [34].

3. Results and discussion

3.1. Econometric analysis on potential drivers and summary of regression results

We conduct an econometric analysis of the potential drivers described above using our newly created panel dataset which includes all power projects receiving Chinese development finance (DF) or Chinese foreign direct investment (FDI) during 2005–2018 in 35 recipient countries. Using the model we describe above, we measure the effects of various factors have on both variants of Chinese finance during 2005–2018. We ran two sets of regressions, for Chinese DF and FDI respectively, with results shown in Table 2. Overall the R-square ranges from 0.13 to 0.28. While this is larger than other econometric analyses of China's overseas finance [11], we stress that this work complements numerous papers in this journal and others of a more qualitative nature to provide a fuller picture [see 5, 7, 14, 15, 17]. For each driving factor, or independent variables in econometric terms, there are two values we obtain from the regression model. The first value, without parenthesis, is the coefficient shown in the first row for each independent variable, describing the level and direction of the effect the independent variable has on Chinese financing with positive (negative) values indicating correlation (anti-correlation). The p-value is shown in parentheses in the second row for each independent variable and describes the possibility that we reject the null hypothesis that the independent variable has no effect on Chinese financing. There are three thresholds for p values to describe the level of significance, 0.05, 0.01 and 0.001. The smaller the p value, the more likely the independent variable is significantly correlated with our dependent Chinese financing variables.

For some of the driving factors in our model, there are endogeneity concerns where it is difficult to infer the direction of the causality in our regression results. For instance, if we find that the amount of power capacity receiving Chinese development finance is strongly related to new power capacity in recipient countries, it is difficult to tell if a fast-growing electric power market in recipient countries drives Chinese financing as a demand pull or if Chinese financing drives the local electric power market's growth. To avoid such a concern, we lag three such driving factors (new power capacity in host country, added power capacity in the last 5 years involving engineering services or equipment from China in host country, and added power capacity in the last 5 years involving engineering services or equipment from US, Japan and Germany in host country) by one year where we use the values of these various factors during 2004–2017 instead of 2005–2018. The underlying assumption is that although Chinese financing practices in a given year could drive new power capacity additions in that same year, they are not likely to have driven new power capacity additions the year

Table 2
Regression results (single asterisk indicates $p < 0.05$, double asterisk indicates $p < 0.01$, triple asterisk indicates $p < 0.001$; p-value in parentheses).

Independent Variables	Chinese Foreign Direct Investment (log, MW)	Chinese Development Finance (log, MW)	Chinese Development Finance (log, US$)
Push factors			
Overcapacity in China (log)	−0.003	0.030***	0.028**
	(0.631)	(<0.001)	(0.004)
UN voting alignment with China	−0.030	0.432	0.313
	(0.953)	(0.467)	(0.708)
Resource rent in host country (log)	0.006	−0.002	−0.001
	(0.276)	(0.949)	(0.932)
Trade value between host country and China (log)	0.060	−0.022	−0.029
	(0.056)	(0.699)	(0.575)
Pull factors			
New power capacity in host country (log)	0.106***	0.182***	0.164***
	(<0.001)	(<0.001)	(<0.001)
Power resource potential (log)	0.013	0.027*	0.035**
	(0.095)	(0.020)	(0.007)
GDP per capita in host country (log)	0.025	−0.004	−0.003
	(0.290)	(0.904)	(0.939)
Control factors			
Added power capacity in the last 5 years involving EPC or equipment from China (log)	0.053***	0.128***	0.164***
	(<0.001)	(<0.001)	(<0.001)
Added power capacity in the last 5 years involving EPC or equipment from US, Japan and Germany (log)	−0.045***	−0.015	−0.043*
	(<0.001)	(0.398)	(0.031)
Population in host country (log)	0.180	−0.562	−0.827
	(0.722)	(0.435)	(0.319)
BRI (0 before signing BRI MOU and 1 afterwards)	0.091	0.051	0.007
	(0.369)	(0.825)	(0.968)
Polity (Institutionalized democracy)	0.004	−0.005	−0.004
	(0.792)	(0.802)	(0.839)
Country Fixed Effect	**Yes**	**Yes**	**Yes**
Year Fixed Effect	**Yes**	**Yes**	**Yes**
R-squared	**0.21**	**0.28**	**0.27**
Number of countries	**35**	**35**	**35**
Number of technologies	**3**	**3**	**3**
Number of observations	**1464**	**1464**	**1464**

before. Such lag regression practices have also been applied in other development finance and energy literature [11,25–28]. Table 3 presents the results when the three variables are lagged by one year while the other variables remain the same. We have also tested regressions with two-year and three-year lags on these variables and the results are shown in Table S1 and Table S2. Descriptive statistics for all variables are shown in Table S3.

Based on the regression results in Tables 2 And 3, we are able to estimate how significant the relationship of each independent variable is on the two dependent variables of Chinese overseas financing. For the push factors we examine, overcapacity in Chinese domestic market is the only push factor we found to have a significant correlation with Chinese overseas financing and such correlation is only applicable to Chinese development finance and not FDI. Our results indicate that an overcapacity in the Chinese domestic market pushes more Chinese development finance to other developing countries. For the other push factors (such UN voting alignment between host country with China, resource rent in host coutry, or trade value), we do not find any significant correlation with Chinese overseas financing. For the pull factors we examine (see table 2), we find the new power capacity additions in host countries to be significantly correlated with the amount for both mechanisms of Chinese financing. When we lag the new power capacity additions by one year as well as the other two control variables (see table 3), we find that new power capacity additions in host countries only have a significant correlation with Chinese foreign direct investment. The lagged results are more credible as the endogeneity issue could threaten the results in table 2. We also find power resource potential to have a significant and positive correlation with Chinese development finance. For GDP per capita, it has no significant correlation with Chinese overseas financing. For the control factors we examine, we find that the added power capacity in a given host country involving China in EPC or equipment supply in the last five years has a significant and positive correlation with the amount of both types of Chinese financing in the same country. We also find that added power capacity in a given host country involving EPC or equipment supply from U.S., Japan and Germany has a significant and negative correlation with Chinese foreign direct investment and Chinese development finance measured in dollar value. For the rest of the control variables (signing of a BRI MOU with China or the level of institutionalized democracy), we find them to have no significant correlation with Chinese overseas financing. We discuss the significant drivers in more detail in the following section.

3.2. Push Factor: Domestic overcapacity in China

We measured the amount of excess technical capacity in Chinese domestic market to build new coal, gas and hydropower projects by comparing the annual new power capacity additions with the historical peak year record. For the Chinese coal power industry, we found that overcapacity emerged in 2007 and grew to be around 40 GW per year after 2013. As shown in Fig. 1, the trend of Chinese domestic overcapacity in coal matches the trend in Chinese overseas finance in coal projects. We also found that about 10 GW of overcapacity in Chinese hydropower occurred around 2010 and remained constant each year after 2015. For the Chinese gas power industry, overcapacity occurred in 2015 and the scale was much smaller - around 2 GW.

Our multivariate econometric models suggest that overcapacity in Chinese domestic market could explain Chinese overseas development finance with statistical robustness but not in the case of Chinese foreign

Table 3

Regression results. One-year lag for new power capacity in host country, added power capacity in the last 5 years involving EPC or equipment from China, added power capacity in the last 5 years involving EPC or equipment from U.S. Japan and Germany (single asterisk indicates $p < 0.05$, double asterisk indicates $p < 0.01$, triple asterisk indicates $p < 0.001$; p-value in parentheses).

Independent Variables	Chinese Foreign Direct Investment (log, MW)	Chinese Development Finance (log, MW)	Chinese Development Finance (log, US$)
Push factors			
Overcapacity in China (log)	−0.005	0.025**	0.024*
	(0.437)	(0.007)	(0.021)
UN voting alignment with China	0.116	0.775	0.715
	(0.826)	(0.331)	(0.398)
Resource rent in host country (log)	0.006	0.003	0.004
	(0.279)	(0.747)	(0.606)
Trade value between host country and China (log)	0.067	−0.005	−0.009
	(0.41)	(0.917)	(0.837)
Pull factors			
New power capacity in host country (log)	0.046***	0.022	0.028
	(<0.001)	(0.245)	(0.197)
Power resource potential (log)	0.016	0.045***	0.053**
	(0.051)	(<0.001)	(<0.001)
GDP per capita in host country (log)	0.022	−0.013	−0.011
	(0.374)	(0.721)	(0.656)
Control factors			
Added power capacity in the last 5 years involving EPC or equipment from China (log)	0.065***	0.108***	0.124***
	(<0.001)	(<0.001)	(<0.001)
Added power capacity in the last 5 years involving EPC or equipment from US, Japan and Germany (log)	−0.0254	0.011	−0.001
	(0.069)	(0.590)	(0.961)
Population in host country (log)	0.168	−0.403	−0.655
	(0.748)	(0.610)	(0.786)
BRI (0 before signing BRI MOU and 1 afterwards)	0.070	0.067	0.006
	(0.508)	(0.674)	(0.974)
Polity (Institutionalized democracy)	0.008	0.005	0.007
	(0.573)	(0.811)	(0.775)
Country Fixed Effect	**Yes**	**Yes**	**Yes**
Year Fixed Effect	**Yes**	**Yes**	**Yes**
R-squared	**0.15**	**0.14**	**0.13**
Number of countries	**35**	**35**	**35**
Number of technologies	**3**	**3**	**3**
Number of observations	**1464**	**1464**	**1464**

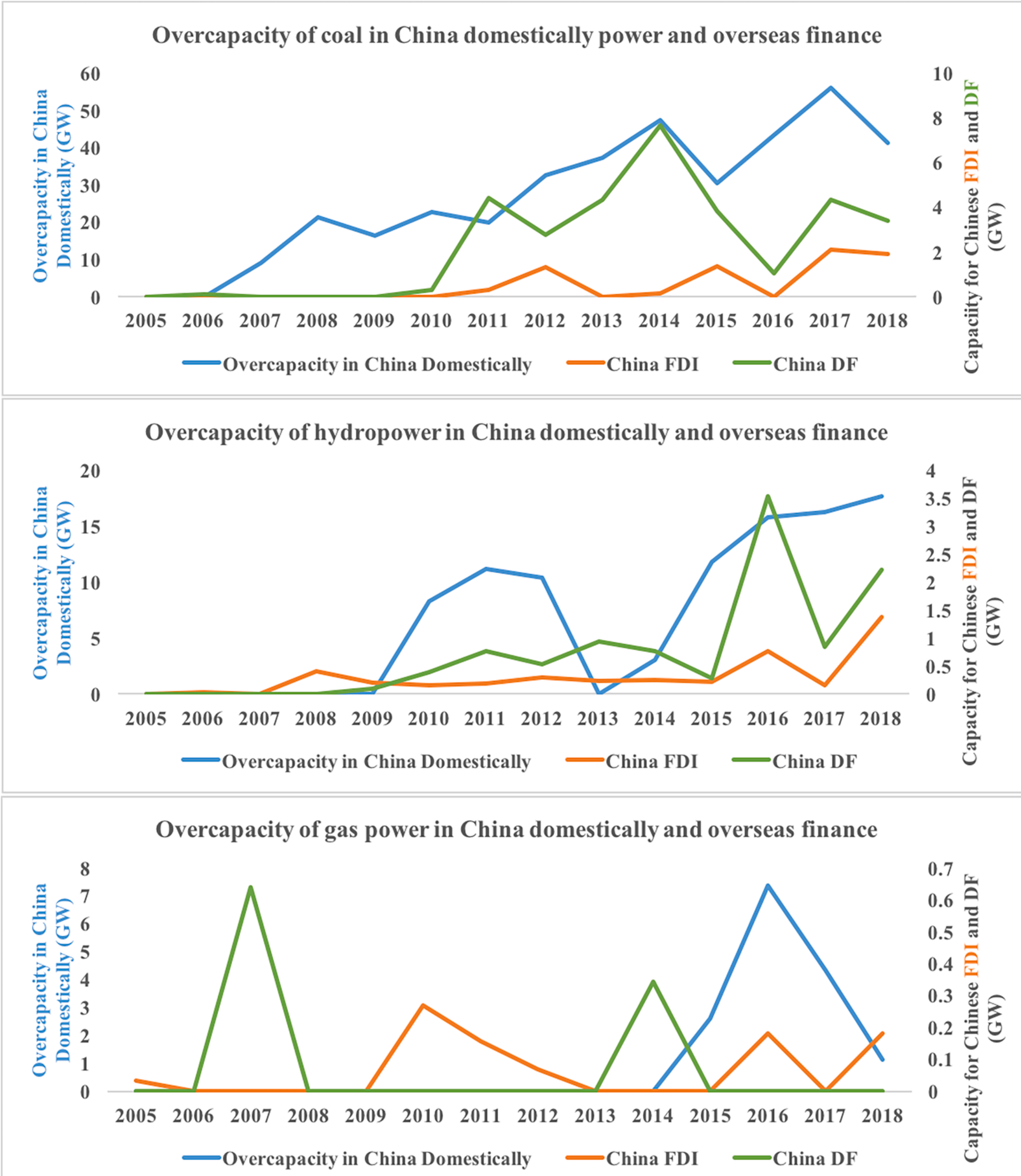

Fig. 1. Measured overcapacity in Chinese domestic power industries (left axis) and Chinese overseas finance in coal, gas and hydropower projects (right axis) from 2005 to 2018.

direct investment. Our results are consistent with case study research which found that China's development finance supported state objectives to export domestic overcapacity. These findings are especially true in the case of coal power and hydropower projects [13]. In the case of Chinese foreign direct investment, such incentives are less important. As a complementary piece of evidence, we also observed a higher utilization rate of Chinese power equipment and engineering services in power plants receiving Chinese development finance than in power plants receiving Chinese foreign direct investment. Out of the 56 GW of power projects receiving development finance from China, 42 GW (75%) utilize power equipment manufactured by Chinese companies, and 49 GW (87%) utilize engineering services provided by Chinese companies for project construction or project design. In comparison, out of the 20 GW of power projects receiving FDI from China, 11 GW (57%) utilize power equipment manufactured by Chinese companies, and 14 GW (69%) utilize engineering services provided by Chinese companies for project construction or project design.

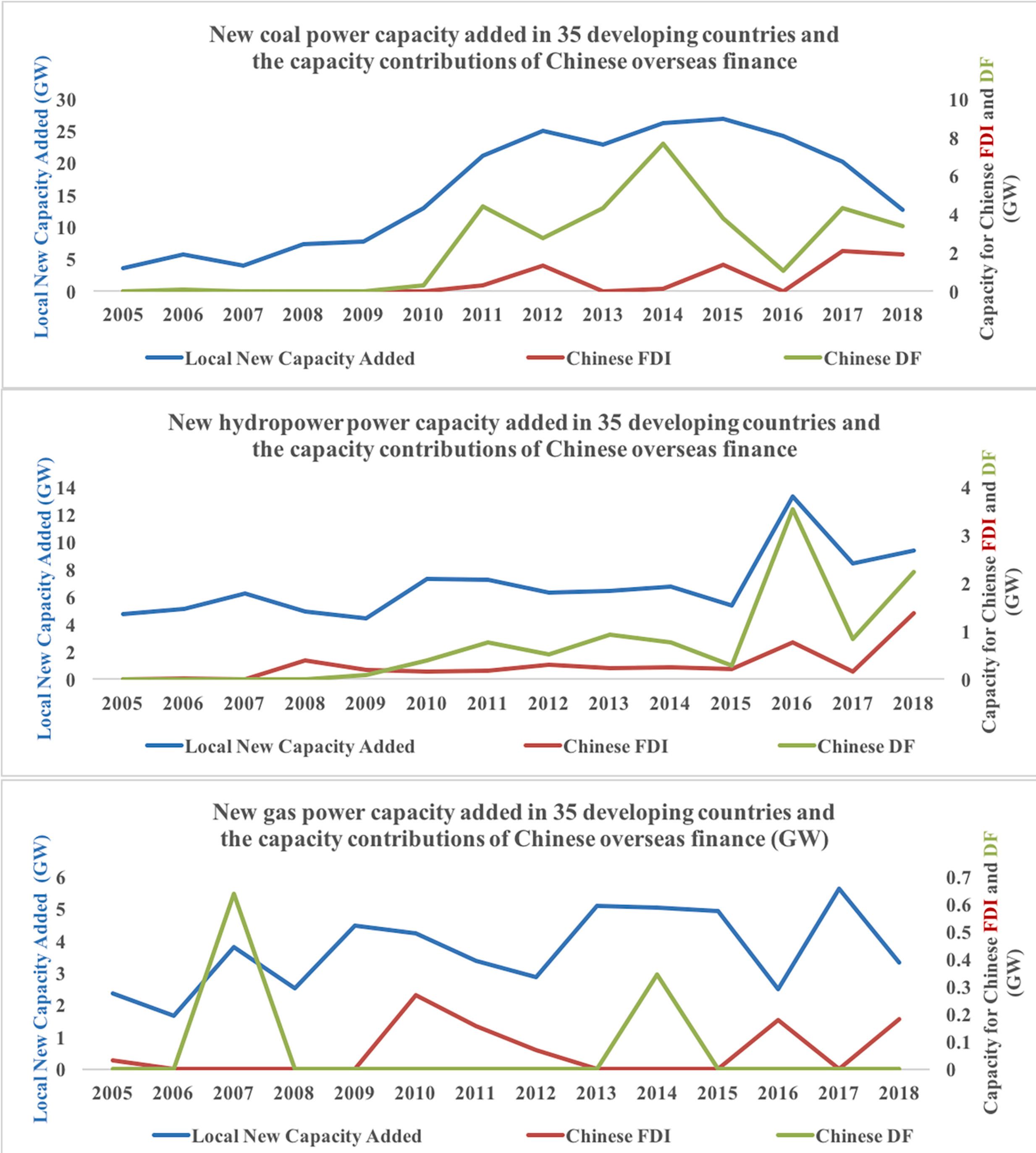

Fig. 2. Local new capacity (left axis) measured as added new power capacity in 35 developing countries receiving Chinese finance and Chinese overseas development finance and foreign direct investment (right axis) in coal, gas and hydropower projects from 2005 to 2018.

3.2.1. Pull Factor: Demand for new power capacity in host countries

From table 2, we observe that new power capacity additions in host countries has are strongly correlated ($p < 0.001$) with the size of Chinese overseas finance (both DF and FDI). This is also seen in Fig. 2. Installation of new coal projects increased substantially in developing countries starting in 2009 and Chinese finance of coal grew starting in 2010. In the case of hydropower, the capacity of new hydropower projects in developing countries remained constant during 2005–2015 and increased after 2015, which also coincided with growth of Chinese development finance in overseas hydropower projects. There are two potential causal mechanisms to explain such correlations. The first is that Chinese finance is pulled by the growing markets in developing countries. The second explanation is that the increasing new demand in developing countries is pushed by Chinese finance and the higher growth rate would not appear without it. If this is the case, a question remains as to what is causing the push. To avoid the endogeneity concern in the second explanation, we lagged new power capacity by one year and examine the effects of new power capacity additions in developing countries from 2004 to 2017 on Chinese overseas finance from 2005 to 2018. The results are shown in Table 3. Although in the no-lag scenario shown in Table 2, both Chinese development finance and Chinese foreign direct investment are found to be positively correlated with market demand in host countries, in the lagged scenario shown in Table 3, only Chinese foreign direct investment is found to be significantly correlated with market demand in host countries. Since Chinese finance is not likely to have an effect on new power capacity additions the year before financing is provided, such results suggest that Chinese foreign direct investment, instead of Chinese DF, is more likely to follow a growing market, rather than creating a new market. This supports the profit-seeking nature of foreign direct investment when compared with development finance.

3.3. Pull factor: Power resource potential in host countries

From our econometric analysis, we observe a positive and statistically significant coefficient for host country power resource potential on Chinese development finance but not on Chinese foreign direct investment. As described in the methodology section, we measure power resource potential as the coal and gas fuel reserves and hydropower potential in a given country. This result suggests that abundant local power resources are an important pull factor for Chinese development finance. In a mature power market, the abundance of local coal and gas, and hydropower potential are important factors determining the feasibility and bankability of individual power projects. Abundant local resources in coal, gas or hydropower would attract investment in the corresponding type of power projects. However, among the poorest developing countries, the low demand for electricity and poor transmission infrastructure results in non-bankable power projects under market conditions, despite abundant local resources. Our results indicate that Chinese development banks could be important sources of finance for power sector development in such cases. For example, in Africa, Chinese development banks have been important sources of finance for new hydropower projects. Out of the 35 developing countries we examine, Democratic Republic of Congo and Republic of Congo have the largest hydropower potential and represent 39% of the hydropower resources in these 35 countries. In Democratic Republic of Congo and Republic of Congo, there is no hydropower project receiving finance from Chinese power developers or other major international power developers in the form of foreign direct investment, although the local hydropower resource is very abundant. However, Chinese development finance has contributed to 68% of all new hydropower capacity, or 35% of all new power capacity from 2005 to 2018 in these two countries. Another 240 MW hydropower project in Democratic Republic of Congo financed by Chinese ExIm Bank is also in the pipeline. Chinese development finance and engineering companies have been involved in electricity transmission projects as well and since 2005 electricity access in these two countries has greatly improved.

3.4. Push and Pull: Building a customer base

We also find that Chinese finance tends to flow where it has been concentrated in the recent past, and to some extent where Western (US, Japan or Germany in this study) finance is not flowing. The "added capacity over the past five years involving power equipment or engineering services provided by Chinese companies in the host country" variable stays consistently significant regardless of whether we test for FDI or DF and whether variables are lagged or not. As the tables show, for both FDI and DF there is a statistically significant correlation showing that as China increases its export of power equipment and engineering services to a given country, there tends to be a positive effect resulting in continually increasing Chinese finance to power plant projects. For the FDI variable, we find a negative correlation for countries that have had a significant growth in import of power equipment and engineering services from non-Chinese countries, indicating a negative effect of increasing power equipment imports from non-Chinese countries on Chinese finance of power plant projects.

As reported by earlier researchers, Chinese involvement in the developing countries' power sector includes not only finance but also export of power equipment and power engineering services [36–37]. From 2005 to 2018, we found such Chinese trade practices to be involved in 173 GW of projects in 58 developing countries, which suggests that Chinese export of power equipment and power engineering services have been an important form of Chinese involvement in the power sector of developing countries.

To avoid endogeneity concerns in our regressions in this case as well, we also lagged existing Chinese trade by one year and obtained similar results. There are two potential mechanisms to explain the facilitating effect of existing trade with China on Chinese finance in the power sector in the same country. First, existing Chinese business in the local power sector smooths interactions and reduces the transaction costs for Chinese financing. Since the early 2000 s, most Chinese power equipment manufacturers and engineering companies have established a global office network to support their global business in power equipment sales and international contracting services. Such existing connections have been important sources of potential project information as well as local connections and market knowledge. In addition, there are also spillover effects where such information could be transferred from frontline companies to Chinese development banks and other power investors back in China. Secondly, greater trade with China in power equipment and engineering services is indicative of local acceptance of Chinese business and technical abilities to produce and deliver key equipment and engineering services. While there is a lack of data to support this assertion, knowledge from the field suggests that Chinese investors have a cost advantage over global competitors through their close alliance with Chinese power manufacturers and engineering companies.

3.5. Belt and Road Initiative: Not much of a pull yet, despite the push

Starting in 2013, dozens of countries signed memorandum of understanding with the Chinese government for bilateral cooperation under the Belt Road Initiative (BRI). Although in 2014, only nine developing countries signed MOU with China, in 2018 the number increased to more than 60. Infrastructure development is a key area for cooperation and many power projects receiving Chinese finance have been included in various BRI project lists. While many would expect that the development of BRI has been a strong driving factor pushing Chinese finance out to overseas power projects, our results do not yet show a statistically significant correlation between signing a BRI MOU with China and the amount of Chinese finance received by a given country. The result is also consistent with knowledge from the field that most power projects secured Chinese financing before the host country signed the MOU. The projects listed in the MOU are simply a list of existing projects, rather than new commitments. It is important to note that we are only analyzing projects built from 2005 to 2018 and power projects usually have a long development cycle. Thus, it could take more time for the newly established BRI framework to have a visible effect on the quantity of Chinese overseas finance available to the developing countries' power sector.

4. Concluding discussion

Utilizing datasets from our previous work, we performed a statistical analysis to estimate the determinants of Chinese power plant finance in the developing world. We considered that such finance and investment would be a function of both the supply of Chinese finance—referred to in the literature 'push' factors, and the demand for such finance in host countries—referred to as 'pull' factors. We deployed a fixed effect model to analyze a vector of push and pull factors on two different channels of Chinese overseas finance in developing countries' power sectors —foreign direct investment and development finance.

In large part, we corroborate many of the qualitative research findings that have been published in this journal and beyond—that Chinese energy finance is largely driven by pull factors in recipient countries [13,14,15]. We find that Chinese foreign direct investment (FDI) in the power sector is likely to be market driven, pulled by demand for electric power in developing countries and in regions where such a 'customer base' is building over time. Only in the case of Development finance is there a significant push factor determinant, where China's policy banks provide outlets for sectors that are facing overcapacity in mainland China, and to make inroads into countries that have abundant energy capacity but that are not yet market competitive. Only in one qualitative study was overcapacity seen as a push factor, in coal [15].

China's activities in other developing countries can have huge implications on local countries' energy development pathways [39,40]. As Cabré et al. [41] estimated there to be $800 billion dollars of solar and wind investment potential based on the National Determined Contributions by all participating countries in the Paris Agreement, Chinese growing finance in developing countries could be important in realizing a share of this investment potential. Our results provide insights on how both Chinese FDI and development finance could facilitate renewable energy transitions in developing countries. As shown in data in Fig. S4, solar and wind projects represent 14% of all overseas power projects receiving Chinese FDI, by capacity. This indicates that Chinese globally competitive renewable energy companies have already been investing in developing countries where they have established distribution networks or where the renewable power market is attractive. As the cost of solar and wind power continues to decrease and becomes more economically competitive, there is an opportunity for developing countries to pull more Chinese FDI into their renewable projects. For Chinese development finance, our analysis suggests that a push from Chinese overcapacity in domestic industries is important in driving Chinese development finance outward, in the case of coal and hydropower projects. While there has also been overcapacity in Chinese solar and wind industries since the early 2010 s, only 2% of Chinese development finance in the power sector has been devoted to renewable projects (as shown in Fig. S3), indicating the existence of other factors impeding Chinese development finance flowing into overseas solar and wind projects. Based on the findings in this paper and the corresponding literature then, developing countries should understand that they have more agency and can propose clean energy rather than dirty—to the benefit of each party.

The future build out of power infrastructure will have multi-decade-long effects on global carbon emissions. As estimated by Tong et al., 2019, all existing and proposed energy infrastructure already commits the world to more carbon emissions than the global carbon budget allows under the 1.5-degree target; two-thirds of the global carbon budget is already committed under the two-degree target [42]. Therefore, it is crucial to substantially slow or even halt Chinese FDI and development finance contributions to new carbon intensive power projects overseas. From a non-climate perspective, coal power projects are also important sources of air pollution and water pollution, which have severe public health impacts in many developing countries. Directing Chinese overseas finance away from coal plants would both benefit climate while also bringing substantial co-benefits for water, air quality and public health.

There is no conflict of interest related to this paper.

Funding for this paper came from the ClimateWorks Foundation and Rockefeller Brothers Fund.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.erss.2021.102441.

References

[1] International Energy Agency. Global Energy & CO2 Status Report 2019. (2019).
[2] S.J. Davis, R.H. Socolow, Commitment accounting of CO2 emissions, Environ. Res. Lett. 9 (8) (2014) 084018, https://doi.org/10.1088/1748-9326/9/8/084018.
[3] D. Gielen Perspectives for the Energy Transition Investment Needs for a Low-Carbon Energy System 2017.
[4] A.M. Strange, A. Dreher, A. Fuchs, B. Parks, M.J. Tierney, Tracking underreported financial flows: China's development finance and the aid–conflict nexus revisited, J. Conflict Resolut. 61 (5) (2017) 935–963.
[5] B.o. Kong, K.P. Gallagher, Globalizing Chinese energy finance: the role of policy banks, J. Contemp. China 26 (108) (2017) 834–851.
[6] B. Steffen, T.S. Schmidt, A quantitative analysis of 10 multilateral development banks' investment in conventional and renewable power-generation technologies from 2006 to 2015, Nat. Energy 4 (1) (2019) 75–82.
[7] Z. Li, K.P. Gallagher, D.L. Mauzerall, China's global power: Estimating Chinese foreign direct investment in the electric power sector, Energy Policy 136 (2020) 111056, https://doi.org/10.1016/j.enpol.2019.111056.
[8] K.P. Gallagher, China's global energy finance: Poised to lead, Energy Res. Social Sci. 35 (2018) 15–16.
[9] M. Jun, Z. Simon, Decarbonizing the Belt and Road: A Green Finance Roadmap. Tsinghua University Center for Finance and Development, Vivid Economics and the Climateworks Foundation (2019).
[10] Y. Tao, H. Liang, M.A. Celia, Electric power development associated with the Belt and Road Initiative and its carbon emissions implications, Appl. Energy 267 (2020) 114784, https://doi.org/10.1016/j.apenergy.2020.114784.
[11] A. Dreher, A. Fuchs, B. Parks, A.M. Strange, M.J. Tierney, Apples and dragon fruits: the determinants of aid and other forms of state financing from China to Africa. Int. Stud. Quart. 62, 182-194 (2018).
[12] S. Morris, B. Parks, A. Gardner, Chinese and World Bank Lending Terms: A Systematic Comparison Across, 157, Countries and 15 Years, 2020.
[13] K.S. Gallagher, R. Bhandary, E. Narassimhan, Q.T. Nguyen, Banking on coal? Drivers of demand for Chinese overseas investments in coal in Bangladesh, India, Indonesia and Vietnam, Energy Res. Social Sci. 71 (2021) 101827, https://doi.org/10.1016/j.erss.2020.101827.
[14] B.o. Kong, K.P. Gallagher, Inadequate Demand and Reluctant Supply: The Limits of Chinese Development Finance for Renewable Power, Energy Research and Social Science, 2021.
[15] Bo Kong, Kevin P. Gallagher, The New Coal Champion of the World: The Political Economy of Chinese Overseas Development Finance for Coal-fired Power Plants, Energy Policy Volume 155, August 2021.
[16] X.u. Chen, K.P. Gallagher, D.L. Mauzerall, Chinese Overseas Development Financing of Electric Power Generation: A Comparative Analysis, One Earth 3 (4) (2020) 491–503.
[17] Gallagher, P. Kevin, Li, Zhongshu, Chen, Xu, Ma, Xinyue, "China's Global Power Database," Global Development Policy Center, Boston University, 2019.
[18] T. Kenderdine, P. Lan, China's Middle East investment policy, Eurasian Geogr. Econ. 59 (5-6) (2018) 557–584.
[19] T. Kenderdine, H. Ling, International Capacity Cooperation—Financing China's Export of Industrial Overcapacity, Global Policy 9 (1) (2018) 41–52.
[20] A. Pepermans, Economic Nationalism in All Its Variety: The Case of China's Construction-and Railway Equipment Industry, J. Contemp. China 29 (123) (2020) 431–453.
[22] China Electricity Council, Zhongguodianlihangyeniandufazhanbaogao. https://www.cec.org.cn/upload/zt/ngfzbg2020/index.html., 2020.
[23] B. Jiang, Z. Sun, M. Liu, China's energy development strategy under the low-carbon economy, Energy 35 (11) (2010) 4257–4264.
[24] L. Yue, Dynamics of clean coal-fired power generation development in China, Energy Policy 51 (2012) 138–142.
[25] A. Dreher, A. Fuchs, Rogue aid? An empirical analysis of China's aid allocation, Canad. J. Econom./Revue canadienne d'économique 48 (3) (2015) 988–1023.
[26] V. Foster, W. Butterfield, C. Chen, Building bridges: China's growing role as infrastructure financier for Africa, The World Bank (2009).
[27] T. Lum, H. Fischer, J. Gomez-Granger, A. Leland, China's foreign aid activities in Africa, Latin America, and Southeast Asia, Russia China and Eurasia-Social Historicaland Cultural Issues 25 (2009) 175.
[28] M.J. Tierney, D.L. Nielson, D.G. Hawkins, J.T. Roberts, M.G. Findley, R.M. Powers, B. Parks, S.E. Wilson, R.L. Hicks, More dollars than sense: Refining our knowledge of development finance using AidData, World Dev. 39 (11) (2011) 1891–1906.
[29] Platts S, Global P. World electric power plants (WEPP) database. (2016).

[30] M.A. Bailey, A. Strezhnev, E. Voeten, Estimating dynamic state preferences from United Nations voting data, J. Conflict Resolut. 61 (2) (2017) 430–456.
[31] UN Comtrade database. In: UN Comtrade Online (2019).
[32] World Bank World development indicators, 2019.
[33] L. Zhou, S. Gilbert, Y. Wang, M.M. Cabré, K.P. Gallagher, Moving the green belt and road initiative: from words to actions, World Resour. Instit. Global Dev. Policy Center (2018).
[34] M.G. Marshall, T.R. Gurr, K. Jaggers, Polity IV project: Political regime characteristics and transitions, 1800–2013, Center for Systemic Peace 5 (2014).
[36] C. Springer, S. Evans, F. Teng, Working Paper: An empirical analysis of the environmental performance of China's overseas coal plants, 2020.
[37] P.M. Hannam, Z. Liao, S.J. Davis, M. Oppenheimer, Developing country finance in a post-2020 global climate agreement, Nat. Clim. Change 5 (11) (2015) 983–987.
[39] W. Shen, China's role in Africa's energy transition: a critical review of its intensity, institutions, and impacts, Energy Res. Social Sci. 68 (2020), 101578.
[40] A. Mori, Foreign actors, faster transitions? Co-evolution of complementarities, perspectives and sociotechnical systems in the case of Indonesia's electricity supply system, Energy Res. Social Sci. 69 (2020) 101594, https://doi.org/10.1016/j.erss.2020.101594.
[41] Cabré, Munoz, Miquel, Kevin P. Gallagher, Zhongshu Li, Renewable Energy: China's Trillion Dollar Opportunity, China and the World Economy, / 1–22, Vol. 26, No. 6, 2018.
[42] D. Tong, Q. Zhang, Y. Zheng, K. Caldeira, C. Shearer, C. Hong, Y. Qin, S.J. Davis, Committed emissions from existing energy infrastructure jeopardize 1.5 °C climate target, Nature 572 (7769) (2019) 373–377.