Working Paper: An Empirical Analysis of the Environmental Performance of China's Overseas Coal Plants

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Abstract: Chinas recent commitment to overseas infrastructure investment through the Belt and Road Initiative (BRI) has ignited concern over environmental impacts. The BRIs environmental impacts will be determined by Chinas decisions not only on what kinds of projects to fund, but also how those projects end up operating. It is critical to understand current performance and establish a baseline understanding of the environmental impacts of Chinas overseas projects thus far. We examine the environmental performance of coal-fired power plants in Asia in terms of carbon dioxide emissions intensity, energy efficiency, and use of best-available air pollution control technologies. Using plant-level data, we estimate the comparative environmental performance of overseas coal plants owned, designed, or constructed, by Chinese companies. We find that Chinese coal plants tend to have lower emissions intensity, higher energy efficiency, and better air pollution control technologies than similar non-Chinese coal plants.

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1 Main

Chinas Silk Road Economic Belt and the 21st-Century Maritime Silk Road, abbreviated as the Belt and Road Initiative or BRI, is often introduced in terms of its scale: trillions of dollars; the largest infrastructure program since the Marshall Plan (Nature Editorial 2019); two-thirds of the global population and one-third of the global economy involved (Ascenso et al. 2018). The BRI could contribute greatly to economic growth, and in the electricity generation sector, it can improve energy access and reliability in areas with rapidly growing energy demand (Powanga 2019). However, the BRIs economic benefits and the expansion of electricity systems may come at the expense of the environment. The sheer scale of the BRI has ignited increasing international concern about environmental damage (Horvat and Gong 2019). These environmental concerns include concern about infrastructure development in ecologically sensitive areas, concern about the large amounts of raw materials needed, and concern about lock-in of environmentally harmful types of infrastructure, such as fossil fuel-related infrastructure (Ascenso et al. 2018). Some studies have estimated the lifetime environmental footprints of individual plants using a variety of metrics (Gallagher 2016) (Alkon et al. 2018).

However, these concerns are not only about the scale of BRI, but also the nature of Chinese investment. Chinas leaders describe the Belt and Road Initiative as a massive effort to guide and expand Chinas overseas investment, facilitate South-South cooperation, and promote the Chinese model of development around the world (Ferdinand 2016) (Yeh and Wharton 2016). At the same time, China is criticized for accumulating resources and going overseas with extractive investment projects that have negative social and environmental impacts in host countries (Hofman and Ho 2012). These contrasting viewpoints in fact both reinforce the notion that Chinese overseas projects are qualitatively unique (Lee 2014).

To understand the potential environmental impacts of BRI, we aim to shed light on the current environmental performance of Chinas overseas projects. We assemble a dataset of coal-fired power plants in Asia owned, designed, or built by different national sources. The project type to be assessed, coal-fired power plants, was selected due to ongoing policy dialogue about the role of international finance for coal-fired power plants. As of 2016, almost half of Chinese investment in overseas power generation was for coal plants (Li et al. 2020). The regional focus for this study is Asia: Asia is the first frontier for Belt and Road projects, and it is a locus of coal plant development. While 41% of operating coal plants (by MW) are located in Asia (excluding China), 64% of planned coal plants and 81% of coal plants under construction are in Asia (CoalSwarm 2018).

To understand the potential environmental impacts of BRI, we aim to shed light on the current environmental performance of Chinas overseas projects, many of which were built before BRI was announced. We assemble a historical data set of coal-fired power plants in Asia owned, designed, or built by different national sources. The project type to be assessed, coal-fired power plants, was selected due to ongoing policy dialogue about the role of international finance for coal-fired power plants. A number of NGOs and academic institutions actively track coal plant projects around the world, with a particular focus on coal plants

featuring Chinese involvement. In recent years, a number of public institutions (such as the World Bank and the lending agencies of the U.S., U.K., and several other countries) and private banks (such as BNP Paribas, Deutsche Bank, Santander, and Barclays) have restricted direct financing of coal power plants. Many environmental advocates have expressed interest in the Belt and Road Initiative and concern over its environmental impacts. As of 2016, almost half of Chinese investment in overseas power generation was for coal plants, as opposed to other generation technologies (Li et al. 2020). While the Asian Infrastructure and Investment Bank (of which China was a founding member) has ruled out finance for coal-fired power plants, no Chinese banks or companies have placed any restrictions on participation in overseas coal projects to date (Buckley 2019). Our dataset enables us to investigate Chinese involvement in overseas projects through Engineering, Procurement, and Construction (EPC) arrangements with Chinese engineering and construction companies, the most common vehicle for Chinese investment prior to 2018 (Wang and Li 2019), as well as direct investments carried out by Chinese parent companies. The regional focus for this study is Asia: Asia is the first frontier for Belt and Road projects, and it is a locus of coal plant development. While 41% of operating coal plants (by MW) are located in Asia (excluding China), 64% of planned coal plants and 81% of coal plants under construction are in Asia (CoalSwarm 2018).

This study aims to provide aggregated, comparable quantitative evidence on the claim of the uniqueness of Chinese involvement and environmental performance. Academic studies from the fields of geography, sociology, and area studies have formed a robust literature of case studies of Chinas projects in other countries. While these case studies document social and environmental impacts for individual BRI projects, they are less useful for understanding relative or aggregated impacts. The BRI will play a large role in the future course of the global energy system based on Chinas decisions on what kinds of energy projects to fund and how those projects end up operating. Therefore, it is critical to understand how these coal-fired power plants perform and to establish a baseline understanding of the environmental impacts of Chinas overseas projects thus far.

2   Identifying Plant Ownership and Estimating Environmental Performance

We collected plant-level data on coal plants in Asia (excluding China) from the March 2018 version of the Platts World Electric Power Plants (WEPP) database. Our dataset enables us to investigate Chinese involvement in overseas projects through Engineering, Procurement, and Construction (EPC) arrangements with Chinese engineering and construction companies, the most common vehicle for Chinese investment prior to 2018 (Wang and Li 2019), as well as direct investments carried out by Chinese parent companies. We used the WEPP data on parent company, engineering company, and construction company to identify the country of origin for each of these types of companies. Each type of company was then coded with an indicator treatment variable for Chinese or non-Chinese ownership. This indicator

variable represents identifiable Chinese involvement in a project, which may include management practices, technology choices, or other mechanisms that are unique. Figure 1 shows a map of the coal plants in this dataset that have latitude and longitude information.

Figure 1: Map of Coal Plants in Asia (excluding China)
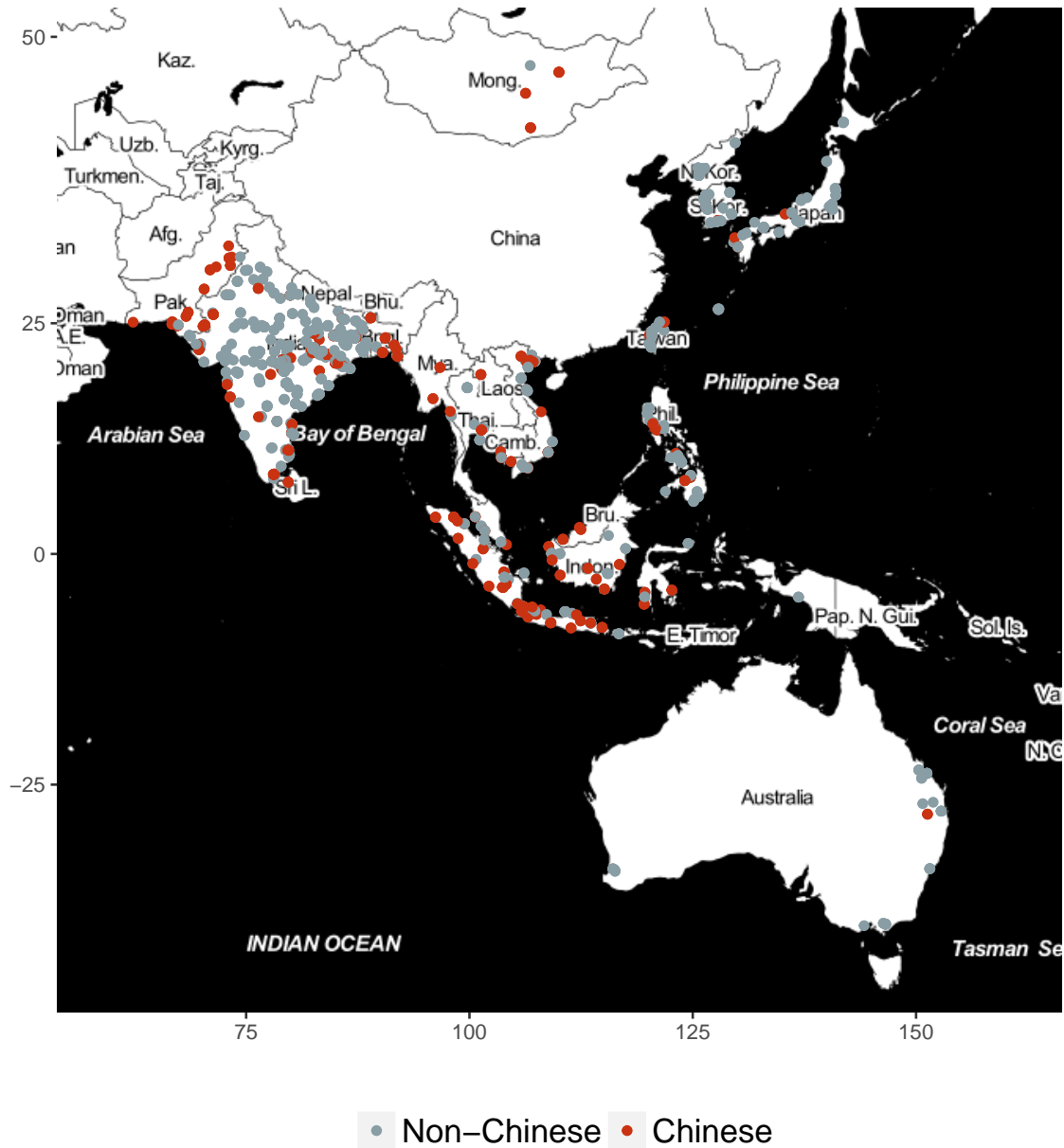
We assessed three metrics of environmental impact: CO_2 emissions intensity, energy efficiency, and air pollution control technology. CO_2 emissions intensity, or the amount of CO_2 a plant produces per unit of energy generated, was constructed using data from the Global Coal Plant Tracker database. For energy efficiency, we used steam temperature and steam pressure provided in the WEPP data. The higher the temperature and pressure of the steam produced by coal combustion used to power the turbine, the more efficient the process. For air pollution control technology, we used the WEPP data on particulate matter, sulfur diox-

ide, and nitrogen oxides control technology types to assess whether each plants technology was best available technology (BAT) or not (see Supplementary Information for details). The concept of BAT is widely used in pollution control laws and refers to the most effective pollution control technology that is commercially available and practically viable.

In addition to ordinary least squares (OLS) regressions, we run a model with year fixed effects and country fixed effects in order to control for unobservable factors that may confound the relationship between company ownership and environmental performance. For example, the year fixed effects will control for differences in the year the plant was built, and therefore differences that could be explained by Chinese investments simply being more recent. Country fixed effects plausibly control for variation explained by Chinese involvement in areas with stricter emissions controls or regulations. In order to address possible selection bias, we also run a regression on a matched data set where Chinese-owned plants are matched to similar non-Chinese owned plants.

3 Comparative Performance of Chinese Coal Plants

Table 1 presents the results from our analysis of CO2 emissions intensity. We show the coefficient for the effect of Chinese ownership, controlling for status and type of coal plant, for four specifications: OLS (models 1 and 5), OLS with controls (models 2 and 6), country-year fixed effects (models 3 and 7; the most restrictive specification), and propensity score matching (models 4 and 8). These specifications indicate a statistically significant effect similarly large in magnitude for plants with Chinese parent companies - that is, plants with Chinese parent companies have around 8-18% lower emissions intensity. We find that the effect on CO2 emissions rate is in the same direction but lower in magnitude for a Chinese engineering or construction company.

Table 1: CO2 Emissions Results, Coefficient of Chinese Ownership Indicator

| | *log(Emissions Factor * Heat Rate)* | | | | | | | |
| | Parent Company | | | | Engn./Const. Company | | | |
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Chinese Parent Company	-0.181***	-0.101***	-0.079***	-0.151***				
	(0.033)	(0.029)	(0.023)	(0.046)				
Chinese Engn./Const. Company					-0.063***	0.038***	0.007	-0.030*
					(0.013)	(0.013)	(0.011)	(0.016)
Controls	No	Yes	Yes	No	No	Yes	Yes	No
Country FE?	No	No	Yes	No	No	No	Yes	No
Year FE?	No	No	Yes	No	No	No	Yes	No
Observations	1,863	1,863	1,796	50	1,054	1,054	1,025	488
Adjusted R^2	0.006	0.599	0.762	0.126	0.051	0.691	0.785	0.027

Note: * p < -0.1; ** p < 0.05; *** p < 0.01

Table 2 presents the results for the energy efficiency analysis. Higher steam temperature and pressure means higher thermodynamic efficiency in converting coal into electric power.

We find that Chinese companies are associated with higher energy efficiency in coal plants, mirroring the direction of results for CO2 emissions intensity (since higher energy efficiency would tend to be associated with relatively lower emissions intensity). Coal plants with Chinese engineering or construction companies have around 3-5% higher steam temperature than those with non-Chinese engineering or construction companies, and 10-30% higher steam pressure, an effect that is significant across specifications. However, the effect of a Chinese parent company is not significant across specifications.

Table 2: Energy Efficiency Results, Coefficient of Chinese Ownership Indicator

	log(Steam Temperature)							
	Parent Company				Engn./Const. Company			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Chinese Parent Company	0.070*	0.002	0.019	0.063				
	(0.040)	(0.036)	(0.032)	(0.040)				
Chinese Engn./Const. Company					0.046***	0.033***	0.027***	0.025**
					(0.008)	(0.008)	(0.009)	(0.012)
Controls	No	Yes	Yes	No	No	Yes	Yes	No
Country FE?	No	No	Yes	No	No	No	Yes	No
Year FE?	No	No	Yes	No	No	No	Yes	No
Observations	1,393	1,393	1,324	16	682	682	662	224
Adjusted R^2	0.001	0.281	0.512	0.089	0.042	0.322	0.408	0.016

	log(Steam Pressure)							
	Parent Company				Engn./Const. Company			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Chinese Parent Company	0.645***	-0.039	0.080	0.469*				
	(0.216)	(0.143)	(0.120)	(0.263)				
Chinese Engn./Const. Company					0.302***	0.100***	0.108***	0.150***
					(0.049)	(0.031)	(0.031)	(0.056)
Controls	No	Yes	Yes	No	No	Yes	Yes	No
Country FE?	No	No	Yes	No	No	No	Yes	No
Year FE?	No	No	Yes	No	No	No	Yes	No
Observations	1,406	1,406	1,337	16	684	684	664	224
Adjusted R^2	0.006	0.599	0.762	0.126	0.051	0.691	0.785	0.027

Note: * $p < -0.1$; ** $p < 0.05$; *** $p < 0.01$

Table 3 presents the results for the air pollution control technology analysis. BAT is coded as 1 and non-BAT as 0, so in interpreting the results we find that positive coefficients indicate a higher likelihood of having BAT technologies. In particular, we find that a Chinese parent company means a plant is 22%-40% more likely to have BAT for sulfur dioxide control technologies, while plants with Chinese engineering and construction companies are 7%-15% more likely to have better NOx control technology. Using a similar dataset, Li et al. (2020) found that Chinese overseas coal plants have more capacity with SO2 and NOx control technologies, though they caveated their results, which are based on self-reported data within the WEPP.

However, we also found that plants with Chinese parent companies were less likely to have BAT for particulate matter controls. In addition, plants with Chinese engineering and con-

struction companies are 4%-7% less likely to have best available particulate matter controls and also less likely to have best available sulfur dioxide control technologies. These opposing results need to be further explored. Although we control for country-level fixed effects, there could be sub-national factors driving environmental regulations of these plants. Additional robustness checks for our analysis are in the Supplemental Information.

Table 3: Air Pollution Results, Coefficient of Chinese Ownership Indicator

| | Particulate Matter Control BAT | | | | | | | |
| | Parent Company | | | | Engn./Const. Company | | | |
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Chinese Parent Company	-0.020	-0.059	-0.258***	0.118				
	(0.084)	(0.078)	(0.080)	(0.081)				
Chinese Engn./Const. Company					-0.045**	-0.038*	-0.030	-0.069**
					(0.022)	(0.022)	(0.023)	(0.027)
Controls	No	Yes	Yes	No	No	Yes	Yes	No
Country FE?	No	No	Yes	No	No	No	Yes	No
Year FE?	No	No	Yes	No	No	No	Yes	No
Observations	1,796	1,796	1,606	34	1,086	1,086	1,003	490
Adjusted R^2	-0.001	0.170	0.421	0.033	0.003	0.088	0.426	0.011

| | Sulfur Dioxide Control BAT | | | | | | | |
| | Parent Company | | | | Engn./Const. Company | | | |
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Chinese Parent Company	0.403***	0.376***	0.280***	0.227*				
	(0.107)	(0.091)	(0.083)	(0.119)				
Chinese Engn./Const. Company					-0.027	-0.037	-0.129***	-0.004
					(0.035)	(0.031)	(0.029)	(0.043)
Controls	No	Yes	Yes	No	No	Yes	Yes	No
Country FE?	No	No	Yes	No	No	No	Yes	No
Year FE?	No	No	Yes	No	No	No	Yes	No
Observations	1,629	1,629	1,419	44	1,103	1,103	1,023	554
Adjusted R^2	0.008	0.312	0.592	0.057	0.0003	0.281	0.566	0.002

| | Nitrogen Oxides Control BAT | | | | | | | |
| | Parent Company | | | | Engn./Const. Company | | | |
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Chinese Parent Company	0.251	0.008	-0.074	0.000				
	(0.217)	(0.167)	(0.176)	(0.000)				
Chinese Engn./Const. Company					0.152***	0.105**	0.077*	0.049
					(0.056)	(0.049)	(0.045)	(0.034)
Controls	No	Yes	Yes	No	No	Yes	Yes	No
Country FE?	No	No	Yes	No	No	No	Yes	No
Year FE?	No	No	Yes	No	No	No	Yes	No
Observations	394	394	372	8	271	271	264	82
Adjusted R^2	0.001	0.500	0.766	0.462	0.023	0.432	0.769	0.013

Note: * p < -0.1; ** p < 0.05; *** p < 0.01

In this analysis, we use parent and engineering/construction companies as proxies for Chinese involvement, suggesting a potential mechanism through which differential environmental impacts occur. The results suggest that the companies that manage, design, and build coal

plants are what drive relative performance. Parent companies are hypothesized to mediate external pressures (i.e. from government, activists, and shareholders) and potentially translate these policies into a specific plants adoption of environmental management practices (Delmas and Toffel 2004). From our dataset, the top 5 Chinese parent companies with the most coal plants elsewhere in Asia are CIIDG Erdos Hongjun Electric Power, China Hongqiao Group, Huadian, Datang, and Gezhouba. Huadian and Datang are among the largest state-owned power generation companies in China, while Gezhouba is one of the largest construction and engineering companies in China. China Hongqiao Group is a state-owned aluminum producer, and the largest aluminum producer in the world. CIIDG Erdos Hongjun Electric Power is a joint venture between a Cambodian investment development group and a Chinese electric power company. For their overseas endeavors, these parent companies receive financial support from Chinese state banks, like the China Development Bank, as well as commercial banks, like Bank of China. These companies are directly subject to various guidelines issued by Chinas state agencies. For example, in addition to complying with host country environmental regulations, firms are requested undertake environmental impact assessments" for their overseas construction and business operation, to apply for environment related permits from the host countryto reduce the emission of pollutants through clean production, and also to actively engage in ecological restoration (Gallagher and Qi 2018). While many of these guidelines are voluntary or unenforced, Chinese parent companies could direct plant-level technology choices and operational practices in order to meet Chinas and host countrys suggestions for environmental performance.

The top Chinese engineering companies from our analysis are large private companies that specialize in engineering services for the electric power sector. Many of these same companies are also the top construction companies, such as SEPCO3, the Shandong Electric Power Construction Corporation. Such companies are vertically integrated, providing logistics and shipping, equipment, design services, etc. Engineering and construction services are often bundled in the form of EPC (Engineering, Procurement, and Construction) contracts. Though not reflected in our dataset, these arrangements may even go further, with Build-Operate-Transfer (BOT) projects or Design-Build-Operate (DBO) projects that receive concessional finance through public-private partnerships (World Bank Group 2019). Chinese state or commercial banks could provide finance for such arrangements. The technology selection, operation, and maintenance of these plants by Chinese companies is a potential driver of relative environmental performance. In addition to different policy, technological, and managerial practices on the part of Chinese companies, the relative difference in environmental performance between Chinese companies and companies with other national origins could indicate consistent political factors in how Chinese plants operate overseas, particularly in how host countries may receive or regulate such plants. We are not able to directly test this mechanism, but advocate for future research in this area.

This study has several limitations. First, the study does not engage with the broader question of what kinds of electric power stations China is involved with in other Asian countries. That is, we do not investigate any sort of displacement effect or fuel switching based on the broader portfolios of different countries involved in the electric power sector in Asia. In the future, we hope to expand this analysis to natural gas plants, which could increase the

robustness of the analysis, and investigate the factors that determine what type of energy projects Chinese companies choose to invest in. In addition, because we lack time series data on ownership, we are unable to characterize how long a given plant has had Chinese involvement, which could be an important consideration given that around half of Chinese ownership of overseas power plants has been through mergers and acquisitions rather than greenfield investment (Li et al. 2018). Although our results are robust to controlling for the year the plant was built as well as within-year country fixed effects, data on the influx of Chinese involvement at different points in time could open up a new set of analyses. Finally, we hope future research can improve upon our characterization of Chinese involvement, proxied by company ownership. There are many complex arrangements in which Chinese finance may reach an overseas power plant, including mergers and acquisitions and other financial instruments that are difficult to track at the firm level. Because we used a dichotomous indicator of Chinese involvement, we were not able to assess how different kinds and scales of involvement affect environmental performance.

4 Discussion

This paper provides a systematic comparison of Chinese and non-Chinese coal plants outside of China, collecting and analyzing data on environmental performance across three metrics: CO2 emissions intensity, energy efficiency, and air pollution control technology. We find compelling evidence that plants with a Chinese parent company, engineering company, or construction company often perform better in these metrics than other plants, contrary to our stated hypothesis in the Introduction. Our results are robust to year and country fixed effects specifications and a matching strategy, indicating that Chinese plants are distinct in their environmental performance for reasons other than Chinese plants being built more recently or Chinese plants being concentrated in countries with more stringent environmental controls.

We aim to provide aggregated, comparable quantitative information on the relative environmental performance of Chinese coal plants in order to better understand how the geopolitics of overseas investment map onto environmental impact. This analysis provides suggestive evidence that coal plants with Chinese parent, engineering, or construction companies perform better in terms of emissions intensity and energy efficiency than those with companies from other countries. This indicates that Chinese coal plants may have technological or managerial characteristics that correlate with better environmental performance by these metrics. We are not advocating for increased Chinese investment in coal, nor should our empirical results be used to problematize efforts to stop investment in coal. In fact, our research further demonstrates the pressing need for BRI host countries to have competitive alternative sources of energy. The BRI will play a large role in the future course of the global energy system based on Chinas decisions on what kinds of energy projects to fund as well as how those projects end up operating. Our research helps establish a baseline understanding for this dialogue, as well as a methodological framework for understanding the relative impact of countries overseas projects.

5 Methods

5.1 Data

We collected plant-level data from the March 2018 version of the Platts World Electric Power Plants (WEPP) database. The WEPP is a regularly published global inventory of units generating electric power. For this analysis, we used a subset of the data for units with coal as their primary fuel. In addition, we only used data on plants that were located in Asia, according to the WEPP classifications. Asia includes the countries of Afghanistan, Australia, Bangladesh, Cambodia, India, Indonesia, Japan, Laos, Malaysia, Mongolia, Myanmar, New Caledonia, New Zealand, North Korea, Pakistan, the Philippines, Singapore, South Korea, Sri Lanka, Taiwan, Thailand, and Vietnam. Because this analysis concerns the performance of Chinas overseas projects, we also excluded coal plants within China. The final sample includes 4,260 plants, after dropping some outliers.

We also constructed several key variables. We used the WEPP data on parent company, architect or engineering company, and construction company to identify the country of origin for each of these types of companies. This was determined by searching the name of the company and identifying the country in which it is registered and located. From the maps below (Figure 2), which show the number of each type of company originating from different countries, we can see that various countries specialize in different services related to coal plant management and construction, to some extent. For example, China has many distinct engineering companies involved in coal plants elsewhere in Asia, but has relatively few construction companies. However, the maps do not reveal the relative sizes of the companies. India clearly has many companies of all types, while China, which tends to consolidate resources in large state-owned companies, may have a fewer number of companies but not necessarily a lower market share.

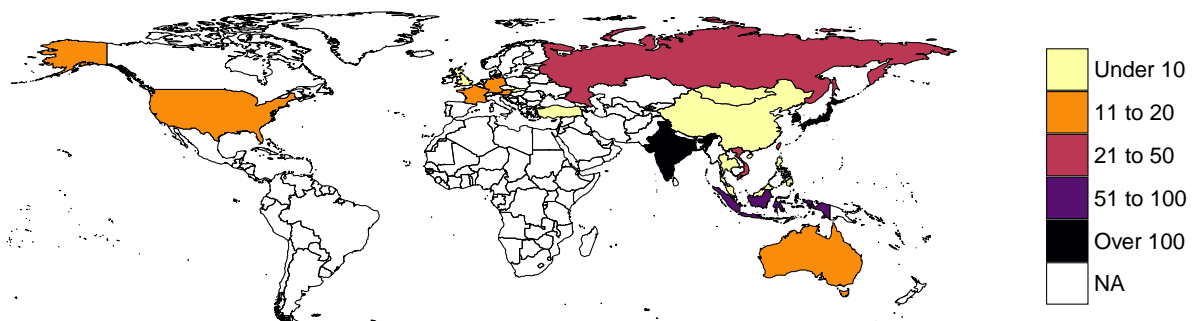Figure 2: Countries of Origin for Coal Plant Company Types

Figure 2: Countries of Origin for Coal Plant Company Types
Number of Parent Companies by Country of Origin
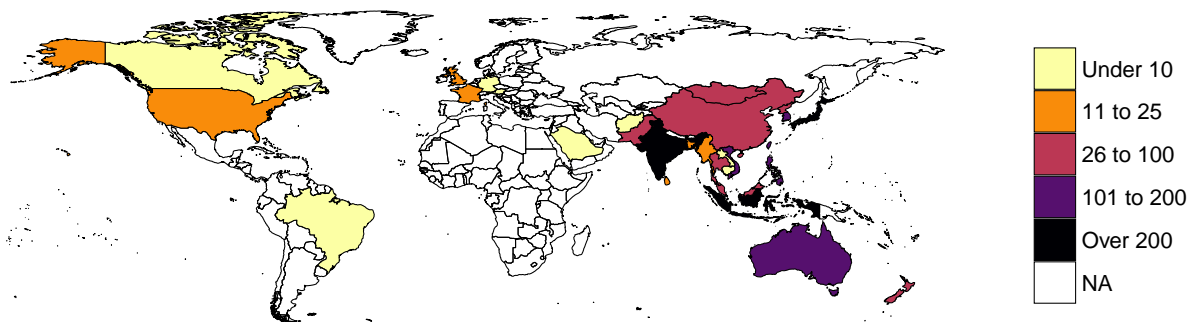
Number of Architectural Engineering Companies by Country of Origin
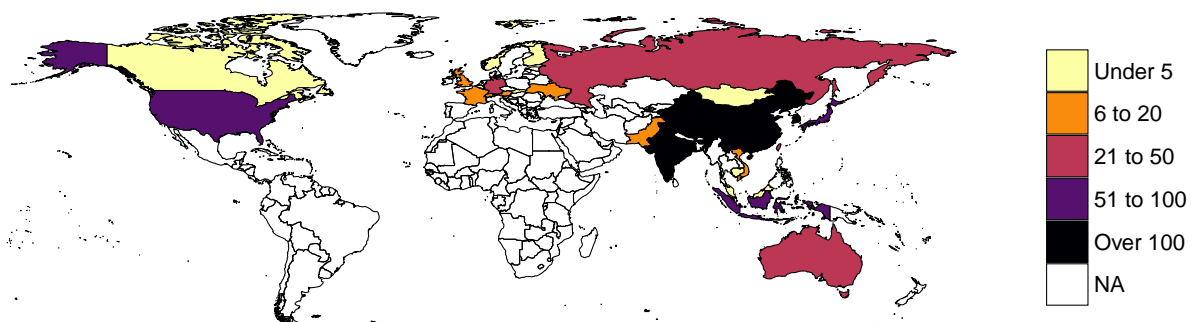
Number of Construction Companies by Country of Origin

Each type of company (parent, engineering, and construction) was then coded with an indicator treatment variable for Chinese or non-Chinese ownership. Joint ventures with a Chinese company were coded as Chinese. This indicator variable represents identifiable Chinese involvement in a project, which may include management practices, technology choices, or other mechanisms that are unique. 94% of observations had either both Chinese or both non-Chinese engineering and construction companies, and for observations with both Chinese engineering and construction companies, these companies were almost always the same, so we combined these two company types in our analysis.

For outcome variables, we assess three metrics of environmental impact: CO_2 emissions intensity, energy efficiency, and air pollution control technology. CO_2 emissions intensity, or the emissions rate, is the product of the emissions factor and the heat rate of a given plant

the amount of CO2 a plant produces per unit of energy generated (Equation 1). We used data on plant-level emissions factors from the Global Coal Plant Tracker (GCPT), another plant-level database for coal plants around the world. We merged the GCPT data on emissions factors into the WEPP data. Heat rate was assigned based on the steam type of each plant (Table 4), and then adjusted for the year the plant was built and the capacity of the plant. This reflects the fact that older and smaller plants tend to be less efficient. This approach is based on the methodology proposed by SourceWatch as well as heat rate data from Source-Watch. Table 5 shows the assumed penalties for plant age and capacity (SourceWatch 2019).

Emissions Factor $(\frac{tonsCO_2}{btu})$ * Heat Rate $(\frac{btu}{MWh})$ = CO_2 Emissions Intensity $(\frac{tonsCO_2}{MWh})$ (Eq. 1)

Table 4: Assumed Base Heat Rate by Steam Type

Steam Type	Heat Rate (btu/MWh)
Subcritical	8.98
Supercritical	8.12
Ultra-supercritical	7.76

Table 5: Adjustments to Heat Rate for Capacity and Age of Plants

	0-349 MW	350-449 MW	450+ MW
0-9 Years	+20%	+10%	0%
10-19 Years	+30%	+20%	+10%
20-29 Years	+40%	+30%	+20%
30+ Years	+45%	+35%	+25%

For energy efficiency, we used steam temperature and steam pressure provided in the WEPP data. For air pollution control technology, we used the WEPP data on particulate matter, sulfur dioxide, and nitrogen oxides control technology types to assess whether each plants technology was best available technology (BAT) or not. For each of these types of pollution control technologies, we coded an indicator variable for BAT or non-BAT. To assess if a technology was BAT or not, we used the authors catalogue of BAT air pollution control technologies based on WEPP data (Purvis et al. 2014). For a list of technology types and their ratings, see the Appendix. Table 6 shows the final balance of observations on control technology classifications by air pollutant.

Summary statistics for the final list of variables are provided in Table 7 below. Other categorical variables included in the regression analysis are plant status (operational, retired, planned, etc.), fuel type (anthracite, bituminous, lignite, etc.), and electricity type (utility, private, autoproducer).

Table 6: Number of Plants with Best Available Air Pollution Control Technologies

	Particulate Matter	Sulfur Dioxide	Nitrous Oxides
Plants with BAT	246	834	296
Plants with non-BAT	1,550	795	98

Table 7: Summary Statistics by Company Type

		Parent Company			Engn./Const. Company		
	Full Sample	Chinese	Non-Chinese	Difference	Chinese	Non-Chinese	Difference
Capacity (MW)	268.6	445.5	264.9	180.5	305.6	267.4	38.26
	(312.4)	(284.3)	(311.9)	(33.73)	(266.7)	(264.2)	(13.87)
Year Built	1996	2016	1995	20.2	2012	2002	10.5
	(21.5)	(8.37)	(21.5)	(3.07)	(7.08)	(16.9)	(0.89)
Steam Pressure (bar)	124.8	206.0	124.4	81.62	185.2	144.2	40.97
	(63.2)	(38.6)	(63.0)	(22.3)	(59.4)	(62.8)	(6.37)
Steam Temperature (C)	520.3	554.7	520.1	34.69	559.8	532.1	27.62
	(54.8)	(12.1)	(54.9)	(19.4)	(78.8)	(37.3)	(4.82)
Heat Rate (btu/kWh)	11961	10226	11988	-1762.3	11113	11653	-539.9
	(1644.8)	(1676.9)	(1630.1)	(239.71)	(1789.9)	(1770.4)	(102.47)
Emissions Intensity (tCO2/MWh)	1.22	1.01	1.22	-0.20	1.11	1.17	-0.06
	(0.18)	(0.14)	(0.18)	(0.04)	(0.19)	(0.21)	(0.02)
Observations	4,260	87	4,173		485	1,468	

5.2 Regressions

A simple comparison of the emissions factors and heat rates for Chinese and non-Chinese plants by company type indicates that Chinese companies have a lower average emissions intensity (see Table 7). To explore this intriguing difference further, we control for other variables using several different regression specifications.

We analyzed the effect of ownership of each type of company separately for each outcome variable. For assessing CO2 emissions, we used ordinary least squares (OLS) regression to examine the effect of a Chinese parent, engineering, or construction company on CO2 emissions intensity of plants. In our OLS regressions, we control for the status of the plant (operational, retired, etc.) and the type of the plant (i.e. producing utility scale electricity or electricity for industrial or commercial use on-site). Capacity and age of the plant are incorporated into the calculation of the heat rate (see the Data section), and are thus not included as explanatory variables. We did a log transformation of the outcome variable, which produces a more normal distribution of values.

Our general model is laid out in Equation 2 below, with the indicator variable for Chinese company being 0 if a company was not Chinese and 1 if a company was Chinese. We ran various specifications for each of the environmental performance outcome variables and company types, beginning with OLS with and without controls.

$EnvironmentalPerformance_{i,t} = \beta(ChineseCompany_{i,t}) + \gamma(Controls_{i,t}) + \alpha_{i,t} + \mu_{i,t} + \epsilon_{i,t}$ (Eq. 2)

In addition to the basic OLS regressions, we run a model with year fixed effects ($\mu_{i,t}$) and country fixed effects ($\alpha_{i,t}$) in order to control for unobservable factors that may confound the relationship between company ownership and environmental performance.

It is clear from Table 7 that there are differences between Chinese and non-Chinese owned power plants other than the ownership structure. Of particular concern is the fact that Chinese plants are generally built more recently than non-Chinese plants and thus differences in environmental performance are due to age, not ownership. In order to address possible selection bias, we also run a regression on a matched data set where Chinese-owned plants are matched to similar non-Chinese owned plants. Plants are matched on the propensity score, which is estimated using the same plant-level characteristics that are used on controls in the basic OLS model. The resulting matched dataset includes plants with similar age and features.

The above approach describes our general strategy to estimating the effects of Chinese company involvement on CO2 emissions intensity. We take a similar approach to estimating the effects of Chinese companies on plant energy efficiency. We use OLS to estimate the effect of a Chinese company on steam temperature and steam pressure, controlling for the size and status of the plant, the type of coal used, the steam type (i.e. subcritical or supercritical), country, and electricity type. We use the same control variables for the fixed effects analysis. The propensity score matching (PSM) strategy is also similar to the CO2 emissions intensity approach. We again did a log transformation of the outcome variables of steam type and steam pressure.

Finally, we perform a similar analysis for each of the air pollution control technologies, controlling for size, status, fuel type, steam type, country, and electricity type of the plant. For each of these regressions, the outcome variable in a binary indicator of whether the plant has the specific air pollution technology or not. We estimate the marginal effects of Chinese companies using a linear probability model. As with the CO2 emissions intensity and energy efficiency analyses, the pollution control technology regressions include OLS with controls, fixed effects and PSM specifications.

6 Data Availability

The Global Coal Plant Tracker database that supports the findings of this study on emissions intensity is available by request at: https://endcoal.org/global-coal-plant-tracker/. Data supporting other findings for this study is available from the corresponding author upon reasonable request.

7 Code Availability

The code used to analyze the data and generate the results is available from the corresponding author upon reasonable request.

8 Acknowledgments

9 References

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10   Appendix

Contact author for appendix information.