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Wind and Solar Sectors in Brazil and China: Interests, State–Business Relations, and Policy Outcomes

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Abstract

This paper examines developments in the renewable electricity sector in Brazil and China since 2000. The two countries share many interests with respect to solar and wind power, but institutional differences in state-business relations led to different outcomes. In China, in a context of state corporatist state-business relations, state interventions were more far-reaching, with the state coordinating with state-owned banks, offering large financial and investment incentives to state-owned or state-connected enterprises. By contrast, in Brazil's private-public partnerships, state support to promote renewable energies was shaped by a stronger preference for competitive auctions and stricter financing rules. The differences in the state-business relations help to explain the observed developmental trajectories in wind and solar power.

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Introduction

International climate negotiations have largely foundered, in part due to conflicting expectations about the role that large emerging powers like China and Brazil should play in reducing their greenhouse gas (GHG) emissions. Their record economic growth rates after 2000 have been accompanied by an equally rapid rise in emissions, and the energy investments they are making to support their economic growth will lock-in emissions levels for decades to come. Even as they grow quickly, the emerging powers continue to have millions of poor citizens, and they have made it clear that any climate mitigation action must be responsive to national development needs.[1]

We take the claim that development is a priority as our starting point in this article, where we examine developments in the renewable electricity sector in Brazil and China since 2000. Renewable energies were almost non-existent in both countries in the 1990s, but over the past decade China expanded its generation of wind and solar power while gaining world leadership in both industries. Brazil now generates substantial wind power and has a thriving wind industry, though solar power lags. Both countries have twinned their renewable electricity procurement with policies to develop related industrial capacity—they do not want to just install imported components—but they have done so in different ways and with distinct outcomes. What explains the differences in the policies initiated and in the development and climate emissions outcomes? We draw on explanatory variables from classic comparative politics theories to answer those questions, examining the roles of interests and institutions in determining policies and outcomes.[2]

We argue that the two countries share many interests with respect to renewable energy, but institutional differences in state–business relations have led to different outcomes. In Brazil, a public–private partnership approach played a key role in promoting wind generation and a new wind industry, but left the solar sector largely moribund. In China, a state corporatist approach meant that the political agendas of national and local governments, as well as the vested interests of powerful state-owned enterprises (SOEs) and state-backed enterprises, shaped policy outcomes.

Our analysis draws on original fieldwork conducted in Brazil and China between 2010 and 2014. In Brazil, we interviewed officials in the energy planning agencies and Brazilian National Economic and Social Development Bank (BNDES), as well as industry and community representatives. In China, we conducted fieldwork in Beijing as well as in Hunan, Jiangsu, and Shandong provinces. The analysis also draws from government policy documents, media reports, and available secondary sources.

Interests, Institutions, and Renewable Sources of Electricity

Why do countries build the electricity infrastructure that they do, and why might they turn to renewable fuel sources for electricity? Many studies of these choices generate straightforward answers related to the energy endowments of a

[1] Harrison and Kostka 2014; Hochstetler and Viola 2012.
[2] Steinberg and VanDeveer 2012.

country and the technical ease and cost of developing them.[3] Assessing the changing balance of concrete material *interests* is a powerful analytical tool for understanding phenomena like energy system transitions.[4] States have distinct endowments in the fuel sources that might power electricity plants; these tend to form the foundation of powerful coalitions supporting the continued use of abundant, cheap fuels. State and market actors also pay close attention to signals like the initially high, but then rapidly dropping, prices of renewable electricity technology after 2000.

Policymakers in Brazil and China have many of the same interests in deploying solar and wind energies. Wind and solar power improve local air pollution and help national leaders meet international climate change commitments. Renewable energy also helps to address domestic energy security concerns. Installing and running wind and solar farms bring potential economic benefits, although benefits are greater if local industries are established to produce components. In this article, we consider how recent developments may be changing those interest calculations.

However, our findings indicate that *institutional* differences may be as important as interests in determining how that transition takes place, and even in shaping the outcomes. In making this argument, we draw on a strong tradition in the study of comparative environmental politics of placing institutions—typically federal versus unitary arrangements or systems of interest representation—at the center of explanations of environmental performance.[5] Over several decades, scholars have especially used cross-national variation in state–society relations to explain differences in environmental outcomes.[6] Most concluded that neo-corporatist institutions lead to better environmental outcomes than pluralist configurations. In corporatism, the close, repeated interactions between the state and centrally organized business interests are thought to build trust, generate better information, and help solve collective action problems.

In discussions of the electricity sector itself, state–society relations take center stage. Here the specific focus is less on the system of interest representation per se (e.g., corporatist vs. pluralist) and more on the balance of interests between state and private market actors in a particular sector. Much of this literature departs from the stylized opposition of state-centered and market-centered approaches. In the former, state ministries and SOEs operated monopoly electricity sectors together, often drawing on subsidized state capital resources and playing a number of social functions beyond mere electricity provision.[7] Market-centered approaches were created by the neoliberal "standard reform model," applied around the world in the 1980s and 1990s. In this model, the electricity sector was unbundled and privatized while independent regulatory agencies were established to oversee the reformulated sector, hewing to market criteria.[8]

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[3] Andrews-Speed 2012; Leite 2009.
[4] See Purdon's introduction to this special issue. See also Hall 1997; Steinberg and Vandeveer 2012.
[5] See the summary in Fiorino 2011.
[6] For example, Crepaz 1995; Poloni-Staudinger 2008; Scruggs 2003; Vogel 1986.
[7] Victor and Heller 2007, 23-24.
[8] Gratwick and Eberhard 2008; Victor and Heller 2007, 6-7.

The virtues and problems of the state-centered model were evident in concrete historical outcomes. On the positive side, the state-centered model could take advantage of economies of scale, with the state coordinating industrial sectors and acting as a guardian for the public interest and national economic development[9]—not unlike the advantages associated with the corporatist system of representation. On the negative side, the model was blamed for tending towards both over-investment (when states had capital) and for failure to discipline demand and invest sufficiently (when states lacked capital). Without market-clearing prices, electricity provision was both expensive and inefficient.[10] The results of the market-centered approach are less clear, in part because the model was rarely fully implemented, leaving hybrid approaches with nationally idiosyncratic outcomes.[11] On the topic of interest here—the adoption of renewable electricity—there was no relationship between economic reforms and carbon emissions for developing countries.[12]

Because of our limited understanding of recent state-centered or market-centered approaches on climate and energy issues, there is a need for the kind of detailed qualitative case study of two important emerging powers presented here. These two countries partially implemented market reforms in their electricity sectors, with Brazil's being more complete than China's. Thus the two cases allow us to look more closely at the relationship between hybrid models and renewable electricity outcomes. Broadly speaking, we would expect the Chinese approach to more closely follow the expectations of the state-centered model. However, both cases have particular national characteristics that shape outcomes.

Brazil's hybrid electricity sector sets up an electricity political economy that toggles between national public planning, procurement, and financing agencies and an increasingly private generation sector.[13] This *public–private partnership* approach came to include a number of state supports for the renewable energy sector after 2002, but since 2009 also imposed a competitive auction system that disciplined prices. The independent regulator holds regular auctions for licenses to supply electricity to the national grid, with both public and private generation firms participating; those that promise to supply electricity at the lowest prices win. Similarly, BNDES provides credit for many projects at subsidized rates, but also then insists on repayment.

In China, state–business relations can be best described as *state corporatist*. The ongoing centrality of the state and state-owned or state-backed enterprises in the political economy and its authoritarian decentralized governance structure locate the calculation of interests primarily in complex relations between central and local governments.[14] The state works with SOEs and mixed-ownership firms to develop a globally competitive renewable energy sector.[15] The state retains overall control of the market and decides the rules and exercises control over market entry. In view of heavy state control of access to

[9] Erdogu 2014, 1.
[10] Kessides 2012, 80.
[11] Gratwick and Eberhard 2008; Kessides 2012; Victor and Heller 2007.
[12] Erdogu 2014, 7.
[13] Leite 2009.
[14] Landry 2008.
[15] Oi 1992.

valuable resources, businesses typically seek to establish close ties to state agents. A unique feature of the Chinese case is the relatively large discretion accorded to local governments in guiding economic development, giving Chinese state corporatism a decidedly local character.[16]

In the next section, we provide a brief overview of the Chinese and Brazilian electricity sectors that shows some of the factors that established the initial constellations of interests in each. Following this, sections on each country and their institutional framework for electricity detail how those interests have been reshaped in distinct contexts.

Renewable Fuel Sources in the Chinese and Brazilian Electricity Grids

Brazil and China use strikingly different fuel sources for their national electricity generation. As Table 1 shows, each draws more than two-thirds of its electricity from a single source, coal in China and hydropower in Brazil.

Table 1. Installed Electricity Generation Capacity by Fuel Type, 2011

Fuel Type	*Brazil (gigawatts)*	*Brazil %*	*China (gigawatts)*	*China %*
Total	**119.1**	**100**	**1100.5**	**100**
Fossil fuels	22.4	19	766.0	70*
Hydro	82.5	69	231.0	21
Nuclear	1.9	2	11.8	1
Wind	1.4	1	62.4	6
Solar	0.0	0.03	3.1	0.28
Biomass	10.9	9	8.2	1
Other	0.0	0	18.0	2

* Installed capacity of coal is 66 percent.
Sources: EIA, 2011.

Table 1 shows that alternative renewable electricity sources like wind and solar power still constitute only a small percentage of each country's national electricity matrix. In contrast, Table 2 reveals substantial changes since 2000 in both countries. New construction increasingly turns to wind and solar power and their rate of growth indicates that an energy transition is underway.

Table 2. Evolution of Wind and Solar Generation Capacity over Time (megawatts)

	Installed Wind 2000–2001	*Installed Wind 2013*	*Installed Solar 2000*	*Installed Solar 2013*
Brazil	28	1,805	n.a.	20
China	340	91,000	19	18,100

Sources: EPE 2013, 99; EPE 2012, 1; GWEC 2014; EIA 2014; Leite 2009, 162; Zhang et al. 2013a, 326.

[16] Oi 1992.

Each country has environmental reasons to turn away from its incumbent fuel. The overreliance on coal, combined with rapid urbanization, created air and water pollution crises around China. It became the world's largest emitter of GHGs in 2007 and the biggest energy consumer in the world in 2010.[17] Brazil's large hydropower plants are generally much cleaner, but studies have found varying amounts of methane emissions associated with them.[18] Other environmental and social costs are high, and Brazil has difficulty developing additional large hydropower plants as a result.

Power supply shortages in 2001 (Brazil) and 2002 and 2005 (China) gave additional incentives to expand and diversify the electricity matrix and help account for the timing of changes we observe.[19] However, the energy transition is uneven and incomplete in both countries, with solar power installation lagging well behind wind power generation in China and still largely missing in Brazil. China's transition has been much quicker than Brazil's, with rapid scaling up of installed capacity, although solar power expanded primarily after the financial crisis in 2009.[20]

Similar patterns are even clearer in the extent to which these countries now manufacture the components of wind and solar plants rather than simply installing imported versions of them. This is the second dimension of the political economy of the new renewables we consider. China now has 70 domestic manufacturers of wind turbines, and the six largest Chinese "national champions" were among the top 15 global wind turbine manufacturers, accounting for 26 percent of total market share in 2013.[21] The technical capacities of these companies have developed rapidly. By 2014, the quality gap between Chinese and foreign manufacturers was offset by a much more significant price gap.[22] Brazil also managed to nationalize some wind production with turbine, tower, and parts manufacturers.[23]

The expansion of solar photovoltaic (PV) manufacturing in China is even more impressive, as it became the largest producer of solar PV modules in the world in 2008, overtaking Japan and Germany. Solar PV production rose from 2 percent of global production in 2003 to 64 percent in 2012.[24] The nine largest Chinese manufacturers accounted for 30 percent of total market share in 2011.[25] The technical capabilities of Chinese solar PV manufactures have continuously improved.[26] In contrast, Brazil currently has very limited production capacity in solar power.

In the next sections, we examine the interests and institutions that created these outcomes in greater detail. We pay attention to state policies intended to generate demand for renewable electricity, as well as those intended

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[17] EIA 2014.
[18] Barros, *et al*. 2011.
[19] Leite 2009, 62; Zhang, Andrews-Speed and Zhao 2013b, 335.
[20] Fischer 2012.
[21] Zhang et al. 2013a, 325; MAKE consulting 2014.
[22] Gosens and Lu 2014, 310.
[23] Brazilian Agency of Industrial Development – ABDI 2014, 11.
[24] IRENA 2014, 4.
[25] Zhang and He 2013, 395.
[26] Zhang and He 2013, 395.

to generate supply. While both countries developed green industrial policies to promote new renewables, related policies have had variable effects under different institutional settings.

Brazilian National Renewable Energy Programs and Incentives

Brazil built very little new electricity generation capacity in the 1990s, and a severe drought in 2001 and resulting widespread blackouts brought the system into crisis. In 2002 the Cardoso presidency initiated the Program of Incentives for Alternative Energy in Electricity (Proinfa). Thus what Brazil calls "alternative renewables"—wind, solar, small hydro, and biomass—were first promoted to reduce the system's over-reliance on large hydro.[27]

Proinfa at first set a feed-in tariff (FIT) to add 1100 megawatts (MW) each of wind, small hydro, and biomass-based electricity to the system, with 20-year contracts for independent power producers. Proinfa called for a second stage wherein renewable energy would reach 10 percent of national electricity consumption by 2022.[28] The new Lula administration amended the law the next year,[29] introducing an auction system. Both FITs and auctions, with long-term contracts, provide the kind of guaranteed demand necessary to draw private generation firms into the sector.

Both versions of Proinfa included national content requirements. These rested on economic calculations within the Ministry of Mines and Energy that the additional costs of adding renewable energy to the grid could be offset in the long run if such requirements successfully localized production and innovation in the sector.[30] The Cardoso administration called for a 50-percent national content requirement only in the first stage of Proinfa—the kind of disciplining often favored by market-oriented proponents of industrial policy, but the Lula administration required 60-percent national content in the first stage and 90 percent in a second stage that was never implemented.[31] The leftist Lula administration favored renewable energy as a central element of a modern economy in which the state would support Brazil's innovation capacities and global competitiveness.[32]

The sense that green industries are part of the economy of the future was repeated in interviews, including within the Brazilian national development bank, BNDES.[33] BNDES' total lending portfolio more than doubled in size from 2002 to 2012, and the electricity and gas sector was a top recipient almost every

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[27] Interview with Elbia Melo, Chief Executive Officer of the Associação Brasileira de Energia Eólica (ABEEólica, Brazilian Wind Energy Association), São Paulo, July 22, 2014. Melo was chief economist in the Ministry of Mines and Energy while the Proinfa program was being developed.
[28] Presidência da República 2002.
[29] Presidência da República 2003.
[30] Interview Melo 2014.
[31] Presidência da República 2003. .
[32] Governo do Brasil 2003, 10.
[33] Interview with five members of the BNDES Infrastructure and Structuration of Projects sectors, Rio de Janeiro, June 2012; Telephone interview with Sérgio Weguelin, then Superintendent of the Environment sector of BNDES, June 2011.

year.[34] BNDES, which is mandated to promote employment in Brazil and has its own domestic content requirements, has effectively become the guarantor of ongoing national production, particularly after the second stage of Proinfa was cancelled in favor of moving directly to auctions with no explicit local content minimums. BNDES has made about 300 project finance loans in the energy sector since 2004, and only one has been non-performing.[35]

The Brazilian political economy under Lula and his successor Dilma Rousseff (both of the Workers' Party, *Partido dos Trabalhadores*) has been broadly pro-business,[36] and the public–private partnerships of electricity generation in Brazil fit that model well. State actors must be sensitive to firms' requirements, since electricity providers will sit out auctions if the renewable electricity contracts offered are not lucrative enough, as they did in a wind-only auction in 2008.[37] But Brazilian auctions are also constructed with many compliance mechanisms that are usually flexibly applied.[38] The two-stage auctions pit firms against each other, and the resulting tariffs are substantially lower and less profitable than was the case for the FIT. Winning bid prices are now almost too low for successful realization of the bids.[39] This outcome supports the Brazilian state's other major concern, which is to keep prices for consumers and industry low.

Wind Power

The programs outlined above summarize the most significant interventions to promote wind power in Brazil. The demand and supply sides have been tightly interwoven. In the Proinfa program, as already noted, demand for wind power for the national grid was directly linked to the requirement of 60 percent local content. After the Proinfa program unofficially ended in 2008, reserve auctions for wind in 2009, 2010, 2011, and 2012 continued to present substantial demand. (While many Brazilian electricity auctions are open to plants using any fuel type, reserve auctions ask for bids for specific fuel types.) These auctions did not formally require local content production, but the only bids low enough to win the auctions were those with financing from BNDES—the development bank's subsidized rates for wind generation are about 4 percent below market rates.[40]

The growth in wind power itself is clear: from essentially no generation capacity, Brazil has contracted to have 8.4 gigawatts (GW) installed capacity in its national grid by 2017.[41] Proinfa established the critical initial demand levels to kickstart a wind generation industry from almost nothing. Its FIT was high enough to attract both generation firms and financiers, even though none had

[34] Hochstetler and Montero 2013, 1491.
[35] Interview BNDES.
[36] Hochstetler and Montero 2013, 1485.
[37] Interview Melo 2014; Interview with Milton Pinto, representative of the Centro de Estratégias em Recursos Naturais e Energia (CERNE), Natal, July 17, 2014.
[38] Lucas, Ferroukhi, and Hawila 2013, 18-19.
[39] Lucas, Ferroukhi, and Hawila 2013, 22.
[40] Melo 2013, 131.
[41] Melo 2013, 125.

much experience with wind power.[42] As prices fell from Proinfa's $150/megawatt-hour (MWh) to an average of $84.79 in the 2009 auction and $42.09 in 2012,[43] participants became more specialized and the winning firms have grown steadily larger.

Proinfa's domestic content requirements have significantly changed the supplier landscape for wind power. As recently as 2008, there was only one manufacturer of wind components in Brazil, the German-based Wobben Windpower, which was unable to keep up with the demand of the first Proinfa stage.[44] In simulations, the national production requirements were shown to reduce early wind-generation capacity below what would otherwise have existed if Brazil had simply imported the components to meet Proinfa's demand.[45] As auctions for wind power showed continuing demand, other firms followed Wobben Windpower to Brazil. By 2014, there were four manufacturers of wind turbines and seven turbine assemblers in Brazil, along with thirteen manufacturers of towers and thirteen of parts and components (with some individual firms producing in more than one category).[46] These tallies come from the Brazilian Agency of Industrial Development, which mapped the Brazilian wind-power production chain in an effort to spur additional private investment and state-based industrial policy for the sector.[47]

Financial incentives in the form of subsidized credit from BNDES also helped draw international wind energy firms to Brazil and spurred domestic firms to set up production. After 2005, BNDES allowed a flexible timeline for implementation of its 60-percent domestic content requirement, making individual agreements with firms that conditioned ongoing support on moving production to Brazil.[48] At the end of 2011, however, BNDES informed six of the eleven firms that they had not nationalized enough of their production to allow BNDES to finance contracts for their products.[49] BNDES has since written an extended document that details exactly how it accounts for domestic content in turbines and the required stages of compliance with the law.[50] By 2015, for example, BNDES will only finance domestically produced nacelles, which are among a turbine's most technologically advanced components. Prices for these domestically produced goods are higher than Chinese and European prices, squeezing installers since the winning prices in the 2011 and 2012 auctions were very low.[51]

Solar Power

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[42] Interview with representative of CPFL Renováveis, São Paulo, July 24, 2014; Interview with representative of Bons Ventos da Serra, Fortaleza, July 14, 2014.
[43] Lucas, Ferroukhi, and Hawila 2013, 16, 20.
[44] Dutra and Szklo 2008, 69.
[45] Dutra and Szklo 2008, 73.
[46] Brazilian Agency for Industrial Development – ABDI 2014, 11.
[47] Interview with Eduardo Tosta, Project Specialist, Agência Brasileira de Desenvolvimento Industrial, September, 2014.
[48] Interview Melo 2014.
[49] Melo 2013, 130.
[50] BNDES 2012.
[51] Melo 2013.

The first stage of Proinfa did not include solar power, which continues to lag well behind wind power. Brazil has many of the same interests in solar-powered electricity as in wind: solar installations can be assembled quickly, adding more capacity to the grid without creating new dependencies on imported or fossil fuel. Solar's higher prices and the technical challenges involved in creating domestic production lines of solar components have been the major blocks.[52]

To date, very few demand-side interventions promote solar power in Brazil. Solar power has been far too expensive to compete in open auctions to supply the national grid. In October 2014, EPE held an auction for solar, wind, and biomass—the first reserve auction for solar power. The solar power generation capacity that does exist—about 20 MW in 2012—is limited to small, distributed solar installations, mostly in isolated and remote areas.

The timing of the demand-side incentives for solar production responded to the drop in global solar prices, as world installed capacity soared and Chinese producers entered the market. That same drop in prices—not yet enough to make solar fully competitive with other electricity sources, but likely to become so soon—has generated a heated debate about whether Brazil should adopt solar power by simply importing the ever-cheaper internationally produced components or by trying to localize production.[53] Unlike wind and other alternative renewable fuels, solar power production involves few heavy, low-technology components of the kind that make a country's entry into component production easy. Instead, solar panels make up 50 percent of the value-added of the installation, and the PV panels likely to be used in Brazil require highly refined silicon.

Brazil has the capacity to build cells and PV modules and has large amounts of high-quality quartz that could be refined into silicon. However, it does not have the technical capacity to do the refining.[54] BNDES has been funding two firms to develop the purification process, and is looking to develop new technology that demands less electricity.[55] ANEEL opened a small research and development competition in 2011 to insert solar power into the Brazilian electricity matrix; around 130 firms have formed an industry association to further explore possibilities.[56] In the meantime, the debate about whether to offer more incentives continues.

As already noted, the Brazilian public–private partnership approach relies on the response of private firms to government auctions by bidding to supply electricity. For them, the exact rules chosen affect their participation.[57] Finding the right balance between the conditions that will draw generation firms into public auctions, the policies demanded by would-be producers of components, and prices consumers will tolerate is a delicate prospect. The future of renewable energy in Brazil depends on it.

Chinese National Renewable Energy Programs and Incentives

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52 EPE 2012, 1.

53 Interview with official of Greenpeace Brasil, São Paulo, July 22 2014; Interview Melo 2014.

54 EPE 2012, 17-18.

55 Interview BNDES 2012.

56 EPE 2012, 1-3.

57 Interview CFPL Renováveis 2014.

The development of renewable energies in China follows national laws and renewable energy programs set by the central government. The Renewable Energy Law (2005) and its 2009 amendments comprise the core policy framework. The most important measures include the introduction of FITs, guidelines on cost-sharing arrangements between utilities and electricity end users, creation of the Renewable Energy Development Special Fund, and various other investment incentives for solar and wind power electricity generation.[58]

In parallel, various national planning targets intended to stimulate the development of solar and wind energy capacity were announced by the National Development and Reform Commission (NDRC), the powerful bureaucracy in charge of China's overall long-term economic and social planning. The leadership's decision to task NDRC with oversight of renewable energy development signals of how integral renewables are to economic planning.

To encourage the implementation of national plans, binding targets are built into the "cadre management system," an incentive scheme used to assess and monitor the performance of officials. To advance up the ladder and receive bonus payments, government officials and managers of SOEs need to meet these targets as part of their annual performance assessment; repeated non-implementation can be penalized through redeployment to a remote locality or even, in principle if not often in practice, outright expulsion from office.[59]

Provincial and sub-provincial governments also initiated numerous preferential policies that played critical roles in the rapid rise of solar and wind energies. In fact, many local governments nurtured home-grown solar and wind manufacturing enterprises well before national support programs were established and well ahead of the official designation of renewables as a strategic emerging industry (SEI) in 2010. As illustrated below, the solar PV manufacturing industry in particular experienced rapid expansion between 2003 and 2008 at local levels, before national supply-side incentives were put in place.

Due to large variations in the patterns and sequencing of governments' demand-side and supply-side interventions, the development trajectories of wind and solar industries in China differ markedly.

Wind Power

In the mid-2000s, the central government launched a slate of demand-side policies to create incentives for wind turbine installation across China. China's Medium to Long-Term Development Plan for Renewable Energy (2007) set non-binding capacity targets for power generation companies with total capacity of over 5 GW, requiring them to generate 3 percent of their capacity from non-hydro renewable energy sources by 2010 and 8 percent by 2020. As no more specific guidance was given as to the proportion of wind versus solar, most power generators identified wind power as the more attractive option, given its comparative affordability and large growth potential.[60] A wind concession program offered five rounds of competitive bidding during 2003 to 2007 to develop large wind farms. Successful bidders received guarantees that provincial

[58] Zhang, Andrews-Speed and Zhao 2013b, 335.
[59] Harrison and Kostka 2014; Kostka 2015.
[60] Zhang, Andrews-Speed and Zhao 2013b, 335.

transmission companies would purchase all electricity generated. Generally, SOEs outbid other investors by offering below-market prices, and they now account for more than 80 percent of the country's installed wind power capacity.[61] The program was seen as a success since it significantly brought down prices and awarded a total of 2.6 GW of permits to developers.[62]

These demand-side incentives were coupled with supply-side interventions that began in 2003 and benefited domestic wind turbine manufacturers. The bidding rounds included domestic content requirements that supported industrial development. Initial rounds required that 50 percent of the content of each wind turbine be made in China; this share increased to 70 percent in 2004. International wind firms transferred technology and know-how to China by setting up assembly plants and local manufacturing facilities.[63] As a result, the domestic share of newly purchased wind power equipment increased from 30 percent in 2005 to 90 percent in 2010. In the context of emerging trade disputes with the US, in 2009 China removed the 70-percent domestic content requirement.

Local governments' strong mandate to create new growth and employment opportunities further benefited local wind turbine and component manufacturers. Some local governments only approved wind projects under the condition that developers would set up local manufacturing.[64] In the early and mid-2000s fierce competition emerged among local governments around the establishment of renewable energy parks, wherein free or subsidized land and generous tax breaks were offered to producers.

One example is the city of Changsha's effort to develop a local wind turbine and component and solar hub in their National Hi-tech Development Zone. Pressures to restructure the city away from reliance on cement and chemical plants were behind Changsha's enthusiasm for renewables.[65] The municipal government offered local renewable manufacturers the purchase of government land for a third of the regulated price, and a few companies even received the land for free. In addition, renewable energy companies benefited from significant tax breaks during the first years of operation and were aided by municipal governments in their efforts to obtain low-interest loans from the state-owned commercial banks. Because these low-cost loans and land provisions fall into the category of disallowed subsidies under WTO rules, the municipal government discontinued interviews on this issue in September 2010, when the topic became too sensitive in the context of emerging China–US trade disputes.

These strategic efforts by national, provincial and municipal governments played a key role in the development and growth of China's wind turbine and component manufacturing industry. At the national level, the NDRC played an important role in coordinating wind industrial policies by introducing binding renewable energy targets, domestic content requirements, concession rounds, financial incentives, and FITs, among others. State interventions in China were

[61] Yang et al. 2012 quoted in Zhang, Andrews-Speed, and Zhao 2013b, 338.
[62] Gosens and Lu 2014, 312.
[63] Lewis 2013.
[64] GWEC 2012, 70.
[65] Interviews with government officials from the Changsha Municipal Development and Reform Commission (DRC), Science and Technology Bureau, Construction Bureau, and Environmental Protection Bureau (EPB), Changsha, September 2010.

more generous than in Brazil, with state-owned banks and ministries offering large bidding rounds and soft loans to producers.

Solar Power

Solar PV installations initially ranked low on the government agenda, since solar energy was perceived to be comparatively expensive.[66] Solar PV deployment programs were small and aimed at off-grid power generation.[67] Before 2009, total solar PV nationwide stood at only 160 MW installed capacity. While competitive bidding rounds during 2003–2007 for wind helped develop this sector, similar government support began only after 2009.

The minimal demand-side subsidies and the absence of large-scale consumer subsidy programs for Chinese citizens are a sharp contrast to the full range of supply-side subsidies used to stimulate a domestic export-oriented solar PV manufacturing industry in China. The booming market for solar PV manufacturing was developed to meet rapidly rising demand in Europe and North America. Solar manufacturers benefited most notably from national FDI attraction policies, financial and tax incentives, R&D subsidies, and access to the national Renewable Energy Development Special Fund. Moreover, for its first solar power plant constructed in 2009, China allegedly required that 80 percent of each panel be made in China.[68]

Local governments were key players in the creation of preferential policies for PV manufacturing. In the early and mid-2000s, local governments offered encouragement for local solar enterprises through local tax revenue, employment, and prestige benefits. For example, the Wuxi municipal government in Jiangsu province convinced various municipal-government-run investment companies and venture funds to provide 50 million RMB as starting capital for Wuxi Suntech, a small solar manufacturing company set up by a foreign-trained Chinese business entrepreneur in 2001.[69] In Xinyu (Jiangxi), the municipal government invested $32 million (200 million renminbi (RMB)) in the newly formed LDK Solar enterprise in 2005 and provided additional land in a high-tech development zone. Xinyu officials also introduced LDK Solar's business to the managers of the local branches of various state-owned banks. As a result, within a year of operation, LDK Solar secured large short-term loans from three banks. Its borrowings increased from $57 million in 2006 to $666 million in 2008, and the company's debt-to-asset ratio increased from 47 percent in 2007 to 75 percent in 2008. LDK was no exception and, over the past decade, the debt-to-asset ratio of many Chinese solar manufacturers passed 0.8; most foreign competitors' debt ratios rarely rise above 0.5.[70]

Baoding municipality in Hebei further illustrates the proactive role of sub-national governments. Baoding is today home to more than 40 solar power equipment producers. Among them is Yingli Green Energy, the largest solar PV manufacturer in the world in 2014. Yingli was set up in 1998 by a private entrepreneur. In 2001, the Baoding High-Tech Zone Administrative Committee designated solar power technologies and wind turbines as pillar industries of the

[66] Becker and Fischer 2013,v449; Fischer 2012, 141.
[67] Zhang and He 2013, 396.
[68] China Builds High Wall to Guard Energy Industry, *New York Times*, July 13, 2009.
[69] Dialogue with Shi Zhengrong 2010.
[70] LDK Annual Reports quoted in Zhang 2014, 28; Energy Trend 2013.

municipality's high-tech zone. Between 2003 and 2006, the Administrative Committee helped Yingli Green Energy to "wear a red hat" —meaning that it was formally registered as a local SOE, but it continued to operate independently. Yingli's new designation helped the company access preferential long-term bank loans.[71] Such state corporatist practices meant that Baoding's solar firms were well positioned to ramp up production quickly when global demand for solar increased in 2004. By 2010, renewables accounted for three quarters of the total $2.9 billion exports from the high-tech zone, and Baoding became known as a clean technology production hub in China.[72]

This rapid expansion of solar manufacturing was reinforced by regional competition between local governments to establish renewable energy manufacturing bases. More than 300 cities entered the solar PV manufacturing industry, leading to overcapacity of almost two times world demand in solar PV panels.[73] In the rush to attract solar manufacturers, hundreds of renewable industrial parks were set up by local governments between 2003 and 2006. The creation of renewable industrial parks also offered additional local revenues to local governments through real estate development.[74] In one municipality in Jiangsu Province, for example, four of nine counties listed solar and wind as their top two priority sectors and created industrial parks to spearhead their development, many of which stayed largely empty as they could not all attract renewable manufacturers.[75] Anhui and Shanxi also had similar failed infrastructure investments.[76] This headlong rush into renewables is partly an adverse effect of a cadre evaluation system that predisposes local officials to place excessive emphasis on achieving short-term economic growth targets.[77]

Since 2009 policy-makers have begun to address the large imbalance between supply- and demand-side measures.[78] In 2009, two large-scale subsidy programs were initiated to promote on-grid deployment of solar energy. The Rooftop Subsidy Program (2009) provides RMB15/W for rooftop systems and RMB 20/W for Building Integrated Photovoltaics (BIPV) systems, while the Golden Sun Demonstration Program (2009) provides a 50-percent subsidy for on-grid systems and 70-percent subsidy for off-grid systems.[79] Large-scale investments in solar installations were also driven by the National Energy Administration's (NEA) two rounds of public auctions for solar-powered projects in 2009 and 2010. These auctions offered successful bidders 25-year operational rights with on-grid prices and also opened the door for numerous SOEs to join the sector.[80] When prices dropped, the NDRC responded to lobbying pressure

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71 Zhang 2014, 38.
72 Shin 2014.
73 Zhang et al. 2013c, 348.
74 Fischer 2014.
75 Interviews with government officials, various Science and Technology Bureaus, Jiangsu, June 2012.
76 Interviews with the standing vice manager at an industrial park administration committee, Anhui province, January 2007, and with government officials from the DRC in Datong, Shanxi province, September 2011.
77 Eaton and Kostka 2014.
78 Fischer 2012.
79 Zhang and He 2013, 397.
80 Fischer 2014, 92.

from manufacturers and suppliers and established China's first FIT scheme for solar PV development in 2011, offering a tariff of RMB 1/kWh for new approved projects.[81] In 2013, the State Council, China's highest decision-making unit in the executive branch of the government, issued a new statement stressing the importance of the domestic solar PV market.[82] In quick succession, various institutions, including the NEA, the Ministry of Finance, the Chinese Development Bank, and the State Grid Corporation of China issued relevant supporting policies, and plans were made to add another 10 GW during 2013–2015.[83]

Local governments actively introduced additional demand-side subsidies to supplement national demand-side interventions. For example, some provinces, such as Shandong and Liaoning, introduced supplemental tariffs to encourage wind and solar installations, offering, in addition to existing national tariffs, an extra RMB 0.10-0.11/kWh for wind and an RMB 0.05-0.25/kWh for solar.[84] Other provinces opted to offer additional tariffs or supplemental tax preferences to wind and solar developers on a project-by-project basis, giving developers a lot of leverage at the bargaining table.

The recent switch in focus to solar PV installation can be explained by the combination of ongoing trade disputes with the EU and US and a struggling solar manufacturing industry. The EU and US initiated anti-dumping and countervailing investigations against Chinese solar PV products in 2011. At the same time, during the world financial crisis, foreign solar PV markets shrank as countries such as Germany cut subsidies. With the rush to solar at local levels, problems of industrial overcapacity and poor quality came to light. Government officials often opted for low-hanging fruit by investing in and supporting firms that focused just on simple solar mass production. As a result, by 2009 the market was flooded with simple solar PV modules with low conversion efficiency.[85] The industry-wide oversupply drove down the prices of solar modules, while at the same time spot prices for silicon rose from $32 per kilogram in 2004 to $450 per kilogram in 2007.[86] The result was a severe crisis in the domestic market, leading to layoffs and bankruptcies. Many solar manufacturers turned to local governments and banks for rescue packages, and local government officials were often only too willing to bail them out in order to protect local jobs and tax revenues, avoid damage to the government's reputation, and secure their own career promotion in the short term. The large-scale demand-based incentives resulted in additional solar PV installations of 13 GW in 2013 alone, and jobs in solar installation tripled in 2013 and 2014.[87] This boost in domestic installations has since helped Chinese solar manufacturers to return to rapid growth and some manufacturers even added production capacity in 2013.

In summary, the institutions of state corporatism help explain the marked preference for supply-side interventions in China. Local state institutions were

[81] Zhang and He 2013, 398.
[82] Government of China. 2013.
[83] For more details on these supporting policies, see Zhang 2014, 35.
[84] Deutsche Bank 2012.
[85] Gosens and Lu 2014, 310.
[86] Trina Solar Annual Report, quoted in Zhang 2014, 25.
[87] IRENA 2014, 12.

particularly important catalysts of the meteoric rise of Chinese solar, as officials eyed the benefits for economic growth, trade, employment, and prestige. Demand-side interventions were employed late and employed primarily to save domestic solar manufacturers from bankruptcy and to reduce dependence on overseas markets.

Conclusions

The policy outcomes in renewable energy development differ markedly in Brazil and China. In Brazil, renewable electricity advances are more modest including some successes in wind turbine manufacturing, with the number of component manufacturers increasing and generation growing quickly. Yet very little deployment or manufacturing activities developed for solar energy, despite abundant solar resources in Brazil. By contrast, over the same period, China gained world leadership in wind and solar manufacturing and deployment.

We argue that the observed difference in renewable energy outcomes is partly explained by variation in state–business relations in Brazil and China. Brazil's public–private partnership model and China's state corporatist model are different approaches to aligning interests between the state and market players. The two approaches presented mirror images in their implications for renewable energy development.

In Brazil, the public–private partnership approach encouraged a more coordinated and deliberate start to renewable energy generation that worked best for wind power. The Proinfa program used generous tariffs to draw private actors into wind production for Brazilian consumers and offered some market protection to encourage local production of wind turbines and components. Ongoing reserve auctions and subsidized finance from BNDES succeeded in drawing firms to both generation and industrial production, but also disciplined the industry by subjecting it to fierce price competition in the auctions and strict oversight of BNDES' lending. Over time these allowed Brazil to develop a fairly lean, if not fully globally competitive and innovative, wind industry that helps meet national demand.

For solar power, the requirement that prices, generation, and parts production all intersect in ways that meet both public and private aims has, so far, failed. Many policy tools cannot be considered, either because private actors cannot be forced to participate or because public actors have been required to make fairly short-term calculations based on market-based fundamentals. Strong environmental interests in solar production and good material foundations for such an industry have run into limits imposed by the contradictions between price and domestic production aims.

In China, the state corporatist model gives central and local governments a greater number and variety of levers to promote solar and wind energies. Top managers in SOEs are part of the same annual cadre evaluation system as public officials, making it easier for central and local governments to steer enterprise behavior. Moreover, the banking system is dominated by a few large state-owned banks, which financed state-owned or state-connected enterprises in renewables. In China's decentralized authoritarian political structure, local governments actively support the expansion of the wind and solar industries, as the examples of Baoding and Changsha illustrate.

Yet China's state-corporatist approach also poses serious challenges for renewable energy development. Excessive interventions by local governments and local branches of state-owned banks sometimes distorted central government plans and policies. The easy provision of bank loans at local levels resulted in huge amounts of short-term debt, much of which seems destined to become non-performing loans.[88] Such easy access to financing combined with the lack of hard budget constraints resulted in large-scale industrial overcapacity and, subsequently, to companies' deteriorating finances.[89]

The pathologies of Chinese state corporatism are partly due to abiding interest misalignments between central and local levels of government. As we have seen, local officials focused inordinately on the short-term benefits of renewables and rushed headlong into the sector without due heed to market conditions, giving rise to a boom-and-bust cycle. This is partly an effect of deeply embedded Communist Party institutions encouraging tournament-style competition between local officials,[90] but it also is a familiar downside of the state-centered approach, which has led to over-investment in other countries.

In sum, while China's state-dominated model provided the institutional foundations of marked success in renewables development, the approach has come at significant cost. In particular, the prioritization of manufacturing renewables over the domestic demand for renewable energy itself created numerous undesirable outcomes, as the deployment of renewable energy was initially sacrificed in the drive to build up a strong renewables production sector.

For other developing countries, the experiences of Brazil and China illustrate the many tradeoffs and dilemmas that grid-based renewable electricity raises. Building wind and solar generation plants continues to be more expensive than fossil fuel plants for most countries, although the last decade of developments in Brazil and especially China have changed those calculations remarkably. For countries that want to balance higher generation costs with the economic gains of adding a dynamic new industry that produces components, the experiences of these two giants suggest they will face a delicate balancing act between these two aims.

[88] Zhang 2014, 24.
[89] Zhang 2014, 44.
[90] Zhou 2007.

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